APRIL 2017 ISSUE #100

MATERION

TECHNICALTIDBITS

MATERION PERFORMANCE ALLOYS

LEARNING FROM **FAILURES AND ENGINEERING DISASTERS**

Disasters frequently happen outside of 1970's Hollywood movies. – Using short-term testing to estimate long-term failure

- **Failure**
- **Engineering Disaster**

The next issue of Technical Tidbits will discuss nonlinear scaling effects.

As an engineer, you can learn more from a single failure than from 1000 successes.

This is especially true if the failure is your own design, as the lessons are personal and deeply ingrained. However, you do not have to learn from your own failures, as engineers, architects and designers have been making design mistakes (and occasionally goofing up royally) for millennia.

After any **engineering disaster**, there is always an inquiry to determine who or what was responsible. Those approaching an inquiry from a legal point of view are most interested in finding out if anyone should be paying compensation and whether or not criminal charges should be filed. Engineers can aid this effort as expert witnesses, but the most important role of the engineer is to find out exactly what went wrong, so that the disaster is never repeated.

Here is a partial list of some of historically important disasters to study:

- Structural collapses (Kansas City Hyatt Regency Walkway and Sampoong Department Store)
- Eschede derailment
- Ship Disasters (Vasa, RMS Titanic, Sultana, Halifax explosion)
- Space Exploration Disasters (Apollo 1, Space Shuttles Challenger & Columbia)
- Bridge Collapses (I-35W, Tacoma Narrows, Silver, Tay, Quebec and Ashtabula bridges)
- Nuclear Disasters (Three Mile Island, Chernobyl, and Fukushima)
- Surprisingly Deadly Fires (Cocoanut Grove, Iroquois Theater, Collinwood school, King's Cross station, Summerland)
- Airship Disasters (Hindenburg, USS Akron)
- Industrial Disasters (Deepwater Horizon explosion, Bhopal Union Carbide leak, coal mine fire in Centralia, Pennsylvania)
- Dam collapses (South Fork Dam, Sayano-Shushenskaya Dam, St. Francis Dam)
- Failure of Levees around New Orleans during Hurricane Katrina
- Therac-25 overdoses

The point here is not to learn to assign blame. It is important to study not just how something failed, but why it failed. Here are some key considerations to look for when examining historical failures:

- What decisions led to the failure?
- Was a previously unknown natural phenomenon to blame (like aeroelastic flutter in the Tacoma Narrows Bridge collapse, or the trench effect in the Kings Cross station fire)?
- Were there flawed assumptions used in the design?
- Was something not communicated properly (such as the valid reasons for delaying the launch of the Space Shuttle Challenger)?
- Were safeguards or warning indications ignored or ineffective (such as iceberg warnings the night of the Titanic sinking?)
- Were previously successful designs used at a scale where they had never been tested (as in the highly accelerated fatigue failure of the low vibration wheels on the Eschede train derailment)?
- Were safety practices ignored in order to meet cost or time pressures (like in the Sampoong shopping mall collapse)?
- Was a process or component changed without examining all the possible ramifications of the change (such as the support mechanism for the Kanas City Hyatt Regency Walkway)?
- Were materials used beyond their safe limits (as in the Space Shuttle Challenger disaster)

LEARNING FROM **FAILURES AND ENGINEERING DISASTERS** (CONTINUED)

- Were materials used in inappropriate ways or in inappropriate locations?
- Were incompatible materials used together?
- Were untried materials with fatal flaws used (like in the Cocoanut Grove and Summerland fires)?
- Was something overlooked when coding control software (as in the Therac-25 controls)?
- Was it tested under conditions that there much less severe than real world conditions?
- Did a series of otherwise survivable circumstances combine or interact in an unexpected way?
- Was a miscalculation made and not caught in subsequent design reviews (like the I35-W collapse)?
- Were unexpectedly extreme conditions involved? (For example, was the dam that was designed to withstand the 100 year storm hit by the 500 year storm?)
- Etc.

Keep in mind that it is often an interaction of multiple causes that separates a true disaster from a simple failure. Combinations of multiple errors tend to make disasters much worse.

There are also lessons to be learned from some more recent, high-profile failures.

- Lithium ion battery fires in aircraft, smart phones, laptop computers and hoverboards.
- Automotive recalls for unintended acceleration, airbag inflator ruptures, ignition switch shutoffs, etc.

The most important lessons to learn from failures and disasters are as follows:

1) Always put safety first. Look for ways that your design can fail. Conduct adequate testing and screening whenever possible to prevent unexpected failures. Testing conditions should at least be equivalent to real world conditions.
2) Clear, concise communication is essential, whether you are speaking, writing, or even creating charts and graphics. You may have to convince a non-engineer to make an engineering decision. You had better be able to communicate why it is necessary. Many organizations provide continuing education on improving your communication skills. Some examples include Wylie Communications Inc., Graphics Press LLC, and most professional skills development organizations.
3) Remember to take into account how properties, forces, pressures, etc. scale when making things larger, smaller, faster, hotter, more powerful, etc. Designs that are successful and robust at one scale may fail miserably in another scale.
4) Finite Element Analysis and other related simulation packages have given engineers the confidence to reduce the safety factors and eliminate the overdesigns that used to be commonplace in engineering. While overdesigned products with very high safety factors would be more tolerant of errors in calculations, the margin for error disappears when the safety factors approach 1. In other words, it is very easy to get false confidence from a simulation, where a single false assumption could very easily lead to failure.

Being an engineer is like being in the medical or police professions, **since the general public expects you to be infallible**. A simple mistake can cost people their lives, or at least result in significant damage to property. When working on any new design that may be responsible for keeping people safe, you need to ask yourself if any of the common causes found in the historical disasters applies. The best way to protect against failure is to study the common causes and lessons learned, and then to apply those lessons to your work. For added benefit, the references section contains a number of key works on disasters and engineering failures. Every engineer should read these multiple times.

Written by Mike Gedeon of Materion Performance Alloys Marketing Department. Mr. Gedeon's primary focus is on electronic strip for the automotive, telecom, and computer markets with emphasis on application development.

References:

Petroski, Henry
To Engineer is Human ©1992 Vintage Books

Fawcett, Bill It Looked Good on Paper ©2009 Bill Fawcett and Associates

Loutham, Mac. Life Lessons of a Failure Analyst ©2016 ASM International

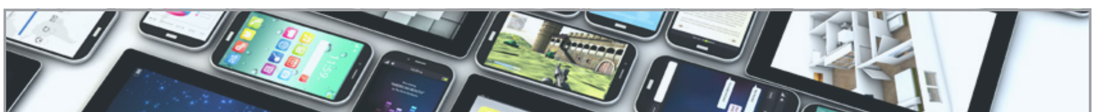
Tufte, Edward R. Envisioning Information ©1990 Edward Rolfe Tufte Graphics Press LLC.

Tufte, Edward R.
The Visual Display of Quantitative Information ©2001 Edward Rolfe Tufte Graphics Press LLC.

Please contact your local sales representative for further information on material hardness or other questions pertaining to Materion or our products.

Health and Safety

Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Materion Performance Alloys or your local representative.



TECHNICALTIDBITS

Materion Performance Alloys
6070 Parkland Blvd.
Mayfield Heights, OH 44124

Sales
+1.216.383.6800
800.321.2076
BrushAlloys@Materion.com

Technical Service
+1.216.692.3108
800.375.4205
BrushAlloys-Info@Materion.com

MATERION