SPECIAL REPORT: EFFECTS OF DUST ON COMPUTER ELECTRONICS, AND MITIGATING APPROACHES

By: Computer Dust Solutions, LLC

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Special Report: Effects of Dust on computer electronics, and mitigating approaches

INTRODUCTION

What is dust? Dust is finely divided solids that become airborne through a fracture process from a larger solid object. Common household dust is mainly composed of decayed skin particles, while industrial dust is commonly generated by sawing, grinding, or polishing of wood, metal, plastic, or masonry type materials.

Dust particles can be as small as a few microns (micrometers) or as large as hundreds of microns in size. The larger and denser particles tend to settle, while the smaller and lighter ones can remain airborne indefinitely.
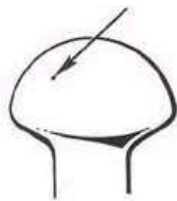
A Micron-Size Dust Particle on a Pin Head

Dust particles can contain moisture (water or oils), organic material (carbon), various minerals, or various chemicals. All of these can affect the reliability and life span of common personal computer electronics if the computer is overexposed.

INDUSTRIAL DUST

Dust generated in factories, woodshops, and workshops are various, and pose a health risk to operators. Dust suppression and dust collection systems are usually employed to capture the majority of the directly generated dust, and various respiratory dust masks are available for human use to minimize the amount of dust inhaled.

Industrial dust that escapes the suppression and collection steps will migrate and settle on and within most equipment left unprotected. One of the most vulnerable and common devices found in modern factories and workshops are personal computer electronics, displays, and printers. These devices were not designed for such an environment, and internal dust accumulation is one of the main causes of computer reliability problems or premature failure.

DUST EFFECTS ON ELECTRONICS

Personal Computers (PCs) are consumer items designed for office environments where the density of dust in the air is low. Most PCs have no dust filter, or at most, only a low-cost mesh filter designed to capture some of the dust that might be drawn into the PC by the PC's cooling fan. The fan draws in cooling air that passes through the filter and exhaust out various vents in the computer case.

Since most offices temperatures are maintained at approximately 75^oF, the electronics can be sufficiently cooled even if the internal dust accumulation is moderate. In most office situations, the PC dust accumulation will begin to affect computer operation within 2 years. Internal cleaning should be performed at least annually to prevent problems.

PCs are electro-mechanical devices, and they have a variety of susceptibilities to dust. For situations where a PC is used in an environment with higher dust levels, these susceptibilities can surface very quickly.

Integrated Circuits and Circuit Boards

Integrated circuits (ICs) can suffer from overheating due to the insulating effect of dust as well as suffer from electrical shorts caused by dust across their contacts.

The most susceptible ICs are those having a metal lid acting as a heatsink cooling surface. To prevent overheating and failure, this metal surface and heatsink need to be essentially dust-free. Dust acts like an insulating blanket, preventing proper convection cooling.
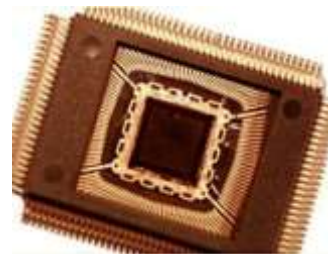
Test show that the temperature of some of the higher power PC components, such as the CPU, can go up nearly 30^oF due to a build-up of dust. This is a significant increase in temperature and can lead to complete and abrupt part failure.

Another reliability problem is circuit shorting. Modern integrated circuits have as many as 100 exposed electrical contacts per inch. Designers rely on an air-gap between these contacts to prevent electrical shorts or cross-coupling of signals. Dust containing conductive material such as water, oils, and metallic elements can cause signal errors and abrupt part failure. Some manufactures now seal the contacts with a plastic coating once the part is soldered onto the circuit board in order to avoid signal shorting due to dust.

In order to avoid these serious electrical problems, dust ingestion into the computer processor case and monitor needs to be minimized.

Mechanical Components

PCs have numerous mechanical devices and manual controls whose performance suffers when exposed to excessive amounts of dust. These include optical disk drives (CDROM/DVD), floppy/ZIP disk drives, keyboard, mouse, and commonly used interfaces such as USB ports.

Internal interface cables and expansion slots can become <u>unusable</u> if exposed to excessive dust as illustrated below.

Of all the vulnerable components in a PC, the Optical disk drives (CDROM/DVD) are the most vulnerable as they contain a series of motors and servos as well as rely on a dust-free light path for the laser-light and optical lenses to function properly.

These optical devices are not sealed. Any dust in the PC will migrate to and through the optical system leading to continuous performance degradation leading to failure.

Optical drives, as well as floppy drives, have rather fragile media load-unload tray systems that can easily become jammed when the tray rail path is not smooth operating. Dust build-up is the main cause of these failures and since these type drives cannot be cleaned easily, the devices usually have to be replaced at considerable expense in money and time.

The keyboard and mouse are also affected by dust. Though these are easy to replace items, their reliability can degrade rapidly when infused with dust. Stuck keys and "sticky" mouse operation are most frustrating to operators and can create both errors and productivity loss.

