Pitfalls of Accelerated Testing

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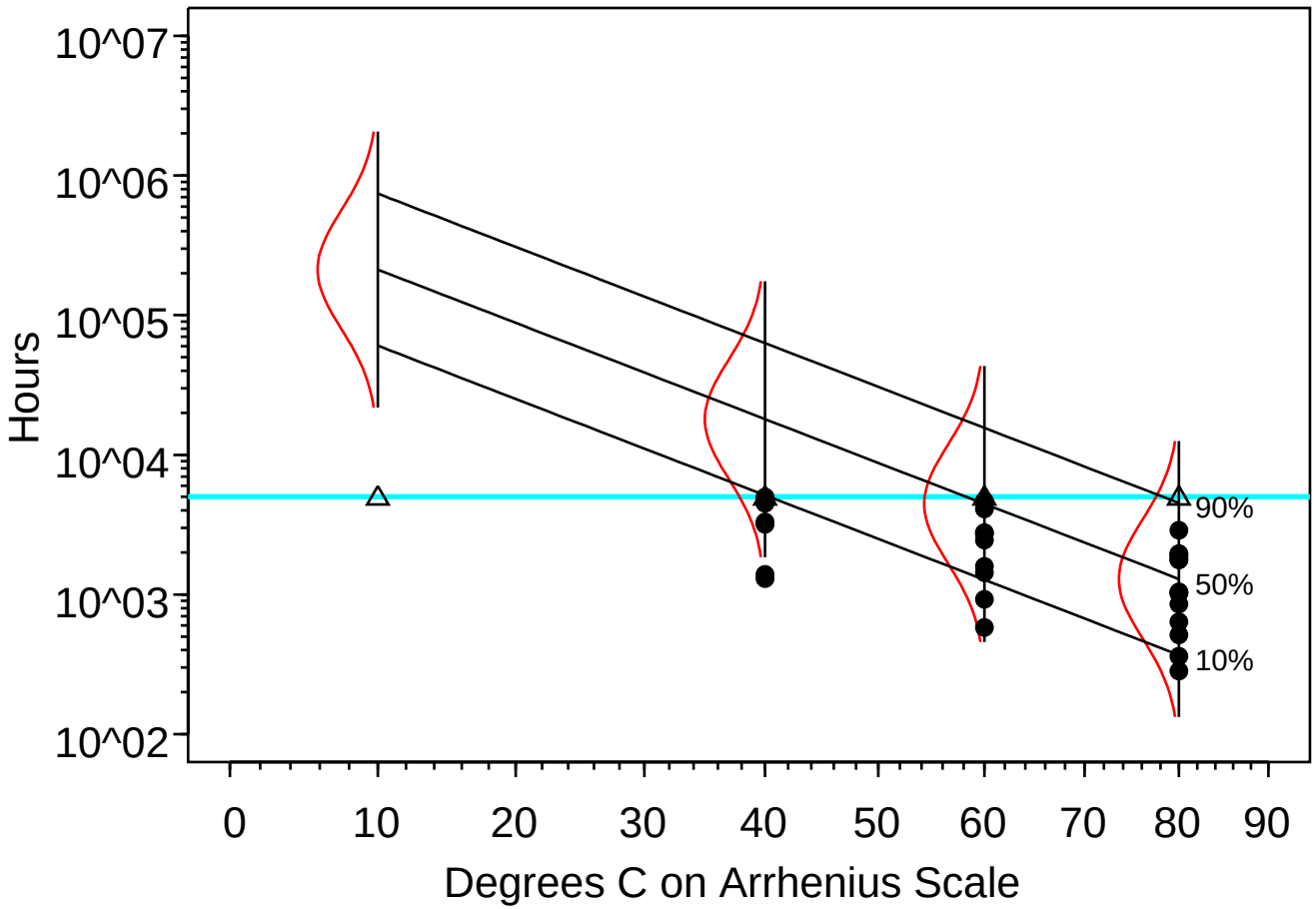
Overview

- Accelerated test overview
- Different kinds of pitfalls
- Examples illustrating particular pitfalls
  - GE Refrigerator Compressor: Faulty accelerated test almost caused GE Appliances to go out of business
  - Electronic component: Accelerated test did not detect a masked failure mode that caused a reliability disaster.
  - Appliance B: Industry-standard accelerated test led to incorrect predictions of field lifetime.
  - Insulating structure: Too much voltage stress caused extraneous failures and incorrectly optimistic lifetime predictions.
- Concluding Remarks

