Optimizing Your Spray System
Spray nozzle maintenance and control
for improved production efficiency
This handbook is a compilation of the knowledge we’ve acquired through more than 60 years of helping users solve spray application problems. Our experience reaches into more than 200 different industries and has led us to develop tens of thousands of spray nozzles and accessories, a turnkey systems division, spray research and analysis services and custom fabrication facilities. We have manufacturing locations around the world and we work with hundreds of thousands of customers.

The intent of this handbook is educational. Our goal is to help you maximize the performance of your spray system by sharing our expertise. Throughout the handbook, you will see occasional references to our company and our capabilities. This information is included so you know where to go for the reference material cited and have a benchmark for comparison when evaluating spray system equipment.
What is Spray System Optimization?

Spray systems are often perceived as pretty simple. After all, what’s so complicated about pumps, piping, liquid and spray nozzles? As long as the nozzles are spraying, the system is working properly, right? Wrong!

Spray nozzles are precision components designed to yield very specific performance under very specific conditions. Just because a nozzle is spraying doesn’t mean that it is working properly. And it certainly doesn’t mean that your spray system performance is optimal. Many other factors can impact your spraying system.

To achieve long-term, efficient, optimal performance you need to consider your spray system in its entirety and develop a plan for evaluating, monitoring and maintaining it. If you don’t already have a Spray System Optimization Program in place, isn’t it time to learn more and get started?

Why is it important?

When your spray system isn’t performing optimally, you can experience a wide variety of problems — all of which will cost you time and money. For example, you could experience:

- quality control issues
- unscheduled production downtime
- increased maintenance
- increased consumption of costly chemicals, water and electricity
- negative environmental impact

The resulting cost of these problems can be surprising and, in some cases, staggering. The cost of wasted water alone can reach tens of thousands of dollars a year in a system with a relatively minor deterioration in performance.
What are the benefits?
When your spray system is optimized, you should experience trouble-free operation including:

- maximum system efficiency
- low operating and maintenance costs
- excellent quality control
- consistent cost of consumables
- predictable labor costs
- normal maintenance schedules and no unexpected downtime
- minimal environmental impact

Sound good?
It will require some effort but it’s well worth it. Your Spray System Optimization Program will go beyond checking system performance against published specifications and will include:

- an evaluation of your current system
- setting system performance standards
- taking steps to optimize your current system
- assessing the costs and benefits of making modifications to your current system and, if appropriate, making changes
- monitoring and maintaining your system to ensure optimal performance

As you read on, you’ll see that a well-executed Spray System Optimization Program can pay for itself quickly.
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Assessing the effectiveness of your spray system

Many spray systems today are manual systems. However, automated systems — with a controller that “manages” performance — are gaining popularity quickly.

Whether you have a manual or an automated system, there are two main considerations when evaluating your spray system.

1. How is your system performing today? Could you improve performance by making some minor modifications or changing your maintenance procedures?

2. Could performance be further enhanced if you automated your system or upgraded your existing control device?

A Spray System Optimization Program begins with an assessment of your current system — manual or automated. In some cases, the signs that your spray system performance could be improved are easy to spot. But most of the time, the signs are subtle and difficult to detect even though the associated costs can be extremely high.
Assessing the effectiveness of your spray system

In general, a good place to start is to review your costs for water, chemicals and electricity. If your present system isn’t performing properly, you could experience significant waste and increased costs. The charts on pages 10 and 11 will give you a feel for how much this waste could be costing.

As you think about your application, keep the following factors in mind as well. They can have a significant impact on cost, too.

• **Labor:**
  Are you spending a lot of time operating or monitoring your system?
  Is manual intervention required to adjust nozzles in conjunction with batch or process changes?
  Is cleanup required due to overspray?
  Are you spending excessive time on maintenance?

• **Increased scrap:**
  Even a slight increase in your reject rate can be extremely expensive.

• **Lost production time**

• **Environmental concerns:**
  such as byproduct disposal and emission costs.
The costly consequences of a spray system that isn’t optimized

If you are spraying water:

Based on a 5 day work week, 24 hours per day, assuming 15% waste rate.
Water/sewage cost: $0.003 (€ 0.0027) per gallon — $0.00079 (€ 0.00071) per liter

Note: The cost of wastewater disposal should also be considered.
In addition, excessive wastewater may aggravate water shortage problems.
All € figures calculated with a conversion factor of 1USD = € 0.90.
The costly consequences of a spray system that isn’t optimized

## If you’re spraying solutions, coatings, solvents, lubricants:

<table>
<thead>
<tr>
<th>Total Spray System Flow (gpm / l/min)</th>
<th>Annual Chemical Waste* (gallons / liters)</th>
<th>Price Per Unit (gallon / liter)</th>
<th>Annual Cost of Wasted Liquid USD (€ Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.10 (.50)</td>
<td>5,620 (28,080)</td>
<td>.50 (.10)</td>
<td>2,810 (2,529)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.00 (.40)</td>
<td>11,240 (10,116)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.00 (1.00)</td>
<td>28,100 (25,290)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.00 (4.00)</td>
<td>112,400 (101,160)</td>
</tr>
<tr>
<td>.25 (1.25)</td>
<td>14,040 (70,200)</td>
<td>.50 (.10)</td>
<td>7,020 (6,320)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.00 (.40)</td>
<td>28,080 (25,272)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.00 (1.00)</td>
<td>70,200 (63,180)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.00 (4.00)</td>
<td>280,800 (252,720)</td>
</tr>
<tr>
<td>1.0 (5.0)</td>
<td>56,200 (281,000)</td>
<td>.50 (.10)</td>
<td>28,100 (25,290)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.00 (.40)</td>
<td>112,400 (101,160)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.00 (1.00)</td>
<td>281,000 (252,900)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.00 (4.00)</td>
<td>1,124,000 (1,011,600)</td>
</tr>
<tr>
<td>3.0 (15.0)</td>
<td>168,480 (842,000)</td>
<td>.50 (.10)</td>
<td>84,240 (75,820)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.00 (.40)</td>
<td>336,960 (303,260)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.00 (1.00)</td>
<td>842,400 (758,160)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.00 (4.00)</td>
<td>3,369,600 (3,032,640)</td>
</tr>
</tbody>
</table>

* 6,240 hours per year based on 24 hours per day, 5 days per week, assuming 15% waste.

