



Spray atomisation for gas cooling and conditioning in cement plants

Spraying solutions

by Wes Bartell, William Hebden, Rudolf Schick, Spraying Systems Co

Fewer kilns, higher production requirements, alternative fuel sources, more pressure to reduce operating costs, compliance considerations and efficiency of downstream equipment. All of these are important issues that must be considered when evaluating the efficiency and effectiveness of gas cooling applications. The very basic issue, however, remains the same – the need to cool hot gases and reduce volume quickly. Spray technology is an answer to these new challenges and this article focuses on recent technological advances in spray atomisation for gas cooling and conditioning.

Spray technology is one of the most effective ways to cool and condition gases. In fact, recent advances in atomisation technology and the introduction of high-efficiency air atomising nozzles make it an even better solution than it was just a few years ago. Users in a wide variety of industries, including cement manufacturing, are experiencing efficiency gains, reductions in maintenance time and lower energy consumption by using these new air atomising nozzles for gas cooling.

Evaporative cooling: two options

Historically, evaporative cooling systems for gas conditioning have consisted of multiple high-pressure, hydraulic spray nozzles, simple manifolds, high-pressure pumps and basic controllers. These systems are effective and are still in use today. However, plants using these systems are often plagued by wetting, build-up on duct or tower walls and bottoms and leaking nozzles – all of which contribute to high maintenance costs. These systems are also costly to operate since they operate at high pressures.

In the last decade, air atomising nozzles have become more sophisticated. New atomisation techniques now produce finely atomised sprays that are comprised of very small drops – significantly smaller than those produced by high-pressure hydraulic nozzles (see Figure 1).

The very small drops produced by air atomising nozzles require little dwell time for complete evaporation. The finely atomised sprays also generate more surface area per gallon and permit the liquid to react more completely with the gas stream for complete absorption. The result? Fast, complete evaporation without wetting.

In addition to better cooling performance, systems using air atomising nozzles

offer several other benefits in the areas of installation, operation and maintenance.

Atomising nozzles over high pressure hydraulic nozzles?

Table 1 shows a comparison of the two options for evaporative cooling which helps illustrate the advantages of gas cooling systems utilising air atomising nozzles.

Performance differences

A hypothetical example will help demonstrate the differences between hydraulic and air atomising systems. Table 2 shows the operating conditions at a fictitious cement plant (assuming this plant is going to build a new gas cooling tower to accommodate this application).

Using standard gas cooling calculations, Table 3 shows a summary of the tower size requirement for each cooling method based on the D_{max} drop size performance of each type of nozzle. If hydraulic nozzles are used for gas cooling:

- tower will need to be 45 per cent taller
- 26 per cent wider
- 10 additional lances required
- evaporation will take twice as long.

Clearly, a system using air atomising nozzles offers better results at a considerably lower cost.

Table 2: operating conditions at the fictitious cement plant

Gas volume: 147,144scfm (250,000 Nm³/h)
Inlet gas temperature: 716°F (380°C)
Outlet gas temperature: 302°F (150°C)
Total liquid volume: 120gpm (454l/min)

Table 3: summary of tower size requirements for each cooling method based on the D_{max} drop size performance

| Tower Size | Air Atomising | Hydraulic |
|--------------------------------|--------------------|---------------------|
| Diameter | 21.3ft (6.5m) | 27ft (8.2m) |
| Height | 65.2ft (20m) | 95 ft (29m) |
| Number of Lances | 8 | 18 |
| Liquid Pressure | 56psig (3.86 barg) | 600psig (41.3 barg) |
| Liquid Volume per Lance | 15gpm (59.7 l/min) | 7.0gpm (26.4l/min) |
| Air Pressure | 50psig (3.45 barg) | -- |
| Air Volume per Lance | 51scfm | -- |
| Residence Time for Evaporation | 5.1 seconds | 12 seconds |

