

Suppression of Machining Fluid Misting by Polymer Additives

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Machining Fluids for Metalworking

Function: *Cool and lubricate working surfaces, remove metal chips.*

Metalworking Processes: *Milling, gun-drilling, grinding, etc.*

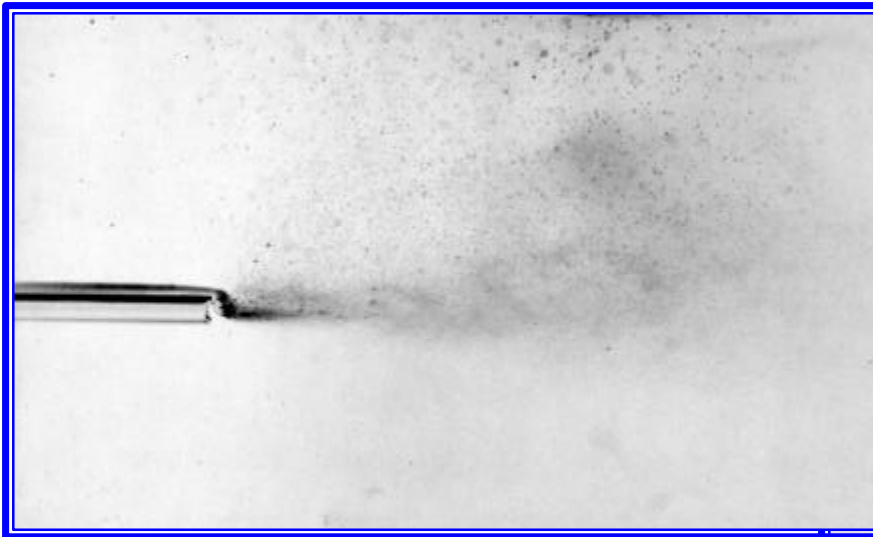
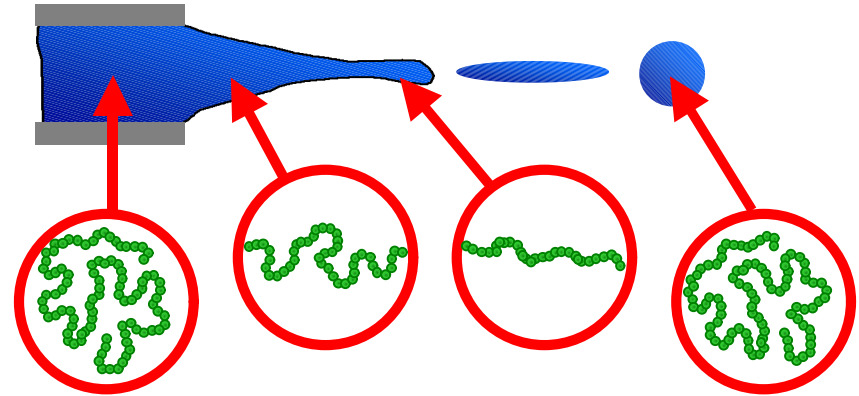
Fluid Types:

Straight Oil *light mineral oils (~20 cp)*

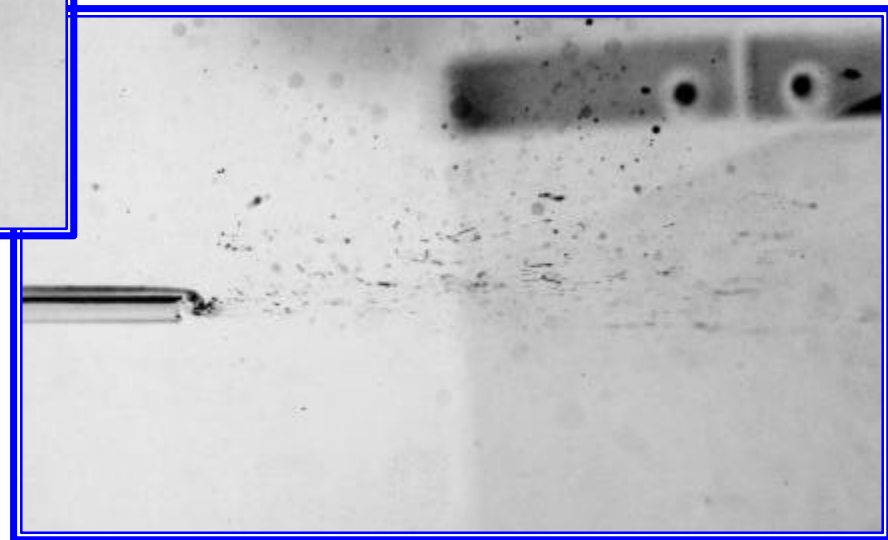
Water-Based *oil-in-water emulsions*

Misting Problem: *Machining fluids break up in high speed machining under impact, shearing, and centrifugal force. Droplets < 5mm are easily entrained in air, leading to worker exposure via inhalation.*

