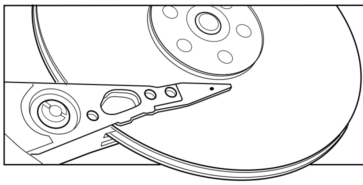

Thermal Reliability

Cool-Running WD Hard Drives Demonstrate Exceptional Reliability in High Duty Cycle Environments

Overview/Executive Summary

WD drives are highly reliable because they are cool-running and thus perform exceptionally at high temperatures and high duty cycles. The thermal reliability of WD drives can be quantified by tests that prove this assertion.

Testing Categories

WD performs rigorous testing to generate data that quantify drive reliability at high temperatures and high duty cycles. The tests are divided into these categories:

- **Reliability demonstration test** (**RDT**) — This is a one-time test at the qualification stage, typically with 1000 drives running for 1000 hours, to confirm that a hard drive design meets customer requirements for reliability before going into volume production.
- **Ongoing reliability tests** (**ORT**) —These tests are performed weekly during a production run. A sample comprising a certain number of drives is drawn weekly and tested over a four-week interval to ensure that the drives meet reliability requirements.

Customer Requirements and Testing

In regard to testing, WD customers want to know the details of how we arrive at the numbers we cite in our literature and how these values may affect their operating environments. WD test conditions typically involve a high temperature and a 100% duty cycle.

The duty cycle is the percentage of time that a drive is reading, writing, or seeking. So, if a drive is engaged in these activities 12 hours a day, or half the time, then its duty cycle is 50%. The percentage of time a hard drive is used functionally is the functional duty cycle; the percentage of time a hard drive is powered on is the power-on duty cycle. WD typically assumes a power-on duty cycle of 3120 hours-per-year (35.6%) for desktop drives and 8760 hours-per-year (100%) for our enterprise drives. In the latter case, 100% means that the drive is powered on all the time.

One way that WD customers measure drive reliability is the mean time to failure (MTTF) value. This is the average time (expressed in hours) that a component works without failure. It is calculated by dividing the total number of operating hours observed by the total number of failures.

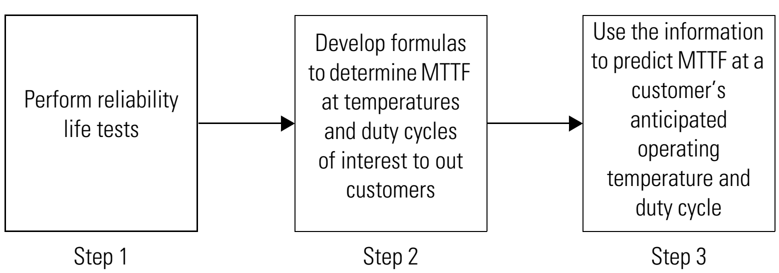

Figure 1. Reliability Prediction Process Steps

Figure 1 is an overview of the steps in reliability testing. It begins by performing reliability life tests as noted in step 1. Then, in step 2, our advanced reliability engineering department models the results in equations. Finally, in step 3, these equations provide a prediction of reliability for a given customer at any operating temperature and at any given value of functional duty cycle.

WD tests and qualifies its drives under precise conditions relating to temperature and duty cycle. Once we have knowledge of how long our products last, we then are able to transform our test results to the operating conditions that our customers plan for their products that use our drives. Almost without exception, customers operate drives at different temperatures and duty cycles than we employ in our tests. For instance, if we test drives at a temperature of 55°C, the MTTF values we obtain must still be valid and applicable to our customer’s operating conditions.

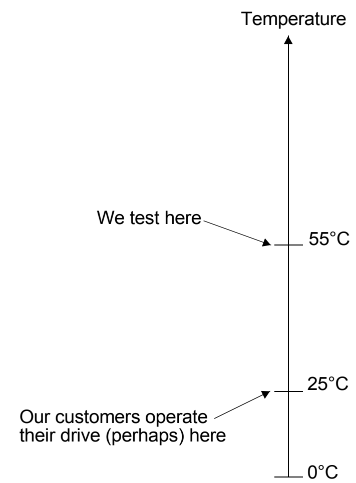

Figure 2. WD Testing Temperature vs. Customer Operating Temperature

Similarly, any given value of functional duty cycle used in WD testing should yield data that is still valid to the customer.

