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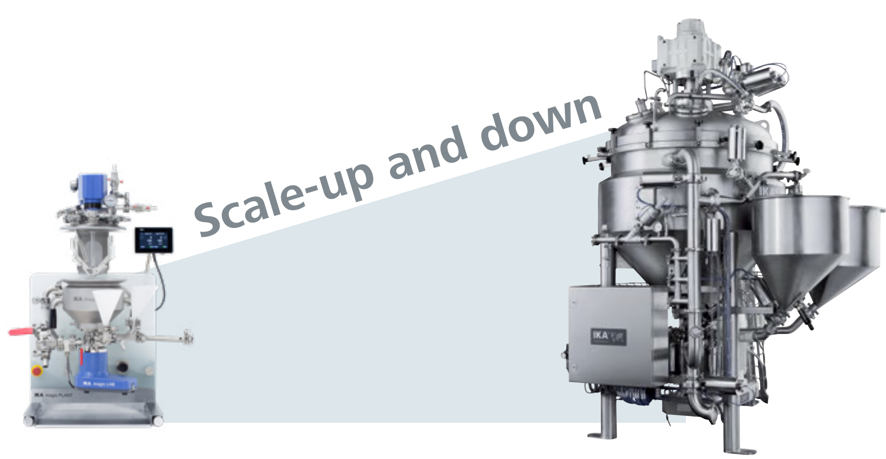

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First, Select the Right Blender

Understand the pros and cons of three key kinds of devices

Tom Blackwood, Contributing Editor

The choice of blender type dramatically can affect end results. Yet, often we put a product in whatever blender is available. That's a mistake. Each blender is unique; they may vary in typical blend time and quality, blender capacity, scaleup, maintenance and attrition. So, let's compare blender types.

The number of options can seem overwhelming. One manufacturer's selection guide I recently looked at showed several hundred blender types. I don't doubt that their differences are real in the eyes of the designer — but I've usually found that the particulate solids characteristics of the material to be blended are more important than some subtle variation in a unit's mechanical design. For simplicity, I suggest concentrating on three overall types of blenders: mechanical, gravity and fluid-assist devices.

MECHANICAL BLENDERS

Most such units are small capacity. Let's look at four options.

- *The double-cone blender* has been the workhorse of the industry, especially for batch operations. Blend times typically run one to two hours. Maintenance is low. Attrition is moderate but particles may segregate on discharge. Internals, which come in many variations (ribbons, baffles, etc.), can improve blend quality and minimize segregation.
- *Paddle or ribbon blenders* provide much lower blend times and often serve in continuous processes. Low-speed units may reach a good blend in one to 15 minutes. In contrast, high-speed devices

The fluidized bed is probably the most effective fluid-assist blender.

may achieve the same blend in five to 30 seconds but the number of fine particles generated may override blend quality. Maintenance is moderate but attrition is high for high-speed devices.

- *Riffle blenders* can match the blend quality of a high-speed blender and create less attrition. However, their maintenance (cleaning) is high and they don't scale up very well.
- *Screw blenders* aren't known for blending applications but can reach a good batch blend in three to five minutes with moderate attrition. Maintenance is high but scaleup is easy.

For continuous operation and the best blend quality, I suggest a loss-in-weight feeder. It scales up easily and creates little to no attrition. The device demands only low to moderate maintenance but often is an expensive alternative.

GRAVITY BLENDERS

Storage of large quantities of bulk material frequently requires some blending to compensate for segregation or process variations. Achieving the best quality blend may call for recirculation via pneumatic conveying. The traditional static flow tube smooths out small variations. However, mass-flow or multi-cone blender designs largely have replaced it because they can reach a high quality blend in a couple of turnovers. Moreover, they are easier to scale up than flow tubes and are lower in maintenance. Other than attrition from the pneumatic conveyor, particle breakage is minimal in these devices.

FLUID-ASSIST BLENDERS

These devices often are costlier than the other two categories but compensate by providing better blend quality. Let's examine four alternatives.

