

E. A. Anderson Engineering, Inc.

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PROJECT REPORT PR-2007-2 PRELIMINARY REVIEW OF THE POTENTIAL FOR EMISSIONS OF PARTICULATE MATTER FROM COOLING WATER DRIFT DROPLETS FROM TOWERS USING WCTI ZERO LIQUID DISCHARGE TECHNOLOGY

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A handwritten signature in blue ink, appearing to read "Eric Anderson".

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1.0 SUMMARY

The Environmental Protection Agency (USEPA or EPA) has regulated droplets emitted from cooling tower drift, originally to control the spread of hexavalent chromium into the environment. Sometime in the 1980s, these standards were modified to include ordinary salt water, presumably based upon the effects of salts on the growth of several plant species. The affected cooling towers were initially for the power industry, and used ordinary seawater.

The scientific basis for the original chromium controls has been overcome by events, as cooling tower operators have moved away from using corrosion inhibitors containing hexavalent chromium salts.

Cooling tower design has also progressed since 1977, and drift eliminators are now standard equipment. According to Chapter 13 of AP-42 as downloaded recently from the EPA website, based upon work done by the Cooling Technology Institute between 1984 and 1991, the emission factors for liquid drift and PM-10 from induced draft cooling towers are: 1.7 lb/1000 gallons and 0.019 lb/1000 gallons respectively. The EPA rates these factors at D and E respectively, where A = excellent. A rating of D = below average or E = poor is only acceptable for a crude, order of magnitude estimate of potential emissions.

The situation gets even more unusual, as the EPA has not accounted properly for the droplet size – and resulting particle size - distribution. Further work by EPRI, analyzed by Reisman & Frisbie shows that the drift from a normal mechanical draft cooling tower has 85% of its mass in size fractions greater than 10 μm . Furthermore, the distribution skews to the right as TDS increases past 4,000 ppm, due to the higher percent solids resulting in larger particles upon drying.

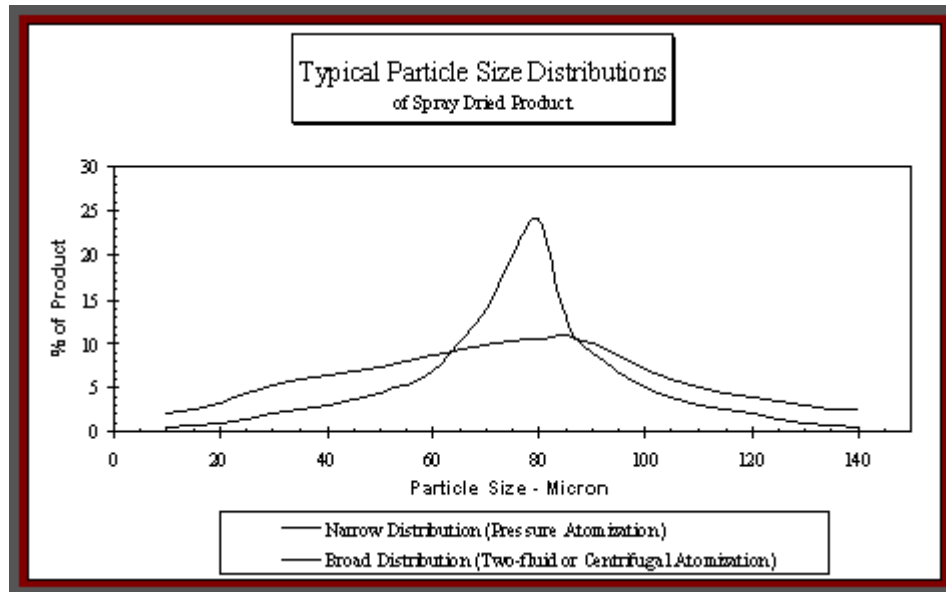
Droplet size via atomization is critical in the spray-drying industry to produce a controllable particle size distribution.

It is extremely difficult to produce PM-10, let alone PM-2.5 sized particles when using pressurized atomization in commercial processes. In spray-cooling applications, spray-drying applications, and the combination known as dry-scrubbing, industrial practice is to use pressures of ~50 psig to produce 100 μm SMD droplets. I have designed spray-cooling towers for several clients, and have developed a computer program to predict the droplets SMD based upon the inlet pressures of the fluids, flowrates, and the orifice diameter. It is not easy to produce a mist of fine droplets. The figures on the next page support this experience.

Therefore, it is even less probable that the relatively low velocity of the induced airflow that entrains cooling tower water droplets (drift) can produce droplets small enough to form this size of dry particles. Higher saturation of TDS salts in the water also results in the formation of larger particles when the droplets dry out. Since the salts formed in tower water with this softened makeup process will be sodium salts, they will also be

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highly soluble in the event of inhalation exposure. The silica concentrated by the process in the tower water is in the amorphous form, which is not subject to the formation of crystalline forms of silicate found in materials like asbestos.



1.1.1 Atomization Energy Comparison

Example based upon atomizing 10 GPM of feed to 70 micron droplets

1. Pressure Nozzle Feed Pump @ 1200 psig: 10 HP
2. Centrifugal Rotary Drive @ 9000 RPM: 25 HP Feed Pump @ 30 psig: 3 HP
3. Two-fluid Nozzle: 180 SCFM @ 80 psig: 30 HP Feed Pump @ 80 psig: 5 HP

All materials property of Spray Drying Systems, Inc. © 2006

This example is from Spray Drying Systems advertising literature. Note that the two-fluid nozzle is using air in this case to atomize the water-based solution to produce 70 μ m droplets – and the pressure required to shear them from the fluid in a small orifice nozzle is 80 psig.