## The effect on electrical power consumption:

### At 40 psi / 3 bar

<table>
<thead>
<tr>
<th>Total Spray System Flow (gpm / l/min)</th>
<th>Annual Excess Pumped* (gallons / m³)</th>
<th>Annual Waste in Kilowatts at 40 psi (3 bar)</th>
<th>Cost of Waste ** USD (€ Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (20)</td>
<td>280,000 (1,120)</td>
<td>112 (129)</td>
<td>9 (9)</td>
</tr>
<tr>
<td>10 (40)</td>
<td>561,600 (2,240)</td>
<td>225 (258)</td>
<td>18 (19)</td>
</tr>
<tr>
<td>50 (200)</td>
<td>2,808,000 (11,200)</td>
<td>1,120 (1,290)</td>
<td>90 (93)</td>
</tr>
<tr>
<td>100 (400)</td>
<td>5,616,000 (22,400)</td>
<td>2,250 (2,580)</td>
<td>180 (185)</td>
</tr>
<tr>
<td>500 (2,000)</td>
<td>28,080,000 (112,000)</td>
<td>11,200 (12,900)</td>
<td>896 (929)</td>
</tr>
</tbody>
</table>

### At 2000 psi / 100 bar

<table>
<thead>
<tr>
<th>Total Spray System Flow (gpm / l/min)</th>
<th>Annual Excess Pumped* (gallons / m³)</th>
<th>Annual Waste in Kilowatts at 2,000 psi (100 bar)</th>
<th>Cost of Waste ** USD (€ Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (20)</td>
<td>280,000 (1,120)</td>
<td>5,616 (4,280)</td>
<td>449 (308)</td>
</tr>
<tr>
<td>10 (40)</td>
<td>561,600 (2,240)</td>
<td>11,230 (8,560)</td>
<td>898 (617)</td>
</tr>
<tr>
<td>50 (200)</td>
<td>2,808,000 (11,200)</td>
<td>56,200 (42,800)</td>
<td>4,496 (3,082)</td>
</tr>
<tr>
<td>100 (400)</td>
<td>5,616,000 (22,400)</td>
<td>112,300 (85,600)</td>
<td>8,984 (6,163)</td>
</tr>
<tr>
<td>500 (2,000)</td>
<td>28,080,000 (112,000)</td>
<td>562,000 (428,000)</td>
<td>44,960 (30,816)</td>
</tr>
</tbody>
</table>

* 6,240 hours per year based on 24 hours per day, 5 days per week, assuming 15% waste.

** $.08/€.072 per kilowatt hour
## Common spray applications and common problems

### Air Control

<table>
<thead>
<tr>
<th><strong>APPLICATION:</strong></th>
<th><strong>POTENTIAL PROBLEMS:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling, cleaning, drying and moving of materials.</td>
<td>– Uneven cooling, cleaning or drying.&lt;br&gt;– Quality control issues from product not being rejected or moved.&lt;br&gt;– Increase in compressed air usage.</td>
</tr>
</tbody>
</table>

### Cleaning, Washing and Rinsing

<table>
<thead>
<tr>
<th><strong>APPLICATION:</strong></th>
<th><strong>POTENTIAL PROBLEMS:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low and medium pressure using centrifugal-type pumps for cleaning of tanks, products, vehicles, plant processing equipment.</td>
<td>– Increased flow rate and uneven cleaning of a surface.&lt;br&gt;– Cross-batch contamination.&lt;br&gt;– Increased electricity consumption.</td>
</tr>
<tr>
<td>High-pressure washers using positive displacement pumps for car washes and descaling hot rolled steel.</td>
<td>– Uneven cleaning due to spray pattern deterioration.&lt;br&gt;– A drop in spray pressure and lower spray impact.</td>
</tr>
</tbody>
</table>

### Coating

<table>
<thead>
<tr>
<th><strong>APPLICATION:</strong></th>
<th><strong>POTENTIAL PROBLEMS:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of rust inhibitors, plastic coatings, release agents, lubricants, protective films, etc., as well as moistening and curing applications.</td>
<td>– Waste of expensive coating materials.&lt;br&gt;– Uneven application or coating thickness on finished products.&lt;br&gt;– Unsafe work environment such as slippery floors and fumes resulting from overspray.</td>
</tr>
</tbody>
</table>
### Common spray applications and common problems

#### Cooling

<table>
<thead>
<tr>
<th>APPLICATION:</th>
<th>POTENTIAL PROBLEMS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling of solid objects such as fabricated products and processing equipment</td>
<td>– Poor product quality such as distortion and cracks and excessive downtime.</td>
</tr>
<tr>
<td>Cooling of air and gases.</td>
<td>– Less efficient cooling.</td>
</tr>
<tr>
<td></td>
<td>– System performance degradation.</td>
</tr>
<tr>
<td></td>
<td>– Emission problems or duct, chimney or equipment damage possible.</td>
</tr>
<tr>
<td>Cooling of pond water and cooling tower water.</td>
<td>– Water system efficiency reduction.</td>
</tr>
</tbody>
</table>