Influence of Polymers on Atomization

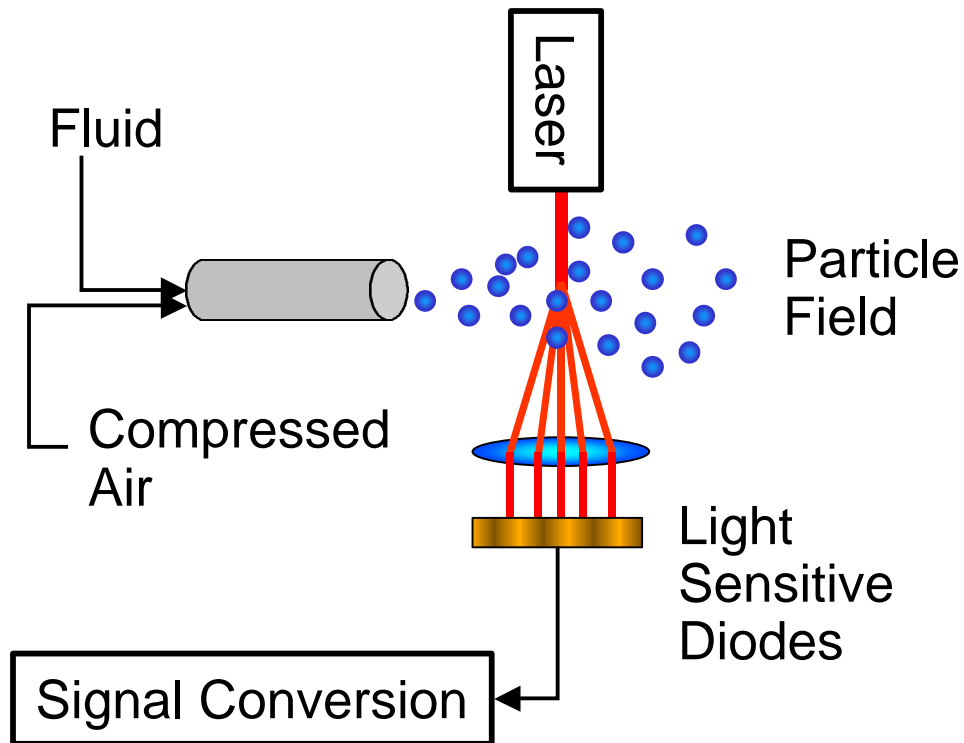


← Mineral Oil

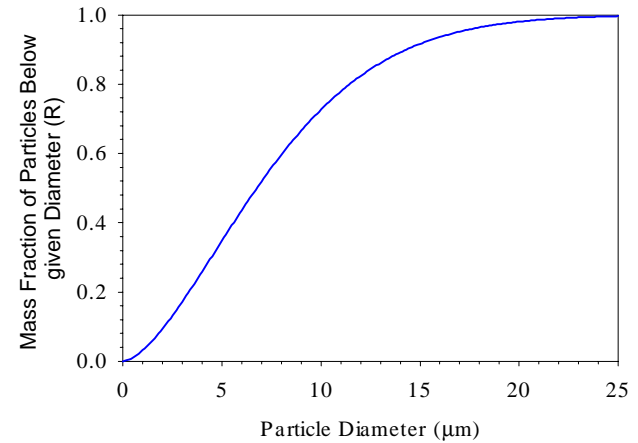


Mineral Oil with 1.0 g/l Polyisobutylene →

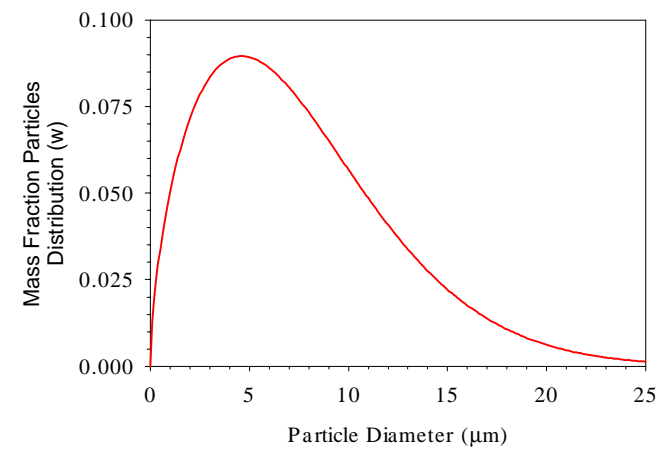
Particle Sizing and Size Distributions



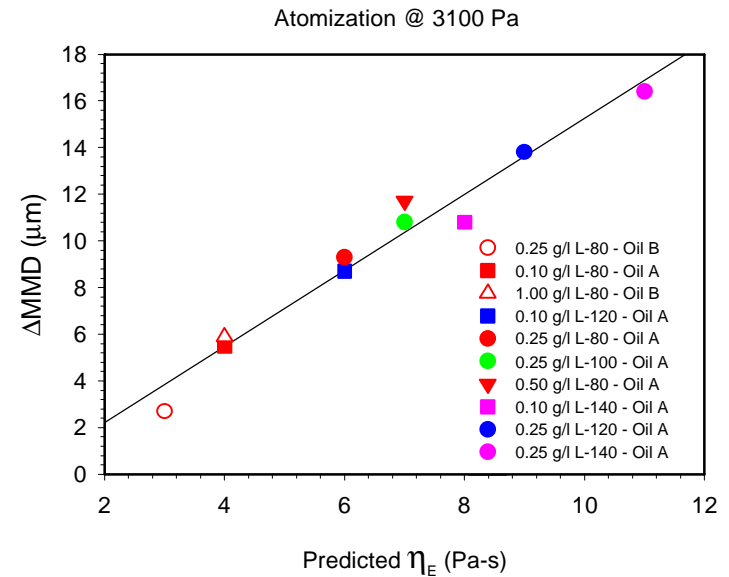
$$R = 1 - \exp\left[-\left(\frac{d}{X}\right)^N\right]$$



