DMC/FIPR

PHOSPHOGYPSUM TO SULFURIC ACID DEMONSTRATION PLANT REPORT

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1.0 ABSTRACT

The Davy McKee Corporation (DMC) and Freeport McMoran Incorporated (FMI) announced in early 1987 that a small scale continuous test plant for the DMC/FIPR phosphogypsum process would be built and operated by FMI at their Uncle Sam phosphate complex in Louisiana. A description of the test plant and its goals was presented to this meeting in May 1987 soon after the announcement.

The test plant came on stream in late 1988 and started producing product in early 1989. In this paper the startup of the test unit will be described as well as the achievement on the test unit with relation to the goals set and how predictions based on batch test data have been verified with relation to design parameters and aggregate quality. Early indications from the aggregate test unit together with recent batch unit work show a real opportunity to deal with the problem of phosphogypsum in its utilization as a source of sulfur.

2.0 BACKGROUND

The Davy McKee Corporation (DMC) and the Florida Institute of Phosphate Research (FIPR) have cooperated since 1982 in the development of a process for the utilization of phosphogypsum. The object of this joint effort has been reported in a number of papers given in the past 5 years (see references).

The most significant recent development in the program was the announcement in the Spring of 1987 of funding for the construction and operation of a large scale demonstration plant. This announcement was made by Freeport McMoRan Inc.(FMI) who were to provide this funding. A cooperative agreement between DMC/FIPR and FMI resulted in the creation of a team committed to the demonstration of a competitive process to recover sulfur values from phosphogypsum.

A description of the demonstration plant and its objectives were presented in a paper (1) before this meeting in May 1987. The major goals of the demonstration plant were to demonstrate the process on a continuous basis and to produce sufficient aggregate for a commercial road test. The demonstration plant was constructed in 1988 and commissioned in late 1988/early 1989.

The batch test unit on which the early test work for the process was completed, was relocated to the FIPR facility in Bartow, Florida in late 1987. An extensive series of tests has been completed over the past two years with this unit. These tests have increased our basic understanding of the process and generated ideas for further process refinements.

The demonstration unit after some shakedown trails in November 1988 was commissioned in January 1989.

3.0 CONSTRUCTION AND INITIAL STARTUP

3.1 Plant Construction - May 1988

Construction of the demonstration plant was started in May 1988. Plant design was essentially the same as detailed to this forum in 1987 with one major exception. The original concept called for two modes of operation. The first mode with a reduced throughput to be used for operator training and a second mode to maximize aggregate production.

The plant design was changed to a single mode of operation (with reduced throughput) but incorporated a recycle gas stream that is an integral part of the proposed commercial design. Since recycle gas cannot presently be demonstrated on the batch unit it was thought important to verify our predictions in this area on the demonstration unit.

The major difference between the demonstration plant and the commercial design is the use of a straight grate instead of a circular grate. The utilization of a circular grate with a water seal, in the commercial design, allows for superior atmosphere control in the process. The use of an existing straight grate offered the most cost effective method to produce aggregate.

The straight grate used is a 30 year old machine. This machine had been used in a variety of sintering and pelletizing operations. (Pelletizing is a much harsher application in terms of temperature.) The machine required extensive modifications.

3.2 Feed System Checkout - Oct 1988

In early October 1988 the feed system was given its first shakedown. It was quickly apparent that we would have problems feeding gypsum and pyrites from their respective feed bins. Gypsum was by far the worst, bridging easily and exhibiting at times a negative angle of repose in the bin.

Several modifications were undertaken to alleviate the problem which included:-

- i) Lining the bins with polyethelene sheet (TIVAR88)
- ii) Installation of bin blasters.
- iii) Modifications to the screws extracting material from the bins.
- iv) Increase in auger feeder motor horsepower.

All the modifications, together with adjustments to the cycle times on the bin blasters and auger feeders above the extraction screws, made it possible to extract material from the bins and deliver it the main feed conveyor.

The demonstration plant is relatively large for a pilot type plant but small for commercial scale equipment. In selecting equipment the sizes always seemed to fall in a crack. As a result the screw conveyors used to extract the materials from the bins are large screws turning at very slow speeds. The effect of this is to deliver slugs of material to the individual weigh belts and hence to the main feed belt.

The feed system became our major problem area for the first four months of operation despite the modifications made, but much useful knowledge has been gained in this area.

3.3 First Startup - Nov 1988

By mid-November 1988 sufficient progress had been made with the feed system to allow the operators to begin training in the making of green pellets. A week was allowed for operators to train on the stepped pan pelletizer (granulator).

Green pellets were fed to the grate in late November. In two 8 hour days of operation it was determined that we had a severe air leakage problem within the windbox area on the under side of the grate. Although some leakage had been allowed for in the design, the leakage encountered was excessive. Leakage under the grate severely reduced gas flow down through the sinter bed. This initial test with the induction fan had been the first opportunity to complete any sort of leak test. Leakage under the grate was from three major sources:-

i) Expansion joint across the middle of the machine under a dead plate.
ii) Expansion joints between the machine frame and the windboxes running the length of the machine.
iii) Gap between the dead plates at both ends of the grate and the pallet cars.

