CHAPTER 8.—HOW TO FIND THE MAJOR DUST SOURCES

By Fred N. Kissell, Ph.D.,[77] and Jon C. Volkwein[1]

In This Chapter

- ✓ Instruments for measuring dust
- ✓ How to calculate the amount of dust from a source
- ✓ How to get a valid concentration measurement
- ✓ Sampling to assess control technology effectiveness

When there is more than one source of dust, sampling may be required to find which dust sources are most significant. Then, efforts to reduce dust can be concentrated where they will have the most impact.

This chapter explains how to perform dust source sampling. It describes two kinds of instruments that are available and discusses their limitations. It explains how environmental variables such as concentration gradients, dust dilution, and production changes can impact dust measurements. It also suggests practical ways to improve the validity of dust source measurements under adverse conditions, such as high-velocity airflow or the presence of water mist in the air.

Dust source sampling at coal mine longwalls and at tunnels is more complicated. Chapters 3 and 7 have more information on sampling in those circumstances.

TWO KINDS OF INSTRUMENTS FOR MEASURING DUST

Gravimetric samplers. The conventional gravimetric sampler is a good device for measuring dust because it is the instrument used for compliance measurements. This dust sampler consists of an air pump, a small cyclone that separates out the respirable size fraction of the dust cloud, and a filter to collect the respirable dust.

In coal mines, the Mine Safety and Health Administration (MSHA)-approved gravimetric sampler uses a 10-mm Dorr-Oliver cyclone operating at an airflow of 2.0 L/min [30 CFR[78] 74 (2002)]. A correction factor of 1.38 is applied to make the results consistent with the U.K. MRE sampler, the instrument on which the 2.0 mg/m^3 coal dust standard is based.

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[78] *Code of Federal Regulations.* See CFR in references.

In noncoal mines, the gravimetric sampler uses a 10-mm Dorr Oliver cyclone operating at 1.7 L/min. No correction factor is applied, consistent with MSHA's metal/nonmetal regulations [30 CFR 57.5001 (2002)].

In tunnels under construction, Occupational Safety and Health Administration (OSHA) regulations [29 CFR 1910.1000 (2002)] apply, so any gravimetric sampler with an OSHA-approved cyclone operating at the recommended flow rate is satisfactory.

To get the best possible accuracy with gravimetric samplers, sampling pumps must be calibrated [MSHA 1999], the cyclones must be clean and the filters must be weighed accurately. For accurate filter weighing, the filters must be desiccated to remove moisture, and the weighing must be done in a temperature- and humidity-controlled room. Extra attention is required if the amount of silica is being measured. Page et al. [2001] found that when the dust mass on the filter is below 0.5 mg, the silica error climbs rapidly. In such cases, it may be necessary to sample with one filter for several shifts to accumulate sufficient mass on the filter.

Even when these precautionary steps are followed, gravimetric dust samplers do not give very precise results when used under field conditions. Recent testing [Kissell and Sacks 2002] has shown that the measured dust concentration has a relative standard deviation (RSD) averaging 12% when samplers are placed within a few inches of each other at a fixed site underground. Under poor sampling conditions, such as outside in the wind and rain, RSD values as high as 50% have been found for a filter mass as high as 3.5 mg [Page et al. 2001].

Direct-reading dust instruments. The most common direct-reading instruments measure dust using a light-scattering technique. These instruments are valuable for short-term relative comparisons, such as comparing dust levels with a fan turned on and then turned off or comparing dust levels at two adjacent locations. Direct-reading instruments can also discern if a background dust source will cloud data interpretation. However, since dust levels are constantly rising and falling as mining proceeds, multiple readings must always be taken to ensure that a representative dust level is being measured.

Dust concentration values from direct-reading instruments cannot be interpreted as absolute gravimetric values. Direct-reading instruments that use light scattering are too sensitive to shifts in the size distribution of the dust, as well as a host of other factors that cause errors [Williams and Timko 1984; Smith et al. 1987; Tsai et al. 1996]. In field use, when compared to gravimetric samplers, measurement errors of 100% in direct-reading dust instruments are not unusual [Page and Jankowski 1984]. These errors are especially high at concentrations under 0.5 mg/m^3.

