This break-through article was originally published some 15 years ago by Professional Testing (EMI), Inc. and along with Professional Testing's equipment, patented equipment awarded in 2008 originally started how computer manufacturers considered actual use environments for their equipment, especially portable and personal equipment. Today, Fibrous Dust testing is utilized by not only ITE manufacturers, but a host of other equipment manufacturers that see real-life dust environments including ITE equipment, personal equipment, audio and lighting.

Today, PANOPTiK Compliance Solutions, Inc., the engineering entity originally associated with Professional Testing continues to manufacture and adapt custom solutions in Fibrous Dust testing for manufacturers world-wide. This updated paper re-states the original engineering and adaptation of Fibrous Dust testing which is being applied today as a standard evaluation program by manufacturers introducing products to market.

Standard Tests

Like most test labs, we try to use standard tests methods whenever possible. Our clients were looking for a test to duplicate field dust problems in laptop computers. We recommended settling dust testing similar to IEC-60068-2-68[1] and MIL-STD-810F[2]. The only modification to these methods was to increase the concentrations of injected dust because a highly accelerated test was required. However, these tests proved inadequate in duplicating timely failures even at grossly unrealistic test levels.

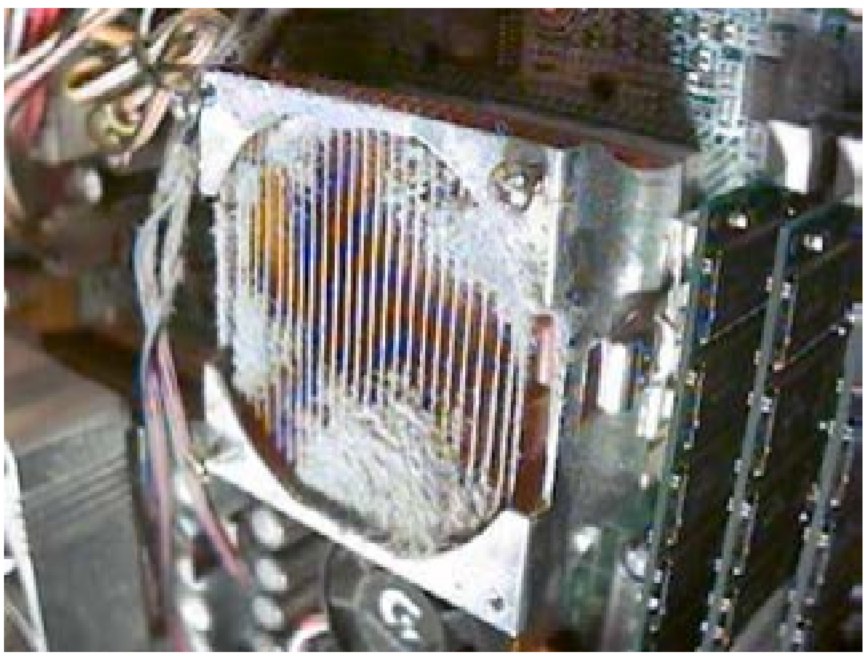
Failure Mechanism

Further information from analysis of the failure dust clogs reveals the reasons. Fiber turns out to be a key factor in any real-world simulation. The test media must contain a similar variety of fiber lengths and smaller particles to duplicate the clogging action to facilitate failures. The longer fibers bridge the leading edge of fine pitched fins building a mat of tangled fiber. In laptop computers, the reduced airflow causes the processor temperature to increase which in turn causes the fans to increase in speed.

More air flow keeps the processor cool but brings in more contaminants. The longer fibers soon block the airways to the point where smaller fibers and dust particles begin to collect on the fiber mat. The contamination buildup escalates to the point where almost no air can pass. To compound this problem the fan impeller can suddenly lose the ability to move air in the intended direction once the backpressure reaches a critical level. When this happens, the pressure differential across the heat sink can also drop to zero. The product now has serious thermal problems. At room temperature, the processors will generally self-protect or shut down but damage from excessive temperatures is always a possibility. The inability of the fan to move air properly can also lead to other parts of the system overheating. These secondary overheating problems occur when the heat sink fans are also used to draw cooling air through other parts of the system.

Clogged Heat Sink Fins (Figure 1)

Laptop Fibrous Dust Clogging (Figure 2)



Desktop Heat Sink Clogging (Figure 3)

Problem

Most dust test equipment and methods used fine particles and powders. The tests in general were designed to test products with air filters. In consumer products, where “filter” is frowned upon, there is a whole range of contaminates these tests do not address. Existing test methods and equipment cannot duplicate the fibrous dust failure mechanism, nor can they be adapted to disburse fibrous dust mixtures. Without equipment and methods to duplicate a problem, effective testing of a solution is nearly impossible. The solution to the problem needed to be two-fold in execution.