In the short time that pellets were fed to the machine it was realized that we also had problems on the top side of the grate. We could see that once the leakage under the grate was dealt with we would be unable to maintain the necessary gas tightness in the hood section unless modifications were implemented.

Modifications would be required to solve two problems.

i) Gaps between the pallet car side walls when the cars butted up to each other on the grate.
ii) Lack of seal between the top of the cars and the grate hood.

A major refurbishment of the grate and the pallet cars was undertaken. The task seemed formidable but the decision was taken to basically rebuild the grate from the bottom up. As a result the grate was stripped and rebuilt during December 1988. Two major activities were involved:-

i) Pallet car refurbishing
ii) Repairs to the grate

3.4 Pallet Car Refurbishing

All 45 pallet cars were removed from the machine and dispatched to a machine shop. The cars were taken completely apart, removing both side walls from the pallet frame and all grate bars.

The original pallet cars fabricated for this machine had an 8" side wall. At some stage the side walls had been modified by casting an extra 4" of material to the top of the original side wall. The ends of the side walls were not in good condition their surfaces being generally jagged and in some cases the additional casting extended approximately 1/8" beyond the original side wall.

Consequently when the cars butted up to each other on the grate a gap was maintained between each car. Figure 1, a side view of the cars, shows the problem. These small gaps in the side wall between each car would allow air to enter the process through the side of the bed. This was not desireable.

To overcome the problem the ends of each side wall were built up by weld overlaying and then machined back to give a smooth flat surface. This was not as straight forward as it originally appeared due to the different types of side wall castings. The different castings required different treatment. A rod that would bond to one casting would not bond to the other casting. Furthermore, some rods that would bond to the castings proved impossible to machine. Experimentation with a combination of rods eventually allowed us to weld overlay and make machining possible.

Solving the problem of sealing the top of each car to the hood section required all the side walls to be constant in height. The previous application for this machine had been in a pelletizing mode and the cars had been under severe temperature conditions. As a result, damage to the side walls was such that there were differences in side wall height of as much as 1" in some cases.

Once the top of the side wall was weld overlayed, and machined to give as even a surface as possible, a 310 SS plate was plug welded to the top of the side wall. The machining and thickness of plate added was such that a constant dimension was maintained between the top of the side wall and the bottom of the car slide rail (see figure 2). With the cars back in the machine this would give a flat surface onto which we could seal the top of the cars to the hood.

All the grate bars, 18 per car, were cleaned and straightened. The bars were then sorted and reinstalled in the pallet frame such that the best bars were in the middle of the frame.

After reassembly each car was put in a jig and checked before shipping back to the site. With the tight tolerances set a number failed and required disassembly and remachining.

3.5 Grate Refurbishing

To allow complete access to the windboxes all the dead plates had to be removed from the grate. Dead plates create a seal with the underside of the pallet cars at either end of the grate. They are also used to create different zones within the grate. Figure 3 shows the location of the dead plates along the grate.

Removing these plates was no easy task since some were completely welded and others bolted. The middle dead plate was completely welded and it was only after its removal that we were able to see the full extent of the problem. At this point in the machine there should have been a packed expansion joint. The packing was no longer there and 1"-2" gap was clear to see. This gap could not be detected from the underside of the grate as a main cross structural beam effectively obscured any direct view from the underside.

Another expansion joint running the length of either side of the machine was also without any packing. This joint was between the grate frame and the windboxes and allowed for the different expansion between the frame and the rest of the grate.

Expansion would have been a major consideration in the initial machine design for pelletizing conditions. Temperature conditions in the phosphogypsum application are not as severe and it was determined that expansion at these joints would not be a problem. Rebuilding the expansion joints would be time consuming and would not guarantee air tightness. It was decided to close the joints and weld them tight.

With the windboxes completely accessible a corrosion resistant lining was added to the first three windboxes. The ability of the carbon steel windboxes to withstand the wet gas at the front end of the machine had been an early concern. A bituminous lining was applied to these windboxes. Conditions in the other windboxes where higher temperatures were predicted precluded the use of this lining.

Removing the dead plates was hard but replacing them was even harder. To ensure they remained fixed all dead plates were welded in position. Whereas the previous tolerance between the cars and the dead plate was 1/8" - 1/4" a new tolerance of 60 'thou' maximum was set. Holding this tolerance as the plates pulled and twisted during welding took long hours of sweat and patience by the construction crew.

Two of the original dead plates were not reinstalled. Two extra dead plates at either end of the machine were added. These plates were of a different design not being a solid plate like the original plates. They were fabricated like an egg crate and then filled with partially sintered material to form a seal with the pallet car. This is a standard dead plate used in sinter machines.

