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"Disasters"

by Andrew H. Wilson
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Abstract

This paper discusses some of the natural and engineering disasters that have occurred over the past century and more. It is a somewhat lengthened version of a talk given by the author to the Ottawa Chapter of the Canadian Society for Senior Engineers in late May 2014.

Its purpose is to examine the different kinds of disasters that can occur, rather than to describe individual ones in some detail. Reference is made to several recently published books that do this, including one on engineering disasters by the late Don Lawson, formerly chair of the CSSE History & Archives Committee.

The discussion extends, in general terms, to the consequences of disasters, to actions taken to 'clean up' after them, to steps that can be taken to predict their occurrence and to prevent their recurrence. It may also provide the basis for the further discussion of natural and engineering disasters and the roles of engineers and their profession in regard to them.

About the Series

Principally, the Cedargrove Series is intended to preserve some of the research, writings and oral presentations that the author has completed over the past half-century or so but has not yet published. It is, therefore, a modern-day variant of the privately-published books and pamphlets written by his forebears, such as his paternal grandfather and grandmother and his grandfather's brother John.

About the Author

He is a graduate in mechanical engineering and the liberal arts and has held technical, administrative, research and management positions in industry in the United Kingdom and the public service of Canada, from which he retired over 25 years ago.

He became actively interested in the history of engineering on his appointment to chair the first history committee of the Canadian Society for Mechanical Engineering in 1975 and served both CSME and the Engineering Institute of Canada in this capacity for varying periods of time until 2003. He has researched, written and edited historical material for both organizations, as well as for the Canadian Society for Senior Engineers. He is also a past president of CSME and EIC.

Introduction…

This paper is really an experiment. The spate of natural and engineering disasters during the past year started me thinking about them and their causes and consequences. Incidentally, I have included natural as well as engineering disasters since both have 'messages' for engineers and engineering.

Over the years I have collected a goodly number of press clippings about disasters of all kinds and have acquired several books about them, some quite recently published. So I have reviewed some clippings and re-read a few of the books. Included was the late Don Lawson's book on *Engineering Disasters: Lessons to be Learned*, published by ASME in 2005. This time around, *wikipedia* was a minor source and, since the media cover most disasters with plenty of pictures, none have been included.

What follows are some thoughts on the results of these exercises.

The Disasters…

Disasters are great misfortunes, events that cause much physical loss and human suffering. They happen on land or on the sea or up in the air, at home or abroad, any day of the week or any time of the day. They affect people as well as buildings and machinery and bits and pieces of the world around us. There are large disasters and relatively small disasters, depending on the amount of physical damage done and the numbers of lives lost. All of them involve risks and incur costs.

The causes of natural disasters such as earthquakes, avalanches, tsunamis, hurricanes, tornados, severe storms, rockslides and some fires have their origins in nature and have little to do with engineering - except in so far as engineering-type actions and scientific studies may have been taken and done in anticipation of the risks of them happening, in prevention, in mitigation of their effects and in cleaning up afterwards. Other natural ones may originate with populations, pandemics and famines, and they may also have potential engineering connections. Some, with engineering connections, have their origins in politics or in wars - for example, World War I, and the collapse of the World Trade Center in New York in 2001. Still others have economic origins, again with potential engineering connections, such as the Great Depression of the 1930s.

However, I consider three types of disaster to be beyond the scope of this paper. One is the potentially widespread natural/engineering disaster in which we currently find ourselves, namely climate change. This will be world-wide in its effects, have controversial aspects, and may well do damage way beyond the scope of the disasters discussed in this paper. Another type is the political/social disaster, such as wars and genocide. And a third is the commercial failure of large companies - for example, Nortel in Canada.

Disasters associated with engineering have their origins in the breakdown of engineered facilities and equipment in use, as well as in the *mis*-assessment of risk and cost, inappropriate design and incompetent manufacture or in the *mis*-use, *over*-use or *under*-use of engineered equipment. Even plants and equipment with well-tried histories may fail, or something relatively small may go wrong that was not anticipated, detected or corrected, and have disastrous consequences. As well, they may be the result of technological innovations implemented too quickly - something today's public and private innovation promoters might remember.

It is also important to remember that disasters of both the natural and engineering kinds - and especially the latter - may be the results of human error or incompetence, and sometimes of sheer bad luck.

