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A dangerous, deadly, profession

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ABSTRACT: Since the First Industrial Revolution, which began about two hundred and fifty years ago, many of the tools and equipment invented, developed, formed and used by engineers have improved society's well being. Having said that one now looks at another side of engineering, and is reminded of the old adage recommending one should not show what one does not want to have talked about (the adage recommends not displaying one's dirty washing) but here the author will point out that in parallel to the above benefits some of those same engineered-outputs have hurt, maimed and killed, both in their building and in their final use. This is a feature of engineering broadly known but not generally put to students, thus, our students do not generally realise that their work situations can surround them with things, which can injure, and kill, people working under their supervision, and themselves.

Keywords: Safety, engineers, education

INTRODUCTION

Before going further into this gruesome-titled exercise here is a word from an archaeologist, Sprague de Camp, pointing out that engineers have, for many centuries, benefitted society:

> *Civilization, as we know it today, owes its existence to the engineers. These are the men who, down the centuries, have learned to exploit the properties of matter and the sources of power for the benefit of mankind. By an organised, rational effort to use the material world around them, engineers devised the myriad comforts and conveniences that mark the differences between our lives and those of our forefathers thousands of years ago* [1].

Of course, de Camp should have included women but when he wrote that in the 1950s there were few women in the engineering profession, so he can be pardoned for omitting them.

There are two important features of this quote; first, it recognises what engineers have done through the centuries to push civilisation ahead, and second, it is from outside engineering, it is not *one of us* preaching how valuable engineers are.

So that is the up-side of engineering, now to look at the down-side.

HOW ENGINEERS DESIGN AND BUILD THINGS

The engineer who might be held to be responsible for creating some artefact is usually not the only person involved in it. For example, very often someone gets an idea of something, which will perform some action previously done manually, the idea may go to a designer who roughs out the shape and how it is to function, that goes to an engineer or a team of people, who produce a prototype, which is refined after trials and, then, maybe it is turned out in hundreds, maybe thousands.

In all that there is concentration on making *it* work. Do any of those people consider side-effects? Just as producers of medications have to consider side-effects? One may wonder...

Interest in this topic has been inspired, the author admits, by working as an expert-witness- safety-investigator for lawyers. Many of the cases investigated have had an element of human error, or worse, sometimes human stupidity, but many of those have had that feature compounded with the nature of the machine-beast which has caused the injury. A further inspiration was provided by a lecture titled *Worse Than War*, part of a series given to metal trades apprentices (of which this author was one) in the late 1940s [2]; much of the content was drawn from American sources (all that was available at that time) but overall it emphasised that industry has many features which can injure a worker.

The first two cases described here are from investigations by this author over ten years ago. Both involved litigation, completed by now, but it seems best not to identify them by names.

FIRST EXAMPLE: THE MINCING MACHINE

The first example is from a butcher's shop, where the proprietor's wife was assisting him by mincing pieces of meat. Her hand was holding meat, or perhaps was pulled in by meat, and it entered the mincing blades and was severely damaged. So she sued her husband, the proprietor.

Trying to explain, in any reasonable manner, how that happened was impossible, the machine was adequately guarded and checking dimensions showed an adult's hand (except perhaps finger-tips) could not reach the mincing screw. However, more detailed examination showed the guard could be removed for cleaning, and probably had been because the nuts securing it were only finger-tight, which suggested the guard could have been removed to reduce effort required to push meat in, then, replaced before the machine was inspected. That hypothesis was strengthened by noting that with the guard off a hand could easily enter the mincing screw space.

Explaining how the injury could have been prevented was easy: there should be a form of interlock between the guard and the power supply, so the machine would not run when the guard was removed. Perhaps the designer thought: *No-one in their right mind will operate this with the guard off.* If so, he was wrong.

No subsequent information was provided, so whether the woman's claim was successful, and whether anything was done to improve the mincing machine's safety, is unknown.

SECOND EXAMPLE: THE BISCUIT-WRAPPING MACHINE

The case of the biscuit-wrapping machine had some distinct differences from the above, to begin, the machine was well-guarded (with one exception) and used infrequently. It wrapped a row of biscuits in cellophane, making a tube, progressively heat-sealed the tube, then, a guillotine cut the tube and finished the end to make the package. On the occasion in question something went wrong with the tube-forming, the cellophane was crooked, so the shop foreman took hold of it and pulled it, trying to straighten it. The cellophane tore, he lost his balance, fell towards the machine, one finger entered the guillotine jaws, which were closing to cut the cellophane to length, and he had flesh stripped from that finger.

It is ironic that he found the one unguarded place. The management re-acted immediately; the injured foreman received adequate treatment and a suitable guard was fitted to prevent another finger being nipped. However, it is obvious that in its original form the machine was capable of injury.

THIRD EXAMPLE: VERY SIMPLE TECHNOLOGY

Those two examples above involve relatively complex machine-technology, manufactured items powered electrically. But all that complexity is not needed for technology to kill.