Lastly, direct-reading dust instruments based on light scattering can be adversely affected by water mist in the air. Water mist causes them to show a dust level much higher than the actual level. Adding a mist eliminator designed by Cecala et al. [1985][79] can correct this problem. The

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[79] A commercial version of the mist eliminator (Model 3062 Diffusion Dryer) is available from TSI, Inc., Shoreview, MN.

mist eliminator consists of a 24-in-long wire-mesh tube surrounded by calcium sulfate desiccant (figure 8-1). It is placed between the detector and the 10-mm cyclone used to preclassify the respirable size range and removes water mist without trapping dust.

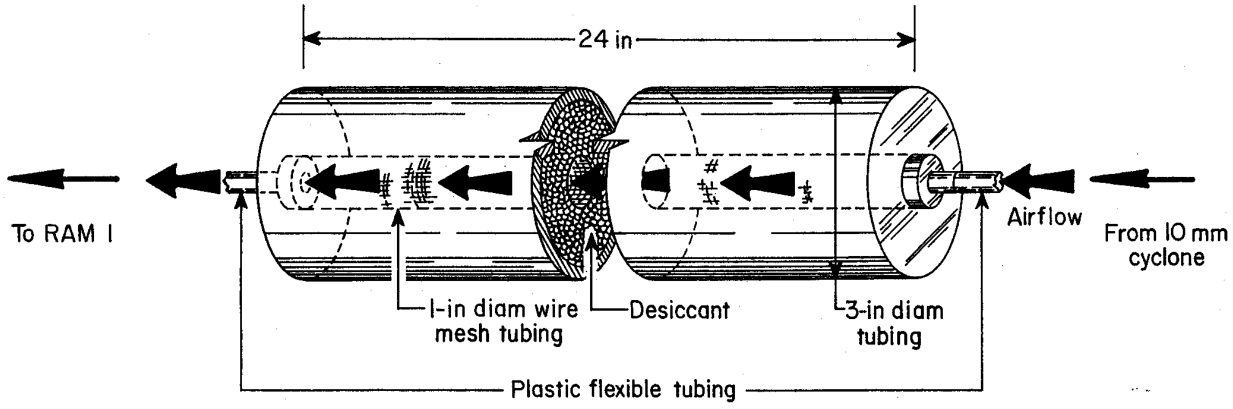

Figure 8-1.—Mist eliminator for direct-reading instruments that use light scattering [Cecala et al. 1985].

The most useful direct-reading dust instruments collect a gravimetric filter sample along with an electronic record of the average light-scattering value. The users of such instruments can then make the comparisons needed to assess the validity of the light-scattering value.[80]

HOW TO CALCULATE THE AMOUNT OF DUST FROM A PARTICULAR SOURCE

Calculating the amount of dust from a particular source is not complicated. The dust concentrations upwind and downwind of the source are measured. Also, the volume of air passing the source is obtained by measuring the air velocity and cross-sectional area of the airway. The difference in the dust concentration values multiplied by the air volume gives the mass of dust generated by the source. This mass of dust can be calculated in terms of unit of time (mg/min) or unit of production (mg/ton), if production data are available [Volkwein 1979].

Another approach to calculating the amount of dust from a source is to turn the dust source on and off, if it is practical to do so. The dust concentration can be measured by a direct-reading instrument or by two packages of gravimetric samplers alternately turned on and off along with the dust source. The amount of dust produced by the source is then calculated from the difference in the readings. The problem is obtaining a valid concentration measurement.

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[80] Currently, only one direct-reading sampler is approved for use in underground coal mines—the personal DataRAM made by Thermo Anderson, Smyrna, GA.

OBTAINING A VALID CONCENTRATION MEASUREMENT

Many environmental factors can invalidate dust source measurements.

To avoid sampling errors caused by environmental factors, review the following dust sampling checklist.

DUST SAMPLING CHECKLIST

1. Is there little to no airway concentration gradient?
2. Is the sampling location within 100 ft of the dust source?
3. Is there no air dilution between the dust source and the sampling location?
4. Is the air velocity past the source and past the sampling location at least 50 ft/min but not over 800 ft/min?
5. Is the type and amount of material mined during sampling representative of normal mining conditions?