A *catastrophe* may be considered to be a larger form of disaster, so I have not used the word. Nor have I used the word *accident*, which may be defined as an unforeseen or expected event, or one without an apparent cause, and usually smaller than a disaster. It may also be called a *mishap* or an *incident*. And I have not included *fiascos*, which are usually more of an embarrassment and are relatively minor in terms of damage and/or effect.

The media's reaction to a disaster is usually to emphasise its most sensational and/or worst aspects. As columnist Eric Reguly wrote in the *Globe and Mail* on March 15, 2014, "nature abhors a bad news vacuum." Bad news is good news. Disasters are put on newspaper front pages with large headlines, and stay there until the next dose of bad news arrives. Disaster follow-up stories often appear somewhere inside the newspaper.

Occasionally, a particular disaster holds the media's attention for several weeks. One example of this was the Copiapò mine disaster in Chile. It has been billed as "the story that captured the world." On August 5, 2010 the mine collapsed underground, trapping 33 miners. Rescue attempts began immediately. Two days later there was a second collapse. The government sought International technical assistance, for example, from Canada and from NASA. Holes were eventually drilled from the surface into the cavity in which the men were trapped. On 22 August they were found alive. Capsules were designed to carry the men singly to the surface through one of the holes. On October 9, a drill broke through to where the miners were. By 13 October all of them had been brought to the surface. The media kept the world informed throughout the drama generated by the rescue attempt. The build-up to the climax was enormous. It has been estimated that 1 billion people watched the final stage of the rescue on television. Nearly 2000 journalists from 40 countries were said to be present for it. It was a media triumph. The 33 became world famous. Not surprisingly, the engineering of the rescue played second fiddle to the human story.

A more recent example has been the disappearance of Malaysia Airlines Flight MH 370 over the Indian Ocean.

In most cases, enquiries are held after a disaster to fix cause, responsibility, blame and, if relevant, compensation. In some cases, usually after new evidence has been uncovered, cause and responsibility may be reassigned and compensation readjusted. In other words, the occurrence of a disaster leads naturally to the desire to know what really happened, to learn from mistakes made, and to prevent reoccurrence.

Incidentally, one of the uses of engineering *history* is to provide experience leading to better design, construction, maintenance and so on and, consequently and hopefully, to fewer disasters.

There are lots of lists of natural and engineering disasters larger and smaller that have happened in times past. What follows are brief listings of a number of those that were notable internationally and in Canada.

Internationally...

- the 'patched' boiler explosion on board the Mississippi steamboat *Sultana* in April 1865, while transporting two thousand Union ex-prisoners-of-war and commercial passengers northwards and resulting in a total death toll of 1,800;
- the wind-induced destruction of the first Tay Bridge, in December 1879, when the centre high girder section of the bridge fell into the river, carrying with it a train and its passengers; 75 people died; responsibility for the failure was attributed to the designer-engineer-builder, Sir Thomas Bouch;
- the 7.8 magnitude San Francisco earthquake of April 1906 that left the city in ruins, destroying 28,000 buildings and killing several thousand people;
- the sinking of the RMS *Titanic* - then the largest passenger steamship in the world and usually included in every list of international disasters - on April 10, 1912, after sideswiping an iceberg in the western North Atlantic, due to a variety of causes and with the loss of 1500 passengers and crew;
- the 1918-1919 'Spanish' flu pandemic infected an estimated one-third (500 million) of the world's population and led to the deaths of more than 50 million of them;
- the crash of the British *R-101*, then the world's biggest airship, in October 1931 near Beauvais in France, on its way to India, in which 48 lives were lost, due in very large

measure to unwise political and bureaucratic interventions in its management;