- *The lift-tube blender* could be considered a gravity blender — but recirculation is internal to the device and blending can take place during tank filling, which smooths out production variations over a longer time frame. Scaleup is moderately easy and maintenance is low. Attrition is negligible because the recirculation loop has no feeders or elbows. The design of the internal cone controls blend quality.
- *The fluidized bed* probably is the most effective fluid-assist blender. It works well in batch or continuous operation. Blend time is on the order of minutes versus

hours and scaleup is easy. Most maintenance is external to the device; proper grid design minimizes attrition.

- *The spouted bed*, a cousin to the fluidized bed, is a favorite for coating particles as well as giving a good blend in only one turnover. Attrition is very low, especially with big and light particles, because most attrition occurs as the particles fall back onto the bed. Scaleup is moderately easy; units require little maintenance and cleanup is easy.
- *Blenders using a jet or venturi* work well with fine materials and can give an excellent blend. Scaleup is easy but maintenance can be high. These devices better suit liquid/particle blending.

Throughout this column I haven't talked much about blend quality because this mostly is a function of the particles in the system. Experimental data are a must to define blend quality. ●

Improve Mixer Performance

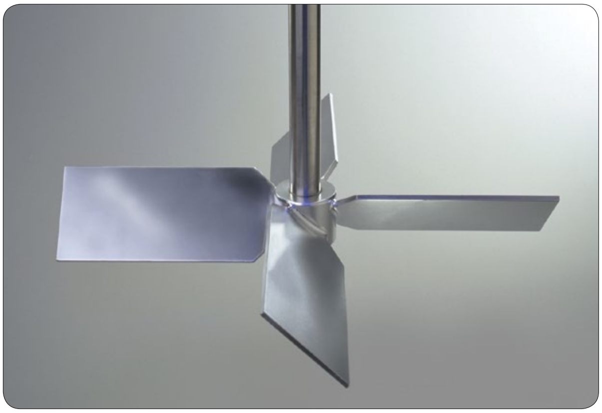
Inexpensive changes may enhance results from long-installed equipment

By David S. Dickey, MixTech, Inc.

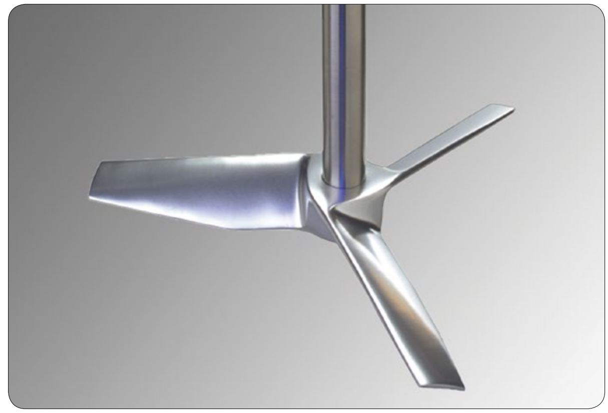
Many processors rely on mixing equipment that is more than 25 years old. Even if the equipment isn't worn out, it almost certainly was designed for different conditions and often different processes or products. The design may not suit the current application or product. In the last 25 years, many products have become more viscous or non-Newtonian, making mixing more difficult.

Over that same period, new types of impellers and ways of applying them have improved mixing with the same power and speed. These developments often open up opportunities to enhance performance without replacing the equipment or resorting to expensive upgrades.

While not a recent improvement, hydrofoil impellers have replaced many pitched-blade turbines in medium- to low-viscosity blending and solids suspension applications. A typical pitched-blade turbine (Figure 1) has four blades made of flat plates. The most common hydrofoil impellers have three blades with a curved cross-section (Figure 2). The curved cross-section is called camber; it furnishes a degree of lift and a smooth change of flow direction. Just like the wings on an airplane, the hydrofoil blades provide a downward force with an efficient transfer of power. The advantage of the hydrofoil impellers is greater efficiency in creating axial flow. The axial flow pattern generated in a stirred tank produces good vertical circulation, which helps to carry surface additions throughout the vessel. In solids suspension, the axial flow directed toward the bottom of the vessel lifts solids off the bottom. Delivering