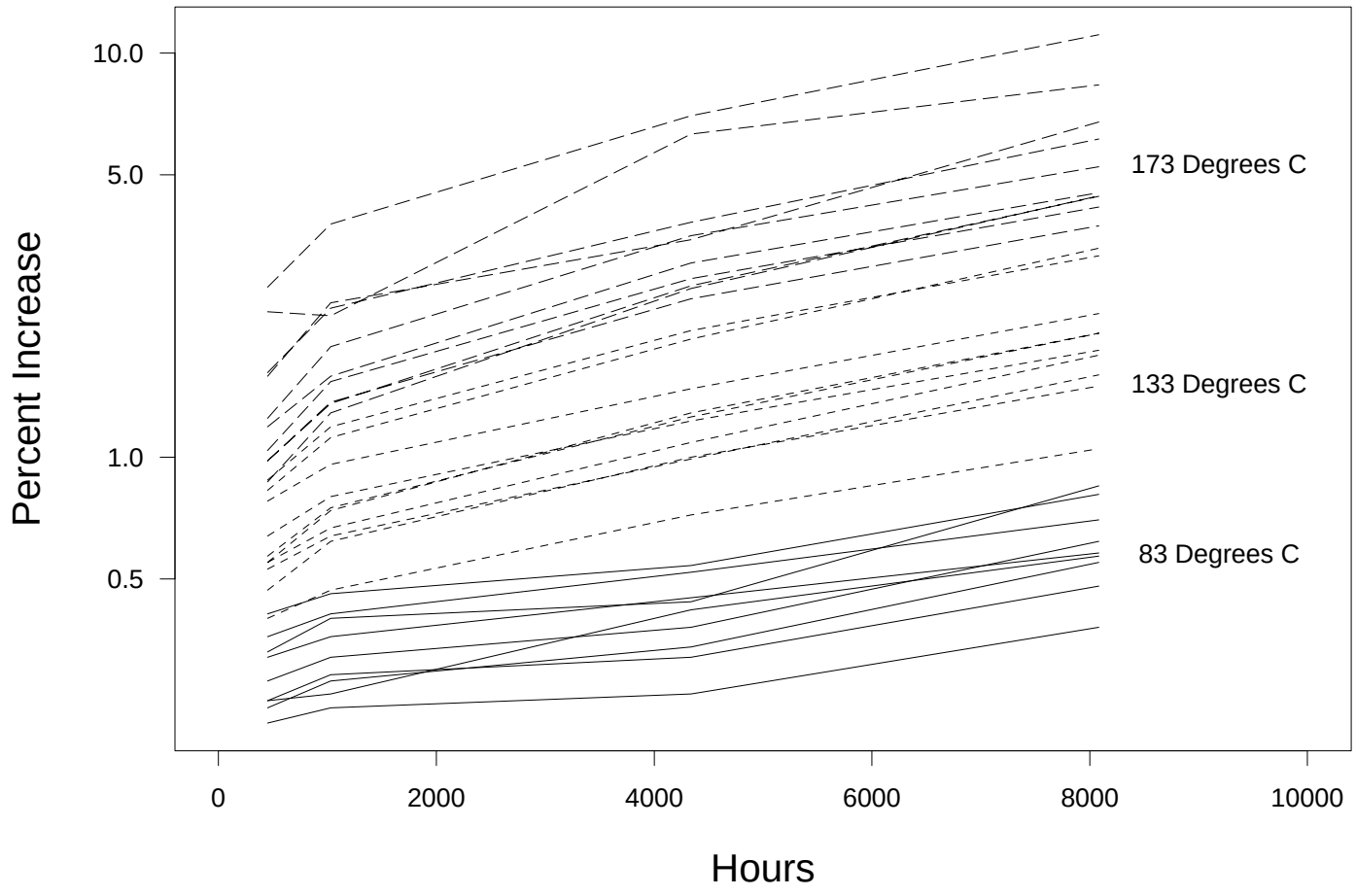
Types of Accelerated Tests

- There are three different kinds of accelerated tests, depending on what one is able to observe.
  - Accelerated life tests (ALT)
  - Accelerated repeated measures degradation tests (ARMDT)
  - Accelerated destructive degradation tests (ADDT)
- These different kinds of ATs have different data structures and thus **different** models and methods of analysis.

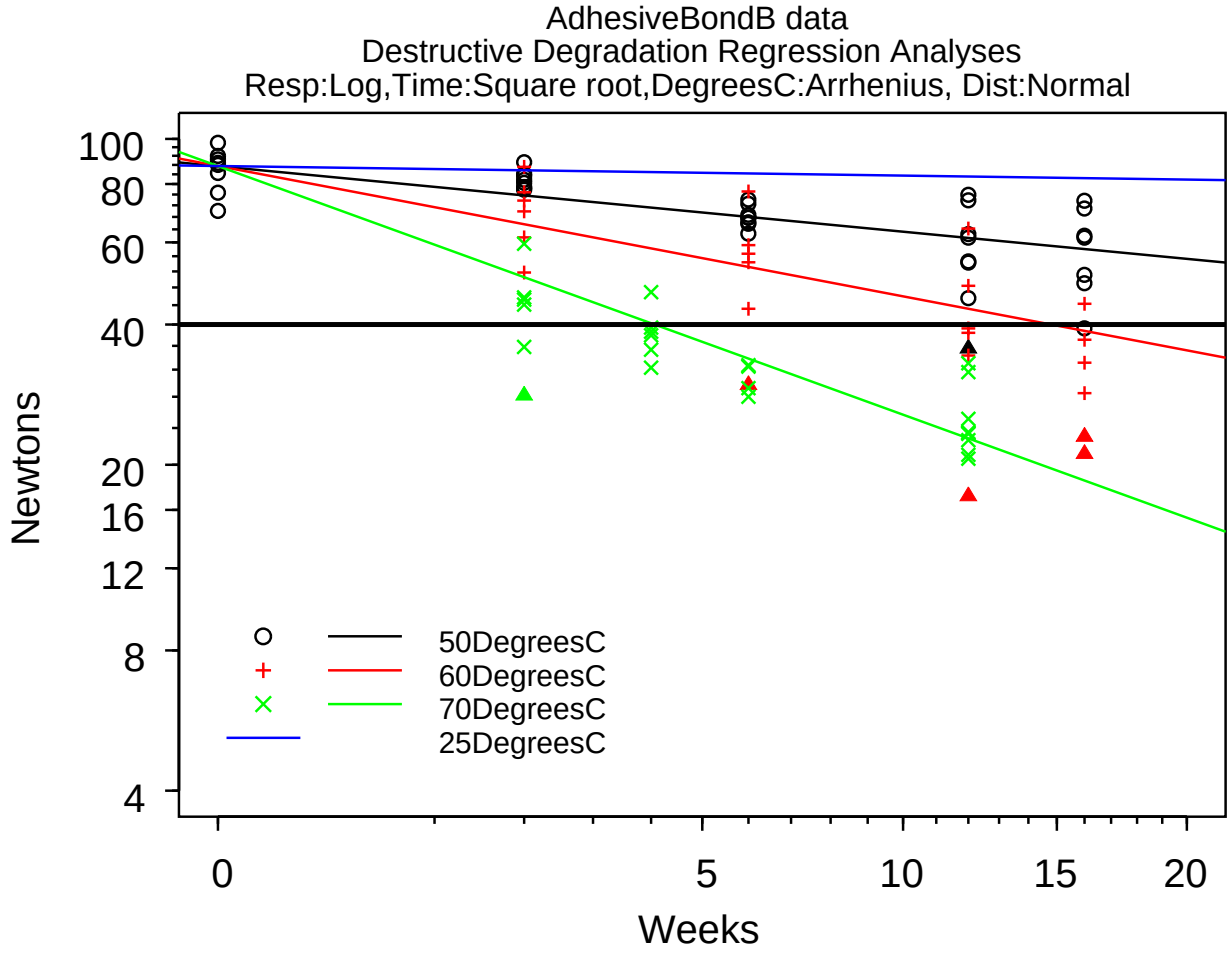
Typical Temperature-Accelerated Life Test