- also in 1931, the Yellow River floods in China, when 4 million people may have died;
- in November 1940 the recently-built Tacoma Narrows Bridge dramatically collapsed into Puget Sound in Washington State in a wind storm, having already acquired the nickname of 'Galloping Gertie' for the movements of its deck in windy conditions;
- in April 1947, the explosions involving two fertilizer-carrying ships and the resulting fires at Texas City harbour in the United States, in which almost 500 workers, firefighters and bystanders perished, for which the origin may have been an unextinguished cigarette; much of the blame for the results of the incident was attributed to jurisdictional problems as well as to failed attempts to contain the fires;
- the evening of Tuesday 9th November 1965 was a cold one; it was also the time of the 'Great Northeast Blackout' when, during the supper-hour surge of power, an improperly set relay caused a significant interruption in electricity supply that affected parts of Ontario and the States of Connecticut, Massachusetts, New Hampshire, Rhode Island, Vermont, New York and New Jersey; over 30 million people were affected and the outage lasted 13 hours;
- in October 1966, at the village of Aberfan in Wales, a 40,000-tonne pile of wet coal-mining waste slid downhill and buried an elementary school; 116 children and 28 adults died in this disaster;
- in December 1984, the release of deadly toxins from the Union-Carbide herbicide manufacturing plant at Bhopal, India, killed at least 35,000 people and ruined the health of thousands of survivors, and for which both poor maintenance and worker sabotage were blamed;
- the Space Shuttle *Challenger* broke up in mid-air in January 1986, only seconds after lift-off from the Kennedy Space Centre in Florida, killing the crew of seven; the failure of O-rings in a solid rocket booster were blamed; a second Shuttle disaster destroyed the *Columbia* and its crew on re-entry in February 2003;
- the meltdown of a reactor at the V.I. Lenin Nuclear Plant at Chernobyl, in the Ukraine in April 1986 incurred some 50 direct fatalities and thousands of cancer deaths and permanent health damage among those taking part in the clean-up and those living in the area of the fallout;
- in March 1989, the grounding of the tanker, *Exxon Valdez*, spilled something like a half-million barrels of crude oil in remote Prince William Sound, Alaska, that eventually contaminated 1,300 miles of shoreline, killing hundreds of thousands of seabirds as well as otters, seals and eagles, and an unknown number of fish;
- and in October 1989 the San Francisco Bay area experienced a 6.9 earthquake, which killed 63 people, injured around 4,000 and left thousands more homeless;

- in January 1995, one of the most devastating earthquakes (another 6.9) in Japanese experience hit Kobe; more than 5,500 people were killed and 26,000 injured and the economic loss was estimated at $US 200 billion; the collapse of the Hanshin expressway - part of the Kobe-Osaka highway - was spectacular; the port facilities were also badly damaged;
- in September 2001, attacks by terrorist-high-jacked aircraft caused the destruction of the World Trade Center in New York and the deaths of 2,800 people; however, many thousands more were able to leave the buildings before they collapsed;
- a massive hurricane system, code-named *Katrina*, ravaged the Gulf coast of the United States from central Florida to Texas and flooded the surge protection system at New Orleans in August 2005, killing some 1,800 people and causing billions in property damage; the designer and builder of the New Orleans system, the U.S. Army Corps of Engineers, was blamed for its failure;
- in January 2010 a 7.0 magnitude earthquake struck Haiti, at the western end of the Caribbean Island of Hispanola, devastating it so badly that the damage is not yet fully repaired;
- also in 2010, in April, an explosion rocked and engulfed in flames the offshore oil-drilling platform *Deepwater Horizon* in the Gulf of Mexico, 40 miles off the coast of Louisiana; the subsequent oil spill, later estimated to have totalled in the order of over 200 million gallons, caused an environmental disaster that - with several setbacks – took until September to bring under control;
- also in 2010, and as noted already above, the disaster at the Copiapó 121-year-old copper mine in Chile that began on 5 August 2010 and ended 69 days later;
- in March 2011 the most powerful 9.0 earthquake/tsunami hit the coast of Japan, generating waves over 100 feet in height and resulting in over 16,000 deaths, the total destruction of over 160,000 buildings and damage to hundreds-of-thousands more; the tsunami also damaged the Fukushima nuclear power plant, causing widespread concern beyond Japan itself;
- in January 2012 the cruise ship *Costa Concordia* hit a jagged reef off the Italian island of Giglio in the Mediterranean and opened a large gash on its starboard side; of the passengers and crew on board, 32 of them died; the ship remained on its side on the reef for 20 months, when it was spectacularly salvaged and towed to a breaker's yard;
- in October 2012, Hurricane *Sandy* formed in the Caribbean but devastated the Eastern Seaboard of the United States, causing damage estimated to be in the billions, with over 100 deaths;
- in April 2013, an eight-storey building housing garment factories collapsed at Dhaka, Bangladesh, killing over 1,100 workers and prompting the temporary closure of hundreds of other similar factories in that country;

- in November 2013, an exceptionally powerful typhoon, named *Haiyan*, devastated parts of Southeast Asia and, particularly, sections of the central Philippines, where over 6,000 lost their lives, out of some 11 million who were affected by it; damage estimates again in the billions;
- in March 2014, Malaysian Airlines Flight MH 370 - a Boeing 777 - disappeared on its way from Kuala Lumpur to China, with 230 on board;
- also in March 2014, a massive mudslide at the town of Oso in Washington State killed at least seven and injured many more.