#### Spray Drying

<table>
<thead>
<tr>
<th>APPLICATION:</th>
<th>POTENTIAL PROBLEMS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying of feed stock to powder</td>
<td>– Incomplete drying; powder never forms.</td>
</tr>
</tbody>
</table>

#### Specialty Applications

<table>
<thead>
<tr>
<th>APPLICATION:</th>
<th>POTENTIAL PROBLEMS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust control</td>
<td>– Dust isn’t contained; turns to sludge/mud build-up.</td>
</tr>
<tr>
<td>Humidification</td>
<td>– Evaporating efficiency reduced.</td>
</tr>
<tr>
<td></td>
<td>– Humidity increases.</td>
</tr>
<tr>
<td>Gas scrubbing</td>
<td>– Increased discharge of SO$_2$ gas into the atmosphere.</td>
</tr>
</tbody>
</table>
Calculating the potential cost in your application

The next step in the assessment of your present system is to obtain information specific to your application. One way to do this is to utilize our Spray System Savings Calculator. Available at www.spray.com/save, this tool will allow you to enter detailed information about your application and determine how much you may save by optimizing your spray system. The calculator prompts you for information about the cost of the liquid you are spraying, the number of nozzles you’re using, your flow rates, the duration of your spray operation, labor costs, downtime costs and more. Once you’ve supplied the requested information, you’ll see just how much you may be able to save. It’s a quick and easy way to understand and appreciate the value a Spray System Optimization Program may bring to your company.
Setting Optimization Strategies for Your Application

Defining performance standards for your spray system .......... 16-17
Setting strategies to achieve your goals .................................. 18
Setting specific performance standards is critical to any Spray System Optimization Program. After all, how can you optimize performance if you haven’t determined what optimal performance is?

The first step is to identify the most critical requirements in your application. For instance, in some spray applications there is one primary purpose such as metering a specific amount of liquid into batches, tanks, etc. In these applications, it is critical to ensure that an accurate flow rate is delivered consistently. In precision coating applications, the spray pattern is as important as the flow rate, and both characteristics must be monitored. In high-pressure cleaning and descaling applications, it is most important to maintain the proper spray impact by holding a constant pressure and spray pattern.

There are other important application considerations as well. Product quality, throughput, operation supervision, maintenance time and flexibility should also be part of the performance standards you set for your spray system.

So how do you turn all these requirements into measurable performance standards for your spray system? Perhaps the most efficient way is to ask the experts for help. For example, we can provide this service — often at no cost. If specialized testing is required to simulate your operating environment, we can provide that service as well.

If you decide to set your performance standards on your own, use this checklist of performance factors to help you get started. Determine which factors are critical to your application.

- Generating spray patterns — full cone, hollow cone, flat or solid stream
- Spray atomization (drop size)
- Spray impact (the force of a spray onto the target surface)
- Precise cycling intervals
- Exact product coverage
Advanced spray analysis requires state-of-the-art spray laboratory equipment and a knowledgeable staff. The equipment used most frequently in determining spray system performance standards includes:

- **Spray nozzle patternators**
  to measure liquid distribution

- **Laser imaging**
  for measuring drop size of large capacity nozzles

- **Laser diffraction**
  for measuring drop size of small capacity air atomizing and fine spray nozzles

- **Devices which measure impact variations**
  throughout the spray pattern

- **Wind tunnel**
  to test spray evaporation and spray performance in conditions that simulate a gas stream

- **Air and liquid flow instrumentation**
  for metering flow and pressure

- **Phase Doppler Particle Analyzers**
  for complete drop size evaluation, particularly where spray velocities are required

- **Minimizing overspray**
- **Chemical / corrosion resistance**
- **Wear life**
- **Flexibility to change between spray set-ups**
- **Real-time monitoring**
- **Spray velocity** (the transformation of liquid pressure into high velocity streams)
- **Real-time adjustment**
- **Metering of a specific liquid flow rate at a given pressure**
- **Minimal maintenance time**
Once you’ve set performance standards for your spray system, the next step to optimization is to identify areas for improvement. To help you do that, the next four sections explain how to detect spray system performance problems, how to solve them and how to prevent them in the future.

Improving spray nozzle performance and extending nozzle life through proper maintenance is critical to optimizing any spray system.

Additional improvements in overall spray system performance may be possible through automated control. Because of continual technological advances, spray control options are more plentiful and more affordable today than in the past. Automated systems can quickly pay for themselves through productivity gains and lowering other costs such as labor and consumables.

If you have a manual system, automation may be the best strategy for achieving optimization.

Keep in mind that some spray applications are better suited to automation than others. Section V will help you determine whether your application is well suited for automation.

After assessing all your options, you’ll be ready to finalize your strategy for optimization and achieve your spray system performance goals.
Detecting Spray Nozzle Problems

Symptoms of spray nozzle problems ........................................  20-23
Seven reasons why spray nozzles don’t perform properly...........  24-26
Some spray nozzle problems are easy to detect. For example, quality control issues and increased maintenance time will become apparent quickly. But, there are several less noticeable symptoms that indicate your nozzles are not performing optimally.

It’s important to remember that visual inspection alone doesn’t tell the full story. Some symptoms can’t be seen and require special testing to detect.

**Flow rate change**

- In all nozzles, the flow rate will increase as the surfaces of the orifice and/or internal vane or core begin to deteriorate.