Accelerated Repeated Measures Degradation Test of Carbon-Film Resistors



Accelerated Destructive Degradation Test of an Adhesive



Methods of Acceleration

Three fundamentally different methods of accelerating a reliability test:

- Increase the use-rate of the product (e.g., test a toaster 200 times/day). Higher use rate reduces test time.
- Use elevated temperature or humidity to increase rate of failure-causing chemical/physical process.
- Increase stress (e.g., voltage or pressure) to make degrading units fail more quickly.

  Use a **physical/chemical** (preferable) or **empirical** model relating degradation or lifetime to **use** conditions.

Different Kinds of Pitfalls

Pitfalls are generally the result of **statistical misconceptions** or the **naive application** of accelerated test methods.

- In the recent JQT paper,

  Meeker, W. Q., Sarakakis, G., and Gerokostopoulos, A. (2013). More Pitfalls in Conducting and Interpreting the Results of Accelerated Tests. *The Journal of Quality Technology*, 45, 213-222.

  we categorized pitfalls according to

  - Pitfalls that occur during the **planning** of an accelerated test
  - Pitfalls that occur during the **execution** of an accelerated test
  - Pitfalls that occur during the **analysis and interpretation** of accelerated test data

GE Refrigerator Compressor Problem

WALL STREET JOURNAL MONDAY, MAY 7, 1990

(1)

Chilling Tale

GE Refrigerator Woes Illustrate the Hazards In Changing a Product

Firm Pushed Development Of Compressor Too Fast, Failed to Test Adequately

Missing: the 'Magical Balance'

GE Refrigerator Compressor Problem

- Early 1980s, GE was losing market share to competitors—Jack Welch was unhappy.
- 1983-1986 GE designed, tested, and began to produce a new higher efficiency, lower cost “rotary” compressor.
- Stopped accelerated testing after one year and no failures.
- One million + in service by 1987.
- First failure after 1.5 years; virtually all would have eventually failed early.
- GE replaced all compressors in refrigerators that it could find. Total cost was more than $450 Million.
- What went wrong?

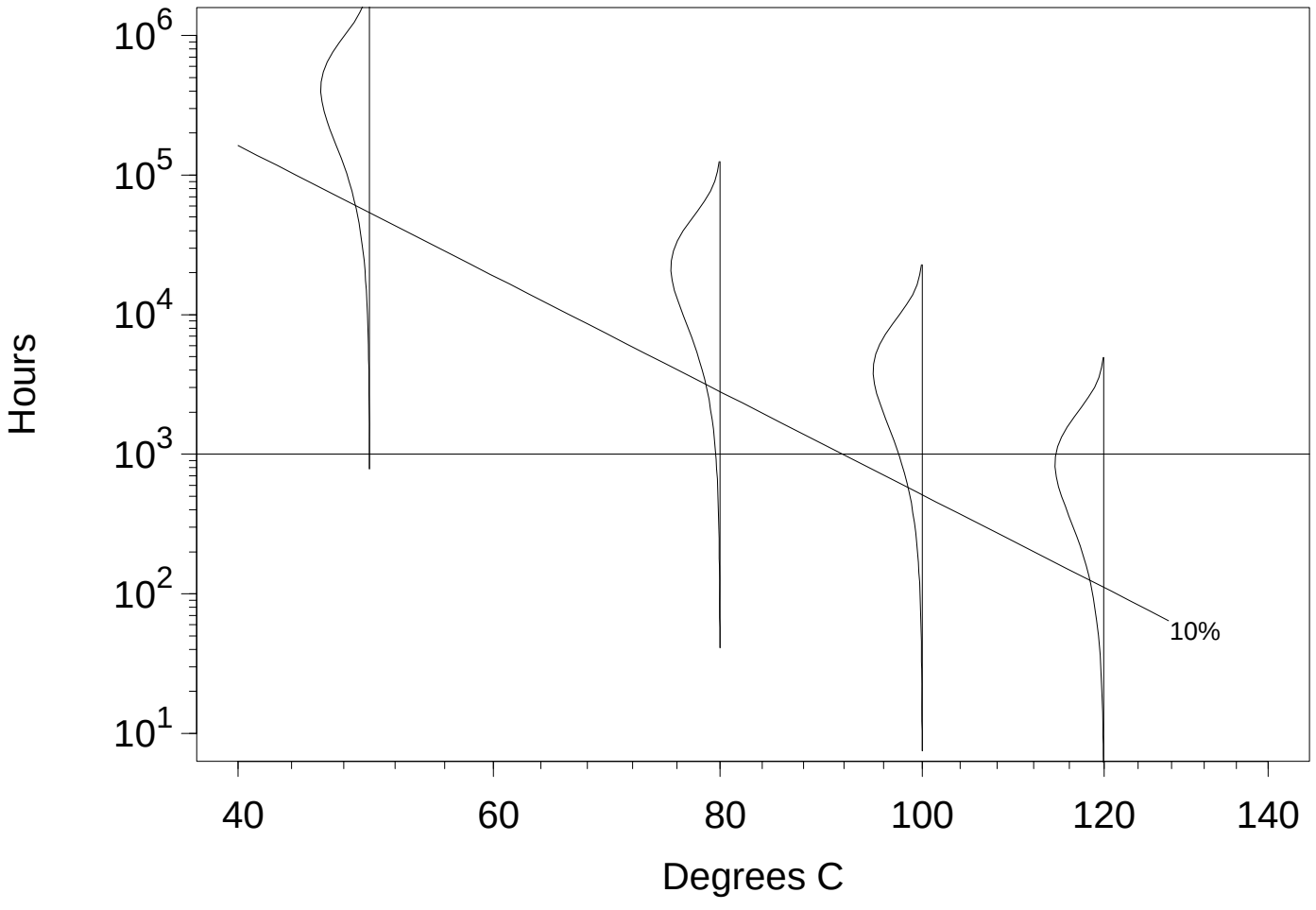
Pitfall I
Not Properly Using Information From Inspected Test Units