PITCHED BLADE TURBINE
Figure 1. Typical unit uses four blades made of flat metal plates. *Source: SPX Flow Lightnin.*



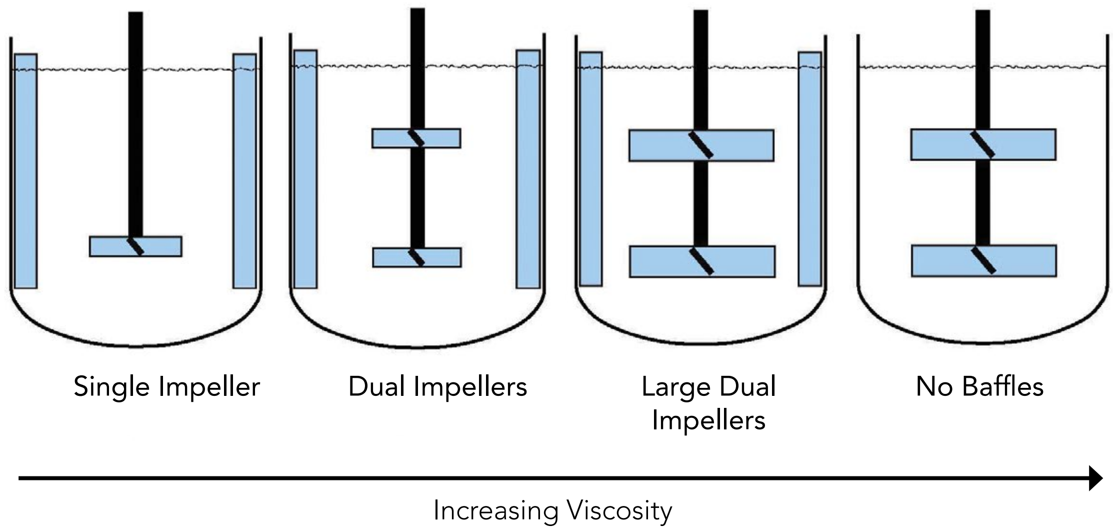
HYDROFOIL IMPELLER
Figure 2. Most-common design features three blades, each with a curved cross-section. *Source: SPX Flow Lightnin.*

the same power at the same speed with a slightly larger diameter hydrofoil impeller may improve mixer performance at a modest cost for a new impeller.

Some mixers have under-loaded motors. A unit with a 25-hp motor actually only may deliver 10 hp to the mixed liquid. This points up the difference between two important and often confused characteristics: motor power and impeller power. The motor power establishes the maximum power the impeller can deliver to the fluid. The impeller power reflects the rotational force (torque) the impeller applies to the fluid and the rotational speed or rate of energy dissipation. Impeller conditions, power, torque, tip speed and pumping rate are the key factors that create the mixing intensity and process performance of a mixer. Increasing the impeller power may offer an opportunity for improvement.

The first step in assessing a unit is to establish the current design. Older equipment may lack good drawings. Even when drawings are available, they may not include modifications made after the original equipment was installed. Many equipment modifications can enable cost-effective improvements to process performance without completely replacing an old mixer. Beyond basic tank dimensions and impeller type, the two most critical characteristics of mixing equipment are impeller diameter and rotational speed. For low viscosity turbulent liquid mixing, impeller power is proportional to the rotational speed cubed and the impeller diameter to the fifth power. For instance, a 10% boost in the rotational speed will raise the impeller power by 33%. Increasing the impeller diameter by only 5% will push up the impeller power by 28%.

When analyzing mixing equipment, you must ensure accurate measurement of the



IMPACT OF VISCOSITY
Figure 3. When using turbine-style impellers, viscosity can significantly affect the optimum equipment configuration.

speed and impeller diameter. Changing the speed of an existing mixer may be difficult and expensive. Modifying or replacing an impeller may be easier and less costly. However, an impeller modification, especially if it adds weight, may cause mechanical problems that require evaluation before changes are made.