There are several dust-tolerant keyboards on the market that utilize either sealed key switches or simple touch operation, but these are relatively expensive and take some getting used to.

For mouse control, the most dust tolerant mouse is the gyro-mouse that bypasses the dust problems of roller-balls or optical type mice. A Touch-pad mouse is also an option.


EFFECT ON PC LIFESPAN

It is not possible to precisely predict the lifespan reduction of operating a PC in an environment that has a higher concentration of dust than the environment the PC was designed for (the office or home environment).

The normal office or home has a mixture of fine dust particles of 2.5 microns in size, and course dust particles larger than 10 microns in size. The total dust concentration, measured in micrograms (a millionth of a gram) in a cubic meter of air is normally under .05 mg/m^3. For comparison purposes, the EPA and OSHA have guidelines for the concentration of certain types of dust particles, such as carbon dust in coal mines, or asbestos dust for commercial buildings. In a factory, machine shop, or woodshop, the density of dust in the air can often be 1000 times the density of dust in an office environment. This suggests that a significant amount of dust can accumulate within a PC in a very short amount of time causing the useful life of the PC to drop dramatically.

The chart below estimates the lifespan expected for an unprotected PC at increasing levels of dust exposure, assuming a 10-year normal life. As shown, under heavy dust conditions the lifespan of a PC can be reduced to under a week if left unprotected.

Lifespan of a PC exposed to Dust
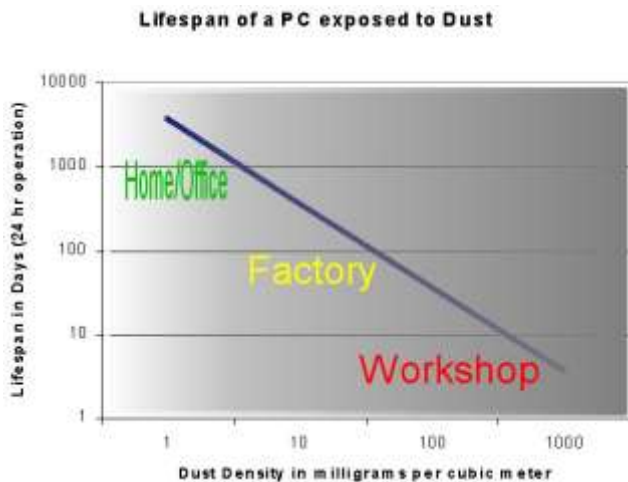
MITIGATING APPROACHES

Assuming dust generation is significantly controlled at the source, there will still be elevated levels of dust in the air space shared with the dust generation source.

A typical example is in a woodshop where a formal dust collection system is attached to each saw station but some percent of the fine dust particles escapes and resides in the room air for many hours until it settles on or in other equipment. Without mitigation at the PC, the dust will quickly accumulate on and in the PC leading to premature failure.

Selecting a mitigation approach is a combination of tradeoffs between:

- Effectiveness
- Maintainability
- Economics
- Impact on PC usability

EFFECTIVENESS
This is a measure of how well the mitigation approach prevents dust from impacting the reliability and lifespan of the PC. A mitigation approach that minimizes dust from entering the PC chassis or settling on the PC controls (i.e.: keyboard keys), even under high dust density conditions, would be considered highly effective.

MAINTAINABILITY
This is a measure of how often, how difficult, or how much time is consumed to sustain the same level of effectiveness using this mitigation approach. A mitigation approach that requires little or no regular maintenance would be considered highly maintainable.

ECONOMICS
This is a measure of the total lifetime cost of acquiring and maintaining a given mitigation approach. A mitigation approach that costs little to acquire and costs little to maintain would be considered highly economical.

USEABILITY
This is a measure of the reduction of normal PC usage or performance due to the given mitigation approach. A mitigation approach that does not reduce a user's ability to interface with the PC (typing, using the mouse, seeing the display) would be considered highly useable.

MITIGATION APPROACH OPTIONS

There are many dust mitigation approaches available on the market. Let's look at the various approaches; one for each of the tradeoff criteria.

EFFECTINESS
The most effective method to mitigate dust is isolation. This involves enclosing all of the components in a "temporary" airspace so that none of the ambient dust is able to enter or settle on the PC. There are many dust enclosures on the market, and there are some that you can build from plans. An example is pictured below.

One significant drawback of the isolation approach is that users may be restricted from interacting with the PC during heavy dust conditions. This is because if they open any access door the PC will not be protected.

MAINTAINABILITY
The most maintainable method to mitigate dust is to use a PC that is designed specifically to operate in dusty conditions, requiring no regular maintenance at all. Wiping-off or vacuuming is all that would be required.

There are many rugged PCs on the market but they cost considerably more than an office PC. Two examples are pictured below.

One significant technical drawback of the sealed PC approach is that the PC performance, media options, and display sizes are often inferior or reduced from that of an office PC equivalent.

ECONOMICS
The most economical method to mitigate dust is to add flexible protective covers to a low-cost standard office PC. There are a wide variety of products developed using this approach, including traditional plastic impervious covers.