- In applications using positive displacement pumps, which provide the same capacity regardless of pressure, the spraying pressure will decrease as the nozzle orifice enlarges. Lower spray velocities and spray impact will result.

- Increased flow rates or lower spraying pressures may also result in larger drop sizes.
Symptoms of spray nozzle problems

Good Spray Tip

Nozzle tips show little visible difference
The tip on the left is new. The same size tip shown below has worn to the point at which it sprays 30% over capacity. Visual inspection shows little evidence of wear.

Worn Spray Tip

Orifice viewed through optical comparator shows evidence of internal wear
A closer inspection and an analysis of spray collection data (see page 22) reveal the difference between the two tips.

Note: All photographs are unretouched.
Symptoms of spray nozzle problems

Deterioration of spray pattern quality

- Hollow cone nozzles: As orifice wear occurs, the spray pattern uniformity is destroyed as streaks develop and the pattern becomes heavy or light in sections of the spray.

- Full cone spray nozzles: The spray pattern distribution typically deteriorates as more liquid flows into the center of the pattern.

- Flat fan sprays: Streaks and heavier flows in the center of the pattern, accompanied by a decrease in the effective spray angle coverage typify deterioration.

Spray patterns of both tips show little difference. Spray collection in tubes gives dramatic evidence of 30% increase in capacity.
Increase in drop size

- As nozzle orifices wear, the liquid flow increases or the spraying pressure drops, resulting in larger drop sizes. Larger drops result in less total liquid surface area.

### Actual Drop Sizes

<table>
<thead>
<tr>
<th>One inch = 25,400 µm</th>
<th>One millimeter = 1,000 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 µm</td>
<td>1,200 µm</td>
</tr>
</tbody>
</table>

µm = micrometres

Lowered spray impact

- Spray impact is lowered as worn nozzles operate at lower pressures.
- In applications with centrifugal-type pumps, impact may actually increase because of the increased flow through the nozzle.

Use the following equation to calculate total theoretical spray impact:

\[
I = K \times Q \times \sqrt{P}
\]

where

- \( I \): Total theoretical spray impact
- \( K \): Constant
- \( Q \): Flow rate
- \( P \): Liquid pressure

<table>
<thead>
<tr>
<th>( I )</th>
<th>pounds</th>
<th>kilograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K )</td>
<td>0.0526</td>
<td>0.024</td>
</tr>
<tr>
<td>( Q )</td>
<td>gpm</td>
<td>l/min</td>
</tr>
<tr>
<td>( P )</td>
<td>psi</td>
<td>kg/cm²</td>
</tr>
</tbody>
</table>

If you suspect you have a spray nozzle problem but can’t pinpoint it, call for help.

The leading nozzle manufacturers can conduct specialized testing in their labs, help determine the source of the problem, and offer recommendations for correction and ongoing prevention.
Seven reasons why spray nozzles don’t perform properly

Nozzle performance can be compromised and even rendered totally ineffective by eroded, damaged or obstructed nozzle orifices.

**Erosion/wear**

Gradual removal of the nozzle material causes the nozzle orifice and internal flow passages to enlarge and/or become distorted. As a result, flow is usually increased, pressure may be decreased, pattern becomes irregular and the spray drops become larger.

**Corrosion**

Nozzle material may break down due to the chemical action of the sprayed material or environment. The effect is similar to that caused by erosion and wear, with possible additional damage to the outside surfaces of the nozzle. In particular, the performance of air atomizing nozzles is highly sensitive to corrosion. Even small amounts of corrosion will negatively impact drop size and uniformity.

*Please note:* Photographs of worn or damaged nozzles illustrate extreme conditions of neglect. Nozzle problems should never be allowed to reach this stage.
Seven reasons why spray nozzles don’t perform properly

**High temperature**

Certain liquids must be sprayed at elevated temperatures or in high temperature environments. The nozzle may soften and break down unless special, high temperature resistant materials are used.

**Caking/bearding**

Build-up of material on the inside or outer edges of the orifice can occur and is caused by liquid evaporation. A layer of dried solids remains and obstructs the orifice or internal flow passages. Bearding, the build up of materials near the orifice of the nozzle, is also detrimental to nozzle performance and can have serious consequences in some nozzle types such as air atomizing.

**Accidental damage**

Damage to an orifice or nozzle can occur by inadvertent scratching when improper cleaning tools are used. Nozzles are also frequently damaged when dropped during installation or operation.
Seven reasons why spray nozzles don’t perform properly

### Clogging
Unwanted solid particles can block the inside of the orifice. Flow is restricted and spray pattern uniformity disturbed.

### Improper assembly
Some nozzles require careful re-assembly after cleaning so that internal components, such as gaskets, O-rings and internal vanes, are properly aligned. Improper positioning may result in leakage and inefficient spray performance. Over-tightening of nozzle caps onto bodies can cause thread stripping.
Before considering how to optimize spray nozzle performance, lower maintenance requirements and/or extend nozzle life, you should spend a few moments reviewing the basic characteristics of your spray nozzles to verify that you are indeed using the best nozzle type for your application.

The reference chart that follows summarizes the performance that each nozzle type is designed to deliver. We have technical bulletins and technical support staff that can provide further assistance upon request.

### Hollow Cone (whirl chamber-type)

**GENERAL SPRAY CHARACTERISTICS**
Available in a wide range of capacities and drop sizes. Provides a good interface between air and drop surfaces.

**COMMENTS**
The extensive range of capacities and drop sizes makes the hollow cone nozzle useful for a variety of applications where a combination of small drop size and capacity is required.