Two spectacular near-disasters should perhaps be mentioned. One was the *Apollo 13* flight to the Moon in April 1970. The mission was aborted 56 hours into the flight, and 200,000 miles from Earth, following the rupture of a service module oxygen tank; thanks to some extraordinary engineering and the skill of the crew, the command module and the astronauts were brought back safely to Earth. The other was the spectacular crash landing of U.S. Airways Flight 1549 - an Airbus 230 - by Captain Solly Sullenburger on the Hudson River, off Manhattan Island, on 15 January 2009, in which all passengers and crew survived with minimal injuries.

Briefly, among *Canadian* disasters were...

- the Red River flood in Manitoba (1826) (5 died);
- the Saint John fire (1877) (11 died) and the Vancouver fire (1886) (over 30 died);
- the first Springhill (Nova Scotia) mine disaster (1891) (125 died);
- the Hull/Ottawa fire (1900) (7 died);
- the Quebec Bridge collapsed during construction in August 1907 (75 died) and, in September 1916, a second accident involving the centre section of the redesigned bridge that fell into the river while being erected (12 died);
- the Rogers Pass avalanche (1910) (62 died);
- the sinking of the *Empress of Ireland* in the St Lawrence (1914) (1012 died);
- the Parliament Buildings fire, Ottawa (1916) (7 died);
- the Halifax explosion (1917) (1963 died);
- the sinking of the *Princess Sophia*, in the Inside Passage, British Columbia (1918) (350 died);
- the Spanish flu (1918-1919) (50,000 may have died);
- the *Noronic* fire, Toronto harbour (1949) (119 died);
- the Red River flood, Manitoba (1950) (1 death);
- Hurricane Hazel, Toronto area (1954) (81 died);
- the Springhill mine explosion (1956) (75 died), and the Springhill 'Bump' (1958) (75 died);
- the Second Narrows Bridge collapse, Vancouver (1958) (18 died);
- the Ste. Thérèse air crash, Québec (1963) (118 died);

- the sinking of the *Edmund Fitzgerald,* Lake Superior (1975) (29 died);
- the sinking of the oil rig *Ocean Ranger*, off Newfoundland (1982) (82 died);
- the Gander, Newfoundland, air disaster (1985) (256 died);
- the Westray mine disaster, Nova Scotia (1992) (26 died);
- the Saguenay floods, Québec (1996) (10 died);
- the ice storm, Ontario, Québec and the Maritimes (1998) (25 died);
- the Swissair Flight 111 crash, off Nova Scotia (1998) (229 died);
- Hurricane *Juan*, Nova Scotia (2003) (8 died);
- the roof collapse at the Algo Centre Mall, Elliot Lake, Ontario (2012) (2died);
- the Alberta and Toronto floods and the ice storm, Ontario, Québec and the Maritimes (2013);
- the Lac-Mégantic rail disaster, Québec (2013) (47 died);
- the seniors' residence fire, L'Ile-Verte, Québec (2014) (32 died).

It should also be remembered that, in Canada currently, there is an annual disaster: over 3,000 die each year in motor vehicle accidents.

The book, *History's Worst Disasters*, by Eric Chaline, was published in 2013. It includes mention of 50 disasters that can be categorized as follows: 17 that involved populations, pandemics, famines....and animals; 14 that were the results of wars or political actions; 13 involving fires, explosions, collisions, floods, storms, hurricanes, tsunamis, earthquakes, landslides, rockfalls and volcanic eruptions; 4 that can be classed principally as engineering disasters, and 2 that were due to economic failure. None have Canadian connections.

James R. Chiles' book *Inviting Disaster: Lessons from the Edge of Technology* concentrates on the engineering variety and is international in scope. It was published in 2002 by Harper of New York. In it, 63 are mentioned, quite a few of which are in the lists above. Using the same breakdown as was used for Chaline's provides these results: 2 were in the war/political action group; 23 were earthquakes, explosions, floods etc.; 38 were engineering in origin (including toxic oil and other spills); and zero in the other two categories. Three of them - the Halifax explosion of 1917, the eastern Canada-U.S. power blackout of 1965, and the sinking of the oil rig *Ocean Ranger* - have Canadian connections.