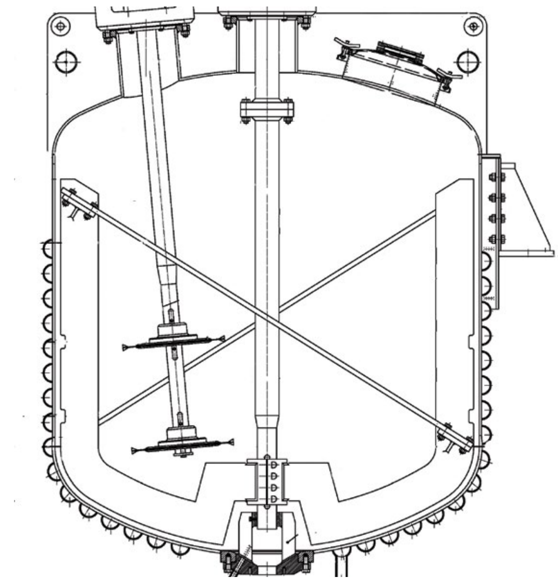
All mixers are 100% efficient with respect to impeller power input. All the power delivered to the fluid eventually becomes molecular motion, which is heat. In most situations involving low viscosity blending, the amount of power input to the fluid doesn't noticeably affect the process temperature. In cases of intense or high viscosity mixing, the power input can cause a measurable and sometimes undesirable increase in the process temperature.

THE IMPACT OF VISCOSITY

In a variety of mixing processes, viscosity plays a major role in determining success or failure. Viscosity basically is the internal resistance to fluid motion. However, that resistance takes many different forms. Newtonian viscosity, which is the simplest type, follows Newton's definition of viscosity, i.e., a constant describes the relationship between shear stress and shear rate. However, that doesn't mean that viscosity is always the same. Temperature affects viscosity. Viscosity usually is lower at higher temperatures, which means that blending becomes easier. Merely adjusting the process temperature can solve some mixing problems.

Many fluids with higher viscosity demonstrate non-Newtonian properties such as shear-thinning or shear-thickening behavior. Shear-thinning fluids have a lower apparent viscosity when they experience velocity gradients in the liquid. Velocity gradients exist around a mixing impeller and in recirculating flow patterns. As shear thickening implies, the apparent viscosity increases at higher shear rates. Many shear-dependent fluids are time independent, meaning that only the current shear rate affects the apparent viscosity. The viscosity of time-dependent non-Newtonian fluids not only depends on the current shear rate but also on whether the shear has been increasing or decreasing. The viscosity of some fluids is permanently altered by shear. Other non-Newtonian viscosity effects include viscoelasticity and yield stress. Viscoelastic fluids exhibit an elastic return, something like bread or pizza dough. Yield stress fluids have a gel characteristic, like ketchup or hair gel. The yield stress limits the initial motion of the fluid but allows flow once the initial resistance is overcome. In all cases, non-Newtonian fluid behaviors make mixing more difficult than for a similar viscosity in a Newtonian fluid.

High viscosity mixing creates several mixing difficulties and often requires special equipment. The term “high viscosity” means different things to different people and in different situations. Using common materials as references helps to understand some ranges for “low” and “high” viscosity. Typical solvents, such as water, acetone, gasoline and kerosene, have viscosities less than 10 cP and are almost always considered to be low viscosity liquids for mixing applications.



HIGH VISCOSITY MIXER
Figure 4. This unit features high-speed disperser blades and a low-speed angled sweep impeller.

(Centipoise (cP) is a metric unit commonly used to measure and express dynamic viscosity. Centistokes (cSt) is used for kinematic viscosity, which is the dynamic viscosity divided by the fluid density. This density can be expressed as specific gravity relative to water or grams per cubic centimeter. Because most hydrocarbon liquids have a density about 0.80–0.90 that of water, their cSt viscosities typically are 10%–15% higher than the cP viscosities for the same fluid.)