$$W = \frac{\partial R}{\partial d}$$



Extensional Viscosity Measurements and its Relationship to Atomization

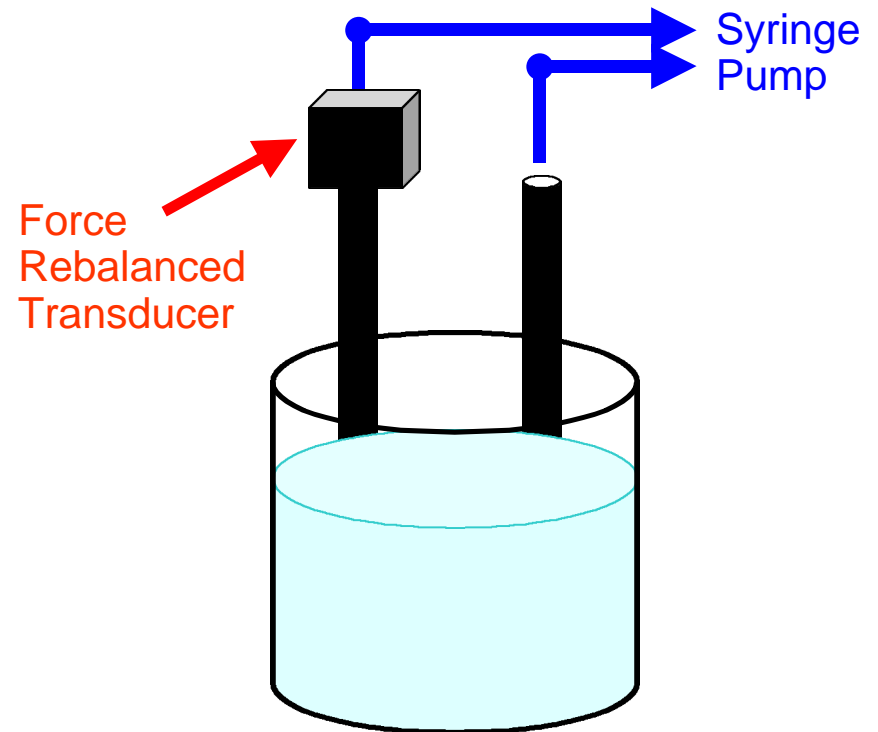


Opposing Jet Rheometer

$$\text{Stress} = \frac{\text{Measured Force}}{\text{Nozzle Area}}$$

$$\text{Strain Rate} \approx \frac{\text{Flow Rate}}{\text{Nozzle Area} \times \frac{1}{2} \text{Gap}}$$