Once the grate was reassembled the seal was fitted to seal the top of the cars to the hood. Figure 2, a cross section through the grate, shows the seal arrangement. The seal consisted of 4 layers of stainless shim stock clamped together in a fashion similar to a leaf spring. One side of the seal was attached to the hood. The other side of the seal rides on the top of the car side wall. The layers on this side are cut 1/4" shorter to create the spring effect to keep the seal in contact with the side wall. These seals were installed the complete length of the grate.

A similar seal was used across the machine in three places to achieve distinct zones in the hood section. These seals were installed to maintain a seal between the hood and the expected height of the sinter bed, after shrinkage. They were positioned between the ignition and sinter zones, sinter and cooling zone and the discharge of the machine.

The hood seal problem is specific to the demonstration plant due to the fact that we are using a straight grate. The commercial design utilizes a circular grate with a water seal specifically to overcome this problem.

3.6 Ignition System

Modifications were also made to the ignition section. The ignition system consists of 12 small premix natural gas burners. The top side of the burner was completely open to atmosphere. During the initial running the heat rising due to natural convection was a problem both to the burner system and as an operational hazard.

The top was closed off, leaving a sufficient gap around each burner for secondary air ingress, using a steel plate. A 2" layer of ceramic fibre refractory blanket was installed on the underside of the plate for insulation.

Despite the two long holiday periods in November and December the grate was reassembled and ready for a leak test by January 04. It was with some trepidation that a leak test was undertaken and revealed that all the hard work had a positive outcome. While leakage was still over the design it was well within what we could live with.

The speed with which the repairs were completed and the end result was a credit to the people on site and their commitment to the project.