Even motor and cooking oils with typical viscosities between 10 cP and 200 cP behave as "low" viscosity liquids in most industrial-size mixers. However, by the time you get to glucose (500 cP), corn syrup (1,400 cP) and honey (5,000 cP), the effects of viscosity on mixing become more evident. The fluid motion at these moderate viscosities begins to decline away from the mixing impeller because the viscosity resists the fluid flow. When using turbine-style impeller mixers with these moderate viscosity fluids, you often must resort to more or larger impellers to accomplish uniform blending. A single impeller in a baffled tank might handle a low viscosity application while a slightly higher viscosity may require two impellers and a moderately high viscosity may demand two larger impellers. At a sufficiently high viscosity, the resistance to motion at the wall may eliminate the need for baffles. As the number and size of impellers increase, so does the impeller power requirement. Figure 3 shows the progression from a single impeller to dual impellers to larger impellers and then to impellers without baffles. More or different impellers might provide the increased mixing required for processes at higher viscosities.

"Extremely high" viscosity materials such as peanut butter (250,000 cP) and caulking compound (5,000,000 cP) barely flow at room temperature. Even at elevated temperature, such materials can be difficult to mix. Creating the desired uniformity in these products requires special mixing equipment, often with large diameter impellers, to cause complete fluid motion. Some mixers for high viscosity applications may have multiple impellers for different process requirements. Figure 4 depicts a mixer for such a service; it has both high-speed disperser blades and a low-speed impeller with angled sweep blades.

Simply blending liquids of different viscosities is difficult but mixing another phase with a liquid can be far tougher. Incorporating the second phase, whether solid particles, a gas or an immiscible liquid, usually begins with a dispersion process. The requirements for a dispersion application differ from those for liquid blending. The mixing intensity necessary to initially disperse particles, gases and immiscible liquids usually occurs in the immediate region of the mixing impeller. The equipment also must provide a recirculating flow pattern sufficient to maintain a degree of uniformity for the dispersed phase. Some dispersions are intended to form a stable product. Others must continue to be agitated to retain sufficient uniformity for the desired process result.

For any mixing process, the equipment should be sufficiently versatile and robust to handle reasonable differences in raw materials or operating temperatures. Predictable raw material variations shouldn't cause frequent failures. In the kitchen or laboratory, increasing stirring speed or extending mixing time often can achieve robust mixing. However, making similar changes in large industrial units can be difficult, especially if those features aren't built into the equipment design. However, production changes, such as order of addition or process intensification, sometimes can result in significant improvements.

ACHIEVING SUCCESS

Identifying process improvements that increase performance and enhance efficiency requires a focus on determining the actual problem. Attempting to correct something that isn't the cause of the problem will result in a waste of time and money or even cause worse problems.

A real difficulty in solving mixing problems is that the equipment can provide a wide variety of results. Its contributions can differ depending on the process. The differences aren't always single or unique characteristics of the mixing requirements. The equipment may need to satisfy a combination of requirements, especially in batch processes where the demands change during different steps. Sometimes those differences may involve competing requirements with disparate operating conditions for optimum results. In some cases, old methods or equipment cause poor results. In other cases, insufficiently robust operations and equipment lead to inconsistent results.

In any attempt to improve a mixing process, carefully evaluate changes to ensure they won't make things worse. In most cases, you can find a path forward that will lead to an improvement with minimal risk to the current conditions.

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Recharge Your Approach to Mixing