If the answer to all of the above questions is "yes," then dust sampling may be done without further precautions other than keeping the instruments at least 3 ft above the mine floor.[81] If the answer to any question is "no" or "I don't know," then the following sampling precautions must be considered.

Checklist item No. 1: Sampling in airways with a concentration gradient. Many sampling locations have large concentration gradients. At such locations, the measured concentration changes as the sampler is moved. In fact, moving the sampler a foot one way or the other may change the dust concentration reading more than any other factor. For example, Kost and Saltsman [1977] showed that a gravimetric sampler located 3 ft in front of a continuous miner operator may indicate a respirable dust concentration twice that of the operator's, whereas only a few feet behind the operator the indicated concentration may be half. This reflects a concentration gradient observed by moving closer to or farther away from the dust source.

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[81] People and passing equipment will kick up dust, making floor samples invalid.

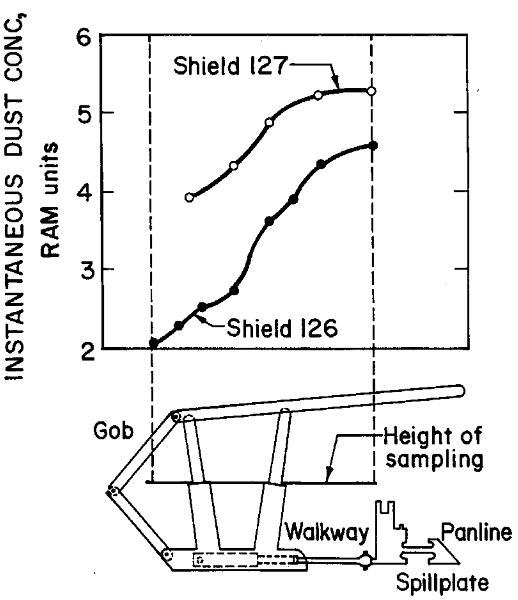

Figure 8-2.—Two gob-to-spillplate dust concentration gradients measured downwind of a longwall shearer [Kissell et al. 1986].

Other concentration gradients can be observed by moving from side to side in an airway. Such side-to-side concentration gradients exist because the dust cloud from the source has not fully mixed into the airstream.[82] The concentration gradient at longwall faces demonstrates this incomplete mixing. The disparity in concentrations depends on the distance between the source (the shearer) and sampling point. Figure 8-2 shows two cross-sectional concentration gradients measured at least 200 ft downwind of the shearer. Even at this distance, shearer dust, mainly in the panline and spillplate, has not dispersed equally into the walkway and area around the support legs.

Because concentration gradients are so common in underground operations, any sampling program to measure the amount of dust produced by a source should test for gradients first. This testing is accomplished by using a direct-reading instrument, moving it back and forth across the airway, or by using three or more gravimetric samplers spaced evenly across the airway. When concentration gradients are found, multiple samplers must be used to obtain valid results.

Checklist item No. 2: Sampling within 100 ft of the source to avoid dust deposition problems. A way to reduce the impact of dust gradients across mine entries might be to move farther downwind from the source so that the dust has more time to mix evenly into the airstream. However, this does not work in practice because turbulent deposition of dust particles causes a decrease in the concentration over relatively short distances. For example, in experiments on a 7-ft-high U.K. longwall face, Ford [1976] found that 45% of a 4-µm particle size dust cloud was deposited within a distance of 600 ft. At other longwalls where face heights were lower, deposition increased. In a U.S. study over a similar 600-ft distance in an uncluttered mine airway, Bhaskar et al. [1988] measured 38% deposition of respirable dust at air velocities over 300 ft/min and 67% deposition at an air velocity of 165 ft/min. Because of this high deposition rate, dust sampling aimed at calculating a source emission should be done within 100 ft of the source.