FIGURE 1

PALLET CAR SIDE VIEW

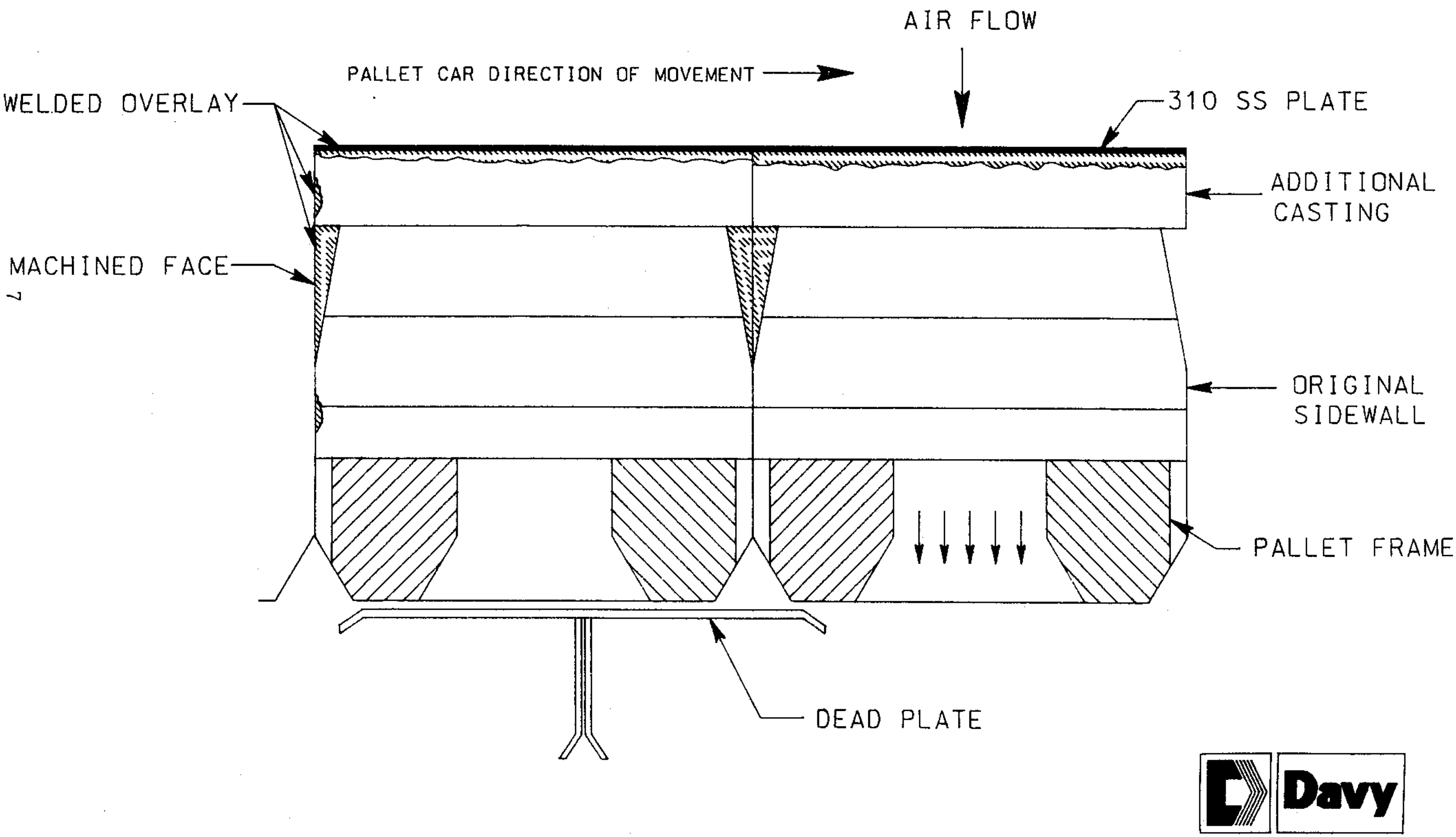


FIGURE 2

SECTION THROUGH