$$h_E \approx \frac{\text{Stress}}{\text{Strain Rate}}$$



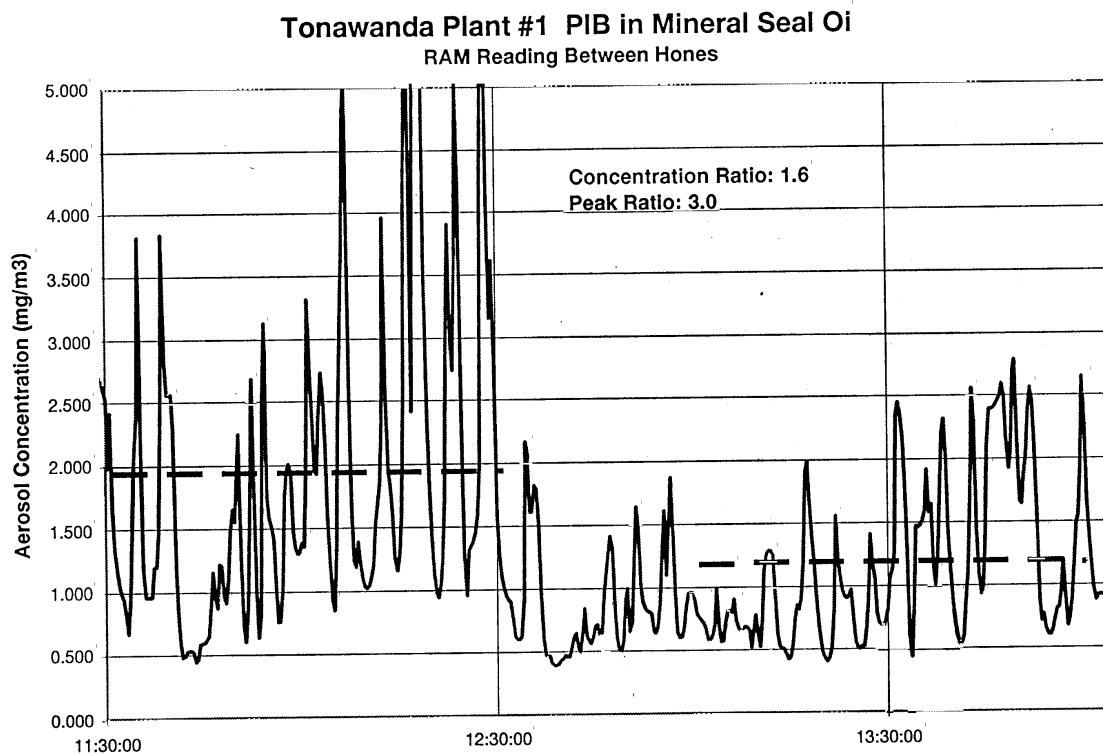
Oil Mist Suppress using Polyisobutylene in Plant Testing

⇒ 70 ppm of PIB add to machining oil

⇒ 40% reduction in average mist levels

⇒ 67% reduction in peak mist levels

⇒ 24 hours plus service life



Use of High-M Polymers for Antimisting Treatment of Machining Fluids in Automotive Industry

Straight Oils

Polymer: 20-50 ppm polyisobutylene ($M= 1-2 \times 10^6$)

Replenishment schedule: daily-weekly

Status: worldwide implementation by Ford, and others.

Water-based Fluids

Polymer: up to 500 ppm polyethylene oxide ($M=1-2 \times 10^6$)

Replenishment schedule: daily

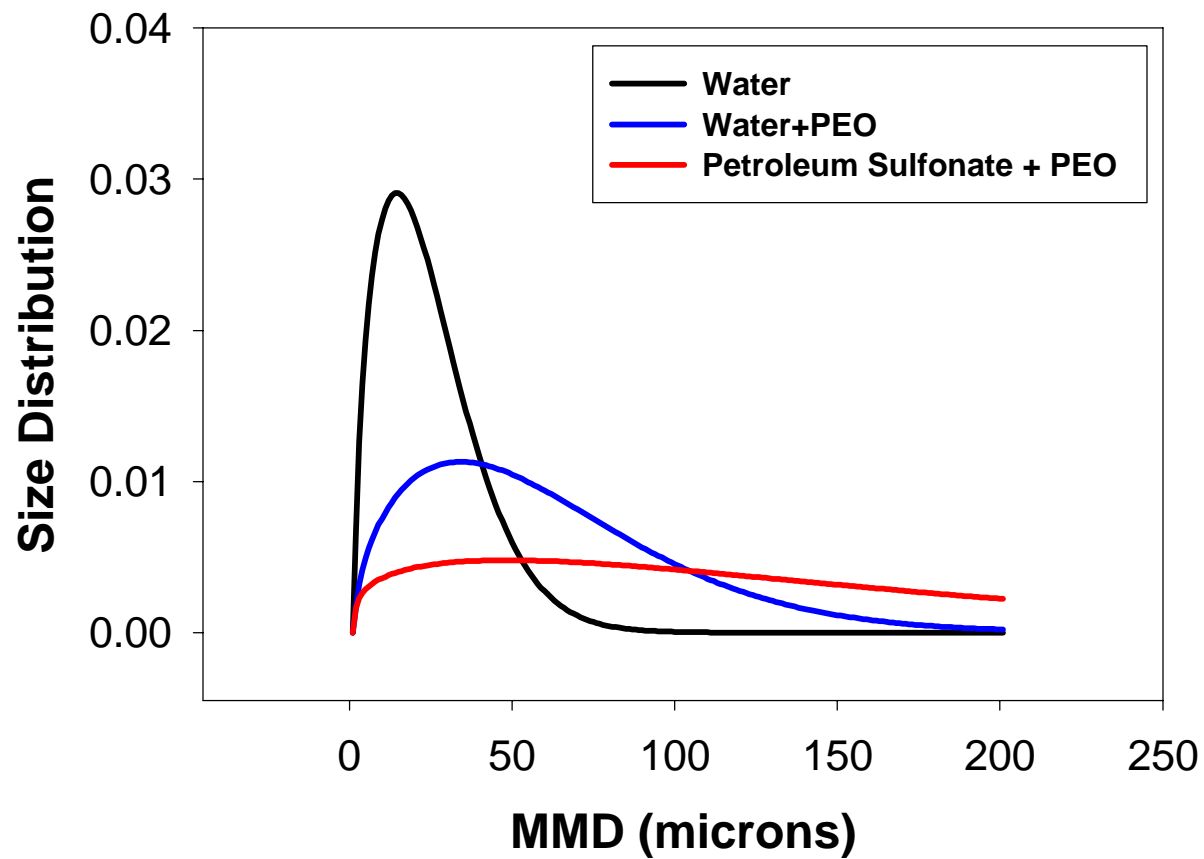
Status: plant-tested but not widely implemented.

