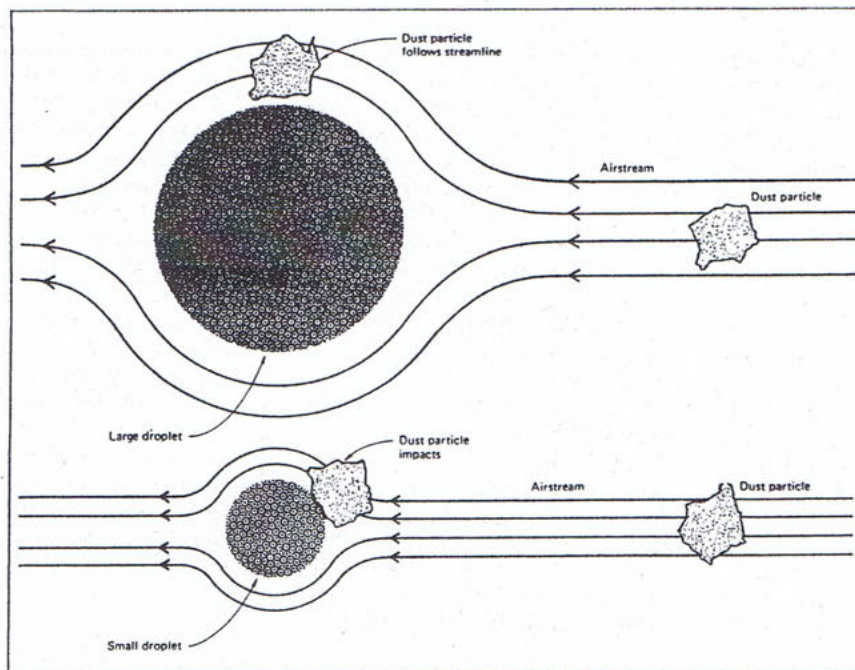




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Airflow around large water droplet (in upper drawing) prevents coal dust particles from contacting the droplet. The dust particle, however, easily impacts a smaller droplet (in lower drawing).

Colorado School of Mines tackles control of respirable coal dust

When water droplets that are sprayed to control coal dust are too large, the dust particles flow around the droplets, and thus are not absorbed—but water droplets too small simply evaporate. So CSM is looking into theories governing formation of clouds to improve existing water spray technology.

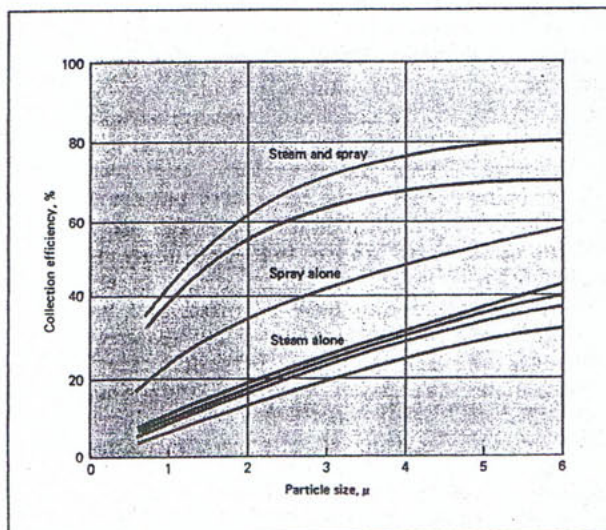
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EXPERIENCE GAINED over the years with water sprays has established the following facts: (1) For a given spray nozzle, the collection efficiency for small dust particles increases as the pressure increases,

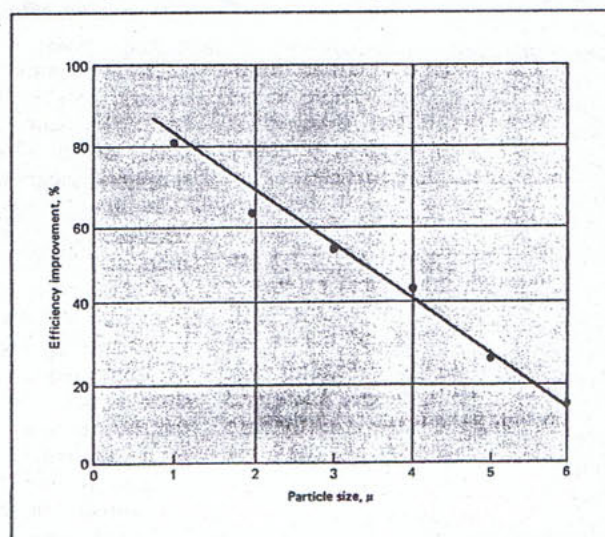
and (2) at a given pressure, the efficiency increases as the nozzle design is changed so as to produce smaller droplets. The conclusion is clear-cut—the smaller droplets are more effective in knocking small

dust particles out of the air. The reason for this is not hard to see.

Consider a water droplet about to impinge on a dust particle, or what is aerodynamically equivalent, a dust particle about to im-



Steam-spray combination is more efficient in collecting dust than either steam or spray (from Cheng and Emmerling, USBM Report of Investigation 7819).



