

Representative Expertise in Machinery and Equipment Failures and Forensics
Stephen Randolph, P.E.

Over the years, my expertise was utilized to investigate many failures in various plants in various countries, many of them third-world locations. The following listing is incomplete, but illustrative of the various types of machinery and equipment failures which I have investigated and which lead to successful conclusions.

Representative Machinery Failures

1. **Large Horizontal Peeler Centrifuge Failure**

Location: South America

Deaths/injuries: no deaths, 3 injuries

Situation: In a large process plant installation, a large, high speed perforated shell horizontal peeler centrifuge failed spectacularly. These centrifuges are used for dewatering large volumes of corn starch on a 24 hr/day, 7 day/week basis. Production of the entire plant was impacted by the centrifuge failure. The machine that failed was one of three essentially identical centrifuges. The perforated shell failed, ruptured the heavy containment housing and almost completely destroyed the entire installation, which was a heavily reinforced five story concrete building. Parts of machinery weighing almost a ton were found several hundred yards from the building.

Action: I made all analyses and calculations to determine the cause of the accident, and then I made detailed calculations to redesign defective parts to prevent reoccurrence of such an incident. I wrote complete forensics reports on behalf of the corporation.

2. **Horizontal Peeler Centrifuge Investigations**

Location: Europe, North America, Australia, Asia, South America

Deaths/injuries: no deaths, no injuries

Situation: Due to the large number of installations that were similar to those in item 1 above, and having recognized my machinery forensics ability, I was requested by the parent corporation to conduct detailed investigations of the various types of designs of horizontal peeler centrifuges (multiple manufacturers, multiple sizes of machines made by each manufacturer) and to investigate the various operations of many plants in various countries in each of the above locations. The corporation's motivation was prevention of any further failures of this type of machinery, now that the destructive (life and property) potential of this machinery had been realized.

Action: I made numerous machinery analyses and calculations to determine the safety of each size of each type and manufacturer of the many worldwide centrifuges. I wrote detailed forensics reports for many of these machines, including detailed design modifications. I obtained the actual machinery design calculations from one of the major manufacturers and discovered significant latent design deficiencies. In a collaborative effort, the corporation and the manufacturer worked to redesign the erroneously designed machinery components, then retrofit them in many installations.

3. **Multiple Co-Products Dryer Failures**

Location: North America, Africa

Deaths/injuries: no deaths, no injuries

Situation: In large corn wet milling and ethanol (both dry and wet milling) plants, very large co-products dryers are used. Various types of dryers are utilized, depending on the specific application, including rotating shell, rotating shell/tube, rotating tube bundle/stationary shell, flash dryers (circular ring, P-type ring, column-type). If improperly designed or operated, these dryers are all capable of spectacular explosions and fires, some of which I have personally witnessed. The results of excessive temperatures within these dryers have often gone unrecognized until further collateral damage is done. Plant reliability and productivity (“uptime”) is almost invariably compromised.

Action: I have performed detailed technical analyses on multiple failures of all of the above types of dryers over a 20+ year time span. For each of these failures, I have performed the equipment inspections, managed/performed the materials testing (both non-destructive and destructive), made all necessary calculations and written the detailed reports and recommendations for equipment modifications or replacement with different types of equipment in cases where the application of the dryer technology was inappropriate for the particular service.

4. **Vertical Pin Mill Failure**

Location: North America

Deaths, injuries: no deaths, 3 injuries

Situation: In a large process plant installation, a large, high-speed vertical pin mill failed spectacularly. These pin mills are used for performing physical starch/fiber separations on a 24 hr/day, 7 day/week basis. Production of the entire plant was impacted by the pin mill failure. The machine that failed was one of six essentially identical centrifuges. The internal rotor failed, ruptured the containment housing and seriously damaged the process installation. Parts of machinery were scattered in virtually every direction and were hurled with such force that they penetrated other operating machinery and piping. The three persons injured were very fortunate that they weren’t very seriously injured or killed, since large projectiles missed all of them by mere inches.

