Engineered Packing System for Acid Contact Towers

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Abstract:

Replacement of an HRS tower presented an opportunity to utilize an engineered packing system designed for low energy consumption. The system combines knowledge gained through many years of experience and computerized modeling to produce packing specific to acid tower service with predictable results. The packing system addresses material, strength, shape and acid surface to maximize mass transfer and minimize gas side pressure drop. The selected system not only resulted in reduced energy consumption but brought with it significant side benefits to the replacement project and to the plant operation.

The installation, the benefits and a brief history of the engineered packing system are presented.

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1.0 Bartow HRS Tower Installation

The HRS tower in the #5 Acid Plant at Bartow was installed in 1992. The tower shell had deteriorated making replacement mandatory and plans were put in place to carry out the replacement in 2007.

Each of the acid plants at the Bartow facility produces waste heat steam that is used to generate electrical power. The amount of electrical power that can be generated is dependent on the amount of steam consumed in plant operation. Replacement of the #5 plant HRS tower presented an opportunity to increase the amount of steam available for export.

Various types of packing were investigated and a decision was made to install a D&M Hodgson system utilizing HP+ packing.

1.1 Installation:

The packing was delivered to site in D&M Hodgson "green" boxes containing 2 cubic feet of packing per box. The boxes were received on pallets in quantities of 20 boxes per pallet or 40 cubic feet of packing per pallet and were stored in the yard pending installation. The packaging system suffered no ultra-violet damage and the green boxes were used for loading the tower.

Empty D&M Hodgson boxes were later used to handle other products whose packaging had suffered ultra-violet damage making handling difficult.

Limited space was available around the tower loading area and trailer loads of pallets were brought in to suit schedules for other activities. The green boxes were used to contain any refuse from the loading and a clean work area was sustained throughout the tower loading.

Reconstruction of the HRS tower allowed loading of the packing before the top was placed on the tower. The first layer of packing was hand placed using notches in the packing wings to support a highly open interface between the packing and the support grid. Saddles, locked in place in this manner, are capable of supporting manpower without incurring damage. Random dumping of green boxes was carried out from this point until the tower packing was completed.

As well, with the top removed from the tower entire pallets were hoisted into the tower and placed on top of packing already in place to allow the work crews to unload the new pallet. No plywood or any other protective device was needed to protect the packing and no damage to the packing occurred.

A wall layer of 2 inch standard saddles was placed to create a high wall pressure drop in the lower part of the tower forcing the gas away from the wall and into the HP+ packing. Metal deflectors, seen in the photo, had been installed in the new shell that could have precluded the need for the 2 inch saddles.

Prior to topping-off the packing, the distributor was placed in position resting on the packing with no need for plywood or other protection to the packing. No damage to the packing occurred.

Following installation of the upper section of the tower, the distributor was supported by hangers, leveled and the topping-off of packing was completed.

Clean-up of the tower below the packing support level consisted of removal of chips and broken saddles created during removal of the previous packing. Only several small pieces of red shale were found.

1.2 Performance

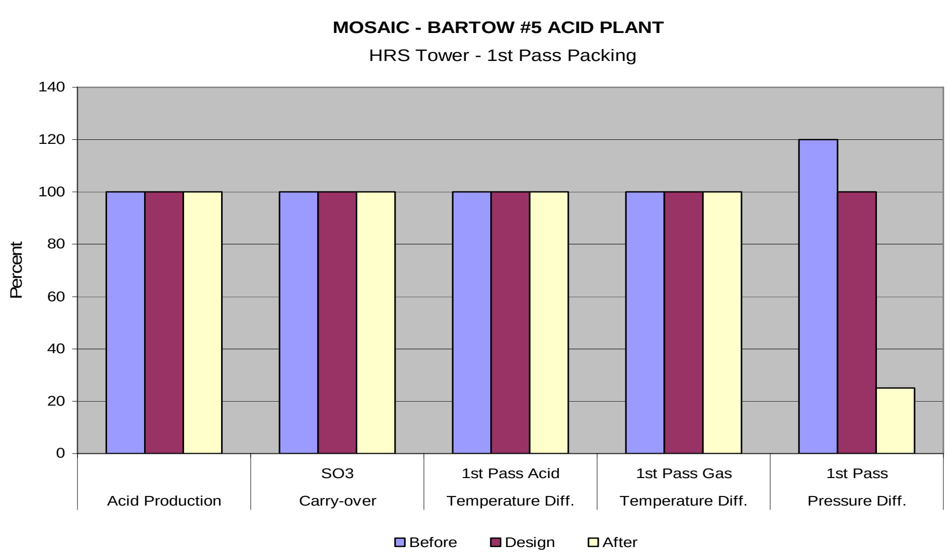
1.2.1 Construction/Installation

Timing:	48 hours had been scheduled for installation of the packing. 18 hours were required including about 4 hours of delay for other activities.
Quantities:	The quantity of packing delivered was more than adequate for the tower volume and some packing was returned to the supplier.
Damage:	There was minimal damage to the packing and any breakage that did occur resulted in large pieces that will not migrate into the acid system.
Refuse:	All packaging was contained and returned to the supplier with the excess packing. There was no contamination of the packing in the tower.

