Variable Frequency Microwave Moisture Leveling

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ABSTRACT

A variable frequency microwave system was examined to replace an existing carousel resistance heating line as the method for drying of mouth swabs for the pharmaceutical industry. A pharmaceutical manufacturer located in Northern Illinois had a resistive heating system that was not drying product satisfactorily, thus requiring additional ambient drying time even after a 30-minute drying cycle. Since the swabs are used for the healthcare industry, the amount of moisture present after drying was critical to avoid the formation of mold on the product that could have lead to dissatisfied customers. Variable frequency microwave moisture leveling allowed better product quality while turning the manufacturing operation into just in time delivery. During pilot scale testing, a 300 times cycle improvement was realized for variable frequency microwave compared to the conventional carousel resistive drying unit (24 hours to 5 minutes). The projected total cost of the variable frequency microwave system is $1 million, with 25% of the cost in the microwave unit and 70% of the cost in a new autobagging system. We projected a $0.58 million saving per year in reduced operational costs with productivity increases. Although the project would have had a 1.8 year payback time, it was not implemented due to the capital expense and risk of an unknown technology.

INTRODUCTION

Energy efficiency improvements and production enhancements have long been issues that many industrial manufacturers have tried to improve on. Unfortunately, in today's manufacturing facilities, many of the engineering services and much of the support that was available 10 to 20 years ago is no longer present due to downsizing. Therefore, many opportunities related to energy efficiency and improvement of production operations have been overlooked in favor of keeping production operating.

ComEd has identified this as an opportunity to assist their customers by providing engineering services and support functions, previously carried out by the customers' internal engineering departments. By focusing on energy efficiency evaluations and production enhancement opportunities, customers are able to reduce operating costs and improve competitiveness. ComEd supports the manufacturer by performing the following:

- Visit manufacturer site and perform a cursory evaluation of electric, gas, water, and wastewater operations.
- Qualify and quantify the opportunities identified from the cursory evaluation in the form of a report.
- Review the opportunities and further quantify initial findings through a detailed engineering analysis.

- Review the detailed analysis with the manufacturer and pursue implementation of the opportunity.
- Implement the opportunity either directly through the utility or through a third party with project management.

By following this format, the customer and utility benefit by increasing relationships and potentially expanding production output of the customer. An increase in production output can mean more electrical consumption, an increase in market share, decreased operating costs, and a satisfied customer, which is crucial in the face of electricity deregulation.

This methodology was followed as described above when a pharmaceutical manufacturer located in Northern Illinois approached ComEd, the local electric utility, to identify technologies that would aid in increasing production line speed and improving product quality. Upon visiting the customers site, the product under review, which consisted of a polyester polyurethane base with a sodium bicarbonate coating on the top surface, required a 24-hour drying cycle time. The existing process of preparing and subsequently drying the product is shown in figure 1.

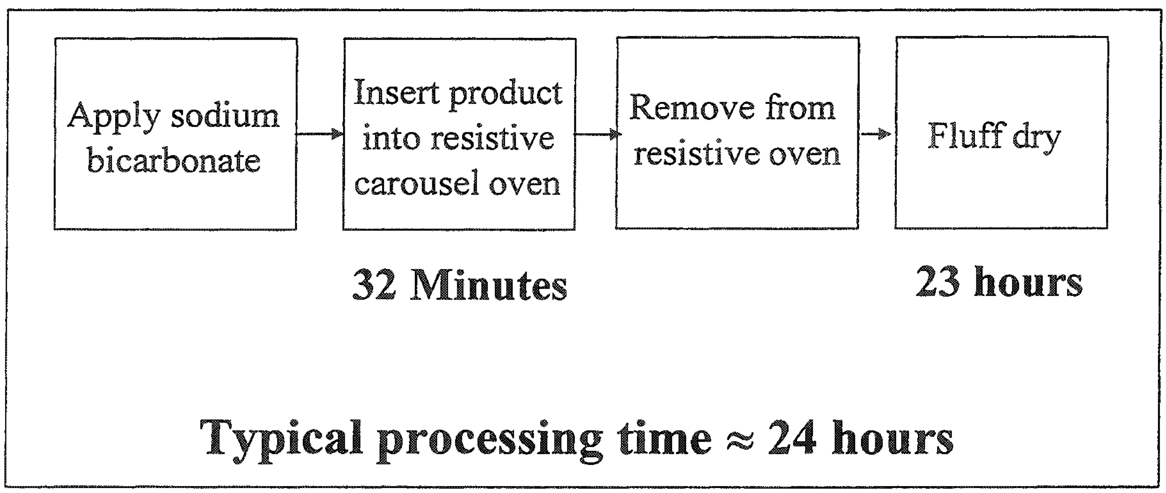

Figure 1. Existing Procedure for Applying Coating and Drying with Average Dwell Times

The long time required to dry product was not acceptable to the customer, however, the end result in quality was satisfactory. The underlying concern of the customer was that a decrease in product quality would not be acceptable. With that key concern in mind, ComEd investigated technologies that would reduce the drying cycle time and meet or exceed existing product quality standards. After consulting with the Electric Power Research Institute (EPRI) on alternative technologies that could dry the product while increasing productivity, the technology that appeared to be capable of drying this product to an acceptable level while increasing production speeds dramatically was microwave - specifically variable frequency microwave. This technology was chosen due to the inherent nature and sensitivity of the product to be dried, since microwave technology does not necessarily heat the surface to the degree that conventional drying does. Once this technology was identified, ComEd contacted Lambda Technologies, a Variable Frequency Microwave (VFM) vendor located in Raleigh, North Carolina, to assist with the technical and economic evaluation of microwave technology. Working with Lambda Technologies would allow the product to be pilot scale tested with minimal involvement or risk from the customer, with ComEd assuming the project management role for the customer.