Action: I made all analyses and calculations to determine the cause of the accident, and then I made detailed calculations to redesign defective parts to prevent reoccurrence of such an incident. I wrote complete forensics reports on behalf of the corporation. Machinery design inadequacies were discovered, but faulty maintenance practices were also discovered.

5. **Vertical Pin Mill Investigations**

Location: North America, Australia, Asia, South America

Deaths/injuries: no deaths, no injuries

Situation: Due to the large number of installations that were similar to those in item 3 above, and having recognized my machinery forensics ability, I was requested by the parent corporation to conduct detailed investigations of the various types of designs of vertical pin mills (multiple sizes and design derivatives of machines made by the manufacturer) and to investigate the various operations of many plants in various countries in each of the above locations. The corporation's motivation was prevention of any further failures of this type of machinery, now that the destructive (life and property) potential of this machinery had been realized.

Action: I made numerous machinery analyses and calculations to determine the safety of each size of each type and size of the many worldwide pin mills. I wrote corporate-wide detailed forensic reports for all of these machines, including detailed design modifications. I discovered a significant deficiency in the manufacturer's recommended maintenance procedure which had serious consequences in a number of these mills. The detailed forensics report, which I authored, contained many detailed recommendations for a more-controlled maintenance effort, including directives NOT to follow the erroneous manufacturer's maintenance procedures, substituting one I authored.

6. **Multiple Crystallizer Failures**

Location: North America

Deaths/injuries: no deaths, no injuries

Situation: In a large process plant installation, a number of drive components for a very large number of crystallizers began to fail. These crystallizers are key pieces of custom-designed machinery used for performing physical purification of one of the corporation's most profitable products. The product is critical to the U.S. pharmaceutical industry and is recognized by the U.S. Department of Defense as a vital wartime product. So many failures occurred so frequently that production volumes were significantly affected.

Action: I made all analyses and calculations to determine the cause of the failures, and then I made detailed calculations to redesign defective parts to prevent reoccurrence of such an incident. I wrote complete forensics reports on behalf of the corporation. Machinery design inadequacies were discovered and were corrected as a result.

7. **Manufacturing Chemical Pressure Vessel Failure**

Location: South America

Deaths/injuries: 7 initial deaths, ~200 injuries resulting in ~40 premature (shortened lifetime) deaths

Situation: In a process plant installation two blocks from a downtown area, a rooftop pressure vessel containing an important, lethal chemical (a manufacturing supply) failed suddenly and spectacularly. The entire contents of the tank escaped from the tank, vaporized within seconds and were inhaled by employees in the process plant, resulting in seven deaths within minutes. The vapor cloud drifted into the adjoining residential neighborhood and impacted approximately 200 residents with varying degrees of permanent lung scarring. Many prematurely shortened lifetimes have resulted since the accident and continue to occur currently. Fortunately, the elementary school next door was unoccupied at the time; otherwise, the potential death toll would have approached 800.

Action: I made all analyses and calculations to determine the cause of the failure. Various metallurgical testing and other types of testing were done to the failed portions of the tank. I determined that the supplier of the pressure vessel had designed and fabricated it in such a way (faulty design and faulty selection of materials) that failure was inevitable. I also determined that the materials used and methods of construction are strictly forbidden by ASME code in lethal services. I also made detailed calculations to redesign the defective vessel to prevent reoccurrence of such an incident. I wrote complete forensics reports on behalf of the corporation.

8. **High Pressure Steam Supply System Failure**

Location: North America

Deaths/injuries: no deaths, no injuries

Situation: In a large process plant installation with a very large utilities operation using high-pressure, coal-fired boilers, through a complicated series of events, a main high-pressure steam header was damaged. Operation continued, but suspecting that there might be some residual problem, operations management requested that I conduct an investigation.

Action: After conducting various inspections and physical testing, I determined that the hidden damage was so severe that immediate repairs were necessary. Because of the physical location of the damage, bypassing was not possible. This required an immediate and total shutdown of the corporation's largest worldwide facility. I directed the design of the remedial work on a 24 hr/day basis until the work was completed. At the completion of the remedial work, I did further physical and metallurgical investigations with the damaged area and found that the damage was so severe that immediate and total failure of the steam header would have been extremely likely. In this event, the initial fatalities would have been approximately 15-30, depending on time of day.