Table 1: a comparison of two options for evaporative cooling

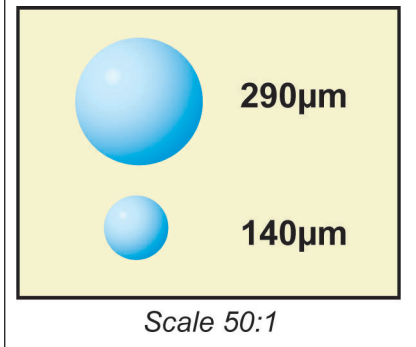
| | Air Atomising Nozzle systems | Hydraulic Nozzle systems |
|--------------------------------------|---|--|
| Drop/size performance | <p>Precise via control of both air and liquid</p> <ul style="list-style-type: none"> • Tight control (drop size remains constant) as flow rate varies • Small size: reduces dwell time and risk of wetting <p>• More surface area generated by sprays: better absorption.</p> | <ul style="list-style-type: none"> • Varies with pressure changes • Constant flow at given pressure. Changes pressure or flow alters drop size. • Larger drop size requires more dwell time for evaporation and increases the risk of wetting. If water isn't evaporated, cooling is incomplete and excess water can turn cement dust into cement • Less surface area. Less absorption |
| Pressure | <ul style="list-style-type: none"> • Low. Low pressure pumps (10HP typical) required & piping • Low maintenance • Low energy consumption | <ul style="list-style-type: none"> • High. High-pressure pumps (50-75HP typical) and piping required. Pumps typically run continuously to maintain pressure at nozzles. • High maintenance • High energy consumption |
| Compressors | <ul style="list-style-type: none"> • Required (125HP) typical • Air efficient nozzles use little air, lowering energy costs and extending compressor life | <ul style="list-style-type: none"> • Not required |
| Nozzle free passage | <ul style="list-style-type: none"> • Large. River water, basins and run-off water acceptable for use | <ul style="list-style-type: none"> • Small. Clogging is a common problem. Clean water supply is required. |
| No of lances/ nozzle capacity | <ul style="list-style-type: none"> • Low. Nozzles are available with capacities up to 65gpm (247L/min) per nozzle • One air atomising lance may replace four hydraulic lances | <ul style="list-style-type: none"> • High. Flow rates greater than 10gpm (37.8L/min) are not possible because the drop size would be too large for effective evaporation |
| Efficiency | <ul style="list-style-type: none"> • High. More efficient reduction in gas volume and faster cooling results in lower energy costs • Downstream equipment (ESP and baghouse) efficiency is improved as gas density is increased and gas volume and velocity are decreased | <ul style="list-style-type: none"> • Low. Gas volume and temperature reduction takes longer; uses more energy • Downstream equipment less efficient. Expansion may be required if volume increases |
| Humidity control | <ul style="list-style-type: none"> • Precise. Improves ESP dust collection efficiency and opacity correction | <ul style="list-style-type: none"> • Less precise. Greater risk of problems. Too much can cause acid dew point problems (corrosion) and damage to downstream equipment. Too little can result in release of particulates into atmosphere |

Figure 1: illustration of a drop from a hydraulic nozzle and a drop from an air atomising

Typically, lances in cooling towers have used hydraulic nozzles with flow rates of 7.0gpm (26.4l/min) for optimal evaporation. At 580psig (40 barg), the D_{max} (the maximum drop size by volume present in the spray) is 290 micrometers.

Many lances in cooling towers are now equipped with high-efficiency air atomising nozzles. At a flow rate of 7gpm (26.4l/min) and 50 psig (3.45 barg), the D_{max} drop size is 140 micrometers.

The drop from the hydraulic nozzle is 107 per cent larger than the drop from the air atomising nozzle.



How air atomising nozzles work

In very basic terms, atomisation is the process of generating drops. The process begins by forcing liquid through a nozzle. The potential energy of the liquid along with the geometry of the nozzles causes the liquid to emerge as small ligaments. These ligaments then break up further into very small "pieces" or drops.

However, not all air atomising nozzles are designed for critical applications such as gas cooling. Most air atomising nozzles are designed for general use and work well in a wide range of applications. The air itself – high volume and high pressure -- is the primary source of atomisation in these nozzles.

In gas conditioning applications, air atomising nozzles must offer tight control of drop size and spray coverage. The goal is to minimise D_{max} and achieve a finely atomised spray with D_{32} (also known as Sauter Mean Diameter, SMD) less than 80 microns at 25gpm (95 l/min). Nozzles that achieve this very small drop use a multi-stage atomisation process.

Figure 2 below shows the basic operating principle of a nozzle that uses a three-stage process to generate very small drops. As shown, the air and liquid combine behind the air guide. The pressure drop across the air guide orifice provides pri-

Table 1 continued...

| | Air Atomising Nozzle systems | Hydraulic Nozzle systems |
|---------------------------|--|---|
| Damage potential | <ul style="list-style-type: none"> • Unlikely. Elimination of wetting reduces risk of deposits breaking free and damaging downstream equipment • Quicker temperature reduction & better control reduces risk of hot gases burning costly filters in baghouse | <ul style="list-style-type: none"> • Possible because of wetting problems or leaking nozzles • Possible because of less precise temperature & humidity control (see Humidity Control) |
| Installation costs | Lower. Fewer lances required. (see No of Lances) | Higher. Greater number of Lances required. (see No of Lances) |
| Maintenance | <ul style="list-style-type: none"> • Low. Nozzles operate at low pressures • Nozzles made of wear-resistant materials • Fast, complete evaporation eliminates wetting and associated problems • No special tools required for maintenance | <ul style="list-style-type: none"> • High • Nozzles typically available in standard materials • Slower evaporation increases risk of wetting • Special tools often required |

mary atomisation of the liquid stream. Then the focused stream impacts the target bolt forcing additional mechanical breakup. The nozzle's air cap then acts as a final mixing chamber.