- Although there were no failures in the ALT, those who ran the test detected discoloration in the test units, indicating a lubrication issue.
- Test units were well on their way to failure.
- The bad news did not flow upward to higher management, as it should have.

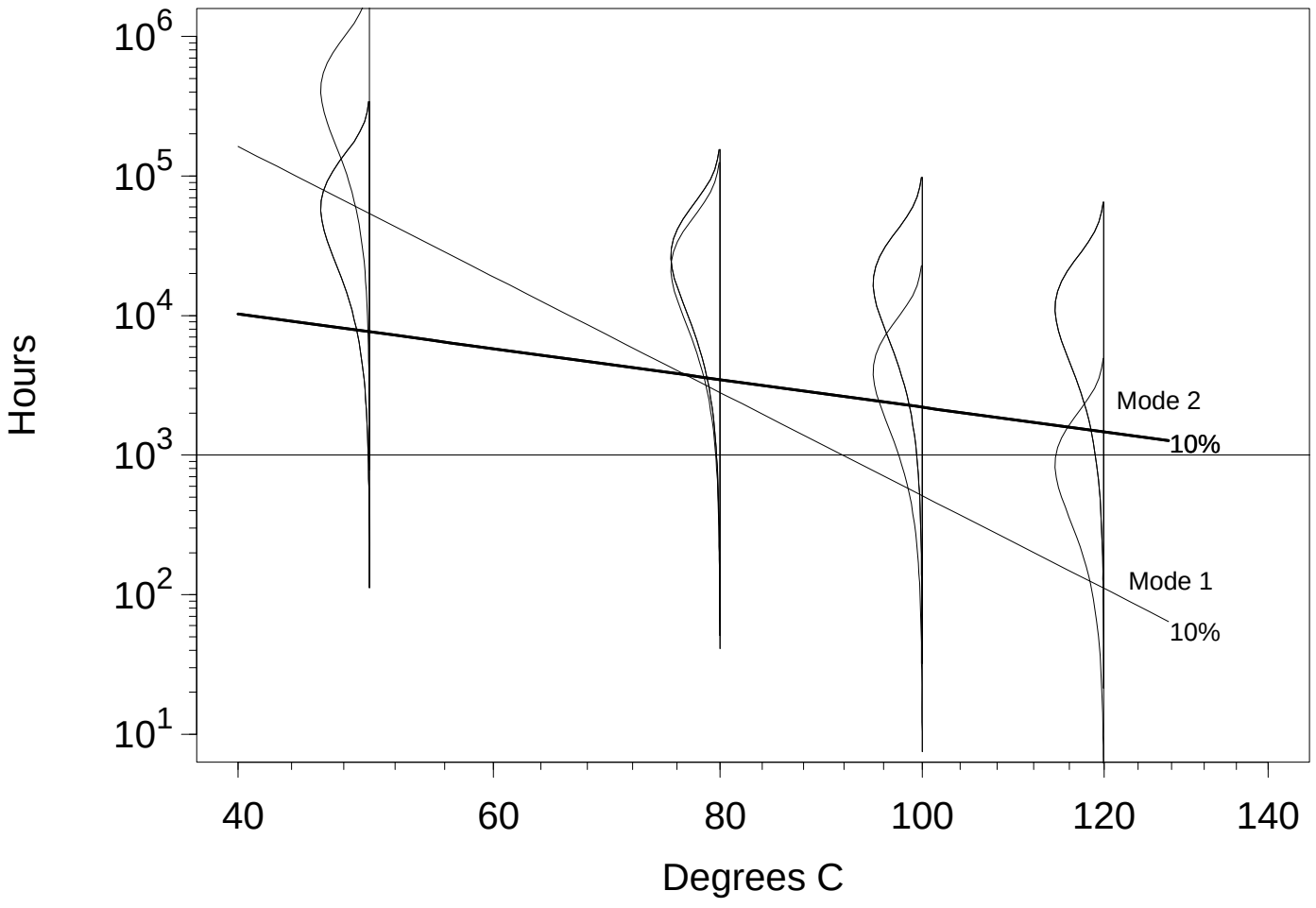
GE Refrigerator Compressor Reference

- O'Boyle, T. F. (1990). "Chilling Tale: GE Refrigerator Woes Illustrate the Hazards in Changing a Product." *Wall Street Journal* (Eastern edition). New York, N.Y.: May 7, 1990, page 1.