1.2.2 Process

Pressure drop across the first pass of the HRS tower has decreased more than 80%. Typical pressure drop in Bartow's HRS towers, 1st stage, with standard ceramic saddle packing, has been 8" H_2O column. This has been measured in both #4 and #6 plants after packing was changed during recent tower rebuilds. The pressure drop in #5 plants' HRS tower with the HP+ packing is 1.5" H_2O column.

This reduction in pressure drop equates to 144 hp savings in main blower steam consumption, or 0,1 MW. This translates to a $60k savings in power purchase annually. Normal functioning of tower internals and the expected absorption rates have been verified by stick tests, carry-over measurements, acid and gas stream temperatures and, the overall plant production rate.



2.0 D&M Hodgson Packing System

Problems with Acid Contact Tower performance have been a persistent part of tower history. These problems together with increased energy cost demonstrated a need to examine the packing systems being used and to engineer a packing that could cure a number of the problems while reducing energy requirements.

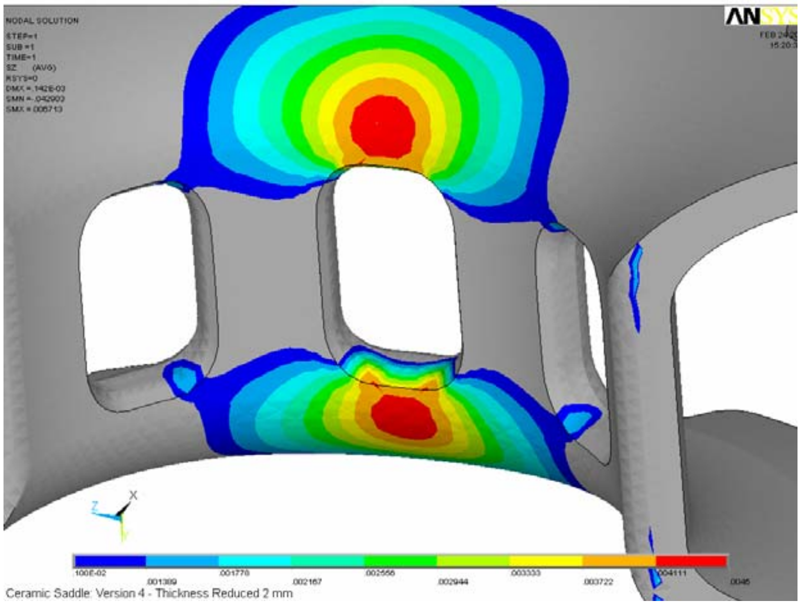
Ceramic packing configuration has been adjusted numerous times trying to address the performance problems. Three such configurations are shown in the photo below. The packing in the forefront is reminiscent of the original packing configuration developed by Dr. Max Leva, the center one is the HP packing developed by Dr. Gordon Cameron and Cecebe technologies and, the background one is the engineered HP+ offered by D&M Hodgson & Associates.

There are numerous other configurations and these are only presented as an illustration of variety.

Much of the work done in the past to develop and improve ceramic packing was largely independent of tower performance until after-the-fact. Work done by Dr. Leva and further refined by Dr. Cameron for tower performance modeling, combined with empirical data from a number of different packing designs helped establish criteria for an engineered product. The basic arch shape and the packing tower calculations are all that remain of previous packing designs.

2.1 Design

Available design techniques presented an opportunity to produce a packing that could address the issues. Computerized finite element analysis (FEA) combined with a computerized packing performance model enabled evaluation of materials, shapes and properties simultaneous to performance modeling. An iterative process was used to narrow down desirable design features that best suited the performance criteria.



Ceramic Saddle: Version 4 - Thickness Reduced 2 mm

An important feature of FEA design is the capability of predicting;

- the breaking strength,
- where breakage will occur,
- the number of pieces that breakage is likely to produce and,
- size of the pieces generated when breakage occurs.

Numerous breakage and chip counts were performed on a variety of designs in engineering the HP+ packing.

As well as breakage, tower internals are never static and a packing system with high resistance to chipping in a dynamic application was not only desirable but was considered to be a mandatory component of the system.

The following photo is of a piece of HP+ packing broken during the Bartow installation. As the photo shows the packing did not shatter but broke where it was designed to break, generated two large pieces and one small (about 1” by 1” by 0.125” thick) piece.