Efficiency of steam-spray over spray alone is much more pronounced in the smaller particle sizes (also from USBM RI 7819).

pinge on a water droplet, as shown in the drawing. If the droplet diameter is much greater than the dust particle, the dust particle simply follows the airstream lines around the droplet, and little or no contact occurs. In fact, it is difficult to impact micron-size particles on anything, which is why inertial separators do not work well at these sizes.

If, on the other hand, the water droplet is of a size that is comparable to that of the dust particle, contact occurs as the dust particle tries to follow the stream lines. Thus the probability of impaction increases as the size of the water spray droplets decreases.

This explains why water sprays are not very effective on respirable dust: typical droplet sizes are 200

are in an area of physics known as "cloud physics" and can draw on the tremendous volume of scientific research results that exists in this area. For example, for over 20 years the US Atomic Energy Commission has studied the basic processes by which radioactive fallout from bombs and reactor accidents is naturally removed from the atmosphere. The fundamental processes involved are nucleation and condensation.

Nucleation is the process by which raindrops are formed in clouds. There are two categories: homogeneous, where no foreign particles are present; and heterogeneous, wherein the droplet formation takes place on foreign particles. The efficiency of the latter depends on many factors, such as

the time required for a given size dust particle to nucleate and grow to a given size in a given humidity.

We also can take measures designed to enhance the efficiencies, such as modifying the particle properties, adding hygroscopic salts and wetting agents, and introducing charges on the particles. It is this type of input that is essential for a thorough test of the feasibility of the method.

The question that is sure to be uppermost is, "Can this process of nucleation and condensation, which works so well in nature, be made efficient in coal mines?" There is sufficient evidence in the affirmative to warrant the full-scale study that we have undertaken.

One such piece of evidence is a recent study by the Bureau of Mines' Dust Lab in Pittsburgh which indicated that dry steam preceding the water sprays resulted in an overall 14% increase in collection efficiency for coal dust. Ironically, the conclusion drawn from these results was that steam did not offer a significant improvement. But if one looks carefully at the data shown in Figs. 2 and 3, it will be seen that an improvement of nearly 100% occurs at particle sizes of 1 micron and less. This is indeed a significant improvement when one considers the importance of this size region, and is enough to justify a more detailed

study. It is certainly evident that droplet growth on coal dust does occur, as was also concluded by the investigators who conducted the study.

The really encouraging fact in all of this is that the growth required is not very great. That is, if the respirable dust can be grown to just 10 to 20 microns in diameter, it easily can be removed by conventional sprays, which, as we have seen, are nearly 100% efficient in this size range.

In conclusion, we are aware of the criticism often leveled at scientists that their ideas might work well in the laboratory but are not practical in the field. But we are also aware that not many real breakthroughs in science or engineering have occurred that were not preceded by extensive basic research. In this particular case the approach we are taking offers a great possibility of improving existing water spray control technology by drawing on existing knowledge from the field of cloud physics, and applying this knowledge to coal dust. ■

Table 1—Factors affecting the efficiency of water-droplet formation

- | | |
|---------------------------------|---------------------|
| ■ Particle size | ■ Charge |
| ■ Particle solubility | ■ Temperature |
| ■ Particle wettability | ■ Relative humidity |
| (Hydrophobic or hydrophilic) | ■ Pressure |
| ■ Presence of hygroscopic salts | ■ Electric fields |

to 600 microns—much greater than the respirable dust, which is less than 5 microns. Thus, water sprays can be improved by increasing pressure or by designing nozzles which produce smaller droplets. Most of the improvements in this direction already have been made. The problem with this approach, and one which prevents much additional improvement, is that when very small water droplets are introduced into an atmosphere where the humidity is less than 100%, many of them evaporate before contacting the dust particles.

Condensation theories

With these facts in mind, we are led, through the logical extension of our approach, to smaller and smaller droplet sizes, all the way to the vapor phase, extending the relative humidity above 100% and condensing the water directly onto the dust particles. In this way, the particles can be made to grow, under the proper conditions, to a size where they will either fall out or can be removed by sprays.

As soon as we take this step, we

particle solubility, wettability (hydrophobic or hydrophilic), the presence of hygroscopic salts, temperature, electric fields, charge and others (see Table 1).

After nucleation occurs, the droplets must grow to a critical size where they will fall out or can be washed out. The efficiency of this "scavenging" phase is also dependent on environmental factors such as temperature, humidity and electric fields, and can be enhanced by certain catalytic effects such as diffusiophoresis, thermophoresis, and dielectrophoresis.

In the research program being conducted in the Physics Department at CSM, we are studying these fundamental processes as they apply to coal dust. By measuring particle size distributions as a function of time, we are able to observe droplet growth and measure the nucleation efficiency of coal dust in a specially designed aerosol cloud chamber. In this chamber we can simultaneously control all the pertinent environmental factors as well as the particle residence time. Thus we can predict