**The role of the spray nozzle in finishing systems**
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Anyone looking for an unsung hero could do worse than the industrial spray nozzle. Because, although they may not be a particularly hot topic of conversation at fashionable dinner parties, they are used in a vast array of applications, from fire protection on oil rigs to spraying relish into mixing vats in the food industry. Indeed, in many such applications, their role is critical.

Nowhere is this more true than in the finishing industry, where they often play a key part in processes varying from washing, phosphating, and plating to painting processes. And here, as elsewhere, not any old nozzle will do. The right design can mean the difference between poor and highly effective performance - yet it is a relatively poorly understood animal, often taken for granted.

Here we look at spray nozzle technology, and explain why it is such an important component of a surface treatment system. We will also discuss the factors which determine the effectiveness of a particular nozzle in various applications, and the parameters which affect nozzle design.

The basic function of a surface treatment nozzle is to convert wet chemical, or water, into droplets with sufficient surface area to provide complete coverage for a specific application. But this is often much easier to say than to do, simply due to the nature of the different liquids being sprayed. The wrong choice of spraying system can be costly and may result in poor coating weights and banding. The correct choice of spray nozzle is therefore essential

So, what factors affect nozzle choice? In fact, there's several. And their relative importance depends on the specifics of the application.

One critical aspect is spray pattern. Four of the most common systems employed in finishing environments are flat spray, hollow cone, full cone and air blow-off.

**Flat spray:** Produces a high impinging spray excellent for cleaning, rinsing, and sometimes phosphating.
**Hollow cone:** Lower impinging spray used where high surface coverage is required, such as in the zinc phosphate stage.
**Full cone:** Used where high flow rates are required, such as in the final rinse to eliminate solution carry-over.
**Air blow-off:** Delivers a wide, uniform distribution of compressed air ideal for blow drying, cooling and surface cleaning.

But deciding on the most effective system set up is only the beginning in terms of nozzle selection. Typically, choosing a nozzle can require the specification of factors such as flow-rate versus pressure characteristics, spray angle, material of construction and the piping which feeds the nozzle. What substance to spray is another important consideration.

For many applications this is a straightforward matter, resulting in a perfectly adequate off-the-shelf device. In others, though this is far from the case. In fact, it is frequently the case that there exists no ideal standard product, and a custom design is necessary. It is here that problems can begin.

Three of the most important characteristics of any spray are the amount of liquid it contains, how that liquid volume is distributed within the spray envelope, and the sizes of the droplets that make up the spray. Measuring and interpreting the flow rate and pressure characteristics of most nozzles is a relatively simple process, but this is frequently not true for pattern and droplet size data.

And, in many finishing applications, droplet size is critical. For such applications, good nozzle design will depend on an accurate technique for measuring droplet size. And this is not easy.

In fact, droplet size analysis can be downright confusing. Years ago, the accepted technique was to collect droplets on glass slides, but the process was slow and problems such as droplet splatter raised doubts about its accuracy. Today, more advanced techniques are available, such as those based on laser light signals. While this approach works adequately for some applications, it also has significant limitations - principally the fact that it does not cope well with the large or non-spherical droplets often found in industrial environments. This is because laser-based instruments use a signal processing algorithm which presupposes that the signal to be analysed comes from a spherical particle. Any signal which deviates from this form is rejected.

However, a more recent alternative - a direct video imaging system pioneered by BETE - does not have this drawback, and offers many significant advantages. Offering very high accuracy for all droplets between 2μ and 32,000μ moving at high speed, the technique uses advanced CCD (charge coupled device) technology and high-speed xenon strobes, together with dedicated image processing hardware. The basic principle of the process is to illuminate the droplets with a strobe light and capture the image on a CCD camera so that it can be easily digitised. The droplets are lit from behind and appear black on the screen. Image processing software counts the number of pixels in each image and converts this area to a physical size using a calibration ratio that is established using an image of an object of known size such as a ball bearing. Today's computers can analyze more than $10^5$ drops in just a few minutes and compute the various statistics describing the droplet size spectrum in real time. The BETE imaging system is particularly good at analysing dense sprays that contain non-spherical droplets which are typical in finishing systems.