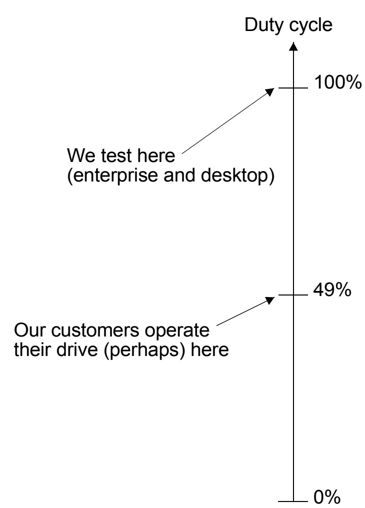

Figure 3. WD Test Duty Cycles vs. Customer Projected Duty Cycle

Accelerated Testing

The purpose of accelerated testing is to determine how long a product lasts without waiting for it to actually fail under normal operating conditions. What we do is accelerate—or deliberately hasten—failure by raising the operating temperature of the drive and operating it 100 percent of the time, when in actual use it may be expected to operate only 49 percent of the time. Thus, the unit fails sooner than it would in a normal operating environment. By using mathematics and concepts such as the acceleration factor (see “Acceleration Factor” on page 3), we can predict on average how long the drive will survive when subjected to our customer's normal operating conditions.

Failure Modes

Every product with moving parts, no matter how well-made, ultimately wears out—which is to say that it fails. Raising the temperature hastens failure. Duty cycle, which means the amount of time the drive is actively reading, writing, seeking, also affects drive reliability. The higher the duty cycle, the sooner the drive fails. What actually occurs within the drive to cause the failure varies.

Reduction in Signal Amplitude

One failure mode that occurs as the temperature of the drive rises is degradation of the head. Specifically, the output signal delivered by the head to the drive electronics diminishes. When the signal becomes too weak, the drive is unable to read or write. This also can occur with aging.

Thermal Asperity

Another failure mode exacerbated by rising temperatures is called thermal asperity (TA). This means that the head is more likely to collide with particles located in the region of the tiny gap between the head and the disk. This gap is extremely small—less than one millionth of an inch (0.3 – 0.4 microinch).

Acceleration Factor

The key to grasping how WD anticipates how our drives respond under various temperatures and duty cycles is the acceleration factor (AF). AF allows translation of an MTTF value derived from any operating temperature to an MTTF value valid for any other operating temperature. For example, if we obtain an MTTF through testing a hard drive at 55°C, then there is an acceleration factor which tells us the MTTF at 25°C. AF represents the extent by which the product life is shortened (failure is accelerated) by increasing the stress level.

Effect of Temperature on Reliability

Figure 4 assumes that WD tested a drive at 55°C.