GRATE AND PALLET CAR

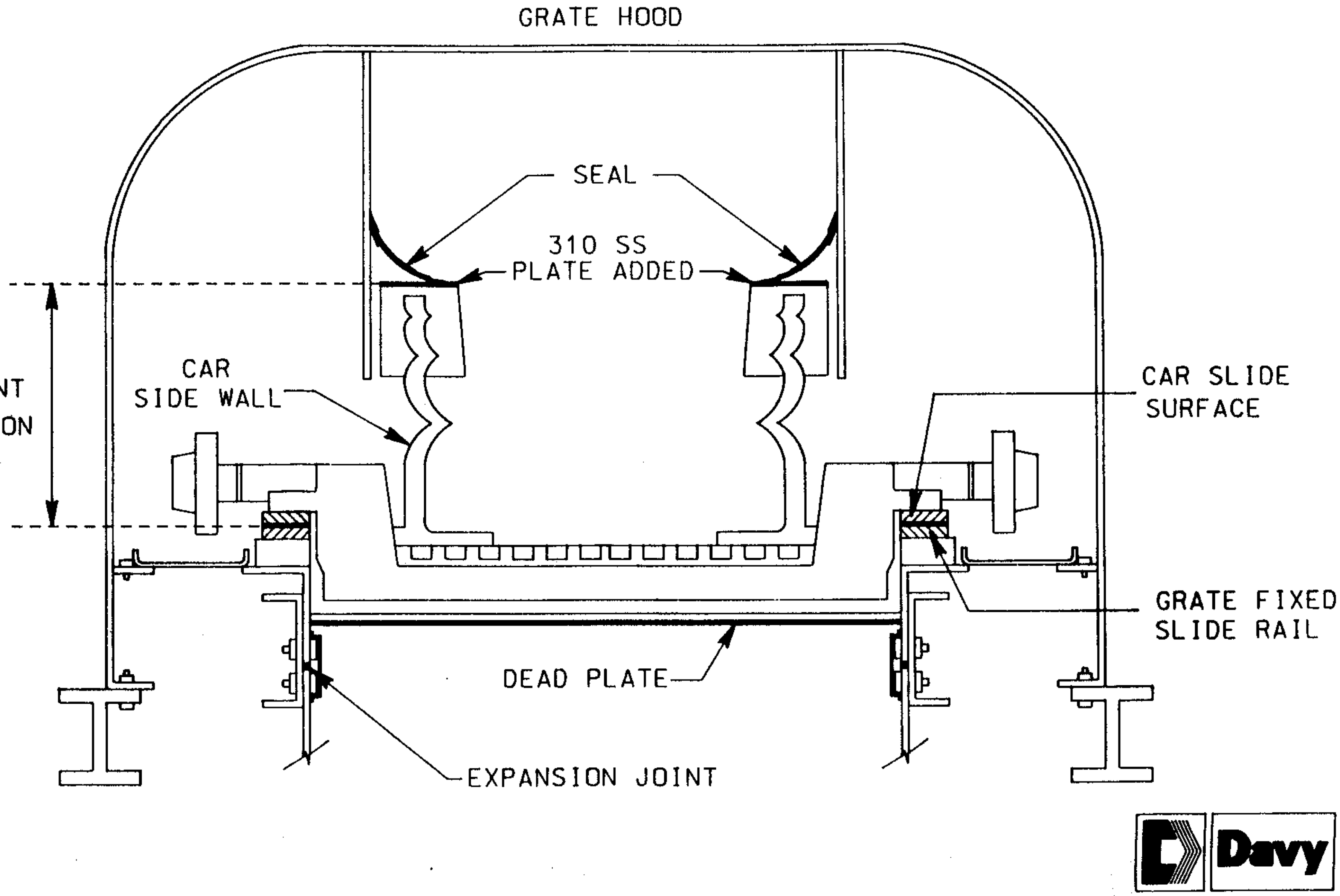
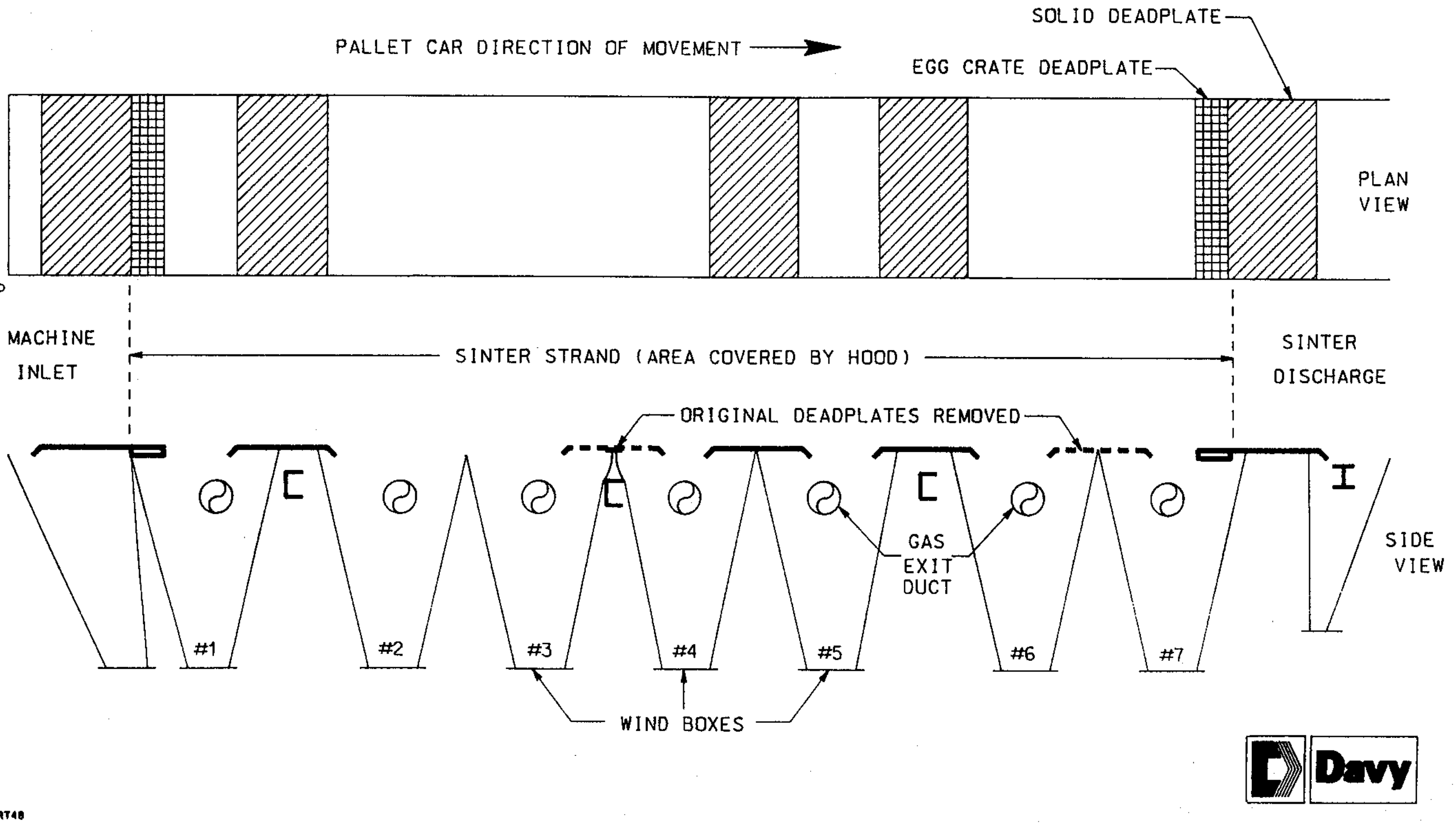