Features of the shape were an important factor in producing a packing suitable to a number of existing packing support systems while minimizing pressure loss across the interface. The support grid at Bartow is a metal grid as indicated in the mock up in the next photo. Where feasible, a mock up of the support interface is used to determine the best arrangement to minimize pressure loss across the interface.

Ceramic support grids on ceramic beams and ceramic dome designs are accommodated by the packing system design with similar minimal losses across the interface.

2.2 Materials:

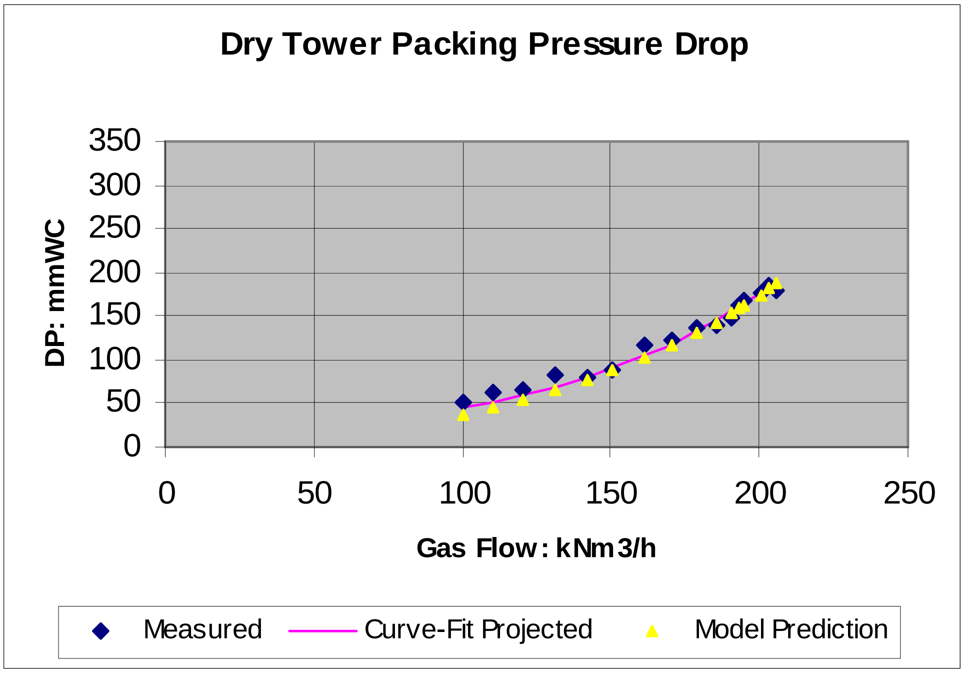
In selecting a material, red shale versus chemical porcelain was evaluated for compatibility with sulfuric acid service while providing a structurally strong shape and having the properties desirable for mass transfer. While both products can be used, the red shale has some superior qualities that make it the material of choice.

Raw material consistency, chemical composition and firing control are used to produce predictable water absorbency, wetting characteristics and chip resistance of the product.

Red shale (acid bricks and tiles) has been used for many centuries in the sulfuric acid plant industry and generally lasts the life of the plant.

2.3 Tower Performance

A packing performance prediction model was used in developing the packing system and was used in predicting the savings that could be expected for the Bartow installation. The information used in the model predicts the quantity of packing required for a given tower and the expected pressure loss for the operating conditions. The model has been proven using blind testing on Cecebe HP saddles versus standard saddles. Blind test results from one test are shown in the graph below.



Using the same model, the quantity of packing required for the Bartow tower was predicted as 25 pieces per cubic foot of tower volume. Actual quantity used was 24.8 pieces per cubic foot. The pressure drop reduction was predicted as a 60% reduction from the standard saddles and actual has been > 80% reduction using the HP+ packing.