Checklist item No. 3: Sampling where air dilution has lowered the dust concentration. The validity of sampling results is also affected if the airstream being sampled is not representative of the dust source. For example, when sampling is done downwind of mining machines, the measured concentration is not always a reliable indicator of the amount of dust produced by that

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[82] In some places, such as behind a coal mine line curtain, there may be a top-to-bottom gradient. Vertical gradients are likely when the air passage height is greater than the width, especially when the dust source releases heat.

machine. The intake air is likely to contain some dust even before it reaches the machine, so the amount of intake dust must also be measured and subtracted from the downwind measurement.

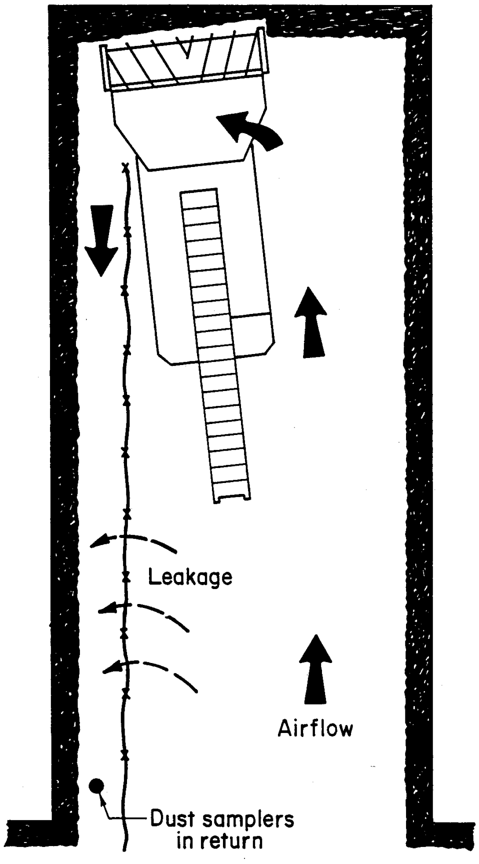

Figure 8-3.—Air in return diluted by line curtain leakage [Kissell et al. 1986].

Also, if air is gained or lost between the source and sampling point, corrections must be made. Line curtain leakage (figure 8-3), a common occurrence on continuous miner faces, is an example of how air is gained, thereby diluting the dust level measured in the return. As the heading advances, the amount of air gained will increase; in fact, a leakage of 50% is common. To calculate a machine dust emission rate in this case, it is necessary to multiply the measured concentration by the airflow at the sampling point. Comparisons can then be made on the basis of dust weight per unit time or per ton of material mined.

If air is lost between the source and the sampling point, no change in dust concentration will occur. However, the machine emission rate cannot be calculated unless it is known exactly how much air was lost.

Checklist item No. 4: Sampling in a low-velocity airflow under 50 ft/min. In workplaces where the airflow is less than 50 ft/min, the magnitude of the source can be *roughly* assessed by moving a direct-reading instrument alternately toward and away from it. This movement must be repeated many times, preferably from different directions, to ensure that any observed increases in dust level result from getting closer to the source rather than from an extraneous factor, such as a change in production.

Checklist item No. 4: Sampling in high-velocity airflow over 800 ft/min. In air streams with velocities up to 300 ft/min, neither the air velocity nor the cyclone inlet orientation has any impact on the dust concentration measured by the sampler [Caplan et al. 1973]. However, at air velocities over 300 ft/min, both the air velocity and the cyclone inlet orientation have an impact. Cecala et al. [1983] found that when the Dorr-Oliver cyclone inlet[83] is pointed directly into the wind, it oversamples when the air velocity exceeds 800 ft/min. At 2,000 ft/min, it oversamples by 35%. When the cyclone inlet is at a right angle to the wind or pointed downwind, it undersamples when the air velocity exceeds 300 ft/min.

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[83] Strictly speaking, it is the vortex finder clamp that is pointed directly into the wind. The inlet enters the cyclone at a slight angle.

Cecala et al. [1983] also tested a shielded cyclone to see if a shield would reduce the over- and undersampling. The shield was a 1-in-wide strip of aluminum sheet bent into a cylinder. This cylinder was then wrapped around the top of the cyclone and bolted to the hole in the back of the vortex finder clamp (figure 8-4). Testing showed that the shield successfully reduced both the over- and undersampling to within 14% of the true value up to the highest velocity tested (2,000 ft/min).