9. **Shaft Failure of Critical Machinery**

Location: North America

Deaths/injuries: no deaths, no injuries

Situation: In a large process plant installation, a large shaft failure of an important piece of process machinery occurred suddenly. Production was impacted. I was requested to conduct an investigation, since there were several other pieces of similar machinery that could have experienced a similar problem in the near future.

Action: After conducting various inspections and physical testing, I determined that the cause of the failure was notch-sensitized fatigue failure. This was brought about by previous maintenance on the machine that was unwittingly improper. Some "minor" maintenance machining had been done on the shaft which created a notch. When the machine was restarted, fatigue began and the shaft failed completely within a few days. I authored the forensics report, which I used to note the improper maintenance procedure, but noted that none of the other machinery was a potential candidate for failure unless the improper maintenance had also been utilized on them.

Other Types of Equipment and Installation Failures

The previously cited examples are merely illustrative of the types of machinery forensics investigations I have performed. I have also conducted many other thorough rotating, pressurized and static analyses for:

- critical piping system failures using finite element analysis
 - carbon steel
 - stainless steel
 - FRP

- other types of pressure vessel failures, all of which involve ASME Code, with jurisdictional consequences:
 - ion exchange columns
 - chromatographic separation columns
 - surface condensers
 - evaporators

- condition assessments and failure analyses of inherently dangerous equipment such as:
 - desolventizer-toasters
 - rotary solvent extractors
 - liquid nozzle centrifuges

- hazardous and/or lethal chemical storage and handling system failures

- heat exchanger failures
 - shell and tube
 - plate and frame

- materials of construction failures of many types
 - inorganic chemical environments
 - organic chemical environments
 - food environments
 - industrial environments

- industrial machinery failures
 - gears
 - shafts and couplings
 - splines
 - bearings
 - structural members of machinery
 - shells and housings

Legal Case Experience

Over the years, as my expertise was utilized to investigate failures in various plants in various countries, I began to have occasion to provide assistance to the corporate Legal Department of my employer, then later, my expertise was used as an independent consultant to legal corporations, both defense and plaintiff. I have been deposed a number of times and have also given testimony in court. Due to confidentiality constraints and judges who have ordered proceedings and verdicts to be sealed under court order, I am limited to the following brief and necessarily incomplete listing of the cases in which I have played a significant role. Nevertheless, the following should be reasonably illustrative.

Case 1

Role: Defense

Type: Project Management

Description: Provided investigations for a large corporation to confirm or refute allegations of unsafe working conditions that lead to multiple personal injury lawsuits stemming from a large capital construction project. Following this, provided deposition to opposing attorneys.

Case 2

Role: Defense

Type: Project Management

Description: Provided several months of intensive investigation and project management counsel to a major U.S. legal firm, due to a very large industrial loss. This was one of the U.S.'s largest civil lawsuits. Following this, provided several days of direct court testimony, followed by vigorous cross-examination. My testimony directly resulted in the client's monetary gain of an amount of \$10-100 MM (exact amount protected by secrecy agreement).

Case 3

Role: Plaintiff

Type: Mechanical Engineering—Equipment Failure

Description: Provided technical investigation services to a U.S. legal firm, due to personal injury involving equipment failure. My written opinions resulted in the defendant's choosing to settle the case out of court, rather than proceeding with depositions and ultimate court testimony.

Case 4

Role: Plaintiff

Type: Mechanical Engineering—Equipment and Machinery Failure

Description: Provided technical investigation services to a U.S. legal firm, due to personal injury involving equipment and machinery failure. Provided depositions, written opinions, and testimony.

Case 5

Role: Plaintiff

Type: Mechanical Engineering—Equipment and Machinery Failure

Description: Provided technical investigation services to a U.S. legal firm, due to alleged wrongful death involving equipment and machinery failure. Deposition was given.