Overcoming the complexities of tank scheduling

For food, beverage, chemical, and other process manufacturers, the use of volume-based assets such as tanks, silos, drums, and vats can make the production scheduling process extremely complex. To effectively schedule volumes, process manufacturers need solutions designed for the unique needs of their industry. However, many solutions are not equipped to manage the challenges of volume scheduling.

Table of Contents

Tanks have many characteristics that make them more complex than other resources. This white paper discusses these characteristics, which advanced scheduling solutions must manage effectively:

- Tanks store
- Tanks store only one material at a time
- Tanks buffer
- Tanks are connected by pipes
- Tanks need cleaning and other frequent maintenance
- Tanks come in different sizes
- Tanks have different characteristics
- What goes in is not always what comes out

Optimized tank scheduling is necessary to maximize utilization and throughput of manufacturing facilities. When evaluating scheduling solutions, it is essential for manufactures to identify products that can dynamically schedule the intricacies of tanks and simultaneously take into account the constraints and processes of their plants. Fixed defaults, workarounds, and rules of thumb simply do not work. They create infeasible schedules requiring constant adjustment, effort, and republishing.

The complexities of tank scheduling

Tanks or tank equivalents, such as vessels, silos, and bins, are likely an integral part of your manufacturing process. The unique and complex characteristics of tanks make it difficult to schedule them accurately, especially under capacity pressure.

Scheduling solutions that cannot manage these complexities effectively generate schedules that are consistently infeasible, forcing the introduction of disruptive changes in the scheduling process. A thorough evaluation of how scheduling solutions manage tank scheduling challenges is essential to maintaining quality and optimizing production.

A scheduling solution must be able to manage independent

inflows and outflows that vary by material, resources, or other constraints.

Why is tank scheduling so difficult?

Tanks have many characteristics that make managing them more complex than the management of other resources. Following are eight such characteristics that advanced scheduling solutions must be able to manage effectively.

Tanks store

The basic fact that tanks store materials constitutes the biggest difference between tanks and other tangible resources, such as reactors, filters, and packing lines. Where other types of tangible resources exhibit only flow or batch behavior, tank behavior includes delays caused by storing materials between inflow and outflow. These delays are primarily determined by the availability of preceding and succeeding resources; since their occurrence and duration are dependent on the schedule, they cannot be rigidly modeled.

Scheduling systems that treat tanks like producing resources typically use a historic average or common duration to determine the effective rate or duration. However, real occurrences often differ from the historic value, resulting in an over- or underestimation of the used tank capacity and timing errors for resources that are feeding and consuming the tank. As these errors occur multiple times, they result in infeasible and unusable schedules that get worse over time as they compound.

A scheduling solution must, therefore, be able to manage independent inflows and outflows that vary by material, resources, or other constraints. It should allow for delays or standing time between inflow and outflow.

Tanks store only one material at a time

The ability of tanks to store only one material at a time is the biggest difference between tanks and generic storage resources. Once a tank is in use by a product, no other product can be stored in it until the tank is first completely emptied (and many times cleaned). Generic storage locations, such as warehouses, have no constraints on the number of different types of products they can store.

When scheduling a product, it is critical to account for storage constraints to avoid overestimating available capacity. For example, if two tanks each have a capacity of 500 units, only two products can be stored at any point in time. As soon as a single unit of product is occupying a tank, the remainder of that tank's capacity is unavailable for other different products, leaving just 500 units of capacity in the second tank. By contrast, a warehouse capable of storing 1,000 units does not have similar limits on the number of different products that can be stored. If one unit of product is stored in the warehouse, 999 units of capacity remain. Just because a tank has additional capacity, doesn't mean it can accommodate additional materials.

Scheduling solutions that don't recognize this constraint might attempt to continue filling a tank to capacity with different materials, creating an infeasible schedule. Those capable of accounting for storage constraints and handling finite-capacity scheduling are far more effective at managing volume-constrained resources.

Tanks buffer

Tanks are often used as buffers before bottlenecked resources to have product available, or following resources as soon as needed in order to remove dependency on resource availability. Tanks used in this way are what keep the throughput of your facilities as high as your bottlenecks allow. Lastly, tanks may be used as buffers where a high unpredictability exists in quality or quantity of produced product, again to keep succeeding processes moving.