Temperature-Accelerated Life Test for an IC Device



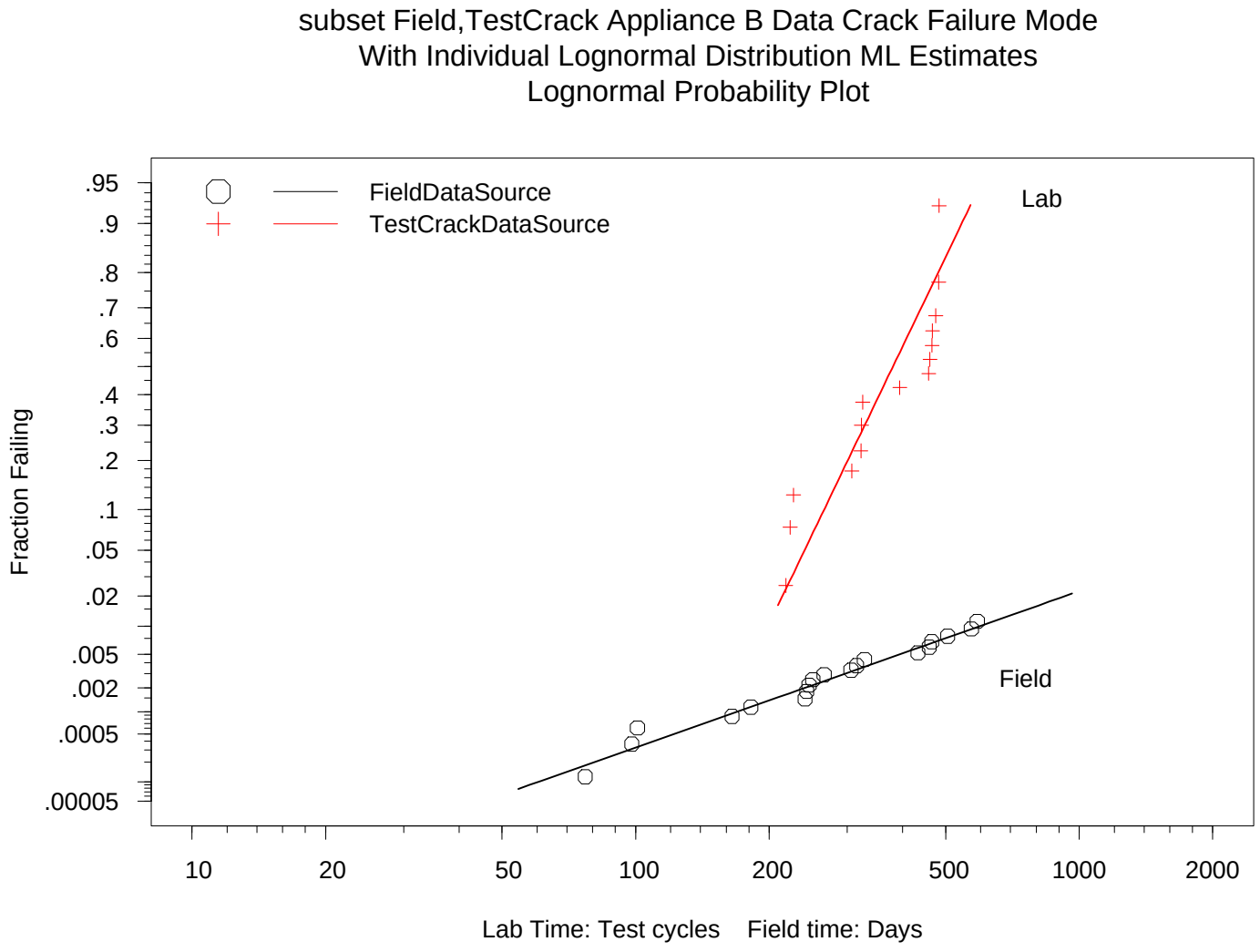
Lower Activation Energy Can Be Masked



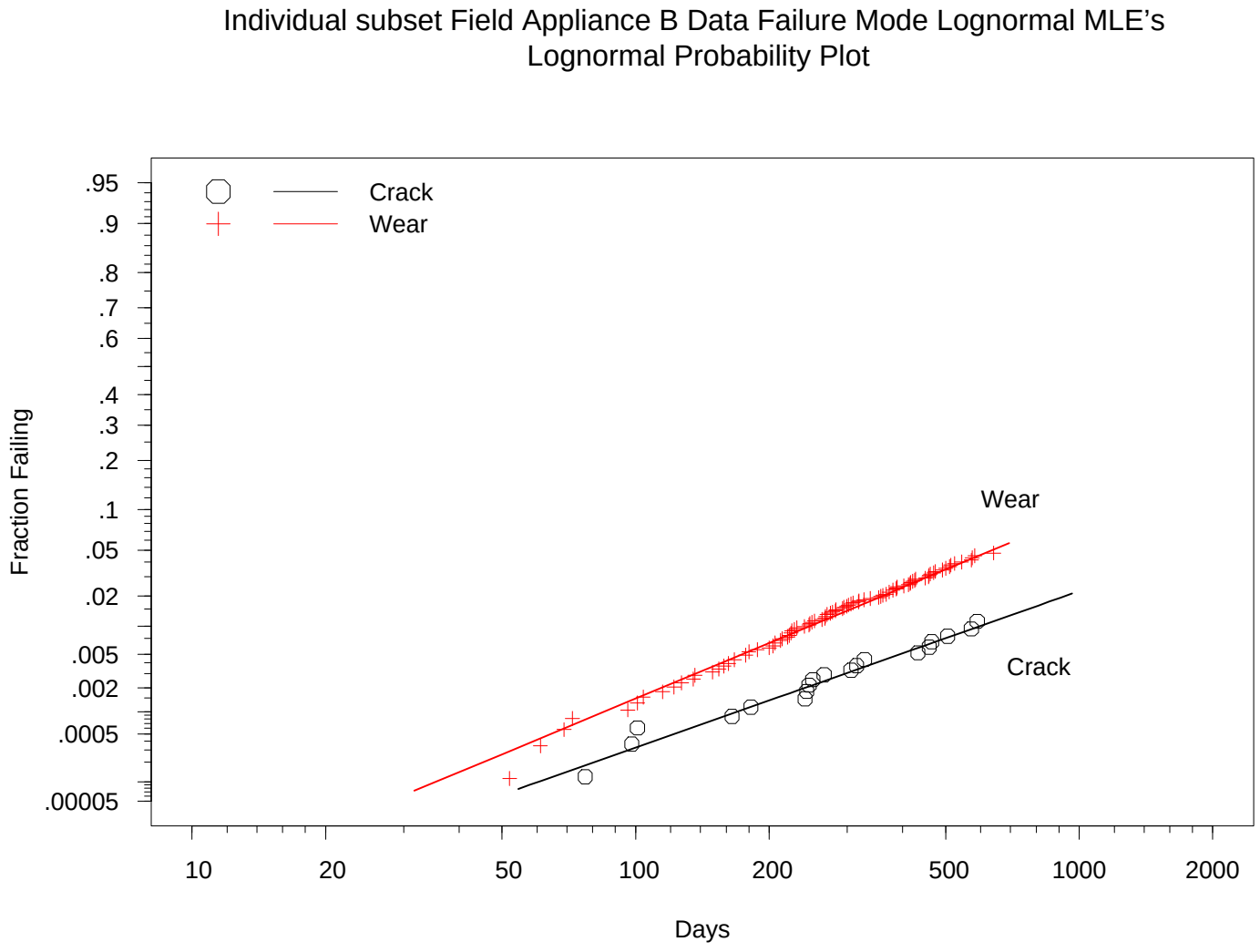
Pitfall 4
Masked Failure Mode

- Accelerated test may focus on one known failure mode, masking another!
- Masked failure modes may be the first one to show up in the field.
- Masked failure modes could dominate in the field.
- Suggestions:
  - Know (anticipate) different failure modes.
  - Limit acceleration and test at levels of accelerating variables such that each failure mode will be observed at two or more levels of the accelerating variable.
  - Identify failure modes of all failures.
  - Analyze failure modes separately.

Appliance B Comparison of **Laboratory** and **Field** Data for the **Crack** Failure Mode