In many sprays the droplet size is not the same everywhere, and imaging systems can also report information about the droplet morphology. This can be a difficult and inaccurate process with other techniques, as most instruments use various options, like interchangeable lenses and filters, in order to fine-tune it for droplets in various size ranges. If, for example, an instrument is set up to detect only droplets smaller than 2000µ, and larger droplets are present in the spray, the reported data will be incorrect. Often the operator needs to try several setups and compare the data to be sure that the instrument is reporting accurate data. It is also important to select sampling locations corresponding to the regions of interest. BETE selects locations based on a pattern test of the nozzle, usually choosing locations where the spray density is at its peak and locations where the density is one-half the peak. This gives six locations per nozzle axis for a hollow cone nozzle. Finally, it is important to consider the most useful definition of “droplet size”. For many applications the *Sauter mean diameter* (SMD) is of greatest interest. This figure is defined as the diameter of the sphere whose surface area to volume ratio is the same as that of the entire spray, and is calculated from the equation:

$$\mathbf{SMD = \Sigma_i n_i d_i^3 / \Sigma_i n_i d_i^2}$$

where:
$\Sigma_i$ = a sampling size interval
$n_i$ = number of drops in that interval
$d_i$ = drop diameter

For this reason, the Sauter mean diameter is a very useful parameter for characterising sprays used in gas-liquid contact systems, and is the preferred method for process calculations.

In many applications, spray pattern distribution is also important. This describes the location and spray density of the liquid emitted from a nozzle. Again, this is not easily achieved and has, historically, relied on a direct collection method. In fact, this technique is still widely used. Usually this consists of a row of tubes placed under the nozzle, and water is allowed to collect in the tubes for a known length of time. Measurement of the elapsed time and amount of water collected allows spray pattern calculation. It is an approach which has a number of limitations. Now, though, BETE has introduced a unique digital video system for accurately determining the volumetric distribution of liquid emitted from a nozzle. This uses digitised information to calculate spray density and spray angle, and is ideally suited to current nozzle development and assessment programmes. Consistently and accurately selecting appropriate sampling positions is extremely important when performing drop size analysis. The challenge lies in sampling the spray in such a way that the number and location of the individual tests chosen present a reasonable representation of the entire spray. Recognising this, BETE has developed a number of unique sampling protocols for droplet size analysis which ensure that the reported drop size distributions most accurately reflect the overall spray performance. This allows a high degree of repeatability and confidence.

Also available from the BETE system are measures of the uniformity of the pattern. This figure, called the *flux deviation* is half the sum of the difference in the height of the water in each tube and the average height. A nozzle with a large flux deviation would not be a good choice for a packing spray nozzle, for example, where even distribution of the scrubbing liquor over the surface of the packing is important. Of interest in interpreting pattern data are the conditions of the test including the diameter of the tubes or other collection devices, the height of the nozzle above the apparatus and the nozzle operating conditions during the test. Wider tubes, for example tend to mask variations in the spray uniformity, and the test height can greatly influence the reported angle.

Once droplet size and flow rate have been established, there are other factors which must be taken into consideration. For finishing applications, there are a number of specific requirements and technologies available.

**Nozzle type**
*Clamp-on nozzles* (see pic.1): Ideally suited to finishing applications, these versatile, adjustable nozzles, deliver flexibility for a wide range of spraying requirements. Clamp-on nozzles emit any desired spray characteristic – with 45° directional adjustment of nozzle tip – and incorporate a stainless steel spring clamp to create a positive connection point to the riser. Typically injection moulded from custom blended polypropylene, they are corrosion resistant, impervious to most chemicals and provide effective resistance to heat.
*Air nozzles* (see pic. 2): With eductor style orifices which entrain air from around the nozzle – reducing noise and maximising air flow to the spray area – FINZ air nozzles are designed to provide quiet, efficient and wide coverage with high-impact distribution. The nozzles are perfect for a wide range of finishing systems such as blow-drying, cooling, cleaning by air jets and surface cleaning along a conveyor.