The scope of the study would involve the customer providing adequate material for testing, along with Lambda Technologies providing the equipment and microwave expertise for the analysis. ComEd would act as the project manager for the project such that the customer would not become burdened with the analysis. The study would take one week and would provide answers to the following:

- Feasibility of technology.
- Potential drying cycle time.
- Conformation to existing product quality measures.
- Cost of equipment.
- Potential decrease of employee intervention.
- Energy cost savings/penalty.
- Integration of microwave system into autobagging and loading stations.

The results would then be presented to the customer for review and acceptance to proceed with full-scale testing.

Methodology

In order to properly analyze the product, several samples from the customer were provided to Lambda Technologies for microwave application feasibility testing. ComEd's and Lambda Technologies goal was to determine whether or not microwave technology would work and what associated costs/savings would be involved. Once the scope and goals were clearly defined, Lambda Technologies set out to identify the following:

- Feasibility of variable frequency microwave technology on product.
- Weight of product, both base and solution, before and after testing.
- Optimum incident frequency.
- Bandwidth.
- Sweep rate.
- Required irradiation time.

The test would involve the use of a Lambda Technologies Vari-Wave 1500 microwave laboratory test unit, a Denver Instruments XL-1800 scale, two teflon 5" X 2" round pedestals, one package of dry Kimwipes tissue paper, and a camcorder to videotape the entire testing process for ComEd and the customer to review.

The test of the product would involve sample sizes of one unit, six units and ten units at one time in the cavity. Lambda Technologies test methodology for this analysis was as follows:

- Based on product composition, preliminarily determine incident frequency, bandwidth, sweep rate, and estimated irradiation time.
- Secure base pad and sodium bicarbonate for test.
- Weigh base pad and sodium bicarbonate solution prior to application.
- Apply sodium bicarbonate solution to base pad according to manufacturer specifications.
- Take total weight reading prior to microwave oven insertion.
- Insert product into microwave cavity.
- Perform multiple tests to determine optimum settings for microwave in order to dry product (moisture level).
- Remove product from microwave cavity and test for moisture content utilizing Kimwipes.
- Using a scale, test weight of dried product.
- Review product for material destruction (e.g. disintegration of base pad, flaking of sodium bicarbonate, arcing marks).
- Provide product to ComEd personnel for presentation to manufacturer.

Results

Through pilot scale testing, several of the previously outlined questions regarding the feasibility of variable frequency microwave technology were answered. The results of the test were as follows:

- No visible damage to the base pad, no arcing of the solution material on the pad, no flaking of sodium bicarbonate solution, and no moisture content as observed with use of Kimwipe
- Original weight of pad = 11.71 grams; Solution weight = 2.19 grams; Total weight = 13.9 grams
- Total post-process weight (pad and solution) = 12.05 grams
- Total weight loss = 1.85 grams
- Incident frequency = 10.7 GHz
- Bandwidth = 800 MHz
- Sweep rate = 100 ms
- Irradiation time = 160 seconds
- Estimated variable frequency microwave production unit cost = $250,000

The results of this test were quite impressive to the customer. However, at the time of research, a conveyorized, constant throughput variable frequency microwave unit was not available. Therefore, in order to incorporate this technology into the existing production line, two transfer tables would be required to stage, load and off-load the product in a timely fashion. Although this was not a negative aspect of the project, it did mean that an additional $60,000 would be required. Also, since the line speed of this operation would increase quite substantially, the customer felt that they could go to a "Just-In-Time" production schedule. In other words, as the orders were received for the product, the customer could produce product and ship it with no warehousing of produced material, therefore requiring no storage areas and achieving a very fast turnaround time for orders. To achieve the "Just-In-Time" approach, the customer would incorporate an autobagging system to take finished product off of the conveyor and insert it into a package without human intervention. The autobagging system would cost the manufacturer an additional $700,000 to incorporate. Therefore, the total cost for incorporating variable frequency microwave into the production line in place of the current electric resistive oven would be:

- Variable Frequency Microwave Oven ≈ $250,000
- Transfer Tables ≈ $60,000
- Autobagging System ≈ $700,000
- Total Installed Costs ≈ $1.01 Million

The proposed VFM arrangement is shown in figure 2.