**Typical Applications**
- Air, gas and water cooling
- Product cooling on conveyors
- FGD applications
- Dust control
- Water aeration

---

### Hollow Cone (deflected-type)

**GENERAL SPRAY CHARACTERISTICS**
Utilizes a deflector cap to form an “umbrella” shaped hollow cone pattern.

**COMMENTS**
Larger capacities can be used to flush or clean tube and pipe interiors and small tanks.

**Typical Applications**
- Water curtain
- Dust suppression
- Fire protection
- Decorative spray
# Basic nozzle characteristics

## Hollow Cone (spiral-type)

**General Spray Characteristics**
Provides a hollow cone pattern with drops that are slightly coarser than those in other hollow cone sprays.

**Comments**
Provides high flow rate in a compact nozzle size. The one-piece design features maximum throughput for a given pipe size.

**Typical Applications**
- FGD applications
- Gas cooling
- Evaporative cooling
- Dust suppression

## Full Cone

**General Spray Characteristics**
Provides a uniform, round and full spray pattern with medium-to-large size drops.

**Comments**
Provides full spray pattern coverage with medium-to-large flow rates. Some vaneless models and oval spray models are also available.

**Typical Applications**
- Washing and rinsing
- Disbursing drops in a chemical reaction process
- Metal cooling
- Dust suppression
- Fire protection

## Full Cone (spiral-type)

**General Spray Characteristics**
Provides relatively coarse drops in a full cone pattern with minimal flow obstruction.

**Comments**
Spray coverage is not as uniform as that from conventional internal vane type nozzles. Provides high flow rates in a compact nozzle size.

**Typical Applications**
- FGD applications
- Dust suppression
- Fire protection
- Quenching ashes
### Flat Spray (deflected-type)

**GENERAL SPRAY CHARACTERISTICS**
A relatively even flat spray pattern nozzle that produces a medium size drops. The spray pattern is formed by liquid flowing over the deflector surface from a round orifice.

**COMMENTS**
Large free passage design through the round orifice reduces clogging. Narrow spray angles provide higher impact, while the wide-angle versions produce a lower impact.

**Typical Applications**
- Washing crushed stone and gravel
- Pulp & paper washing applications; deckle-edge showers, knock-off showers
- Washing of photographic film

---

### Flat Spray (tapered)

**GENERAL SPRAY CHARACTERISTICS**
A tapered edge flat spray pattern nozzle that is usually installed on a header to provide uniform coverage over the entire swath as a result of overlapping distributions.

**COMMENTS**
Designed to be used on a spray manifold or header for uniform, overall coverage across the impact area.

**Typical Applications**
- Spray coating
- Product washing
- Sheeting or plate cooling
- Moistening
- Dust control

---

### Flat (even)

**GENERAL SPRAY CHARACTERISTICS**
Provides even distribution throughout the entire flat spray pattern. Produces medium size drops. Ideal where high and uniform spray impact is required.

**COMMENTS**
The thin rectangular pattern of this nozzle provides uniform coverage. In manifold set-ups, the nozzles are carefully positioned for edge-to-edge pattern contact. Designed primarily for high-impact applications.

**Typical Applications**
- High-pressure washing
- Descaling (hot rolled steel)
- Label removal
- Band spraying
<table>
<thead>
<tr>
<th>Basic nozzle characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid Stream</strong></td>
</tr>
<tr>
<td><strong>GENERAL SPRAY CHARACTERISTICS</strong></td>
</tr>
<tr>
<td><strong>COMMENTS</strong></td>
</tr>
<tr>
<td><strong>Typical Applications</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Spray Pattern</strong></td>
</tr>
<tr>
<td><strong>Atomizing (hydraulic, fine mist)</strong></td>
</tr>
<tr>
<td><strong>GENERAL SPRAY CHARACTERISTICS</strong></td>
</tr>
<tr>
<td><strong>COMMENTS</strong></td>
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<tr>
<td><strong>Typical Applications</strong></td>
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<tr>
<td><strong>Spray Pattern</strong></td>
</tr>
<tr>
<td><strong>Air Atomizing and Air Assisted</strong></td>
</tr>
<tr>
<td><strong>GENERAL SPRAY CHARACTERISTICS</strong></td>
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<tr>
<td><strong>COMMENTS</strong></td>
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<tr>
<td><strong>Typical Applications</strong></td>
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</tbody>
</table>
A comprehensive nozzle maintenance program will help ensure trouble-free performance of your spray system as long as it is performed properly and routinely. Since this is a critical step in spray system optimization, we offer nozzle maintenance workshops as a service to our customers. Workshops typically include a review of the customer’s current program and recommendations for improvement, on-site inspection of spray nozzles and training of maintenance personnel.

Here is a typical manual spray nozzle maintenance program. The actual factors you need to check and the frequency with which you need to check them will be determined by your individual application. You will need to modify this list as appropriate.

It’s always a good idea to document system performance immediately after nozzles are installed to establish a “baseline” for later comparisons. Check these factors frequently to monitor changes in system performance.