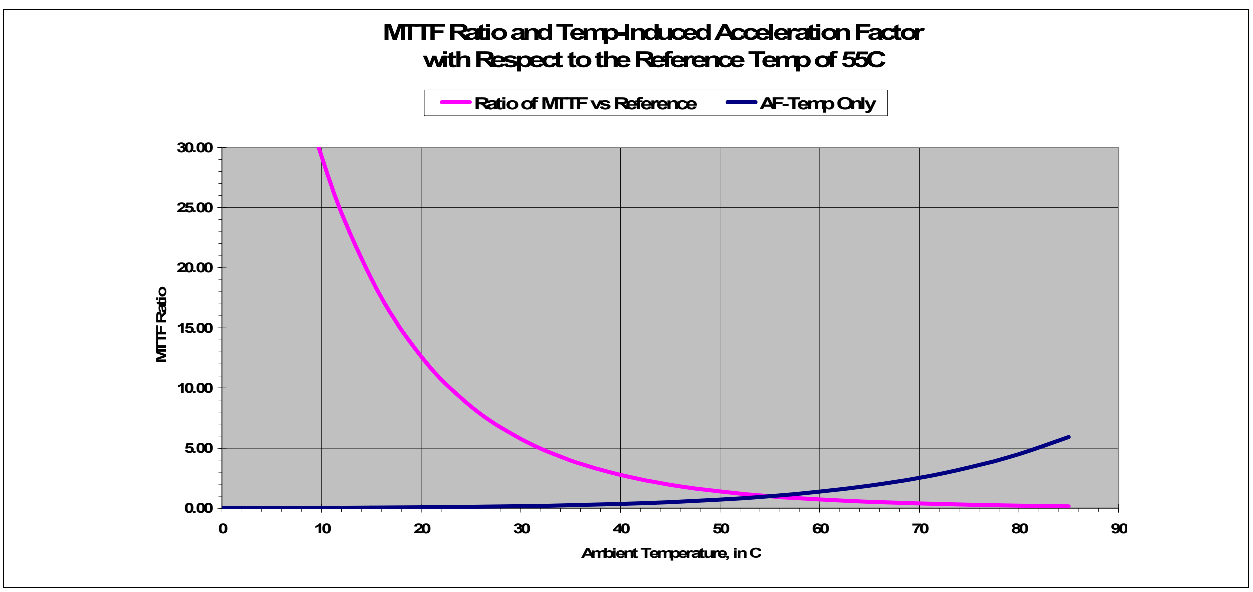

Figure 4. MTTF Ratio and Acceleration Factor—55°C Reference Temperature

Read Figure 4 shows an acceleration factor of 1.00. This means that if a customer operates the drive at the same temperature at which we test the drive (55°C), they divide our MTTF by 1 to obtain their MTTF. Since dividing any number by 1 does not change it, the customer's MTTF is the same as our MTTF.

Assume that the MTTF at 55°C is 200,000 hours. In Figure 5, MTTF rises up the MTTF scale instead of AF. So, if again we look at 55°C degrees on the bottom scale, go straight up to the curve, and follow the horizontal line to the left, we determine that the customer's MTTF is 200,000 hours.

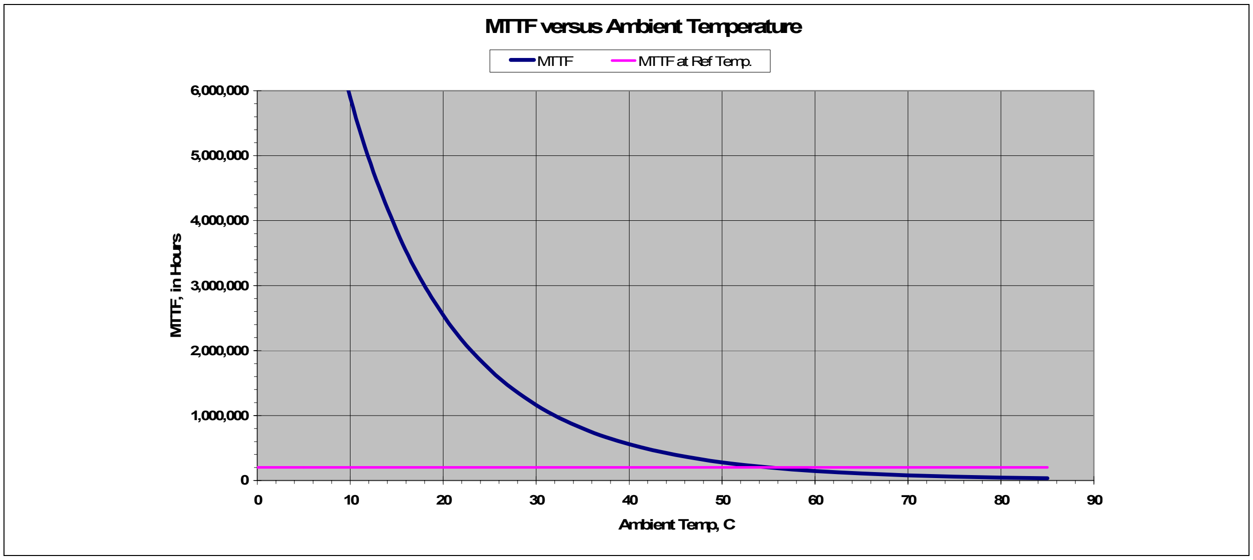

Figure 5. MTTF vs. Ambient Temperature

Note: The temperature inside the product housing is the ambient temperature. WD normally measures the ambient temperature 1 inch from the drive housing. The temperature of the drive housing (case temperature) is typically 5 to 10°C higher than the ambient temperature.