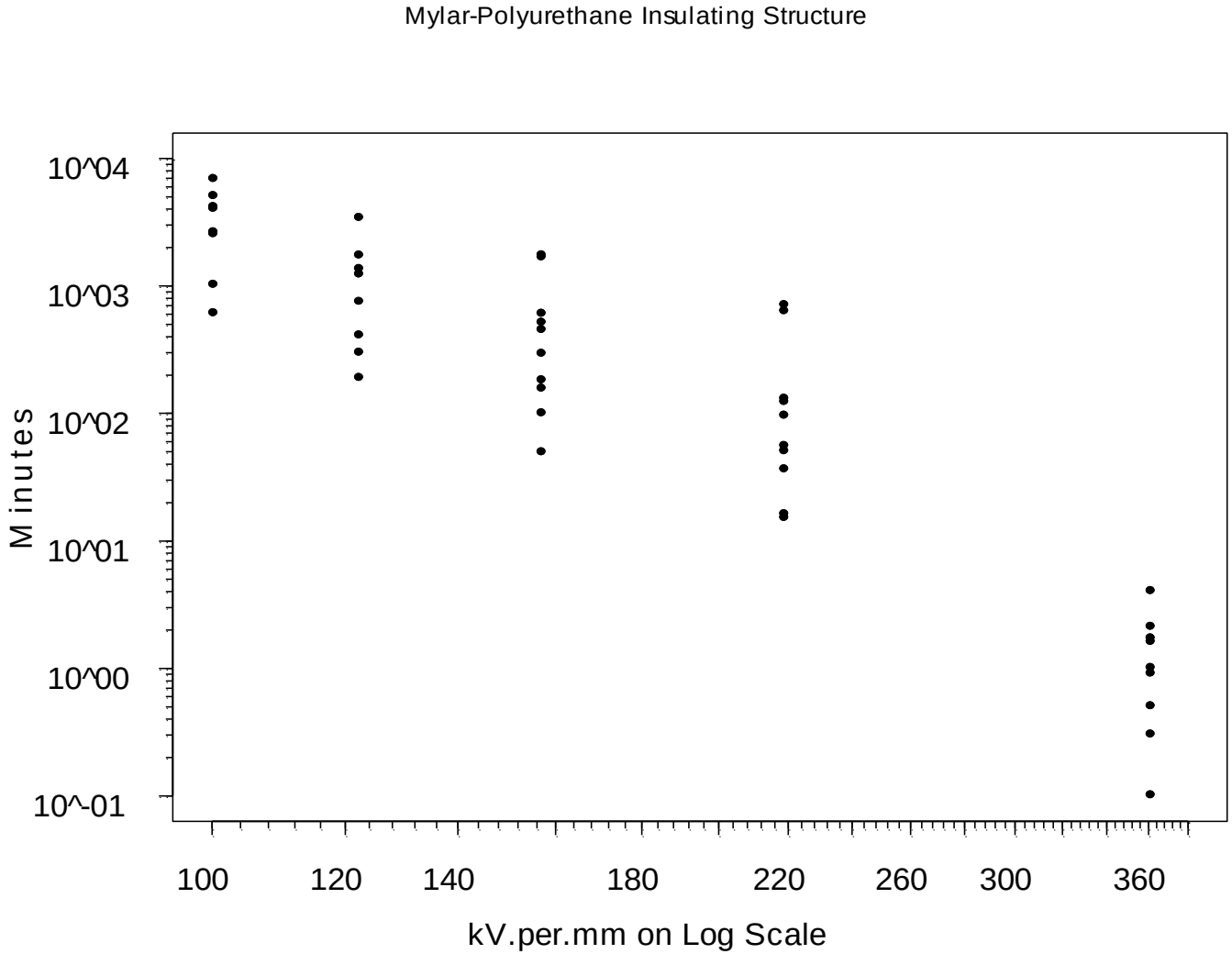


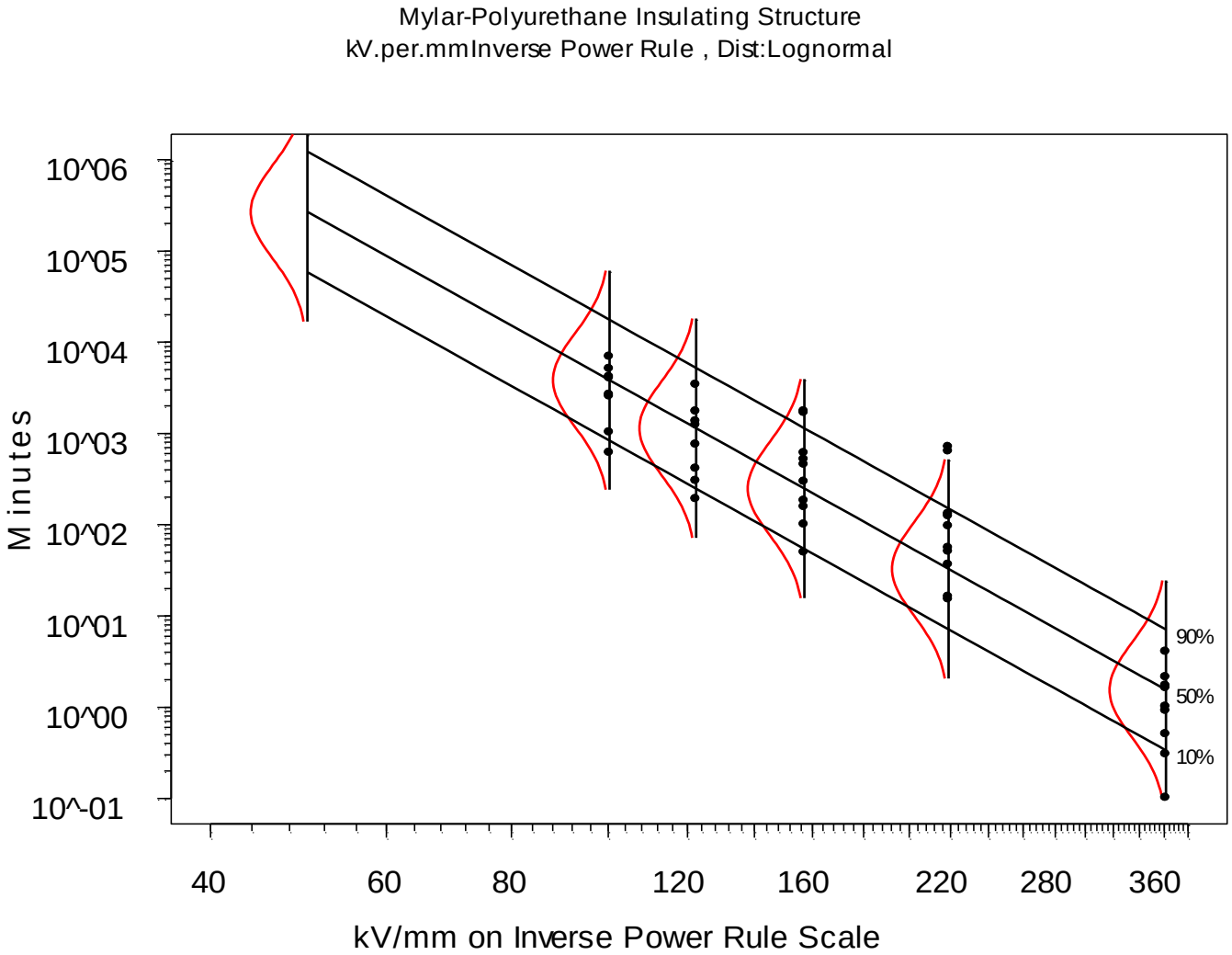
Appliance B Warranty-Return (Field) Data **Wear** and **Crack** Failure Modes

