

Case Study Impact

We used the finding of choked flow during the primary drying of freeze-drying to further define the primary drying design space. By elucidating the failure limits of each freeze-dryer and showing how sensitive they were to chamber pressure, we were able to successfully optimize the primary drying conditions for a key product. This led to a 29% cycle time reduction, projected to increase freeze-drying productivity by \$20 M/yr. In addition, it made available 23% more dryer time for other products of more of the same product.

A six-sigma project resulted in rapid implementation of new product thermocouple holders and improved decision making for the end of freezing, primary drying, and secondary drying. The benefit of this project was projected to be \$3.9 M/yr.

SPECIFYING A NEW FREEZE-DRYER

When spending millions to purchase a new freeze-dryer it is important to ensure that it will have the highest drying rate capability possible. Information in this chapter is intended to help engineers accomplish this. First and foremost, be aware of how to accurately measure the drying rate capabilities of a freeze-dryer (as described in this chapter), and put these procedures into freeze-dryer specification and procurement documents. Test freeze-dryers to ensure they meet your requirements for drying rate capability before they leave the factory. A minimum guidance value of 1.0 kg/hr·(m² of shelf surface for product), when run at 100-mTorr chamber pressure, is recommended. The freeze-dryer should be able to handle twice that rate at 200 mTorr. In addition, the heat transfer coefficient for each shelf should be at least 40 W/m²·K at a shelf fluid inlet temperature of +20°C. Condenser coil/plate surface area should be greater than that for product on the shelves. Shelf fluid flow rate should be continuously monitored and alarmed. Ice slab studies should be repeated every year after major maintenance to ensure that each shelf is performing to specification and that the entire system is functioning properly.

SUMMARY OF RECOMMENDATIONS

This chapter provides definition of critical freeze-dryer performance attributes and, just as important, how to measure them. This will help ensure the procurement of quality equipment, ensuring that equipment capabilities are maintained over the service life, and also provide for surprise-free transfers of new products and processes from development into full-scale manufacturing and from one production freeze-dryer into others. Specific recommendations are

- Use ice slab studies to measure the drying rate capability over the desired range of chamber pressures (before taking delivery, after taking delivery, during qualification, and periodically through the service life).
- Thoroughly characterize and document each product's failure modes.
- Ensure that freeze-dryers are equipped with flow meters or switches on the shelf heat transfer fluid, and that they notify operators when flow falls below an established limit.
- Remember that what is measured by the thermocouple on the shelf heat transfer fluid is just that—it is not the actual shelf surface temperature when