Now let us suppose a customer plans to operate the drive at 32°C. We go follow the same steps: In Figure 4, we find that the MTTF ratio and AF of 32°C with respect to the 55°C reference temperature are 5 and 0.20, respectively, whereas in Figure 5, the MTTF is 1,000,000 hours. So, we can see that the AF is the number which is divided by the MTTF at our test conditions to arrive at the MTTF at the customer's test conditions.

The percentage of drives that fail in the first year represents the annualized failure rate (AFR). AFR is a method of measuring failure rates or trends for a group of units at a site. These rates are based on the monthly total number of returned failed units divided by the cumulative total installed base and multiplied by 12 (to annualize the failure rate). Customers expect that between 0.5 percent and 0.8 percent of the drives we deliver to them may fail in the first year (i.e., less than one percent).

Effect of Duty Cycle on Reliability

How much a drive is used—its duty cycle—depends very much on how a computer is used. High-end data transfer, graphic processing, and gaming result in a high duty cycle. On the other hand, if a user does no more than read and write an occasional e-mail message, the duty cycle is low.

To characterize a drive with regard to duty cycle, we accelerate the duty cycle which means we run the drive at 100 percent (35.6 percent for desktop drives) to determine the worst case MTTF. AF is then determined by equations developed as a result of the test for duty cycles that are lower than the duty cycle we employ in testing.

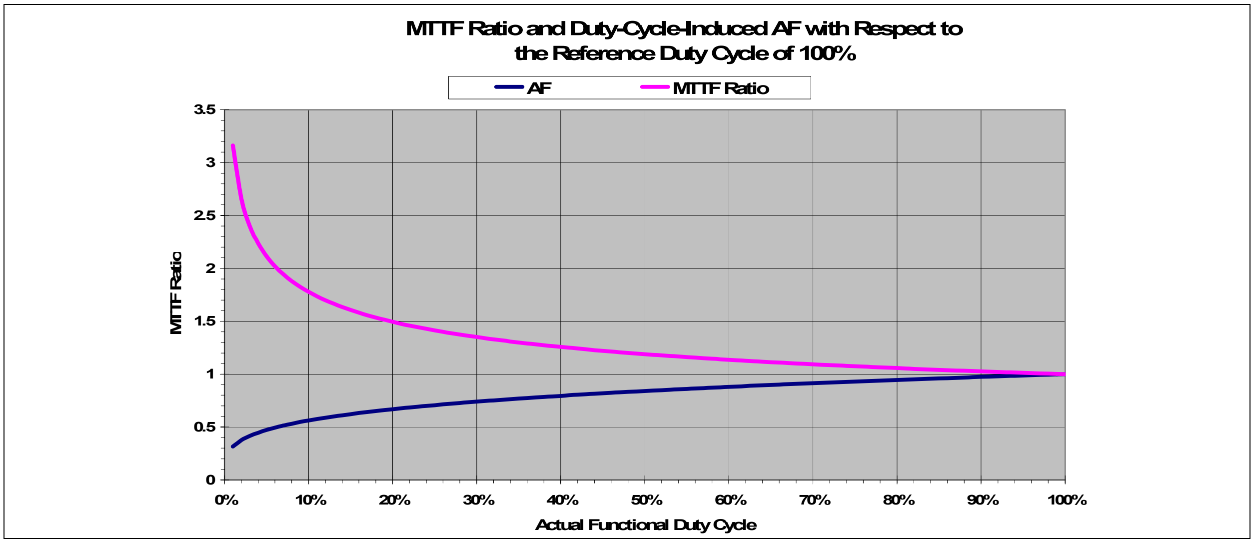

Figure 6. MTTF Ratio and Acceleration Factor—100% Reference Duty Cycle

If we follow along the bottom scale to the far right side in Figure 6, we find 100% which is where we qualify an enterprise drive. Now, go straight up to the curve and see that, along the MTTF scale, the curve at 100% duty cycle has an acceleration factor of 1. This means that if a customer operates the drive at 100%, that is exactly where we characterize it. The MTTF our customer can expect is exactly the same as when we tested the drive.