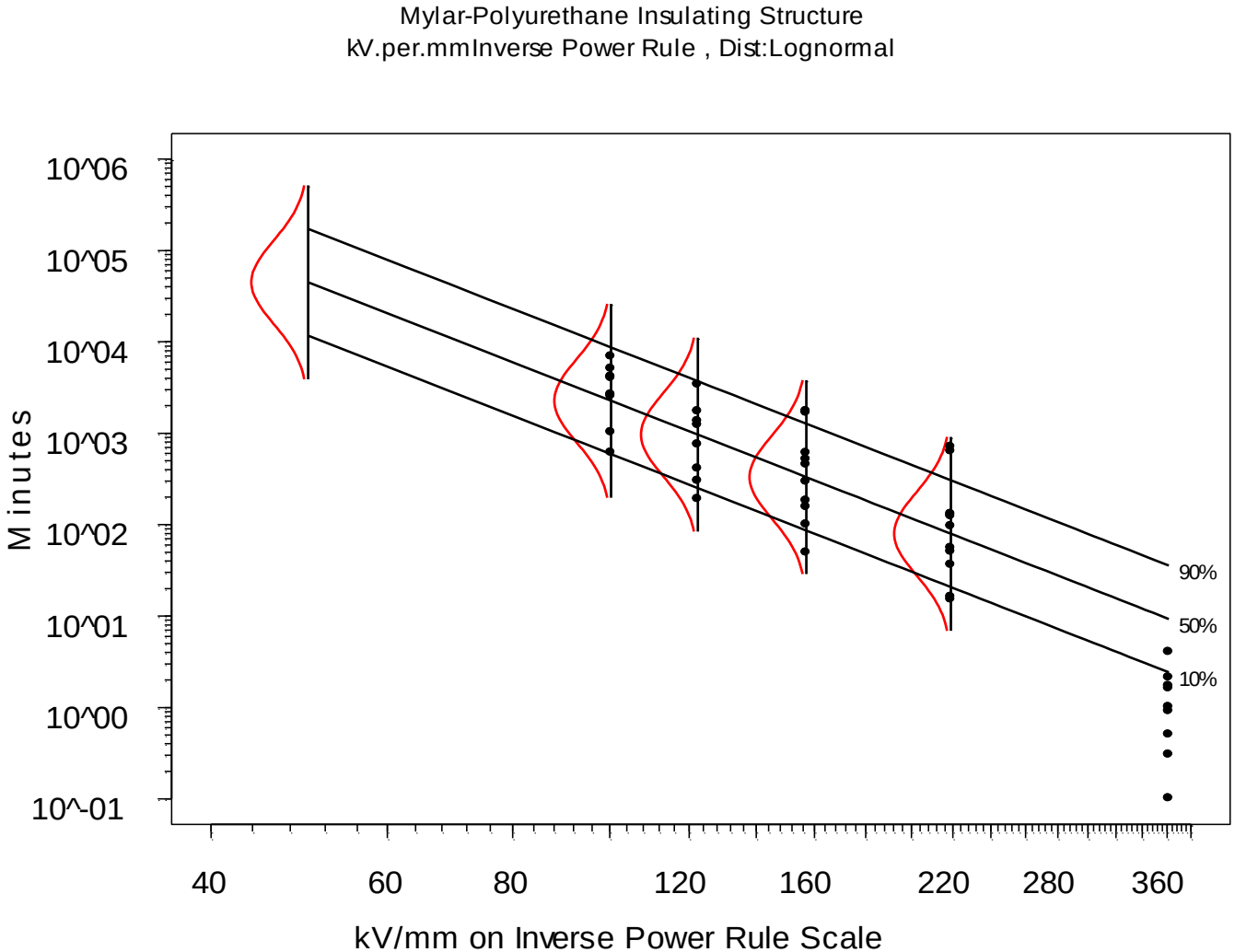


Pitfall Q
Not comparing failure modes in the field with failure modes in the laboratory

- Accelerated tests must generate failures in the same manner that they will be generated in actual use
- Often doing physical failure mode analysis is required
- When the mechanism is due to chemical change, analytical chemical measurements can be used to assure that AT and actual use have the same chemistry.


Mylar-Polyurethane Insulating Structure
Minutes
10^04
10^03
10^02
10^01
10^00
10^-01
100
120
140
180
220
260
300
360
kV.per.mm on Log Scale


Mylar-Polyurethane Insulating Structure
kV.per.mmInverse Power Rule , Dist:Lognormal
10^06
10^05
10^04
10^03
10^02
10^01
10^00
10^-01
Minutes
90%
50%
10%
40
60
80
120
160
220
280
360
kV/mm on Inverse Power Rule Scale


Mylar-Polyurethane Insulating Structure
kV.per.mmInverse Power Rule , Dist:Lognormal
10^06
10^05
10^04
10^03
10^02
10^01
10^00
10^-01
Minutes
90%
50%
10%
40
60
80
120
160
220
280
360
kV/mm on Inverse Power Rule Scale

Pitfall E
Testing at High Levels of Accelerating Variables That Cause New Failure Modes

- Using too much acceleration, generating new failure modes, is one of the most common AT pitfalls
- Early failures from a new failure mode at high levels of the accelerating variable will cause incorrectly optimistic predictions of lifetime at the use conditions.
- Knowledge of failure mechanisms and physical failure mode analysis can help avoid problems.

Concluding Remarks

- Accelerated tests are an important part of product development processes and are often needed to achieve high reliability.
- Accelerated testing requires extrapolation in several dimensions. **Extrapolation is dangerous**.
- It is important, when possible, to understand the physics/chemistry behind failure mechanisms.
- Knowledge of the potential pitfalls can help in avoiding serious mistakes.

The End

Thank You