Another way to sample high-velocity airstreams is to use an isokinetic probe, in which the velocity of the air entering the probe is matched to that of the airstream [Quilliam 1994]. However, because the equipment is more specialized and less portable, isokinetic sampling is more suited to labs and industrial sites than underground mines.

Checklist item No. 5: Sampling during changes in the type of material cut and changes in production. In coal mines, cutting rock bands in the coal will cause a wide variation in dust levels. A rock band is a band of rock, typically shale, layered within the coal seam. The amount of dust generated by cutting the rock band is much greater than that from cutting the coal, so even a minor rock band will cause dust levels to increase substantially.

Variations in production also cause substantial dust level changes. Shift-to-shift changes in production by a factor of two are common in all types of mines. Dust concentration values may be corrected for shift production when production changes are due to incidents such as equipment breakdowns. In this case, a lower shift dust concentration is due to less mining time. However, if shift production is low because of hard cutting through rock, dust levels may be higher due to the rock itself. If the concentration level data are then corrected for production, the errors will be magnified greatly. The only course of action is to sample when the type and amount of material mined are representative of normal mining conditions.

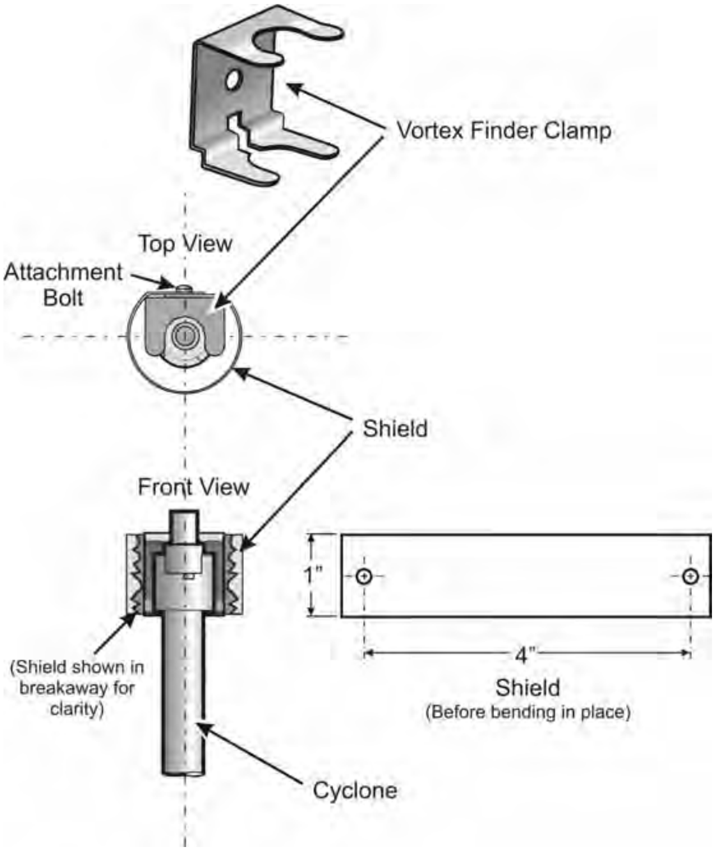

Figure 8-4.—Cyclone shield for high-velocity air streams.

In-depth information on dust instrumentation and measurements can be obtained from Baron and Willeke [2001]. Raymond [1998] describes the equipment and procedures used by MSHA to maintain a modern dust sample weighing facility. Parobeck and Tomb [2000] describe MSHA procedures to measure the silica content of mine dust samples.

SAMPLING TO ASSESS CONTROL TECHNOLOGY EFFECTIVENESS

Most mine operators depend on compliance sampling to assess whether any control technology that they installed works as promised. Although the methods described above require more effort, they are a better way to measure control technology effectiveness simply because it is easier to measure a change in a dust source when that source is isolated from other dust sources. However, it pays to keep in mind that the relative standard deviation of gravimetric samplers under typical field conditions is 12%. Additional error is contributed by environmental variables such as production changes and concentration gradients. In addition to these errors, the evaluation of a dust control method is constrained by the combined error of measurements with and without controls. For these reasons, assessment of dust control effectiveness is limited to those technologies that give at least a 25% change in dust levels.