As liquid crosses multiple orifices, an additional pressure drop provides the final atomisation.

Drop size data: critical & complicated

As discussed, tight control and small drop size are critical in spray atomisation. But when evaluating spray performance data, numbers that indicate small drop size aren't enough.

It is important to be sure to understand the drop size measurement tech-

Definition of terms

- **D_{32}** , also known as Sauter Mean Diameter (SMD): Expresses the fineness of a spray in terms of the surface area produced by the spray. The SMD is the diameter of a drop having the same volume of all the drops to the total surface area of all the drops.
- **D_{max}** : The maximum drop size by volume (or mass) present in the spray.
- **D_{min}** : The minimum drop size by volume (or mass) present in the spray.

niques, type of drop size analyser, sampling data analysis and reporting techniques being used because they all have a strong influence on the results.

For gas conditioning applications, here are guidelines for drop size measurement testing:

- avoid using drop size measurement instruments that rely on high-speed photography and/or light scattering techniques. These instruments may not be adequate for measuring high-density sprays
- phase Doppler Particle Analysers (PDPA) are typically better suited for measuring high-density sprays. These instruments are equipped with a high-power laser that can be used to offset the obscuration caused by high-density sprays. In addition, these instruments are capable of measuring drop size and velocity for every drop in the spray.
- report drop size distribution conservatively. ASTM Standard E799-92 permits D_{max} to make up as much as one per cent of the volume. Look for tighter standards as a safety net. For example, D_{max} less than 0.20 per cent of volume is preferred
- report information in terminology consistent with definitions in ASTM Standard E1296-93 (1,3). For gas conditioning applications, be sure that at a minimum,

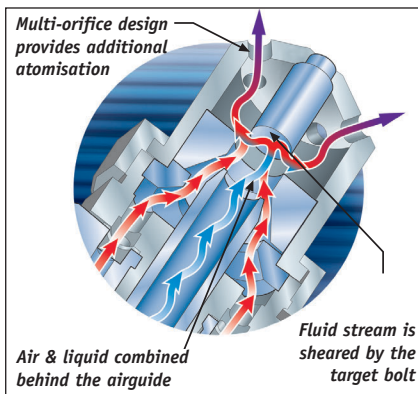


Figure 2

information on D_{32} (Sauter Mean Diameter), D_{max} and D_{min} is included.

Turnkey gas conditioning systems: latest advances

Gas conditioning systems for cement manufacturing have typically been configured by integrating components from a variety of suppliers. Controls, nozzles, pumps, compressors, regulators, etc usually come from different manufacturers.

Recently, a new turnkey system solution has been introduced. This system features a proprietary spray controller designed to optimise the performance of this manufacturer's spray nozzles. The system controller monitors and adjusts the closed loop system by regulating liquid and air flow to the nozzles based on information provided by temperature sensors. Because the controller software was written exclusively for spray nozzle and spray system control, it offers the highest level of temperature control, reactivity and accuracy possible.

Table 4: turnkey systems offer significant cost savings

Installation

Air atomising system Hydraulic system

| | |
|---|--|
| 5 lances | 10 lances |
| 2 low-pressure pumps | 2 high-pressure pumps |
| low-pressure piping, valves, skid, thermocouples, etc | high-pressure piping, valves, skid, thermocouples, etc |
| 2 air compressors | |

Cost savings

With the general benefits air atomising nozzles offer compared to hydraulic nozzles already addressed, Table 4 takes one more specific example that shows the installation and ongoing operating cost differences of a turnkey system equipped with air atomising versus hydraulic nozzle. The total estimated installation savings of a system equipped with air atomising noz-

zles is five per cent (approximately US\$25,000). The operating savings are:

- 50 per cent less electricity
- 50 per cent less in replacement parts
- 75 per cent less labour/maintenance.

The annual operating savings of system equipped with air atomising nozzles is estimated at approximately US\$16,000. Over five years, the savings would be approximately US\$80,000.