It is possible, Chiles notes, that the basic cause of a disaster may never be known, no matter how extensive or lengthy the subsequent investigation. This may be the case for Malaysian Airlines Flight MH 370.

The Popular Mechanics book *What Went Wrong: Investigating the Worst Man-made and Natural Disasters* was written by William Hayes and published in 2011. Something like 70 disasters are discussed in some detail. About half are natural ones, such as earthquakes, volcanoes, fires, explosions, tornadoes, hurricanes and floods. The engineering ones cover aviation and space, ships, chemical and industrial accidents and rail transportation.

A major contribution to the analysis of engineering disasters has been made by the late Don Lawson - the only engineer among the authors - in his book *Engineering Disasters: Lessons to be Learned*. His analysis includes consideration of many that are well-known, including the airship *Hindenburg*, the *Challenger* and *Columbia* shuttles, the de Havilland *Comet,* and the Chernobyl nuclear disaster. He also deals with a number of railway and bridge examples.

Janet Looker's book *Disaster Canada*, published in 2000 by Lynx Images Inc. of Toronto, actually lists 132 separate Canadian natural and engineering disasters that took place between 1583 and 2000. She describes 62 of the more serious ones in some detail, roughly two-thirds of which fall into the natural category and the others into engineering.

Looker notes that disasters were first depicted in books, magazines and newspapers by artists. Then came photography. The first live radio coverage in Canada was at Nova Scotia's Moose River mine collapse in 1936. The first television coverage was also from Nova Scotia - the Springhill collapse of 1958. TV coverage has often changed victims/survivors and their families from unknowns into widely recognized individuals. Nowadays, agencies such as Emergency Preparedness Canada respond to disasters. And from space, the RADARSAT satellites have been observing and assisting those on the ground to cope with them and their consequences.

The lists above are varied enough that general conclusions about them can be difficult to draw. However, I will risk a few...

- the threat of disasters is constant;
- *natural* ones usually involve larger numbers of human casualties and much more extensive property damage than do the *engineering* ones. Indeed, restorative work may continue for years afterwards;
- poorer countries are less able to cope with natural disasters and ask for, and receive, promises of international assistance; they are also less able to do the research and make the preparations for anticipated disasters;
- at a more local level, and with particular regard to the time factor after natural disasters, the victims/survivors expectations of relief, replacement and compensation have increased with time, with the help of the media, and their patience with delays in the provision of information and direct help has decreased;
- with regard to potential engineering disasters, the risk-free and 'not in my back yard' attitudes among members of the public are much more in evidence than they once were.

The principal feature of many of the natural disasters that occur has been their unpredictability. We may have some idea that they *might* happen, but their timing is usually unexpected. On the other hand, hurricanes and typhoons have their *seasons* in the Atlantic and Pacific oceans and appear every year, although not always in the same numbers or with the same ferocity, and preparations for their arrival are routine. Less predictable disasters due to floods, snow and ice occur with regularity in some parts of the world, so that precautions and combative measures are widely known if not always implemented in time, so that damage can still be extensive. Where they occur much less regularly, or where resources and expertise are scarce, the tendency is to let the, potentially costly, precautions and measures lapse.

One of the more positive sides of natural disasters is that they often force jurisdictions to take precautions and actions, to apply up-to-date engineering to infrastructures and other facilities that are obsolete technologically, and to look again at working machinery that was thought to be quite safe.

Lawson has drawn attention in his book to writers on engineering subjects who have contributed significantly to analyses of disasters. One of them is Henry Petroski, currently the Aleksander S. Vesic Professor of Civil Engineering and, unusually, professor of history at Duke University, North Carolina, whose publications cover a wide range of subject matter.

In his writings, Petroski views an engineering disaster as a failure of design and effective design as the avoidance of failure. A disaster may also herald the end of one design philosophy and the introduction of a newer, safer one. For example, in his book *Pushing the Limits: New Adventures in Engineering*, he writes:

> The 13th century collapse of the cathedral at Beauvais marked the end of an era of Gothic building during which *taller* and *lighter* had been the watchwords. In more modern times, the tendency to build even longer and more slender bridges led to such catastrophic failures as the collapse of the Québec cantilever bridge during construction and of the infamous Tacoma Narrows suspension bridge just four months after it was completed.

In his book, Lawson draws many conclusions - too many to include in this paper. However, some from his closing statement may be noted. He writes:

> Poor decisions lie behind all (engineering) disasters...
>
> Better knowledge makes better decisions; this is generally accepted, but little is done to help individuals...