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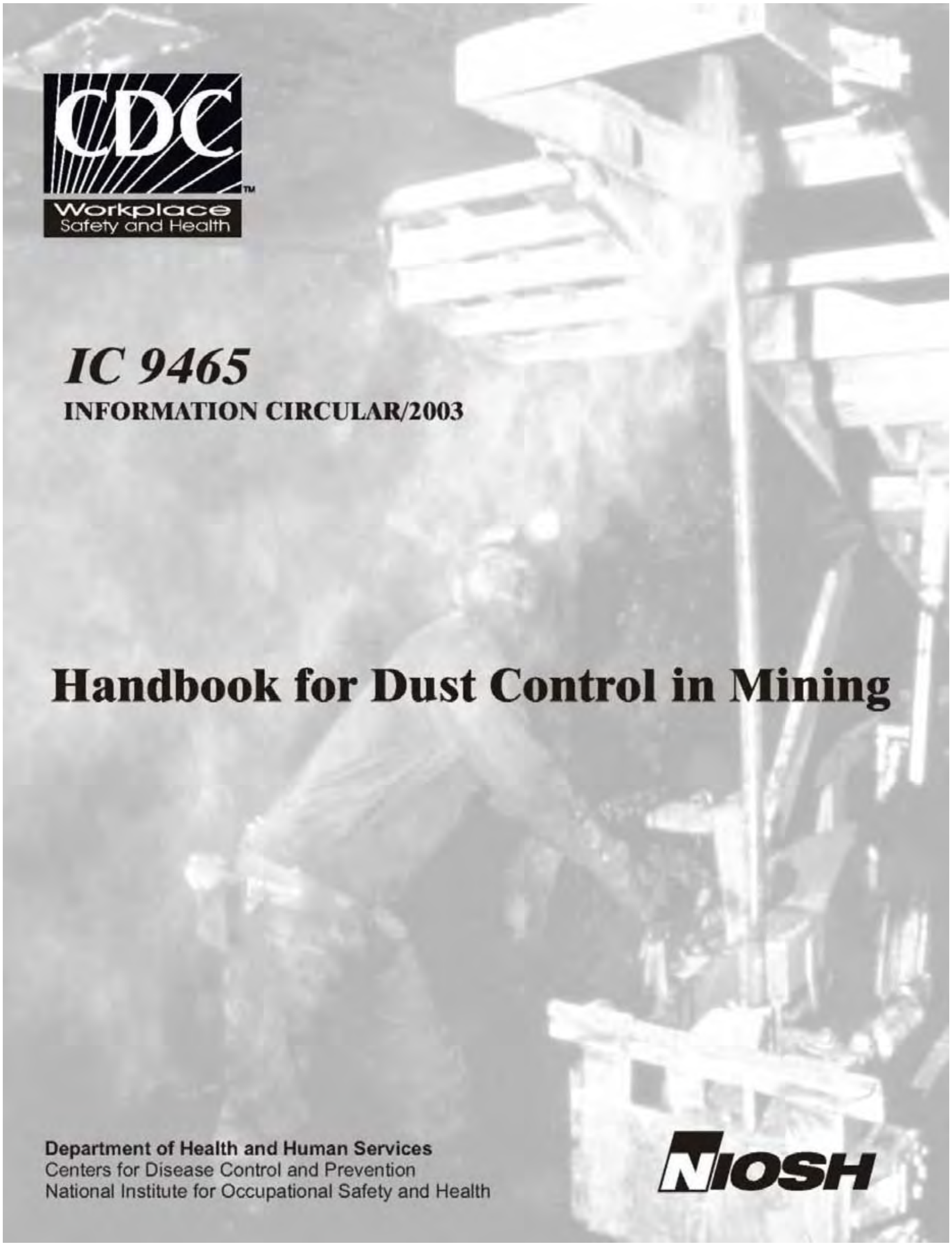

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