Challenge: Improve economics of treatment for water-based fluids by reducing mechanical degradation and/or reducing treatment concentrations.

Associative Chemistry: Polymer-surfactant and polymer-polymer interactions.

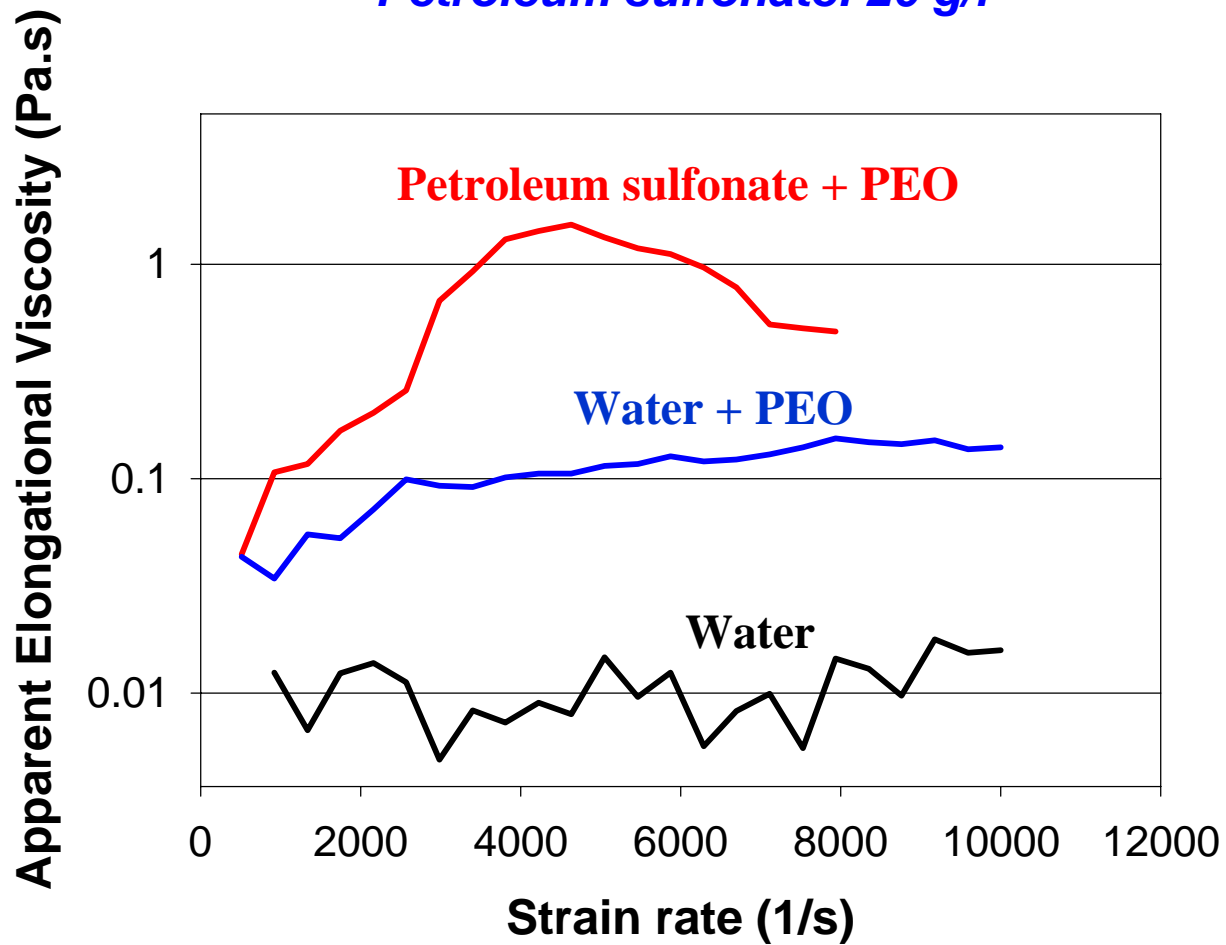
Effect of PEO and Surfactant on Drop Size Distribution