Consider inline mixing to minimize costs and improve quality

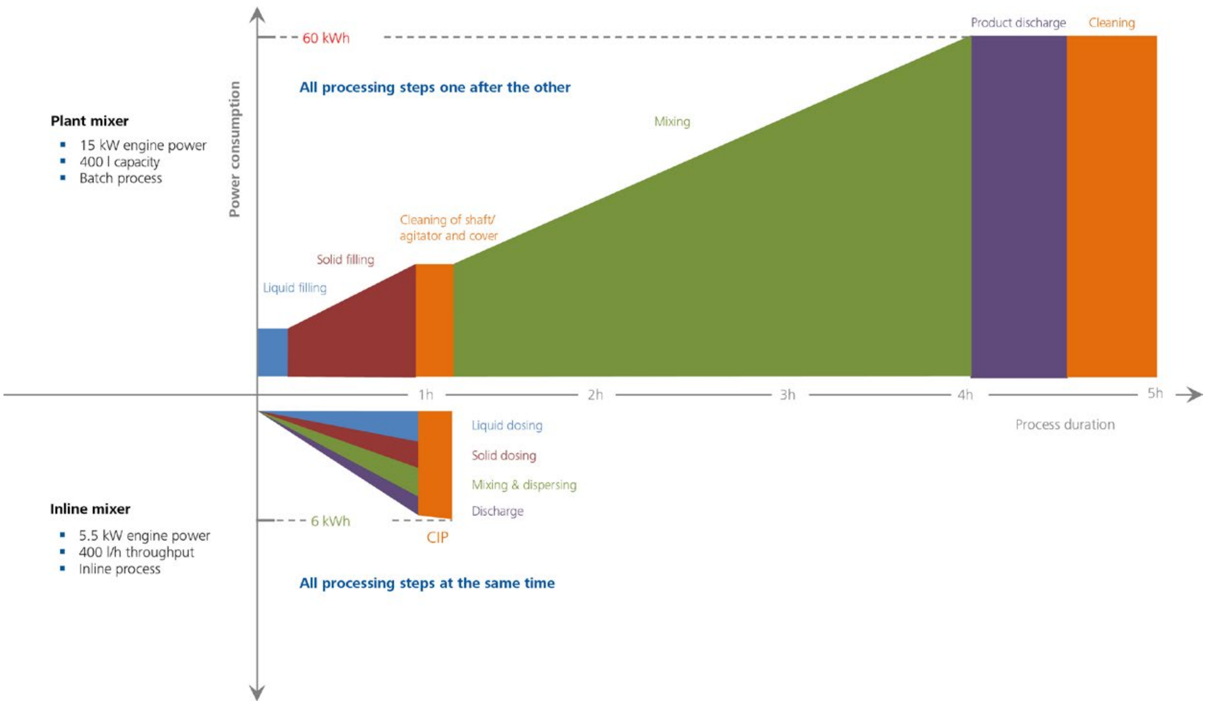
By Ralf Buergelin, IKA

Whether regenerative energy, electro mobility or mobile electronics, all these electrical systems require a storage medium of electrical energy to function. Capacity needs for such systems are skyrocketing and are expected to grow exponentially. Rechargeable batteries based on lithium-ion technology are state of the art.

Battery research focuses on choosing the best materials and formulations. The use of a suitable manufacturing technology for mass production is important to produce rechargeable batteries with consistently good quality at the lowest cost. While only minor optimizations are possible in terms of material costs, potential remains for reduced production costs, shortened process times and automated production.

Lithium-ion battery (LIB) technology combines high-energy density, high available capacity per cell with short charging times and long life. A LIB rechargeable cell usually consists of an anode, cathode, separator and conductive electrolyte. It is essential that the high-viscosity coating compositions on the electrodes be homogeneous and without changes in the material properties. This achieves identical electrical properties and full performance, which is critical during production.

To prepare the coating compositions, liquid solvents are mixed homogeneously with pulverulent solids, such as binders and active material, to give a high-viscosity mass, with the risk of agglomeration formation. The incorporated solvent volatilizes as temperature increases. Because mechanical



MIXER COMPARISON
Figure 1. Compared to a standard plant mixer, inline mixers can cut processing time significantly while also reducing power consumption.

mixing processes inevitably release heat energy, dispersing with high efficiency is important.