### Flow Rate – Each Nozzle

| CENTRIFUGAL PUMPS | Monitor flow meter readings to detect increases. Or collect and measure the spray from the nozzle for a given period of time at a specific pressure. Then compare these readings to the flow rates listed in the manufacturer’s catalog or compare them to flow rate readings from new, unused nozzles. |
| POSITIVE DISPLACEMENT PUMPS | Monitor the liquid line pressure for decreases; the flow rate will remain constant. |

### Spray Pressure – In Nozzle Manifold

| CENTRIFUGAL PUMPS | Monitor for increases in liquid volume sprayed. (Spraying pressure likely to remain the same.) |
| POSITIVE DISPLACEMENT PUMPS | Monitor pressure gauge for decreases in pressure and reduction in impact on sprayed surfaces. (Liquid volume sprayed likely to remain the same.) Also, monitor for increases in pressure due to clogged nozzles. Visually inspect for changes in spray coverage. |

### Drop Size

Examine application results for changes. Drop size increases cannot be visually detected in most applications. An increase in flow rate or a decrease in spraying pressure will impact drop size.
## Spray nozzle maintenance checklist

### Spray Pattern

| EACH NOZZLE | Visually inspect for changes in the uniformity of the pattern. Check spray angle with protractor. Measure width of spray pattern on sprayed surface. Note: If the orifice is wearing gradually, changes may not be detected until the flow rate has increased substantially. If accurate uniformity of spray coverage is critical, special equipment or tests will be required. Contact your nozzle manufacturer. |
| FLAT SPRAY | From an elliptical orifice, the nozzle delivers a flat fan or sheet-type spray with tapered edges, ideal for overlapping adjacent patterns. Inspect visually for a decrease in the included angle of the spray pattern; a heavier liquid concentration in the center of the pattern; and/or streaks and voids in the pattern. |
| HOLLOW CONE | Visually inspect for heavier and/or streaky sections in the circular ring of fluid. |
| FULL CONE – ROUND, SQUARE OR OVAL | Visually inspect for heavier liquid concentrations in the center of the pattern; and/or distortion of the spray pattern. |
| AIR ATOMIZING | Visually inspect for heaviness, streakiness or other distortion of the spray pattern. |

### Nozzle Alignment

| FLAT SPRAY NOZZLES ON MANIFOLD | Check uniformity of spray coverage. Patterns should be parallel to each other. Spray tips should be rotated 5° to 10° from the manifold centerline. |

### Application Results

- Check product for uneven coating, cooling, drying or cleaning.
- Check temperature, dust content, humidity as appropriate.
As you continue to monitor your spray system, you will detect variations in spray nozzle performance.

**There are two major factors to consider when determining how frequently to replace nozzles.**

1. The cost of wasted water, chemicals and energy.
2. The deteriorating quality of the finished product or application result and resulting rework, warranty and customer service problems.

**Does it cost more to keep using problem nozzles or to replace them?**

You should develop criteria for replacing nozzles on a routine basis.

For example, a flow rate increase of 15 percent over rated capacity could be your signal to change nozzles. Our Spray Systems Savings Calculator (available at [www.spray.com/save](http://www.spray.com/save)) may be useful in your analysis work to determine replacement schedules for your application. Decisions can also be made on the basis of using statistical process monitoring systems, which indicate the frequency and nature of the quality control problems caused by deteriorating orifice spray nozzle performances.

In some applications, it may be possible to compensate temporarily for worn orifice problems by decreasing the spray nozzle pressure to deliver the original required flow rate. However, this lower pressure performance may compromise the actual spray coverage as well as the uniformity of the spray distribution, while simultaneously resulting in larger drop sizes and possibly lower impact. In such cases, the acceptance of the lower pressure operation may be a false economy, possibly costing more in product quality than new nozzle replacement costs.

You may find that changing to a different nozzle may be the best solution in the long run. If spray performance can be improved, maintenance time reduced and/or uptime can be increased due to longer nozzle life, you should seriously consider making a change. The additional short-term cost is usually quickly recouped.

If you’re not sure about making a change in nozzle type, you should contact your nozzle manufacturer. If necessary, various nozzles can be tested to determine what type of performance you can expect in your application.

**In fact, performance testing in these applications is fairly common:**

- Coating
- Cooling
- Dust Control
- Fire Suppression
- Food Processing
- Gas Absorption
- Cleaning
- Humidification
- Pharmaceuticals
Evaluate the following options to determine if nozzle life can be extended in your spray application.

**Change nozzle material**

Materials having harder surfaces generally provide longer wear life. Standard nozzle materials include brass, steel, cast iron, various stainless steels, hardened stainless steels, many plastics and various carbides.

**Spray nozzles can also be supplied in other materials upon special request:**

- AMPCO 8®
- CARPENTER 20®
- Ceramics
- CUPRO NICKEL®
- Graphite
- HASTELLOY®
- INCONEL®
- MONEL®
- Nylon
- Polypropylene, PVC and CPVC
- REFRAX®
- Silicon carbide
- STELLITE®
- TEFLO®
- Titanium
- Zirconium

The chart below provides standard abrasion resistance ratios for different materials to help you determine if you should consider a different material for your nozzles, orifice inserts and/or spray tips.

<table>
<thead>
<tr>
<th>SPRAY NOZZLE MATERIAL</th>
<th>RESISTANCE RATIO</th>
<th>SPRAY NOZZLE MATERIAL</th>
<th>RESISTANCE RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>1</td>
<td>Hardened Stainless Steel</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Brass</td>
<td>1</td>
<td>STELLITE®</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>1 - 2</td>
<td>Silicon Carbide (Nitride Bonded)</td>
<td>90 - 130</td>
</tr>
<tr>
<td>Steel</td>
<td>1.5 - 2</td>
<td>Ceramics</td>
<td>90 - 200</td>
</tr>
<tr>
<td>MONEL®</td>
<td>2 - 3</td>
<td>Carbides</td>
<td>180 - 250</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>4 - 6</td>
<td>Synthetic ruby or sapphire</td>
<td>600 - 2000</td>
</tr>
<tr>
<td>HASTELLOY®</td>
<td>4 - 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Materials that offer better corrosion resistance are also available. However, the rate of chemical corrosion on specific nozzle materials is dependent on the solution being sprayed. The corrosive properties of the liquid being sprayed, its percent concentration and temperature, as well as the corrosion resistance of the nozzle material to the chemical must all be considered. We can supply you with this information upon request.