PEO (MW = 2,000,000) : 0.5 g/l
Petroleum sulfonate:20 g/l



Effect of PEO and Surfactant on Solution Elasticity

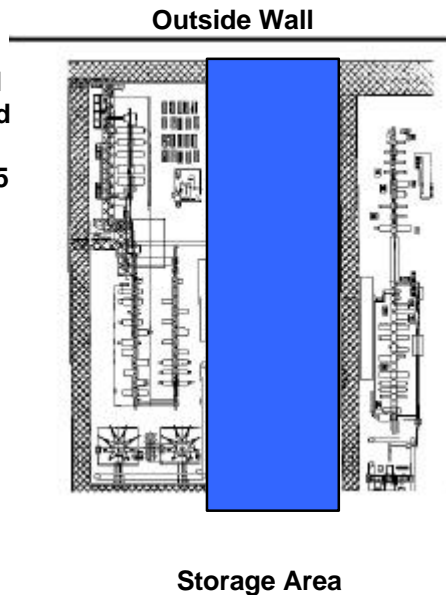
PEO (MW = 2,000,000): 0.5 g/l
Petroleum sulfonate: 20 g/l



Plant Testing of Polyethylene Oxide as a Mist Suppressant at a Detroit Daimler-Chrysler Facility

Layout of Plant Test

- Aerosol measured by TSI DustTrak and RAM-1 units, at a grid resolution of 15 ft by 15 ft covering an area of 240 ft by 90 ft.
- Two 40,000 gallon soluble oil systems treated with 150 ppm of PEO added as a slurry.