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2.0 INTRODUCTION & OBSERVATIONS

Atomization is the process by which droplets are sheared from a fluid and carried off into an open space or stream of air or other gases. Several useful industrial processes use atomization to produce a controlled distribution of droplet sizes, and there is still some research going on today to improve control of droplet production, especially for the pharmaceuticals and electronics industries.

The perfume atomizer was copied by the automotive industry in the jets of the carburetor as a method to inject suitable droplets into the intake manifold of the gasoline engine. As a mechanic is aware, the optimum droplet size from the jets gives the best possible power and fuel economy when the fuel-air mixture enters the cylinder of the engine.

Air atomization is still one of the most common industrial methods of producing mists of useful droplets.

In addition to combustion, spray painting and spray drying are common applications of air atomization, as are exhaust gas cooling and dry-scrubbing for SO_x removal (a variation on spray-drying where a slurry of lime is injected into the gas instead of bubbling the flue-gas through a wet scrubber). Particle size distribution is a direct function of the liquid flow rate and pressure, the orifice diameter, and the air flow rate and pressure going into the atomizing nozzle.

The process engineer is faced with a complicated balancing act in an effort to produce droplets of a suitably fine distribution, as expressed by a Sauter Mean diameter. A typical SMD for air drying water droplets is ~100 µm. (see the figures on page 4)

Human health concerns have led over the years to the regulation of respirable particulate matter with mean diameters (usually expressed using a Rosin-Rammler distribution) of less than 10 µm, called PM-10. There has been some advocacy for regulations at the 2.5 µm particle size, or PM-2.5, although there have been arguments over the actual effective size of these particles, as they tend to agglomerate.

Silicate minerals, such as quartz grains and asbestos particles have been demonstrated to cause permanent respiratory distress and death when inhaled into the lungs. The earliest known worker safety regulations for these minerals involved the use of water injection into compressed air drills to make a slurry of the dust particles, preventing inhalation.

I have seen references from the 1930s (Hatch & Drinker: **Industrial Dusts**) which show that the mechanism of silicosis and asbestosis in the lungs was known at that time.

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The tissues of the lungs are set up to filter normal dusts out of the air we breathe. The lymphatic system produces mucosal fluids, and the cilia of the mucosa attempt to move the particles out of the lungs. Larger particles are dissolved in the mucous, and some are removed by circulation of the lymphatic system.

Jagged particles, such as quartz or coal dusts are lodged in the tissues. Quartz does not dissolve, so the lymphocytes encapsulate them and encyst them to defend the body from these intrusions. This is a cumulative effect, leading to reduced lung capacity with prolonged exposure.

Certain minerals and dusts really inflame the immune system, such as chrysotile asbestos with its highly reactive and jagged particles. These particles are typically liberated by operations which impart a high degree of shear force to the substrate.

Cooling towers operate in a completely different regime.

The droplets which are liberated from a mechanical draft cooling tower (drift) are not sheared from the cooling water with anything like the energy of an atomizing nozzle. While they are arguably "air atomized", the shear forces and power applied to the fluid are markedly less than the levels in an atomizer, and so the obvious conclusion is that the SMD is much larger than 100 μm .

While the EPA has tried to come up with data for the production of PM-10 from cooling towers, the data is scarce, and indicates extremely low rates of evolution of such dust and fume.

According to Chapter 13 of AP-42 as downloaded recently from the EPA website, based upon work done by the Cooling Technology Institute between 1984 and 1991, the emission factors for liquid drift and PM-10 from induced draft cooling towers are: 1.7 lb/1000 gallons and 0.019 lb/1000 gallons respectively. The EPA rates these factors at D and E respectively, where A = excellent. A rating of D = below average or E = poor is only acceptable for a crude, order of magnitude estimate of potential emissions.

In a seminar paper presented to the California Energy commission in support of a permit application, Reisman & Frisbie show that the AP-42 methods predict PM-10 emissions from cooling water drift which are at least twice those that can be realistically expected. Using normal drift eliminators, the emissions of droplets can be expected to be 0.0003% of the flow rate $[0.000003 \times 8.34 \text{ lb/gal} \times 1000 \text{ gal}] = 0.025 \text{ lbs}$ of droplets per 1000 gallons of cooling water. Compare this with AP-42 at 1.7 lb per 1000 gallons.

The situation gets even more unusual, as the EPA has not accounted properly for the droplet size – and resulting particle size - distribution. Further work by EPRI, analyzed by Reisman & Frisbie shows that the drift from a normal mechanical draft cooling tower has 85% of its mass in size fractions greater than 10 μm . Furthermore, the distribution skews to the right as TDS increases past 4,000 ppm, due to the higher percent solids resulting in larger particles upon drying.

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The other aspect of the silicate minerals in a ZLD cooling tower such as is setup by WCTI is that they are precipitated by drying amorphous sodium salts of silicon dioxide. The mechanism is just not present for shearing a rough or jagged particle from the drying dust, and the minerals are soluble in water.

There are still issues with the plant toxicity of accumulated sodium silicates in the soil or in contact with leaves, but the risk to human and animal health, especially from properly sited cooling towers with functioning drift eliminators, can safely be expected to be quite low.

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