CHART44

FIGURE 3

DEADPLATE LOCATIONS



4.0 TEST PLANT OPERATION

4.1 Summary

The major objectives of the demonstration plant were twofold:-

1) To demonstrate the process on a continuous basis
2) To produce sufficient aggregate for road testing.

The operation to date has shown that the process does work on a continuous basis. The problem with the operation to the end of April has been the consistency of operation. While wide variety of mechanical problems have contributed to inconsistent operation the main factor for the inconsistency has been the raw material feed system.

The plant was started up on 5 January 1989 with 8 hour operating days scheduled for operator training. Since start-up we have progressed from a scheduled operating time of 8 hours per day 5 days per week to a full continuous 7 day 24 hour operation. This was achieved in early April 1989.

By the second week of operation we had witnessed a full bed of sinter being discharged from the grate. While it was recognized that conditions were still not right confidence was high. As with most new processes there is a lot of hard work and this has been no exception, but enthusiasm in the team is progressively overcoming the problems.

A batch mixing system has been in operation since the end of April. Batches are made by weighing the individual components and mixing in a cement truck. The mix is then fed into the old component storage bins before feeding to the plant. By the end of May we expect to have fully implemented the batch system and improved consistency of operation.

Although we have not yet commenced the aggregate production run we expect to see this in the near future. We have seen that the process does work. Our major task in the months to come is to make it work consistently and produce sufficient aggregate for a road test.

4.2 Experience to Date

January

From the initial startup on January 05 operation was planned for 8 hours a day on a 5 day week basis. This was to allow all the operations personnel to be present for training. Up to mid month (Jan 17) the grate was available for 40 hours of operation and was on line for approximately 20 hours.

During this time we encountered numerous teething problems with both the equipment and the system which called for various small modifications and/or additions to existing equipment. Most of these problems centered around the feed system. Changing conditions of the feed materials (particularly gypsum) required experimentation with the timers on the auger feeders and the bin blasters to maintain flow from the bins.

Problems with the feed material sticking to the main feed belt required the addition of an air header at the discharge point to blow material off the belt. An air drier had to be installed to dry the compressed air for this application.

Excessive pressure drop generated by the venturi scrubber required modification to the throat dimension.

By mid month despite limited operation and the ability of the operators to make good feed pellets consistently we had achieved some success. We had produced 'returns' (in large quantities!) and also some sinter. The sinter produced was sufficient for use as hearth layer and allowed us to discard the limestone used for the initial startup. Conveying the limestone from the main storage bin to the hearth layer feed bin had been a problem. The feed bin had been filled manually using the old standby of manpower and lots of pails!

Operating hours were extended to 16 hour days as from 18 January. For the rest of the month the grate was available for 90 hours and on line for approximately 50 hours. The change to extended operating hours was due to the 4-5 hours of operating time required to warm the grate to normal operating temperature. With the 8 hour shift we were starting to make sinter just as we were planning to end the shift.

The first day of extended operation gave us our first full bed of sinter to be discharged from the grate. The sinter was so hard that it partially tore the sinter breaker from its mounts in the sinter discharge chute and badly bent a couple of the sinter breaker prongs.

Later investigation revealed the gypsum feeder to be out of calibration. This had altered the chemistry of the mix and driven us into a point on the phase diagram were melting occurred. The material discharged from the machine was completely solid instead of the porous sinter it should have been.

February

Although some sinter had been made during January we had struggled to make a good feed pellet on a consistent basis. While this was partly due to operator inexperience the variability in the feed system was a major factor. The feed pellets being made in early February were too high in moisture content and variable in size distribution. These variations caused excessive pressure drops across the sinter bed leading to the bed collapse and loss of air flow across the bed.

To overcome the poor pellet quality the bed depths was reduced by increasing the hearth layer depth to 4". The improvement in performance was substantial, with the grate discharging a higher proportion of cars sintered than partially burned material. Some of the aggregate produced during February gave some of the best LA abrasion tests we have ever seen with numbers less than 30%.

While operation seemed to improve during the first two weeks we were still plagued with minor mechanical and feed system problems. Cold weather especially during the evening caught us unaware and frequent changes in the correct coke addition rate had to be made.

During this period operation was planned for 112 hours with the grate actually running for 73 hours. When one allows the warm up time of 4-5 hours as the plant was started each day this only left approximately 40 hours of true operation.

Planned operation time was extended from 13 February to a full 24 hours a day. The first day of 24 hour operation was cut short by a mechanical breakage on the nodulizer feed conveyor. The second days operation however gave us our best day to that stage. Confidence was such that feed rates to the plant were increased from 60% of design to over 80% of design.

The next days operation however was not good. This complete turn around from good to bad operation has been typical during the first months of operation as we have come to grips with the plant. Externally everything looked good. The feed mix had not changed and gas flows looked good. From the material discharged it was obvious that gas flow was a problem.

Another leak test on the grate revealed no leakage problem. Abnormally high readings on the flow instrumentation led us to believe the problem was probable due to a blockage in the gas ducts exit the windboxes. Inspection revealed severe blockages in the windboxes and ducts due to material dropping between the grate bars.

Modifications to allow material to be removed from the windboxes were required. A number of maintenance items were in need of completion and a combination of factors dictated that a change would have to be made, at some stage in the future, with regard to the acid plant train accepting gas from the grate.

The plant was shutdown after operation on the 21 February for nearly 4 weeks to make the changes. Over the period from the 13 Feb to 21 Feb 85 hours of operation out of a possible 168 hours were achieved. Although a continuous 24 hours of operation was never achieved restart time had been reduced as the operators became more familiar with the operation.

March

Pellet feed quality remained a real concern during February. The pellets were weak and had no integrity. When fed to the grate many would just break apart as the pellets fell off the feed conveyor onto the grate. The opportunity was taken to complete some tests in Florida with the plant feed mix.

Tests in Bartow indicated that we had been losing a good proportion of the bentonite from the feed mix. Bentonite is used in the mix purely as a binding material for the pellets. The bentonite was the last material to be fed to the main feed belt and being the lightest material it was thought the air blower at the belt discharge was blowing much of the bentonite into the dust extraction system. Since installation of the air blower header a significant increase in material collected by the dust extraction system had been noticed.