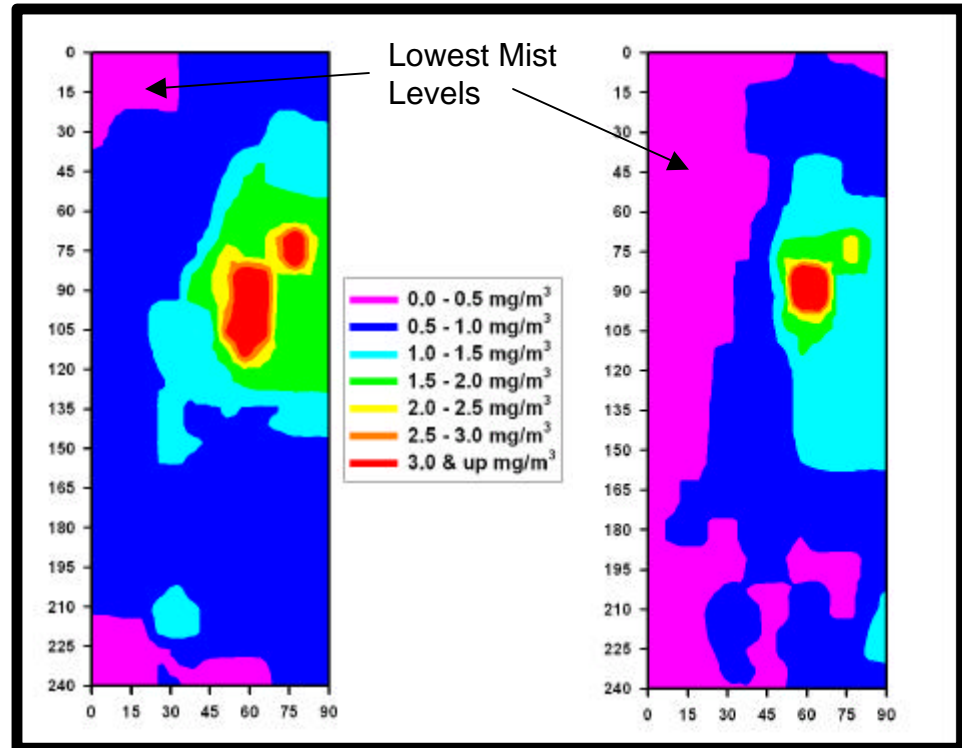
Mist Suppression with PEO

Before

After

Background
Mist Levels

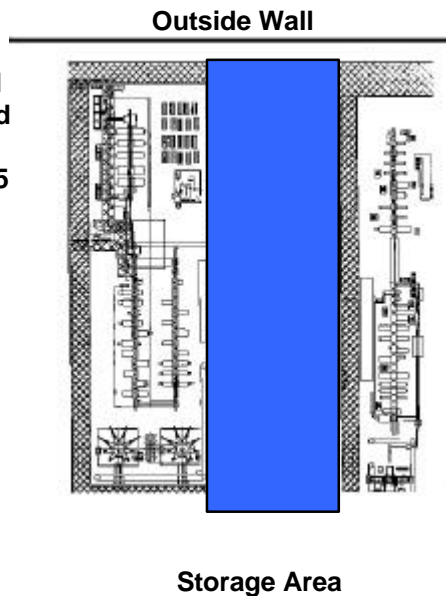
Mist Levels 0.5 hour
after PEO Addition



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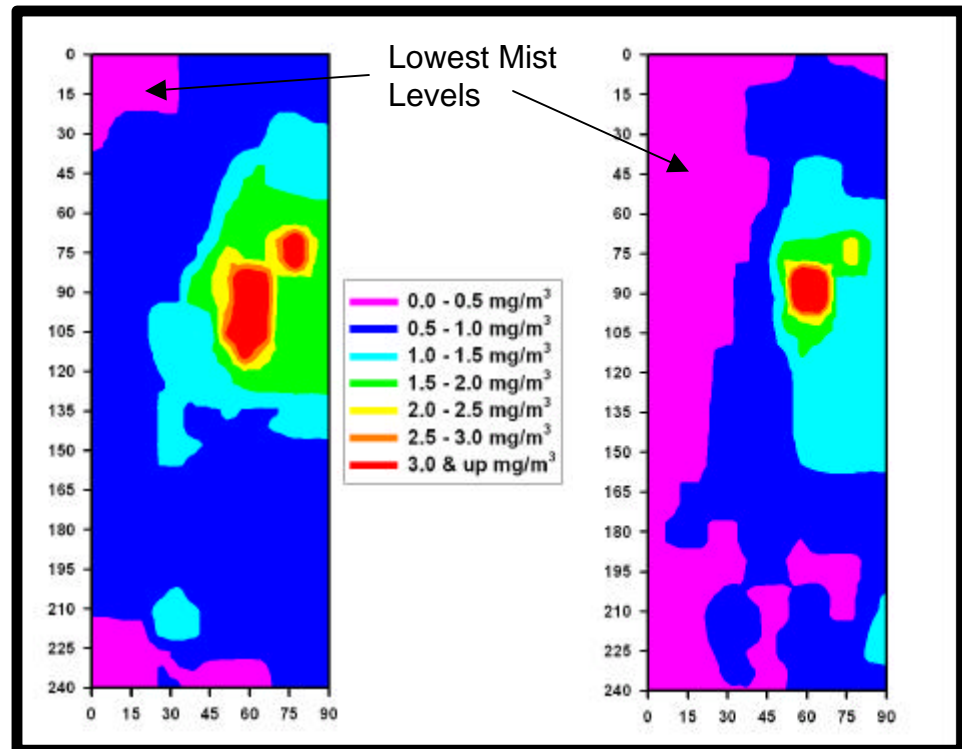
Mist Suppression with PEO