> Engineering is based on economy of material and labour, and time spent on learning may appear to reduce productive time...
>
> Another way of making better decisions is highlighted by the proverb...*two heads are better than one*; the two heads make the biggest contribution if there is a challenging debate that brings to the surface all the issues and views...
>
> In the wake of a disaster, there is often denial by those involved - *I could not do anything about it*...
>
> Errors can coalesce over time and lie in wait to make a failure more likely; the data show that the highest human effort together with the ideas of the high reliability organizations can reduce the probability of failure by one or two orders of magnitude; to achieve these results, engineers have to adopt the highest professional and ethical standards - and maintain them at all times...
>
> The shuttle accidents are good examples; NASA has had a string of outstanding achievements - the result of millions of good decisions in the details; this success was, however, overshadowed by just two examples of poor decisions.

Lawson's view is that most engineered products do not fail, and that few failures occur in obvious ways since the designer takes care of them. The less obvious ones are the real problems, especially when the engineered designs step too far over contemporary practice without sufficient foresight and testing.

So Lawson clearly places anti-disaster responsibility with the engineer. But in his discussion of the contributions to disaster-free engineering within the U.S. Navy's nuclear submarine fleet, he also recognizes talents of the late engineer and admiral, Hyman Rickover, with regard to the *management* of its growth and its engineering record, and his influence in the choice of the preferred reactor type for use in U.S. applications generally.

In his book, Lawson also includes recommendations made by Charles Steinmetz, Edison's colleague, that researchers dealing with disasters should prepare three kinds of reports: a thorough technical paper for the record and the information of peers; a more general technical review for other professionals; and a report in layman's language for a wider audience.

It is also possible, as James Chiles notes, that the basic cause of a disaster may never be known, no matter how long the investigation may take...and some take a long time. On the other hand, lengthy and careful enquiries may well get to the root of the cause. For example, several months ago Philip Cockshutt showed us a video of the extended and extensive enquiry into the air disaster at Ste. Thérèse in 1963, which illustrates this. He has since provided me with a concise summary of the findings of the enquiry. It says:

> The prime cause for the crash of Flight TCA 831 at Ste. Thérèse was that the aircraft had been trimmed into a dive, through the application of full nose-down trim to the (rear) horizontal stabilizer. The aircraft then accelerated downwards and, given the relatively low altitude to which it had climbed, it was impossible to pull the aircraft out of the dive before ground impact.
>
> The reasons for the application of full nose-down trim by the pilot are unknown but are believed to be a combination of faulty instrumentation, control system failure...and/or pilot error. A very similar accident had occurred with the same model of DC8 aircraft crashing into Lake Pontchartrain, Louisiana, just a few weeks after the crash at Ste. Thérèse.
>
> Subsequent modifications to similar aircraft served to limit the inadvertent application of full nose-down trim, and no further similar events occurred. Shortly after the accident, Canada moved to require the installation of flight data recorders in all turbine-powered commercial aircraft.

From the number of disasters affecting aircraft that have been mentioned in this paper, one might conclude that commercial flying is dangerous. The author of *What Went Wrong* would disagree. He writes:

> Flying in a jetliner is extraordinarily safe: between 2002 and 2007, there was only one fatal crash in the United States, an astounding record considering that more than thirty thousand flights take off every day. How did flying become so reliable? In part because of accidents that triggered crucial safety improvements.

In the aircraft field, it is also important to remember that the passenger-carrying capacity of commercial aircraft has increased significantly since World War II and that the numbers of casualties in air disasters have increased correspondingly.

Disasters also spur action in support of improved prediction and prevention...

For example, research continues unabated at the international, national and regional levels and in universities and government laboratories into the origins, mitigation and prevention of natural disasters, by organizations such as the Geological Survey and National Research Council of Canada.

Similarly for engineering disasters, but including much more industrial participation, and particularly in the air, sea and ground transportation, materials testing and structures fields. The wind tunnel work of Alan Davenport's laboratory at Western University and elsewhere in Canada are examples of this. Fire prevention, detection and extinction get attention from both natural and engineering specialists. The growth in the numbers of liability lawsuits has also stimulated research activity. Within the engineering profession itself, and especially with regard to post-disaster investigations, the relatively new specialized sub-discipline of forensic engineering is continuing the process of development.