**Footnote:** AMPCO 8 is a trademark of Ampco Metal. CARPENTER 20 is a trademark of Carpenter Technology Corp. CUPRO NICKEL is a trademark of Cooper Chemicals Co. Inc. HASTELLOY is a trademark of Haynes International, Inc. INCONEL and MONEL are trademarks of Special Metals Corporation. REFRAX is a trademark of Stemcor Corporation. STELLITE is a trademark of Deloro Stellite, Inc. TEFLO is a trademark of E.I. Du Pont de Nemours & Co.
Decrease spraying pressure

Although it is not always possible, decreasing pressure, which will slow the liquid velocity through the orifice, may help reduce the orifice wear/corrosion rate.

Reduce the quantity of abrasive particles or concentration of corrosive chemicals

While these changes cannot be made in most applications, possible reductions in the amount of abrasive particles in the feed liquid, and changes in the sizes and shapes of the particles may reduce the wear effects. Also, the corrosive activity of a solution can occasionally be reduced by using different concentrations and/or temperatures, depending on the specific chemicals involved.

Add line strainers or change to nozzles with built-in strainers

In many applications, orifice deterioration and clogging is caused by solid dirt particles in the sprayed liquid. This is particularly common in systems using continuous spray water recirculation. Strainers or nozzles with built-in strainers are recommended with a screen mesh size chosen to trap larger particles and prevent debris from entering the nozzle orifice or vane.

Improve cleaning procedures

As part of your routine maintenance, nozzle orifices should be cleaned regularly and carefully. Cleaning probes made of materials much softer than the nozzle orifice surface should be used. It is easy to damage the critical orifice shape or size and end up with distorted spray patterns and/or increased capacity.

Check to be sure you are using plastic bristle brushes and/or wooden and plastic probes. Wire brushes, pocketknives or welders’ tip cleaning rasps should be avoided at all costs. In some stubborn clogging problems, it is advisable to soak the clogged orifice in a non-corrosive cleaning chemical to soften or dissolve the clogging substance.
The following solutions to common spray problems may give you ideas on how to address issues you are presently facing.

**Problem:** Uneven coating on a moving web resulting in costly quality control problems?

**Solution:** Add adjustable ball fittings to the spray nozzles for more exact control of the spray direction. Ball fittings allow convenient nozzle positioning without disturbing pipe connections.

**Problem:** Excessive maintenance downtime in parts washing due to plugged nozzles?

**Solution:** Replace standard threaded nozzles with clip-on or quick-connect type. These nozzles allow fast and easy installation and maintenance. No tools are required.
**PROBLEM:** Dust build-up at coal transfer points?

**SOLUTION:** Use hollow cone in-line nozzles to effectively suppress dust without wetting coal.

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**PROBLEM:** Tanks still soiled after cleaning cycle?

**SOLUTION:** Increase spray pressure to improve spray impact or upgrade tank wash nozzle to high impact type.

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**PROBLEM:** Excessive moisture content in spray dried powders?

**SOLUTION:** Replace hardened stainless steel nozzle cores and inserts with wear-resistant carbide inserts and cores.
Can you benefit from spray automation? ........................................ 40-41

Automated spray systems improve productivity .......................... 42

Managing performance with a dedicated spray controller .............. 43

Examples of automated solutions that improve productivity .......... 44
Now that you understand how to optimize spray nozzle performance, it’s time to consider whether automating your spray application can further improve your operations. If you’re unsure whether automation makes sense for your application, a quick review of the list that follows should help.

If you answer “yes” to any of these questions, an automated spray system may improve your operations.

- Do variations in your spray process affect your application or quality of your product?

- Is coating coverage critical to your product’s success or are you concerned with coating costs?

- Does your production require spray performance that can change with:
  - Conveyor or line speed
  - Product size, shape or position
  - Temperature
  - Humidity

- Do you need to frequently monitor and inspect your spray application to ensure optimal performance?

- Is your spray system enclosed, making visual inspection difficult?

- Does your process require you to frequently choose among multiple spray set-ups?
Can you benefit from spray automation?

- Do you need to shut down your spray system under certain operating conditions?
- Is liquid overspray on equipment or floors creating a hazardous work area?
- Would you like to reduce maintenance costs?
- Would you like to automate cleaning cycles?
- Do you buy more regulatory emissions or discharge permits than you need to?

For many users, an automated turnkey spray system with a dedicated spray controller is the best way to achieve optimization.

We can help you assess and document how automation may optimize spray performance in your application. We can also help you calculate the potential savings of spray automation and the expected payback period.
Spray nozzles can only perform properly if the entire spray system operates efficiently.

In today’s advanced manufacturing and processing environment, spray systems typically require more than a nozzle and a pump. In addition to the nozzles, spray systems often include special headers or lances, pressure tanks or pumps, sensors, valves and many other hydraulic and pneumatic components. Each of these components must be carefully selected and accurately controlled to ensure optimal results.

From basic on/off control to fully-automated, closed-loop spray control, turnkey spray systems are available to provide the exact level of control required for your application. Dedicated spray controllers with complete spray nozzle performance data can also provide control functionality for the entire system.

Powerful on-board software eliminates the need for on-site programming and ensures optimal spray performance.
Managing performance with a dedicated spray controller

Spray controllers can monitor and automatically adjust spray performance and can compensate for changes in conditions that can affect the efficiency of the operation. If the controller cannot maintain the desired system performance, alarms are activated to prompt human intervention and/or shut down the system before quality suffers.