But assume that a customer plans to operate our drive at a duty cycle of 20%. Following the bottom scale back to 20% and moving up to the curve, we find that the curve intersects the MTTF scale at 1.5 for MTTF ratio and 1/1.5 for AF. At this lower duty cycle, we expect a higher reliability (i.e., the less a drive is used, the longer it lasts).

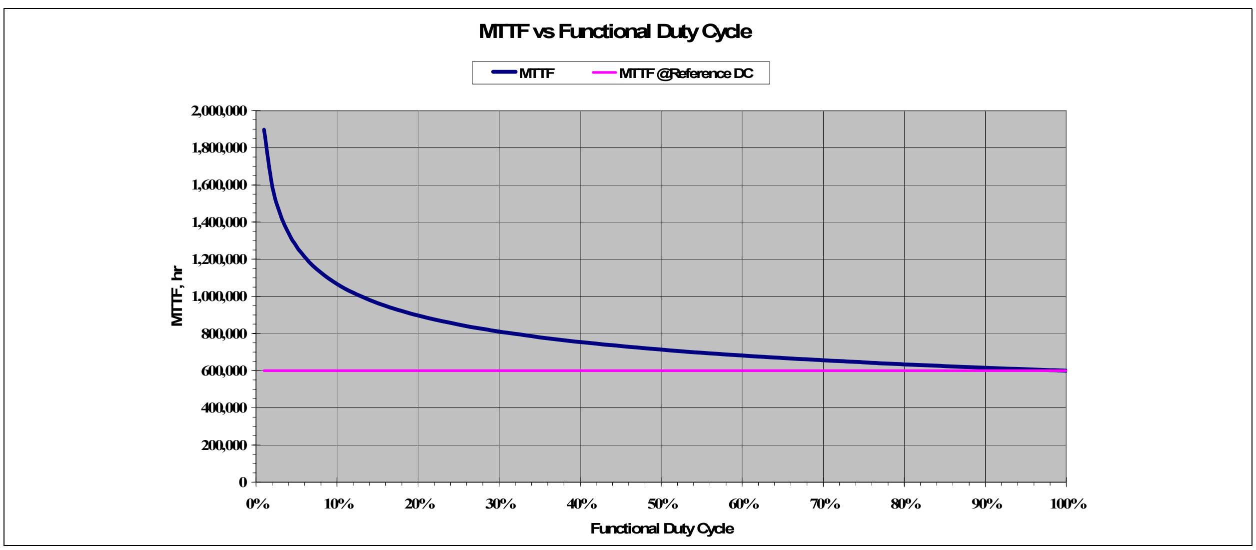

Figure 7. MTTF vs. Functional Duty Cycle

In Figure 7 we see the actual MTTF values. In our characterization, we obtained a MTTF of 600,000 hours at 100% duty cycle. Now, following back to 20%, we find that the curve intersects the AF scale at around 900,000 hours which is about 1.5 times the MTTF value at 100%. In other words, the MTTF at 100% duty cycle multiplied by the acceleration factor of 1.5 yields an MTTF of 900,000 hours.

In summary, the AF at lower user duty cycles is lower with respect to our test conditions. This means that when the drive is used less, it lasts longer.

Combined Effect of Drive Temperature and Duty Cycle on Reliability

Figures 8 and 9 show the combined effect of both temperature and duty cycle on reliability. Figure 8 has nine curves representing different potential operating temperatures. If a customer's operating temperature is 30°C, we follow the green curve to the left until we reach the 40% duty cycle vertical line and identify an acceleration factor of 0.26 with respect to our test conditions of 55°C and 100% duty cycle.