Speaking of the engineering profession, the Engineering Institute of Canada's publications in years past have included technical reports on disasters. Nowadays, the provincial associations take a direct interest in disaster investigations involving engineering - such as the rooftop parking deck failure at the Algo Centre Mall at Elliot Lake.

Nor do governments usually stand idly by after a disaster strikes. They legislate, write new regulations and set up committees to study the occurrences and bodies to write and promulgate better standards of performance. In Canada now there are Building Codes, Electrical Codes and Plumbing Codes. The ASME in the U.S. has, for at least a century, been responsible for a Boiler and Pressure Vessel Code. Sir John Kennedy, an early president of the Engineering Institute of Canada, shared responsibility for the establishment of the Canadian Engineering Standards Association, now known more simply as the CSA. There is an International Organization for Standardization. There are, again in the U.S., an American National Standards Institute and an American Society for Testing and Materials. Britain, Australia and other countries around the world have their own institutions.

An interesting statistic I found quoted in regard to the ASME Boiler Code: in the year 1900, around the time ASME began to take an interest, there were 400 boiler explosions; in 1975 there were none.

While providing safeguards, codes and standards may be mandatory or optional, applicable locally, nationally or internationally, apply to producer or consumer goods, to the mitigation of persistent problems such as reductions in levels of danger and the generation of waste and pollution. They may be the result of research and experience, or they may not, and be written by groups of experts. But they may also be costly for both producers and consumers.

In 1971, the Science and Economic Councils of Canada published what was intended to be a 'bible' of standards-writing - a report *Standards in Canada* by Robert F. Legget. Towards the end of it, Legget writes:

> It would be well to be reminded of the purpose of Standards. They are

> documents prepared by a reasonably careful procedure and they are intended to: specify acceptable levels of quality, reliability and performance; assist with the interchangeability of manufactured products by laying down agreed-upon limiting dimensions; reduce unnecessary variety in commercial products; and codify essential provisions for public safety in all fields in which safety regulations are regarded as a social necessity. In order to achieve these objectives, Standards must also include clearly defined test methods by which properties may be accurately determined.

Another example...

The Foreword to *What Went Wrong* notes:

> After the earthquake in the Indian Ocean triggered a tsunami in December 2004, the United Nations started work on the Indian Ocean Tsunami Warning System, which was completed in 2006. The flooding in New Orleans after Hurricane Katrina spurred FEMA to require all levees to carry a 100-year flood mark certification, a robust standard that requires the entire system to withstand a storm the likes of which we see no more than once in every hundred years.

Also improved have been the main components of aircraft: the airframe, the engines and the electrical systems. At the same time, commercial jets have become even larger, the largest carrying over 600 passengers and crew so that, when there is a disaster, the casualties are more numerous. Also, if an aircraft is hijacked, its superior performance qualities mean little in terms of passenger safety. In Lawson's view, few failures occur through the most obvious modes, which have usually been well taken care of by designer. The less obvious ones are problems. So are the engineered designs that overreach contemporary understanding and go a step too far without adequate information, foresight and testing. As well, familiarity with an engineered product, process or situation, and especially when combined with long, safe service, may lead to pre-disaster clues being overlooked.

Risk assessment and management are obvious areas for engineers to lend their expertise to assessors whose qualifications are non-technical, as well as informing the general public on issues involved in risk-taking. Public safety is a formal responsibility of the provincial engineering associations in Canada.

Speaking of risks and public safety, much has been made in recent months in Canada of the problems involved in transporting crude oil long distances by rail and by pipeline and the risks of future disasters. Also in 2014, concerns have been expressed in certain quarters in Canada and the United States that the process of obtaining oil and gas by 'fracking' will have similar results. Both of these concerns have political dimensions. They also have significant economic implications.

Finally, engineered products that have nothing to do with the disasters themselves may assist significantly in the analyses of search, rescue and analysis that may follow them - for example, computer hardware and software, earth satellites, sonar equipment and helicopters.

To conclude...

Unfortunately, no matter what is done to predict and prevent natural disasters, they will continue to occur, but more prediction and prevention are possible with engineering ones. It would also appear that disasters of both kinds may lead over the longer haul to fewer risks and more disaster-proof engineering. Lawson may have overstated his case when he says that most engineered products do not fail. But it hardly needs emphasising to an audience of engineers that disasters of any kind present them with challenging opportunities to practice their profession. They should also be listening for the warning signs!

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