By definition, all buffers have inflow that is independent from outflow, resulting in both timing and capacity considerations. To begin buffering, inflow must start sooner than outflow; and to guarantee buffering capability, inflow and outflow rates should be different. In cases where a buffer is placed before a bottleneck, inflow capacity cannot be less than outflow capacity. When the buffer use occurs after the bottleneck, the opposite holds: higher capacity on the outflow side and multiple simultaneous consuming resources.

Buffers also have special constraints introduced by physical limitations, such as minimum fill levels before buffering can start, maximum depletion after buffering finishes, etc. These constraints, combined with the above-mentioned characteristics, form highly variable limitations on tank behavior that cannot be managed through workarounds or rules of thumb.

Buffers are critical for achieving maximum throughput for a manufacturing facility, and scheduling solutions must be able to effectively manage all of these various buffer characteristics, not just one of them. In addition, scheduling solutions should include a single buffer to perform all the characteristics simultaneously. It is crucial that your solution be able to handle all buffer characteristics at the same time in a single resource.

Tanks are connected by pipes

Tanks and similar resources store fluid materials, such as liquids or very fine solids (e.g., flour). Transportation of these materials in the plant is commonly done through pipes or blow lines that connect tanks to each other and to feeding and consuming resources. These pipes add a number of different constraints to the behavior of tanks.

The first issue is that only a limited amount of material can pass through the pipe in any given period of time. Therefore, the tank and the pipe that connects it to another resource are in use at the same time; one is feeding while the other is consuming. None of these resources is available for anything else during this period. If a scheduling solution cannot manage these constraints, manual tracking of every tank batch and related production batches is required. Otherwise, capacity will be over-estimated and production mistimed, not to mention potential serious consequences if different materials are mixed together.

Second, equivalent resources may not be able to connect to equivalent tanks, because the connections may not physically exist. Even though a product is produced using certain resources and stored in certain tanks, there may not be a pipe connecting them. In addition, routing constraints may also be product-dependent, since some pipes may not be appropriate to use for some products. As a result, product constraints can still exist even if there is a physical connection of the resource to the tank.

Finally, pipes may converge or diverge through nodes that allow various products to flow through the same pipes either from multiple sources or to multiple destinations. However, some products cannot share the same pipes, adding more schedule-dependent constraints. In addition, when multiple tanks are feeding or draining the same resources through a shared pipe, the flow rate is different than if only one resource was using the pipe, and again, certain products absolutely can't mix with others due to regulatory compliance issues, or other consequences.

Routing and product constraints are common when dealing with tank scheduling, but they can be handled efficiently when using a scheduling solution that accounts for simultaneous feeding and consuming resources, connection and product-dependent constraints, and multiple flow rates. A solution that can manage these limitations and constraints will allow you to more accurately determine capacity and provide optimal production schedules.

Tanks need cleaning and maintenance

Some routine cleaning and maintenance can typically be scheduled with most systems. However, to prevent contamination, most cleaning is dependent on the characteristics of the products and the order in which they pass through the tank.

For example, storing a low quality product after a similar high quality product may require little cleaning, but the opposite order may require extensive cleaning. This so-called variable changeover must be managed to create feasible tank schedules. However, even when a scheduling system supports variable changeovers, there are both effective and ineffective methods for handling the variable changeover situation.

A simple and commonly used ineffective method is to supply historic changeover values from product to product. Unfortunately, this approach leads to enormous changeover matrices that require a lot of maintenance. For example, 100 SKUs would require supplying and maintaining 10,000 changeover values. This is a daunting task for even a relatively small product set and will inevitably lead to deterioration in the quality of the schedule.

Scheduling solutions specifically designed to handle the intricacies of tanks are able to supply changeover values for the various characteristics that actually cause the change-over, such as color, quality, brand, lot number, etc. This requires maintaining significantly smaller matrices and preserves accuracy.

To maximize plant utilization,

decisions about which size tank should be used for which batch need to be carefully considered. Future batch requirements, such as due dates and quantities, should also be part of the equation.

Tanks come in different sizes

Tanks that perform similar functions often have different capacities. When scheduling tanks, it is beneficial to match larger batches with larger tanks; however, certain constraints influence what the best choice is at a given time. For example, differences in due dates may mean compromise. Scheduling a near-term large batch in a large tank may mean that a later large batch will need to be split across smaller tanks.

To maximize plant utilization, decisions about which size tank should be used for which batch need to be carefully considered. Future batch requirements, such as due dates and quantities, should also be part of the equation. Using rules of thumb or having fixed default tanks for products will not consistently provide accurate results. Additionally, the product manufacturing formulas usually change based on the size of the tank. Your scheduling system has to account for formula constraints and requirements.