During the shutdown the bentonite feed bin was moved to a different feed position. Bentonite is now fed upstream of the gypsum & pyrites.

Plant modifications were complete by March 14 and plant systems tested on March 15. With the bentonite problem addressed and a clean gas system optimism was high that by month end aggregate production would not be problem.

Consistency of pellet feed was still a problem. Size distribution and moisture level was a continuous problem. A number of days were set aside explicitly to allow the pellet operator to vary the pellet making parameters without regard to the sinter quality. By learning the relationship between disk speed, disk angle, feed addition point and water spray patterns it was hoped a better and more consistent pellet would be achieved. The operators were encouraged to experiment with these variables by a restriction placed on the amount of water that could be added to the material in the pan.

Problems with the feed system persisted during the month. The feeders especially the gypsum feeder required almost constant calibration. The vendor was called to site in late March to completely overhaul and reset the system. With a reset feed system and operators much more familiar with the pellet making process April was looked forward with anticipation.

April

The feed system problems were brought to a head in April which dictated a major change in operating philosophy. At the end of March a continuous recording had been connected to each of the raw material weigh belts. Reviewing the charts showed that delivery of gypsum and pyrites to the main feed belt was anything but constant.

At times gypsum and pyrites flow would drop to zero then regain its set rate. A fall off in these flow rates had been noticed on the local indicators but frequency and extent of these fluctuations was not realised. This was causing slugs of material to be delivered to the pelletizing dish.

Early in the month we were suddenly unable to extract pyrites from its feed bin. Previously, with the pyrites bin full, extraction had not been a problem. By early April, with pyrites level below the augers, extraction was practically impossible.

During storage the pyrites had changed in nature due to some oxidation. This oxidation had produced a wetter, sticker pyrites. The flowing characteristics were worse than anything we had experienced with gypsum.

By mid April we decided to abandon the continuous feed system. A batch mix system using a standard cement mixer truck was set-up. Initial experiments with gypsum were not encouraging, with most of the gypsum sticking to the cement mixer internals. Persistence paid off and a way to mix the feed was determined. All the feed components, apart from the fuel, are now weighed and dumped into the cement truck mixer. The feed mix is then stored in the old feed hoppers and fed to the plant. Coke is still added as previously to allow on line fuel control.

Since going to the batch mix we have seen an improvement in consistency. To further control the feed mix and to account for the variability in the gypsum we will go to a bedding type operation. Bedding is a technique used in the iron and steel industry to successfully control the sinter mix.

Bedding involves making two piles. The first pile is laid down in thin layers length wise. The end pile will consist of some 400-500 layers of the mixed material. The first pile is then cross cut and a second pile made in the same manner as the first. The second pile is then feed to the plant.

This bedding technique will be applied to the gypsum, pyrites and returns before the feed mix is prepared in the cement mixer. The mix from the cement truck will then be bedded to give a 4-7 day supply of feed mix. This will allow much greater control of feed mix chemistry.

By the end of May the whole batch mix system with the necessary weighing equipment will be in place. Control of the mix will be more precise. While the feed mix flows out of the bins better than pyrites or gypsum feed rate control is still a problem, though not as serious as previously, and we still have to work on this aspect.

5.0 TEST PLANT ACHIEVEMENTS

While we have struggled to maintain a consistent operation we have learned a tremendous amount in the past few months and achieved much. Mechanical troubles, problems with the feed system and consistency of operation should be looked on with a positive note.

This has added to our knowledge particularly in relation to the design and operation of a commercial scale plant. If the plant had run without any problems from November of 88 we would never have encountered the pyrite oxidation and the subsequent dramatic change in flow characteristics. We have seen erosion problems in the feed system and the importance of the feed system design.

In terms of operation we can now recognize the different causes of bad sintering. To date we have covered a whole range. Problems due to low fuel, excessive moisture in the pellet, loss in feeder calibration etc. are now more easily identified. The problems encountered now will make commercial operation much easier.

A number of goals were set out for the test plant. These goals were spelled by Kendron in 1987[1] and are summarized below:

1) Demonstrate continuous production of a solid product suitable for road construction.

2) Produce sufficient quantities of aggregate for road tests.

3) Develop steady state solids side data for scale up.

4) Collect gas side data and verify continuous SO_2 production.