**Conditions that can be monitored or adjusted by the controller include:**

- Liquid pressure
- Atomizing air pressure
- Fan air pressure
- Flow rates
- Cycle time and duty cycle of automatic spray nozzles
- Conveyer/production line speed
- Liquid availability
- Liquid temperature
- Sensor errors
- External process conditions including temperature and humidity
- System Integrity Checking that automatically detects worn or plugged spray nozzles

If you have an automated system but your controller does not monitor or control all of these conditions, it may be time to consider an upgrade to achieve optimization.
Examples of automated solutions that improve productivity

PROBLEM:
A major meat processor needed to apply a precise dose of antimicrobial agent into a bagged ready-to-eat meat product to control Listeria monocytogenes.

SOLUTION:
An automated spray system injects a predetermined volume of antimicrobial agent into the shrink-wrap bag prior to insertion of deli-style hams. A dedicated spray controller and a special sensor ensure the proper volume of antimicrobial is applied. The system has helped improve food safety while reducing operating costs and increasing throughput.

PROBLEM:
A manufacturer of particleboard was upgrading its line for increased production. Part of the rebuild included a system to apply a release agent to prevent boards from sticking to the conveyor belt.

SOLUTION:
An automated spray system applies the release agent based on board type and line speed. The system provides independent flow control for two different spray headers, verifies spray performance and detects plugged nozzles. Pulse Width Modulated flow control allows for very low flow application without the use of compressed air. Throughput and board quality have increased and the system was less expensive and more reliable than other technologies.

PROBLEM:
A leading international mining company needed to cool hot gases created in their copper smelting operations. Gases needed to be cooled from 1100°F to 700°F (593°C to 371°C) so the exhaust gases could be used in further processing operations.

SOLUTION:
Automated gas cooling systems provide closed-loop temperature control, efficiently cooling the gas stream with an air atomized mist. The system, which replaced expensive-to-maintain air-cooled heat exchangers, maintains the proper gas temperature and also decreases particulates in the gas.

PROBLEM:
A tissue mill needed to evenly apply a new adhesive to multi-ply tissue. Precise application of the adhesive was required to ensure bonding without oversaturating or affecting the softness of the tissue.

SOLUTION:
An automated system, using a spray controller, positive displacement pump, flowmeter and line speed signal, provides accurate flow control to the header to prevent over- or under-application of the adhesive. Automated cleaning cycles wash the spray nozzles in the clean-in-place header and purge the air lines to prevent clogging and ensure optimal operation. The system provides better bonding using less adhesive for 50% lower operating costs than other bonding technologies.
Preventing Spray System Problems
Before They Occur

Avoid potential problems and help ensure the best performance possible ........................................ 46
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Avoid potential problems and help ensure the best performance possible

Most spray system problems are avoidable whether you have a manual or automated system. A Spray System Optimization Program will help ensure trouble-free spraying while maximizing the performance of your system.

In the previous sections, you learned that setting up a Spray System Optimization Program requires you to focus on your spray application and define optimal performance. You also learned about the importance of documenting current performance levels, determining if there’s room for improvement and whether you should consider alternatives to your current system.

Sound like a lot of work? That will depend on the size and complexity of your application. However, your effort will be rewarded since it’s an investment that will pay for itself many times over.

Below is an example of the difference spray optimization can make in a manufacturing operation.

<table>
<thead>
<tr>
<th>COSTS DUE TO AN INEFFECTIVE SPRAY SYSTEM*</th>
<th>GOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cost of liquid sprayed is $2 per gallon at a flow rate of 5 gpm</td>
<td>• Eliminate liquid waste from worn spray nozzles</td>
</tr>
<tr>
<td>• Three hours of manual labor (at $15 per hour) are required for operating, maintaining and documenting the performance of the spray system each day</td>
<td>• Reduce manual labor for spray operation, system maintenance and system documentation</td>
</tr>
<tr>
<td>• Current spray system problems result in 2.5 hours (at $100 per hour) of lost production per week</td>
<td>• Reduce downtime and scrap rate resulting from poor spray performance</td>
</tr>
<tr>
<td>• Poor spray quality results in scrap valued at $100 per day</td>
<td></td>
</tr>
</tbody>
</table>

* Example assumes a spray system operating 8 hours per day, 250 days per year
Can spray system optimization really save you money? You won’t know until you take a careful look. Begin with an audit of your spray system and develop a preventative maintenance plan based on your findings.

Keep in mind that help is readily available. Involving an expert at the beginning of the process will save you time and money. Spraying Systems Co. often provides application assessments and maintenance program recommendations as a service to our customers at no charge. To see how much optimizing your spray system could impact your operations, refer to the Spray Savings Calculator at www.spray.com/save.

Why not get started today?
There’s absolutely no downside risk, and the benefits can be significant.

**Spray System Optimization:**
it’s your roadmap to better spray performance and lower costs.

<table>
<thead>
<tr>
<th>RESULT</th>
<th>SAVINGS DUE TO SPRAY OPTIMIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 10% savings of liquid flow due to optimized spray nozzle operation</td>
<td>$60,000</td>
</tr>
<tr>
<td>• Elimination of manual labor due to system automation</td>
<td>$11,250</td>
</tr>
<tr>
<td>• Elimination of downtime and 75% reduction of scrap rate due to precise spraying</td>
<td>$33,750</td>
</tr>
</tbody>
</table>

**TOTAL ANNUAL SAVINGS DUE TO SPRAY SYSTEM OPTIMIZATION** $105,000