Perhaps the most novel is an approach that uses translucent but breathable sleeves. These can be easily sized to fit any computer or monitor and they allow the computer to be fan cooled while remaining

dust-free. Sometimes referred to as a computer dust bag, the "ShopShield™" is a cover that doubles as a huge dust filter. Unlike traditional plastic covers, it remains on the computer at all times, even while the computer is operating.

When properly applied, solutions such as the ShopShield™ can prevent dust from settling on or in the computer case and monitor while still allowing adequate cooling. The portion of the ShopShield™ cover over the monitor screen is a clear anti-static vinyl to allow for a clear view of the screen.

Economical keyboard protection include stiff or solid plastic covers as well as the newer "X" style that permits the ability to type while attached.

A drawback of using flexible protective keyboard covers is that they may need to be replaced at some point. A drawback of the traditional plastic computer covers is that the computer cannot be safely used at all during high dust conditions.

USEABILITY
The method that provides best usability consists of a combination of isolation and dust-tolerant operator input devices. In this approach the main PC unit and the display are placed in a transparent isolated case while the keyboard and mouse are fully exposed to the dust environment.

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Transparent face

Dust-tolerant keyboard   Dust-tolerant mouse

A drawback of using this approach is both the added expense of the dust case and specialized keyboard/mouse, as well as some difficulty in access to the less-frequently used devices such as the DVD/CDROM drive.

CHOOSING A MITIGATION APPROACH

The best dust mitigation approach for a given situation is sometimes difficult to derive. A person needs to consider the 4 factors discusses above in combination with the particular dust environment expected.

The best solution may likely be a combination of the methods described above, such as using the low-cost ShopShield™ for the main PC unit and display, but use a keyboard protector and a touch-pad mouse rather than an optical mouse.

The following example can provide some guidance on how to develop and compare the various mitigation approach options.

DECISION METHODOLOGY

First take the criteria factors and give them each an importance point value (weighting) so that the total adds up to 100:

EXAMPLE:

- Effectiveness   25 points
- Maintainability   10 points
- Economics   50 points
- Impact on PC usability   15 points

In this example, economics is considered by far the most important with maintainability being the least important.

Then identify the various options. In this example, 8 approaches were considered by identifying the protection approach, the PC that would be used, the keyboard/mouse that would be used, and an estimate of the initial and annual cost to maintain (from a dust perspective) for each. Solutions as low as $765 to as high as $2060 were established (the cost of the PC included):

Total Cost of Ownership: Options for Protecting PCs in a Dusty Environment

Option	Protection	PC Type	Keyboard/ Mouse	Initial Cost	Annual Cost
1	Isolation rack	Dell Office	Dell Office w/protector	$1800	$60
2	Isolation rack	Dell Office	Dust tolerant	$2000	$60
3	Built in	Rugged sealed	Built in	$1600	$0
4	Built in	One-piece sealed PC w/ touch panel display	Built in	$1700	$0
5	ShopShield™	Dell Office	Dell Office w/protector	$700	$65
6	ShopShield™	Dell Office	Dust tolerant	$900	$60
7	Dust enclosure	Dell Office	Dell Office w/protector	$1200	$60
8	Dust enclosure	Dell Office	Dust tolerant	$1400	$60

Then compare the various options by ranking them (8 being the highest/best) within the criteria, multiplying each rank by the point value, and deriving a final scoring across the group:

	Eff.	Maint.	Econ.	Use.	
	25	10	50	15	
Option		**RANKING**			**SCORE**
1	7	5	2	6	415
2	8	6	1	7	415
3	5	7	4	3	440
4	6	8	3	2	410
5	1	1	8	4	495
6	2	2	7	5	495
7	3	3	6	1	420
8	4	4	5	8	510

In this example three approaches surface for closer consideration. Option 8, which is a hard transparent isolation enclosure coupled with an exposed dust-tolerant keyboard and mouse provides an attractive approach.

Other high-scoring solutions are approaches that use ShopShield™ type breathable dust covers. One of these solutions utilizes a dust-tolerant keyboard and mouse to allow great usability but at a higher total cost. The other ShopShield™ approach places an X-

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Style cover over the keyboard and has the benefit of being the least costly solution.

In this example, the team decided to go with Option 5, a ShopShield™ approach with X-style keyboard protection. If there were a need later for a more accessible mouse during high dust density conditions, then they would buy a dust-tolerant mouse.

This illustrates a simple exercise of how to go about the decision making process for a given situation. If the weights are different or if there are different approaches that need scored, a similar process can be followed to yield a decision that you and the team can stand behind.

SUMMARY

Dust can cause irreversible harm to computer electronics and its associated electromechanical components. Without protection from dust, serious computer errors, loss of information, or complete failure can result.

The standard PC is not inherently designed to be tolerant of high levels of dust so steps are required to mitigate such conditions. There are a variety of low-cost but effective solutions available that are well worth implementing.

HELPFUL REFERENCES

OSHA Dust Control Handbook http://www.ohaa.gov/

OSHA Wood Dust Evaluation http://www.ohaa.gov/

EPA Indoor Air Quality report at http://www.epa.gov