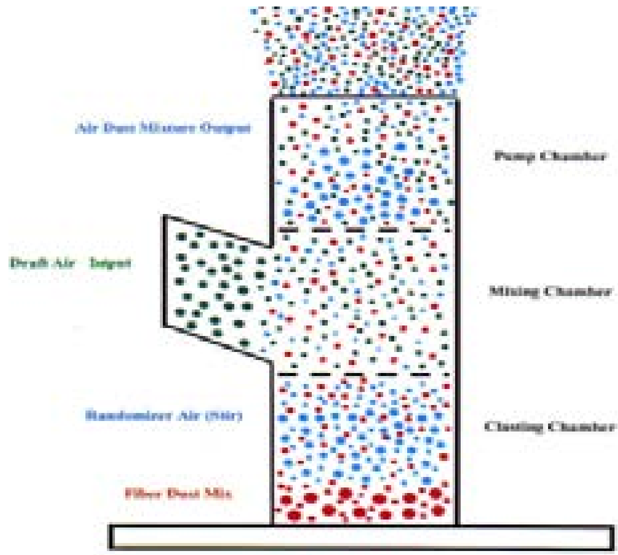
Dust Test Media

The first problem to start addressing involved searching for a fibrous dust test media that duplicated the efforts of a household environment with its collection of fine dust, hair (human and animal) of various lengths and textures, clothing fibers and the like. The obvious consistency and repeatability issues of using natural dust made it an unlikely candidate so formulating a synthetic dust media was the only choice. Environmental dust contaminations contain fibers and particles from a near infinite number of sources. The percentages of each ingredient in a synthetic dust should mimic the general physical size properties of actual field return heat sink contaminations. However, getting a variety of cut fiber and mixing with standard test dusts components created a tangled clumpy mess that at first seems impossible to disburse in any controlled fashion. (See Figure 4.) Standard dispersal methods did not work with this kind of weighty mixture.

Pre-Injected-Dust-Mixture (Figure 4)

Fibrous Dust Generator

Our reliability team experience with previous testing with non-standard dusts held part of the answer. An air randomizer system used to propel large lightweight particles in a special application dust test was a good start. The randomizer design was incorporated into a chamber system that combined with a high-powered jet pump. The first prototype proved to be more successful than imagined. Within a couple of weeks, we were able to produce field failures in as little as 2 hours of test time.



Cycloclastic Dust Generator (Figure 5)

Settled Dust, Chamber Floor 16 Hour Accumulation (Figure 6)

Acceleration Conundrums

Accelerated testing with fibrous dust produced issues not seen in standardized dust testing. One of the first problems identified centered around air inlet clogging. While inlet clogging can be a design concern for stationary products, it is less problematic for portable equipment. Portable equipment such as laptop computers are likely to have input air vents cleared of dust accumulations through handling and normal use. In addition to frequent handling, the user of portable equipment often sees these accumulations and periodically cleans the inlet vents. In accelerated testing, fibers tend to form a natural filter on the inlets before heat sink clogging can occur. This action causes only very small particles to reach the heat sink and stops the fiber failure mechanism from occurring.

We determined that to facilitate normal use actions and allow heat sink clogging to occur, periodic clearing of input vents was a test method necessity. Through much trial and error, it was determined that a systematic cleaning of the input vents needed to occur in a regular and timely manner.

The periodic clearing of dust buildup stops an unrealistic thermal blanket from forming that could disrupt radiant heat dissipation or block topside air vents.

16-Hour Dust Accumulation (Figure 7)

Ingress Modes in Laptops

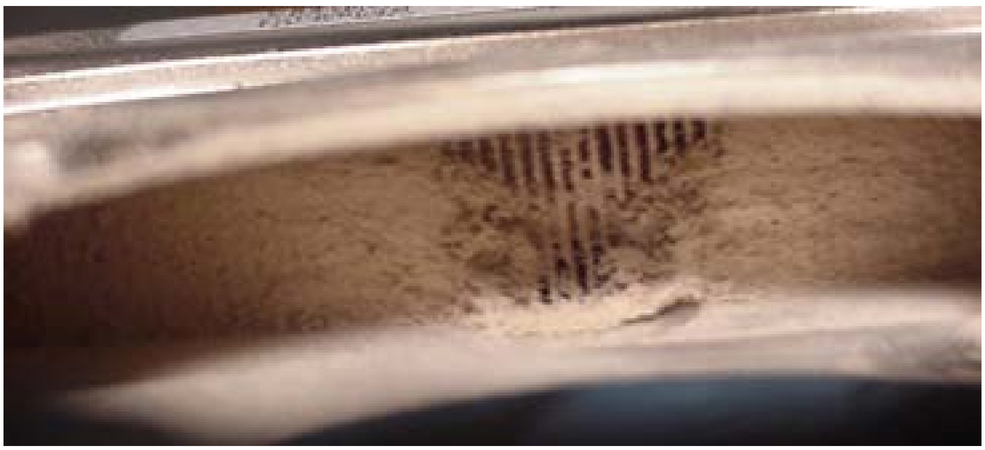
With periodic inlet cleaning, the settling dust test method can duplicate the fiber clogging failure mechanisms in portable computer heat sinks. However, even with inlet cleaning the heat sink accumulations tended to contain higher concentrations of fine particle dusts and lower fiber content than desired to correlate to field data. While it may seem logical to assume the synthetic dust mixture requires adjustment (i.e. reduce the fine particle dusts vs. fiber), we must first look at how dust enters these systems. A laptop's portable nature solicits two major modes of dust ingress:

1. One mode is from active (airborne dust),
2. The second is from passive dusts previously settled on surfaces or from direct contact with dust producing materials.