**Nozzle tips**
Installed with a bayonet mount, quick-release nozzle tips simply require a 90° twist to install the device into a clamp-on nozzle base. Greatly reducing downtime, these components enable convenient replacement and eliminate the need to realign the adjustable tip angles and orientations on every nozzle. Adjustable to up to 20° off-axis in any direction, quick-release nozzle tips can be supplied in various flat spray configurations.

**Couplers**
Cam operating couplers provide you with easy access to cleaning and installation of risers and are typically available in NY-glass, poly-glass or PVDF. Couplers can adapt to standard steel or non-corrosive risers and headers and eliminate "in washer" riser assembling/disassembling. With wide temperature tolerance and

working pressure, couplers should be non-conductive and resistant to strong alkaline, phosphate cleaners.

**Headers**
Most commonly manufactured in CPVC, PVC, polypropylene or PVDF, headers are often deigned to make use of pipe tapping saddles for creating an outlet point from the header for the risers. This design maximises the strength of the header pipe while maintaining the threaded integrity of a moulded thread for the outlet.

**Risers**
The most efficient riser design will eliminate the need for costly elbows or tee's. Indeed, a one piece formed construction allows for better drainage and cleaner nozzles, helps control pressure fluctuation and chemical foaming. High performance risers should also allow removal or replacement in seconds without tools.

**Riser supports**
Riser supports allows easy access to positioning and/or removal of individual risers. Supports should be simple to install and, when used in conjunction with advanced couplers, can be set in position or removed in a matter of seconds

**Nozzle adaptors**
Enabling quick and easy introduction of new nozzles into the operation, fixed, clamp-on nozzle adaptors fit securely on to iron or plastic pipes and eliminate the need for threading or welding of adapters or couplings to the pipe.

**Saddle adaptors**
Typically injection-molded pipe fittings which can be installed on an existing pipe, a good design will allow installation to be completed in less than two minutes. As with all finishing components, pipe saddle adaptors should be highly resistant to a wide range of caustic and acid based chemicals and operate effectively at high pressure and temperature. Pipe saddle adaptors eliminate the high cost of back welding female couplers to thermoplastic, steel or iron pipes.

**Tank mixing eductors** (see pic. 3)
Tank mixing eductors enable small pumps to circulate liquid within large tanks. The eductors are placed in the tank to maintain the critical velocity of the solid particles with the suction produced by the venturi action of the eductor greatly amplifying the maxing ability of the pump. Solids in the tank are kept from settling by the velocity of the discharge plume while a slight downward angle of the eductor can be helpful to maintain critical velocity on the tank floor.

**Spray angle selection and spacing**
When selecting the nozzle spray angle for finishing applications, and the quantity and distance between nozzles, it is necessary to consider the size and shape of the largest component that will pass through the washer. Nozzles must be sized

and spaced so that the spray covers the entire component, with at least 25mm overlap between adjacent spray patterns. The spray should be at least 23cm from the end of the tip to the component for even coating. The nozzles should be rotated $15^{o}$ from the riser axis to avoid interference from the overlap of spray patterns.

These then are some of the most recent advances in spray nozzle design for the finishing industry. A complete range of finishing equipment is available from BETE, in a wide range of materials and sizes, and BETE is the only manufacturer to offer a number of advanced designs including special tooling for 17mm spigot holes, unique, custom formed, non-corrosive risers and easy-to-use ¼ turn nozzle tips. Introduced as a new system, or as a retrofit or expansion of existing equipment, the entire range is colour-coded for ease of identification and pipe size compatibility, or custom designed for specific applications. All equipment is designed for ease of use and can be quickly and simply modified by hand, even when wearing protective gloves.