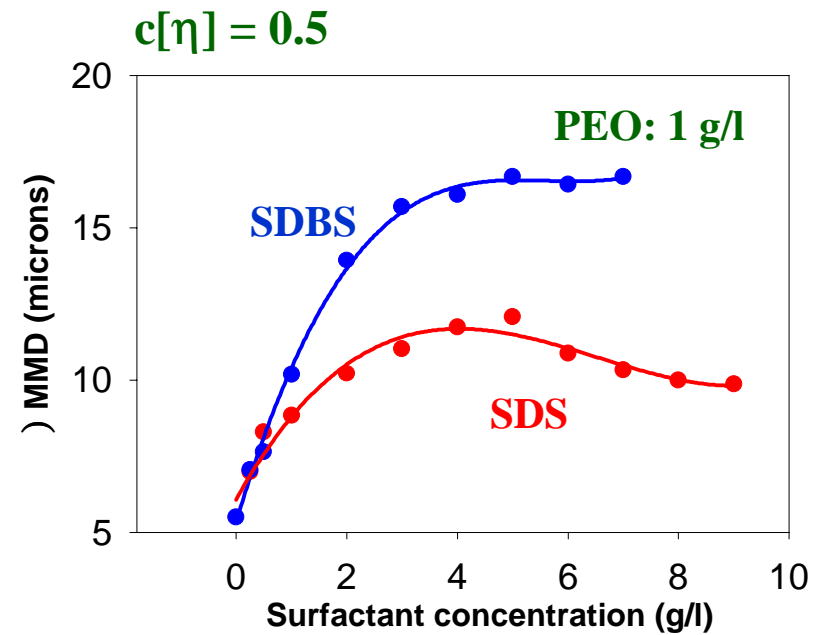
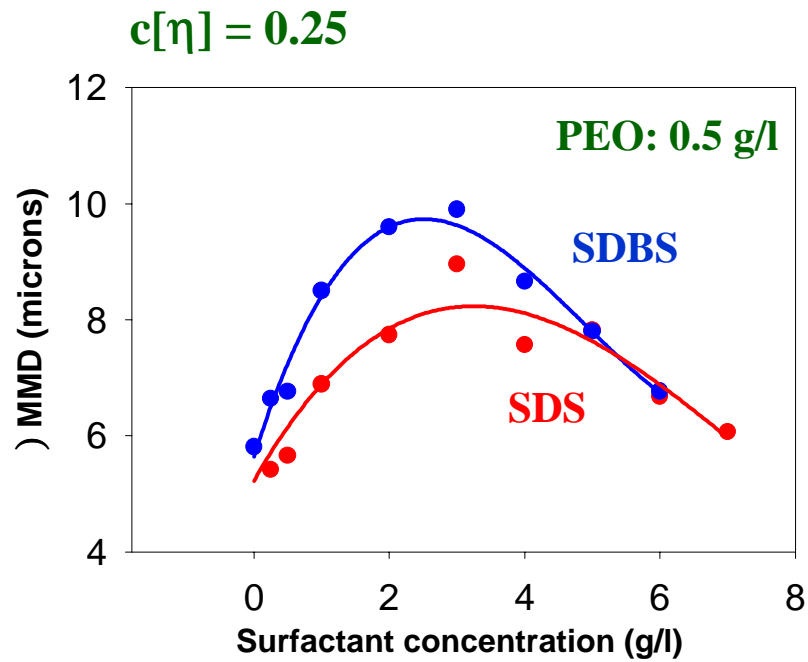
Before

After

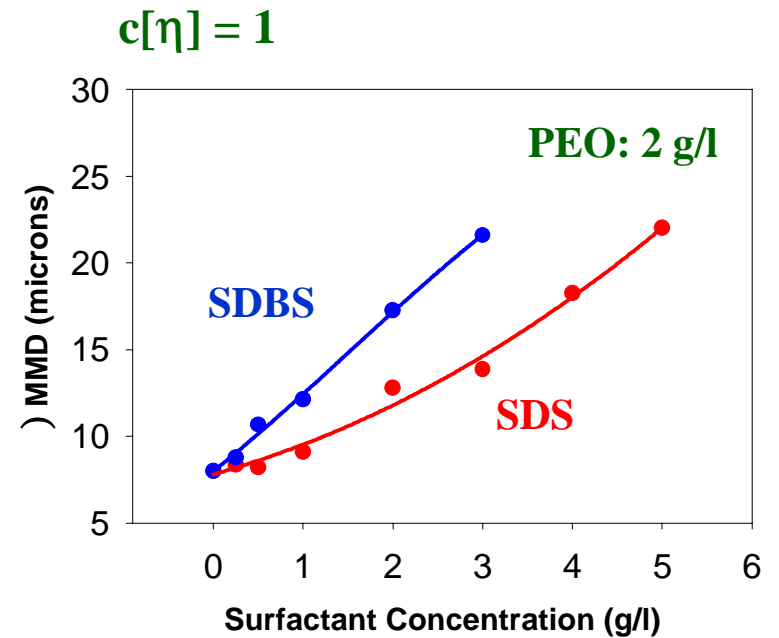
Background
Mist Levels

Mist Levels 0.5 hour
after PEO Addition





EFFECT OF PEO CONCENTRATION ON DROP SIZE



Conclusions

Polymer additives are very effective in reducing machining fluid mist.

Economic barriers remain for treatment of water-based fluids:

high treatment levels (up to 500 ppm)

mechanical degradation of polymer (daily replenishment)

higher cost of water-soluble polymers

PEO-surfactant interactions greatly improve antimisting effectiveness in laboratory and plant tests - *reduces treatment to 150 ppm.*

Further improvements are expected through optimization of polymer-surfactant interactions and synthesis of “designer” antimisting systems.