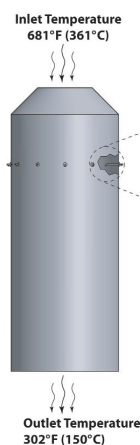
Variety of plant uses

Depending on the layout of the plant, there may be multiple locations where spray atomisation for gas cooling can be used. Common installations include: in duct, cooling towers, clinker coolers, rotary dryers and kilns. The examples below show how three cement plants are utilising spray atomisation and the benefits they are experiencing.

Example #1: rotary kiln gas cooling

A plant in Africa is cooling gases when ball mills are not in operation. Gas temperature is reduced from 681°F (361°C) to 302°F

Gas Conditioning Tower



Operating Data 1

Gas volume: 225,199cfm (328,616Nm³/h)
 Inlet gas temperature: 681°F (361°C)
 Target discharge temperature: 302°F (150°C)

Installation

14 lances equipped with high-efficiency air atomising nozzles

Air pressure: 40psig (2.76 barg)

Air volume: 44.1cfm per lance
 (75 Nm³/h per lance)

Liquid pressure: 47psig (3.25 barg)

Liquid volume: 10.3 gpm per lance
 (39l/min per lance)

Operating D_{max} : 185 micrometers

(150°C) to prevent damage to the ESP. The increase in gas humidity also increases ESP efficiency by improving particulate removal. See Operating Data 1.

Example #2: rotary dryer gas cooling

Clinker gas is prepared for baghouse entry by cooling in the rotary dryer in a plant in the southeastern US. Clinker gas is 640°F (334°C) when released to the dryer and is reduced to 270°F (132°C) before entering the baghouse. Baghouse efficiency is improved as a result. See Operating Data 2.

Example #3: gas cooling in clinker cooler

Reducing gas from 800°F (426°C) to 300°F (148°C) in the clinker cooler in one midwest USA plant ensures costly fiberglass bags in the dust collection system don't burn (see Operating Data 3).

Rotary Cooler

The diagram shows a horizontal cylindrical rotary cooler. On the left side, there is an inlet with an arrow pointing right and the text 'Inlet Temperature 640°F (344°C)'. On the right side, there is an outlet with an arrow pointing right and the text 'Outlet Temperature 270°F (135°C)'. A circular inset at the top left shows a close-up of a lance and nozzle assembly.

Operating Data 2

Gas volume: 386,164 cfm (656,098 Nm³/h)
 Inlet gas temperature: 640°F (344°C)
 Target discharge temperature: 270°F (132°C)

Installation

Six lances equipped with high-efficiency air atomising nozzles
 Air Pressure: 60psig (4.14 barg)
 Air Volume: 40cfm per lance (68Nm³/h per lance)
 Liquid Pressure: 75psig (5.18 barg)
 Liquid Volume: 23gpm per lance (87.1l/min per lance)
 Operating D_{max} : 340 micrometers

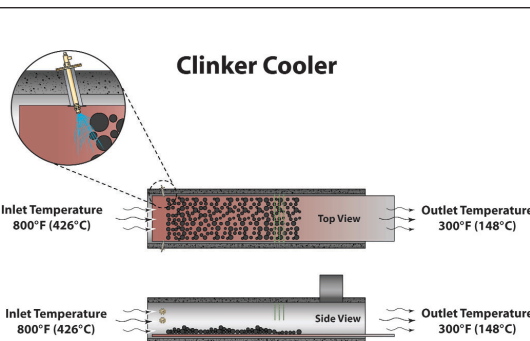
Additional resources

- ILASS- Americas: The Institute for Liquid Atomisation and Spray Systems, North and South America, is an organisation of professionals engaged with spraying liquids. Information requests should be directed to the ILASS Americas Secretariat: 715-824-5468

- ASTM International: Sub-committee E29.04 is involved with writing standards on particle terminology, data processing, imaging and non-imaging instrumentation and reticle calibration equipment. Info requests: 610-832-9693. □

For additional information, contact Spraying Systems Co. Performance data, technical articles, product specifications and no-obligation workshops and evaluations are available upon request from:

Spraying Systems Co
 PO Box 7900, Wheaton
 IL 60189-7900
 USA
 TeL 1-800-95-SPRAY
 Outside US, +1 (630) 665-5000



Operating Data 3

Gas volume: 210,000cfm (356,782Nm³/h)
 Inlet gas temperature: 800°F (426°C)
 Target discharge temperature: 300°F (148°C)

Installation

Two lances equipped with high-efficiency air atomising nozzles

Air pressure: 60psig (4.14 barg)

Air volume: 40cfm per lance (68 Nm³/h per lance)

Liquid pressure: 75psig (5.18 barg)

Liquid volume: 23gpm per lance (87.1l/min per lance)

Operating D_{max} : 170 micrometers