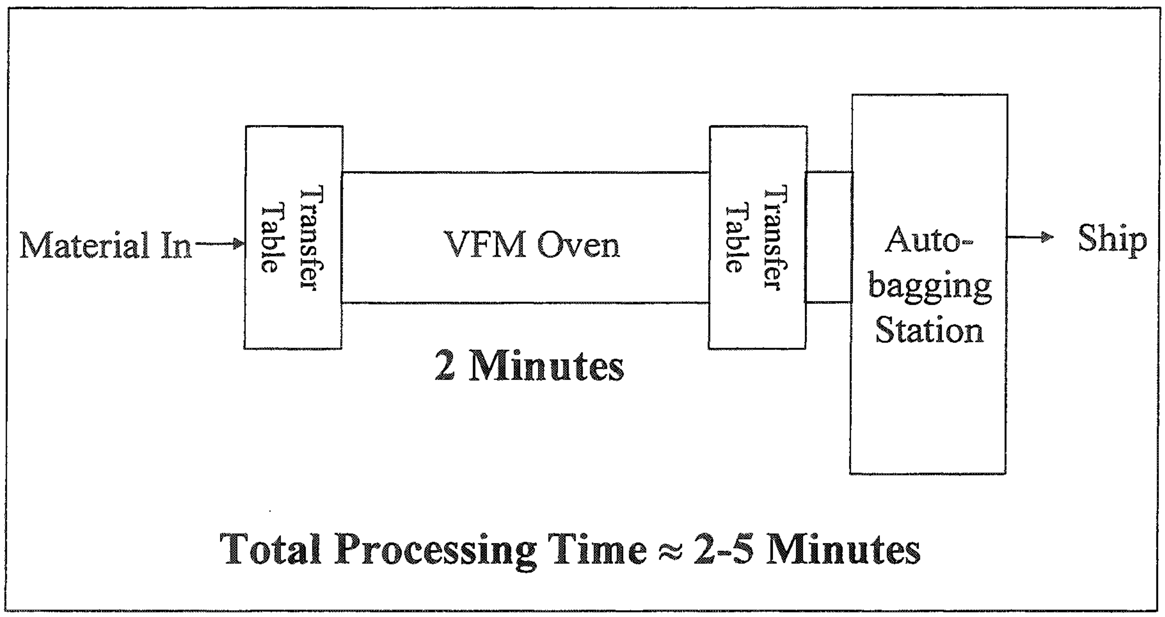

Figure 2. Proposed Layout for Variable Frequency Microwave (VFM) Installation

The next step in evaluating the incorporation of a variable frequency microwave system was to analyze any potential savings, both direct and indirect, associated with the VFM technology. The first analysis would determine if any energy savings would manifest between electric resistance and variable frequency microwave. Unfortunately, full-scale testing was not performed to determine the exact power output of the VFM oven. However, energy savings alone would not justify the implementation of this project. ComEd and the customer proceeded to evaluate any impact in manpower. By implementing the VFM oven and installing an autobagging station, an estimated $575,000 per year savings would result. This was accomplished due to the operators and maintenance staff having less involvement with production associated with the VFM system. The existing electric resistance system had a substantial maintenance overhead associated with it due to jamming of conveyors and poor zone temperature control. Therefore, the simple payback for the variable frequency microwave system was 1.8 years, well within most industrial facilities financial criteria of less than two years.

Conclusions

The implementation of variable frequency microwave drying for this manufacturer proved to be a complete rethinking of the way that product is currently manufactured and sold. Before this technology was introduced, just in time manufacturing was not even thought of, due to the inherent speed of the resistive drying system. After the results of variable frequency drying were presented, this manufacturer realized that just in time manufacturing, improved product quality, and decreased labor intervention would be required for the product. Unfortunately, the variable frequency microwave technology did not get implemented. The feeling from the manufacturer was that the high capital cost of the equipment was the leading factor - basically "sticker shock". Even though this technology offered benefits in labor, quality, and timeliness, the technology was put on hold. The decision to add on another resistive drying line at 20% of the cost of a new microwave line was pursued. Test data was still being collected on system performance at the time of this paper. Others felt that the manufacturers fear of microwave technology (fear of an unknown technology), was the leading decision influence. For whatever reason, the technology only made it to the pilot scale level.

Microwave technology is not a newcomer to the general population. For many years, most people have used microwave technology in one form or another. Whether microwave technology is used for heating up a cup of coffee or cooking meat products, it has shown the general population that it is an effective technology. However, most of the same people have a concern of the terms "microwave" and "irradiation", believing that there are dangerous inherent health risks associated with this technology. It is true that microwave energy needs to be contained to within the cavity, however, there are technologies in place to contain this energy. Even with the information provided to the general public, there still appears to be a reluctance to embrace microwave technology as an efficient heating method. Perhaps the largest hurdle for this technology is to properly inform and educate the general population on the costs and benefits. With the proper understanding and promotion of microwave technology, the use and development of microwave systems can only grow.

Acknowledgements

The author wishes to thank Tina Christensen of Lambda Technologies, Inc. and Gary Walzer of the Electric Power Research Institute for their assistance and guidance in developing this paper.

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