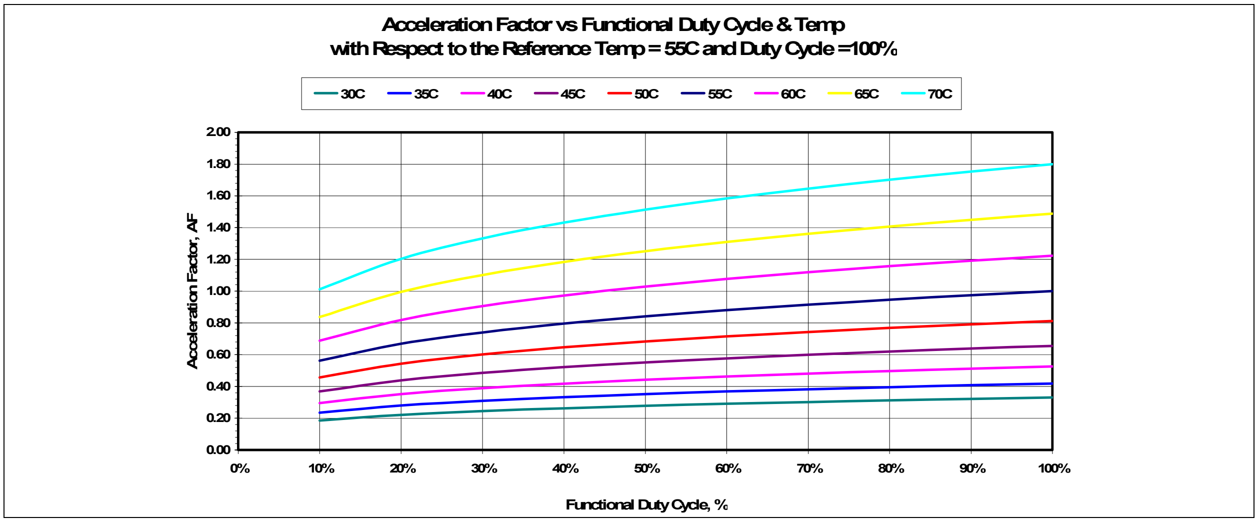

Figure 8. Acceleration Factor vs. Temperature and Duty Cycle

In Figure 9, again we follow the green curve and find that at a temperature of 30°C and duty cycle of 40%, the MTTF is 1.32 million hours. When we divide the MTTF at 55°C and 100% by the AF in Figure 8, we obtain the same MTTF value.

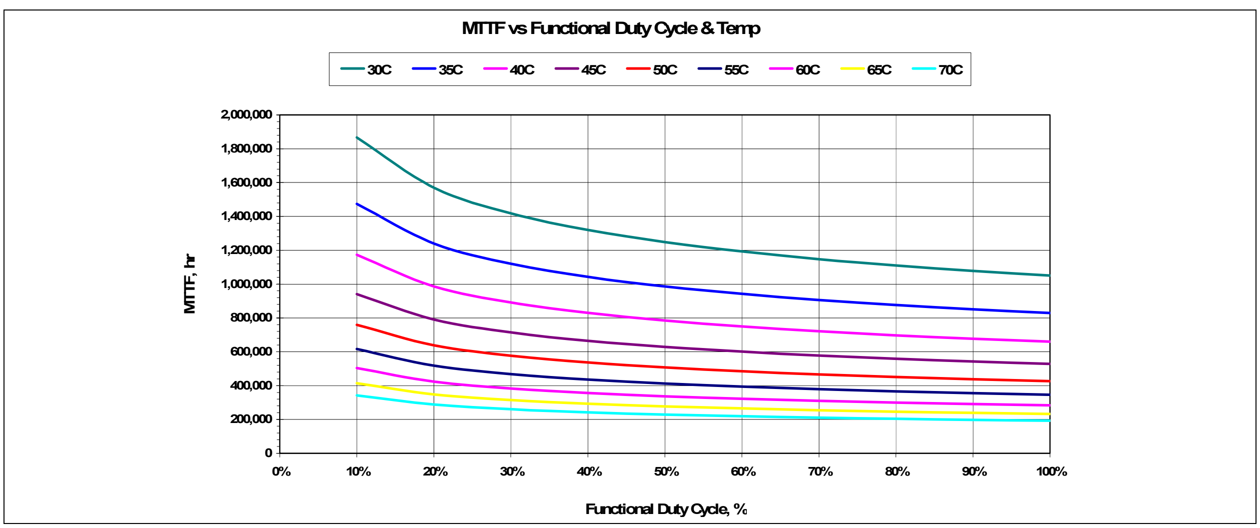

Figure 9. MTTF vs. Temperature and Duty Cycle

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