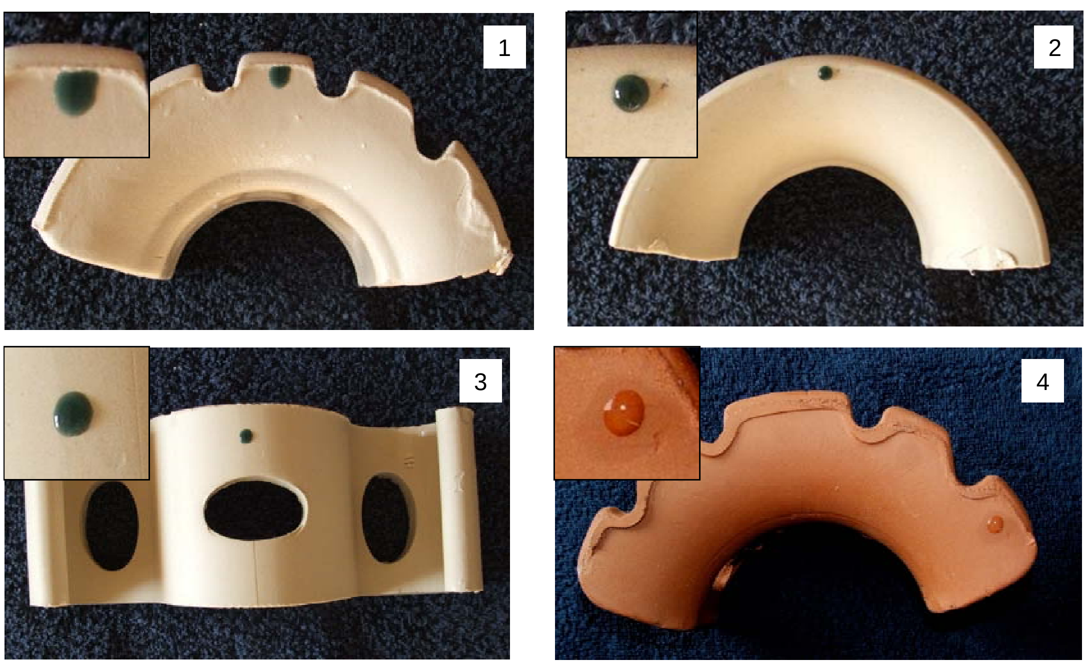
2.4 Wetting

HP+ packing has been engineered to maximize acid surface exposed to gas. The effectiveness of this is reflected in wetting ability. Wetting is dependent on “actual” area as opposed to “apparent” area with wetting ability being directly proportional to the actual area of a droplet in contact with the surface.

The surface topography of HP+ packing is controlled to provide a high actual area and thus achieve a high level of wetting ability. In the photos below, the droplet size is identical in all cases and the apparent area can be considered identical. The actual area in Photo 1 is somewhat larger than in Photo 2 & 3 but considerably smaller than the actual area in Photo 4.

The photos were taken under the following conditions:

1. All were collectively pre-soaked in hot water for 2 hours then wiped dry of superficial water.
2. Identically sized droplets of colored water were placed in locations where gravitational forces were minimal.
3. 30 seconds elapsed time was allowed from placement of droplet to photo
4. Because of the high surface area and superior wetting characteristics of HP+, the droplet shape would not remain competent and the elapsed time had to be shortened to 15 seconds.



Wetting ability of the ceramic surface is directly proportional to the actual area of the droplet in contact with the surface

2.5 Construction

Considerable effort was expended in engineering a product suited to the service. In keeping with the high standard that demanded this effort, construction/installation methodology was engineered to achieve similar improved performance.

The engineered results are:

- Shipped packing fills the tower. No running out during installation. What is normally referred to as "settling allowance" is the result of an inability to accurately calculate the quantity required for specific volume. The model used is capable of doing this calculation accurately.
- A packaging system not sensitive to weathering.
- A system that minimizes potential for contamination within the tower. Minimal packaging material and no need for protective plywood, etc. during installation.
- The packaging material and boxes are easily removed from the tower and subsequently from the work site.
- A clean work site during and following installation.
- Ergonomic handling of packing.
- Minimal clean-up of chips following packing placement.

3.0 Summary

There are opportunities in sulfuric acid plants for increased efficiencies. Application of the following can result in realization of these efficiencies.

- Historical experience
    - Operating towers with different packing systems
    - Empirical data accumulation
    - Plant experiences
- Today's knowledge
    - Manufacturing techniques
    - Service criteria
- Current engineering techniques
    - Fluid Dynamic Analysis (FDA)
    - Finite Element Analysis (FEA)
    - Process Modeling
    - Physical modeling
- OWNER SPONSORSHIP
    - Risk versus benefit analysis
    - Capital cost comparison
    - Operating cost analysis

4.0 Credits

Significant progress events are almost always due to inspired effort by one or more individuals and the authors would like to recognize the input of two such individuals and

the inspiration their work provided to others of us, facilitating the packing system presented herein.

Dr. Max Leva
Dr. Leva pioneered the packing systems currently used around the world by developing accurate methods for predicting the performance of these systems. Following his invention of the saddle type packing, his work has been the basis of packing development and was a stepping stone in arriving at the system presented here-in.

Dr. Gordon Cameron
Dr. Cameron has taken the work that Max Leva did to the next stage of refinement. Dr. Cameron used his extensive experience together with field performance data to establish design criteria for packing and a method of modeling to enable prediction of performance.

5.0 Acknowledgements

We would like to acknowledge the efficiency of the installation teams from Southeastern Industrial whose input and comments during the installation were much appreciated.

D&M Hodgson would also like to acknowledge the engineers at the Minerals and Metals Division of WorleyParsons, in their Toronto office, for their patience and expertise in running FEA simulations of numerous prototypes during the engineering stage.

6.0 References

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