Early experiments in passive only dust testing, resulted in the opposite results of active only, with high fiber content clogging of heatsinks and relatively low concentrations of smaller dust. The bottom facing fan inlet creates airflows that tend to vacuum up fibrous dusts leaving finer dusts behind.

An adjustment made to the dust mixture in active testing resulting in accumulations close to field compositions would still seem an effective test method. Test experiments prove this method worked quite well as long as all laptop designs remain the same. However, any design with only top or side air inlets could eliminate most passive modes of ingress. Because passive (settled) dust concentrates on surfaces, such a system could prove to be more robust in actual use, yet it would be at a distinct disadvantage in an active (settling) mode only test. It is apparent that any realistic evaluation of future portable system designs must include both active and passive modes of dust ingress. Figures 8, 9, 10 demonstrate the differences in accumulation composition using active, passive and the combined active/passive test methods.

Passive Only Dust Test Accumulation (Figure 8)



Active Only Dust Test Accumulation (Figure 9)

Combination Active/Passive Dust Test (Figure 10)

Passive test experiments were extremely labor-intensive requiring moving the test units every 10 minutes to a new pre-dusted location. The process also required once per hour removing the units, cleaning the test accumulation surface, and recoating with dust. With much experimentation and input from our engineers, a prototype system was created by a local design firm that included a rotating fixture

table with a facilitated bottom air inlet cleaning with rotating brushes, a dust dispersal system and a large thermal chamber designed to accommodate heating, cooling and humidity control.
The ability to test multiple products at one time means this dust testing system is a robust means of active and passive testing of the electronic units.

Dust Test Chamber Accommodates Active/Passive Testing. (Figure 11)

Acceleration Rates

Information on acceleration rates from existing standards provided some rough guidelines to calculate acceleration rates. Using the existing guidelines, the acceleration variance is very large, based on product use location. As an example, in MIL-STD-810F the worst-case industrial location can be 200 times that of the best-case rural location. We spent a lot of time working on calculated rates but there are so many variables it is difficult to gauge accuracy. Measured acceleration rates of products with known time to failure in field use, **have demonstrated the rates to be around 45 days per test hour or approximately 2 years in a 16-hour test**. Because these demonstrated rates are based on early field failures, they must be considered worst-case location based. Equipment with higher or lower usage rates and/or restricted locations will differ. As with any type of accelerated testing, acceleration factor predictions tied closest to field data are always the most reliable.

Conclusion

Full details of the testing performed to date, remain client confidential. However, over 70 tests on dozens of designs have produced a stable repeatable test process. A significant number of the products tested had known field performance histories, and the test results correlate with those histories. Products with no history of dust related issues generally do well in fibrous dust testing, while those with histories of dust complications have problems. With ever increasing semiconductor performance, the demand for high efficiency cooling systems will continue to progress. The effects of fibrous dusts on these systems will be critical. Industry standard test methods and criteria for fibrous dust testing do not exist at this time. However, the methods and equipment described in this paper have proven to be effective at producing realistic results. Even if test standards are developed, manufactures will still have to assess risk based on individual product dust evaluations and best engineering judgment. Accelerated testing early in the design process is always a good idea regardless of the type of environmental stimuli applied. Testing for heat sink/system immunity to fibrous dust contaminates is a crucial step in identifying problems and assessing risk. While there appears to be no easy solutions to fibrous dust contamination issues, testing services and equipment are now available to analyze designs for fibrous dust susceptibility. An accurate test to reproduce a problem is always the first step on the road to successful solutions.

Panoptik Compliance Solutions

PANOPTiK Compliance Solutions continues to offer fibrous dust testing chambers and testing services. From the original design in the mid-2000s to the present, we have continued to innovate fibrous dust systems. We manufacture and install our legacy **DT550** (9m x 9m x 9m test volume chamber) as well as our new **1m x 1m x 1m** small-form test chamber, ensuring we can provide a testing solution tailored to your product's needs. Additionally, we offer finely tuned fibrous dust mixtures customized to support your quality program, along with in-house testing and consulting services. With **PANOPTiK** fibrous dust chambers deployed worldwide in industry-leading companies, our 20+ years of experience can help ensure your product is reliable and prepared for real-world conditions.

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