CONVENTIONALLY MIXED

Coating compound production previously was done with low-efficiency, slow-running batch processes. High-speed stirrers for binder solutions and planetary mixers were and are mostly used for blending. The low energy input is one of the reasons why these machines have such long mixing and dispersing times. As a result, many batch devices are required, which are expensive to purchase, maintain and clean. To achieve an even dispersion, the complete batch always is circulated with a large stirring tool. Because this process often leads to lump formation and the mixture remains inhomogeneous despite long mixing times, additional filters and subsequent dispersing processes must be used. After the container has been emptied, residual amounts adhere to the stirring tool as well as the container wall, which leads to complicated cleaning and high solvent use.

ADVANCED MIXED

The rapidly increasing demand for coating materials and requirement for materials down to nano size necessitate advanced production technology that works efficiently and is suitable for mass production. At the heart of advanced dispersion technology are in-line devices. The product to be dispersed forcibly is fed by a pipeline to the mixing tool. In this case, mixing energy is entered in the smallest volume with high-speed tools, thereby completely processing all product components in an efficient manner.

Output and results now are measurable with throughput and possibly with the number of runs. In-line devices can be used both in a recirculation batch in-line process and as fully continuous systems operating in one pass. Material losses are minimized, and cleaning is carried out in a continuous clean-in-place (CIP) cycle (Figure 1).

THE OPTIMAL PROCESS

The optimal process for the production of coating materials for rechargeable batteries consists of two process steps:

1. The binder solution is prepared with an in-line suction-dispersing device. For this purpose, the solvent is introduced in the mixing vessel. The necessary amount of binder and conductivity agent is metered in using two solid funnels. The disperser circulates the solvent and draws in the binder powder. Solid and liquid combine in the smallest volume under highest turbulence. As a result, the binder powder is optimally wetted and dissolved agglomerate-free. The carbon powder then is inducted in and dispersed. The machine generates a vacuum that processes large quantities in a short time. After completion of the carbon paste, the product is transferred to a buffer tank.
2. The active powder is introduced and dispersed by gravity using an in-line dispersing unit. The goal is gentle dispersion of a large percentage of powder with low temperature increase and minimized air intake. The binder-C paste, produced in the first process step, forms the liquid phase. This is supplied continuously with a mass flow-controlled positive displacement pump. At the same time, the active powder also is metered in through a differential dosage scale and regulated in the correct proportion.

In this in-line dispersing process, the product components are mixed, dispersed and discharged at a high intensity in the smallest volume. The throughput is determined by the feed systems for the liquid phase and the solids. Additionally, the mixing intensity is determined by the speed and choice of the product-adaptable dispersing tool. Through the process management in each pass, the finished product is made with minimal temperature increase and the highest efficiency. ●

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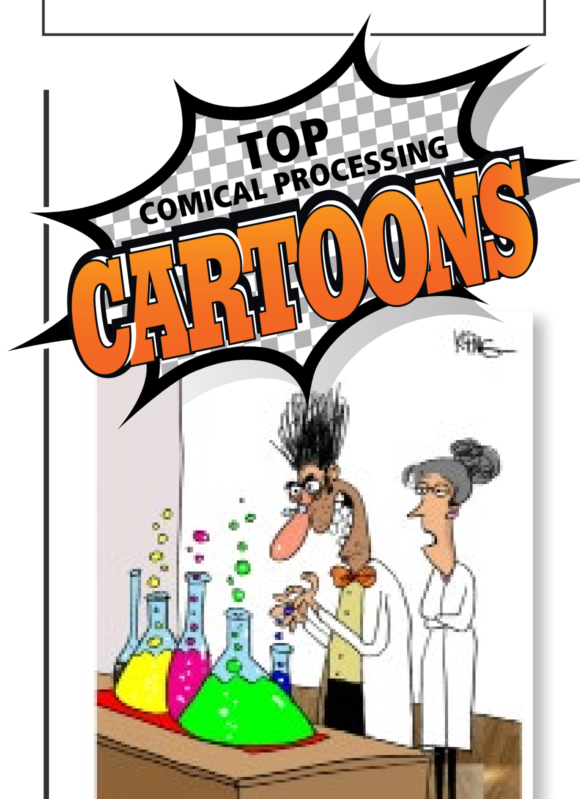

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