During the limited operating period we have seen some objectives achieved. When the feed pellet to the grate is within the specification we have witnessed process performance measuring up to expectations. Predictions based on the batch unit results and the plant simulation (using ASPEN/SP[5]) have been verified. In particular we have been able to demonstrate the process works in that we have achieved:-

- Continuous sinter bed
- Constant SO_2 gas strength

During the periods of good operation we have seen things that have confirmed initial predictions as well as some things that have surprised us. In particular:-

i) Reduction in the ignition layer (the top surface of the sinter bed) compared to batch unit operation. This is important since the ignition layer generated a significant amount of returns in the batch unit. Reduction in this removes concerns that too much recycle would be generated.

ii) The reduction in return material due to the grate wall effect has met our predictions. In the batch unit a thin layer of material remains unsintered. This gives a material similar to ignition layer which again becomes part of the recycle stream. The amount of material produced by the wall effect per total material produced was predicted to be considerably less and indications are that this is true.

iii) The grate factor is an important design parameter extracted from the batch unit. Before any commercial design raw materials to be used in any commercial plant will be run in the batch unit. Data extracted from these tests will then be used to size the commercial plant. This is standard sintering practice. Time to sinter the complete bed is closely matched to that predicted by the batch unit tests. The demonstration unit is showing that we can apply this technique to the phosphogypsum process.

iv) Gas Temperatures. Temperatures exit the different sinter and cooling zones are close to our predictions based on data from the batch tests and the plant simulation.

When operation has been good, i.e. good consistent pellet feed, we have seen continuous sinter beds and constant SO_2 gas strength.

We have produced product with excellent LA abrasion results. Our problem has been to produce it consistently. Periods of good operation to the end of April had not been frequent, but the situation is improving progresstively.

We believe we are starting to bring our mechanical problems under control. Some of the major breakdowns to date have been with the old grate equipment as a result of age. In general new parts and even modifications by the plant staff to this equipment should prevent these problems occurring in the future.

Repetitive downtime due to pugmill trips and windbox blockages is being reduced by introducing set maintenance and operating procedures. With the new feed system in place by the end of May we hope to find the consistency that has been so elusive the past 4 months.

In the months to come the specific goal is to produce sufficient aggregate for a road test. While a certain amount of process data can be extracted from the operation to date a longer consisted operational period is required.

6.0 BATCH UNIT

Since last reporting on the process (1) the batch test unit has been moved to The Florida Institute of Phosphate Research facility in Bartow, Florida. This has allowed completion of approximately 300 tests in the unit since its installation in late 1987. Mike Lloyd, now, can virtually tell before he fires the batch unit what the performance is going to be by the quality of the feed pellets and the initial ignition performance.

The substantial number of batch tests has dramatically increased our database of information and has played an important part in fixing some of the parameters in the demonstration unit. As problems have arisen with the demonstration unit we have been able to use the batch unit to produce solutions.

With the batch unit at FIPR we have the ability to control the batch work more closely. With Mike Lloyd able to control the analytical and test work, much progress has been made in both refining and understanding the process. Previous batch work had been concentrated in determining what mix of components would work. We now have the ability to purposely push the process towards a failure mode to fully determine its limits.

From the tests completed in the past year, we are predicting an increase in grate factor. This is an important step as this leads to a reduced grate area and hence reduced capital cost.

7.0 ECONOMIC CONSIDERATIONS

At this time we see no reason to update previously published economic data [2,3]. The case presented by Kendron [2] proposed a retrofit phosphogypsum plant to a 1000 TPD P_2O_5 complex with a natural gas turbine to cogenerate power and steam. For this case, at 1989 costs, we forecast a sulfuric acid production cost in the \$35 - \$40/st range with a 20% ROI before taxes.

Present indications from the demonstration plant show that we do not require additions to the flowsheet or equipment and hence increase capital cost. Batch tests are indicating that we can reduce the grate area and initial data from the demonstration plant is confirming this. Initial data from the demonstration plant also indicates we may have been too conservative with regard to materials of construction in previous capital estimates.

It is our intent to collect as much data as possible from the demonstration plant and fully review this data before reviewing the economics. A complete review of the demonstration plant data will allow for better capital cost estimate.

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Prior to FIPR, Mike worked at Agrico Chemical Company and held positions in research, process engineering and production of fertilizers, phosphorus, and both wet and furnace phosphoric acid. He received a BChE degree from Clemson University in 1950.

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9.0 REFERENCES

(1) Kendron, T.J., Marten, J.H., Lloyd, G.M., "Phosphogypsum Recycle - Aggregate Production Test Plant". American Institute of Chemical Engineers, Central Florida Section, Clearwater, Florida (May 1987).

(2) Kendron, T.J., Marten, J.H., Lloyd, G.M., "Phosphogypsum - The newest sulfur resource." Sulphur 87, Houston, Texas (April 87).

(3) Kendron, T.J., Lloyd, G.M. "Phosphogypsum To Sulfuric Acid With Cogeneration - A Competitive Edge." Second International Symposium on Phosphogypsum, Miami, Florida (December 86).

(4) Marten, J.H., Lloyd, G.M., Kendron, T.J. "Phosphogypsum: A problem becomes an opportunity." Spring National Meeting, AIChE, New Orleans, Louisisana (April 86).

(5) ASPEN/SP is a trademark of JSD Simulation Service Company Denver, Colorado.