A scheduling solution with advanced tank scheduling capabilities will create an optimal tank schedule by considering tank capacity and providing dynamic batch-sizing capabilities, allowing the best utilization of the plant without adding additional costs.

Different tanks have different characteristics

Different products can be stored in different but overlapping sets of tanks, due to the specifics of the tanks or the products. In the food industry, for example, some tanks may be made of metals that result in an aftertaste. Some products may require additional floating resources, such as tools, stirrers, or clean-in-place equipment, that aren't available or located close to particular tanks. In some cases, history shows bad results from certain tanks, even though no definitive cause can be identified. An undesirable near-term choice for storing a product in a tank may mean that a suitable tank is not available for a later batch of a different product.

Furthermore, tanks may be part of multiple groups, and groups can contain multiple tanks. The same applies to products. Different tank groups must be available for a single storage step in the production process of a product, and each group must be capable of having different characteristics for different products. For example, if a product is stored in a group of tanks that are known to be undesirable for that product, additional standing time may need to be reserved for quality assurance.

An effective scheduling system will be able to dynamically determine what product goes in which tank, in what batch sizes, and at what time based on current conditions and constraints. An effective solution will also be able to flexibly group tanks and products to support the scheduling process in a maintainable way.

What goes in is not always what comes out

In some industries, it is common for products to change while stored in tanks. This is especially true for organic products; for example, cheese matures, alcoholic beverages ferment, etc. Administrative differences are also common. The product itself may not physically change, but certain administrative processes can affect it. For example, completed quality assurance measures or incubation time cause the product to change. Sometimes a change to the product is desired behavior and sometimes it is not.

Product changes are critical to the scheduling process, because the outcome of physical checks or quality assurance determines when outflow can begin and what the outflow product turns out to be. As the state of the product changes, the schedule needs to be adjusted to accommodate. If succeeding batches on a tank can be started sooner or need to start later, all related parts of the schedule need to be adjusted quickly and easily.

When scheduling tanks, constraints caused by changes to the product must be dynamically calculated, considering that the duration of the batch is not only schedule dependent, but also qualification dependent. The right scheduling solution will take into account the fact that what goes in to the tank is not always what comes out and will allow for easy adjustments to accommodate these changes.

Solution evaluation

The following is a review of tank scheduling characteristics and the functionality that a scheduling solution should have to manage these challenges effectively. Also included are details about the workarounds used by scheduling products not designed to manage volume-based storage assets.

Characteristic	Solutions designed for tank scheduling	Solutions NOT designed for tank scheduling
Tanks store	▪ Independent rates or durations for inflow, storage, and outflow of tank batches for dynamically determined optimal schedules.	▪ Simulation of tank behavior through use of historic averages to determine effective rate. Can cause an over or underestimation of used tank capacity and error in timing for resources that feed and consume the tank.
Tanks store only one material at a time	▪ Finite capacity scheduling is required. As soon as a product occupies a tank, the entire tank capacity is unavailable for other products. It may also be unavailable for the same product from a different batch.	▪ Simulation of tank behavior through discrete storage locations. Can cause errors in timing of resources and an inaccurate picture of available capacity. ▪ Rules of thumb for estimating used capacity. Approach can lead to infeasible schedules.
Tanks buffer	▪ Different inflow/outflow rates. ▪ Multiple inflows and outflows. ▪ Capacity dependent on resources feeding or consuming that produce or consume the particular product. ▪ Single buffer handles all tank characteristics simultaneously.	▪ Single buffer does not perform all characteristics simultaneously. This results in lack of flexibility when handling the variable set of constraints commonly associated with tank behavior.
Tanks are connected via pipes	▪ Routing constraints and product dependent constraints can be handled. ▪ Feeding and consuming resources are occupied simultaneously for a quantity-dependent time.	▪ Inflows/outflows of tanks not simultaneous with outflows/ inflows of feeding or consuming resources and not quantity-dependent. Results in over estimation of capacity and mistiming of production. ▪ Routing constraints cannot be used or are not product dependent. Causes scheduled resources to be unavailable or leads to improperly scheduling products for inappropriate tanks.

For more information, visit infor.com/SCM

Share this :

641 Avenue of the Americas, New York, NY 10011

INFDTP1482070-en-US-0116-1