This example came to the author from a lawyer based in a major country town where an abattoir is located. Carcases were (and, probably, still are) divided by workers wielding sharp knives. On a particular occasion, one worker performed a slicing action, perhaps too zealously or perhaps with excessive follow-through motion, and his knife penetrated the chest of the young man working next to him. It entered the heart and within minutes he died.

An ambulance rushed to the spot and revived him, raced him to the hospital and he was whizzed into the operating theatre, where he died again. He was revived again, was repaired, and recovered completely.

A knife? Such simple technology? Knives have been in use for thousands of years, a very useful item, they are in every domestic kitchen, and dangerous if improperly used.

A MAJOR INDUSTRIAL EXAMPLE

The two small-machine examples above, and the abattoir case, are interesting but lack real drama, so let us look at a major event which occurred in Australia and demonstrates that engineers' work can kill [3].

This was the Westgate bridge affair, in Melbourne, in October 1970. A main span of the bridge, formed as a steel box-girder had been lifted into place on concrete piers, and when it settled into place, it did not line up with the adjacent span because a plate had buckled. After some discussion between engineers a load was applied to correct camber, the result was insufficient, then, a decision was made to remove bolts holding sections of the beam together, in the expectation that would allow movement and the sections would line up. The alternative was to lower the bridge section back to ground level and work on it to correct the mis-alignment, but that would take more time than available in the project programme.

So bolts were removed, the buckling increased, the span literally kinked and slipped off the concrete piers, one of which was, then, hit by the falling girder and also fell. The estimated total weight which fell was 2,000 tones.

Engineers were not only involved in that decidedly risky action, someone had decided to place the project huts under the bridge alignment, and when the steel structure fell it, of course, landed on the huts, just before lunch.

Thirty-five were killed.

The firm involved in the bridge project had not long before had a similar structural failure in Wales, when four were killed. One may wonder: what did they learn from that, to apply to the Melbourne project?

Without wishing to over-dramatise the example, this author must point out the thirty-five fatalities resulted from decisions made by, and actions supervised by, engineers. Such an event is, very fortunately, very rare. There is no need to go further, by including others, for example, the Challenger incident in which engineers made the fatality-causing decision, to emphasise both how such engineering events come about, and, fortunately, their rarity.

A MINOR (BUT FATAL) INDUSTRIAL EXAMPLE

Back in the 1960s, when this author worked as a draftsman in a company which no longer exists, a rigger was killed at the factory site. He was controlling a crane, which was being used to pull a concrete block out of the ground; the crane could not get close enough to lift directly over the block, so the rope was about thirty degrees from the horizontal. The crane's engine proved to be strong for the hook, which straightened, was pulled back by the taut rope and hit the rigger. The probability of this happening was certainly very low, for reasons such as he had to be in the path of the flying block and hook. His chest was crushed and he died shortly after getting to hospital.

The young engineer (yes, *one of us* was on the job, but not this author) who was supervising the overall job was unable, for reasons not recalled now and perhaps not mentioned at the time, to stop this from happening. It is most likely he was not at the workplace at the precise time and the rigger went ahead with the best intentions: *get the job done*. Knowledge of this incident has left such a mark in this author's memory he has used it in a recently-published novel, suitably dramatised for use in a work of fiction [4].

EVEN A TRIVIAL FEATURE CAN HURT

Kletz has recorded a situation in a factory where there was a row of seven pumps, and for some reason they had been numbered 1-2-3-4-7-5-6 [5]. A fitter was given the job of working on Number 7, which, logically, would be the one at the right-hand end, so he opened a flanged joint and found the pump had not been isolated. He was sprayed with hot oil which caused minor injuries.

The message is: numbering should be logical, from one end to the other, and, preferably, such equipment should be tagged for easy and precise identification. The numbering may not have been due to a professional, fully-qualified, engineer, maybe a junior, maybe a foreman, but an engineering-person would have been involved.

IMPLICATIONS FOR ENGINEERING EDUCATION

An aim of this paper is to show by referring to a variety of cases, one well-reported and others known personally, that there is that down-side, the ability to cause damage, injury and/or fatality, in a professional engineer's work. The above examples of what can happen are sufficient to show it is there. The up-side, unfortunately, is so enthralling, so enjoyable, that in general neither teacher nor student refer to the opposite.

It is reasonable, therefore, that those who enter the professional engineering education system should, in some part of the teaching-and-learning process, perhaps in design subjects, be given some understanding of the deadly nature of the processes and materials with which engineers deal. This does occur in one department of the university with which this author is associated; the School of Chemical Engineering informs students that gases, such as hydrogen sulphide are particularly hazardous, and even the nitrogen one breaths can cause a person to become unconscious if the concentration is sufficiently high, which knowledge led to changing operation of a lift which was used, occasionally, to transport liquid nitrogen flasks from floor to floor. However, mechanical engineers (such as this author) get very little similar warnings.

AN EXPERIMENT AND APPLICATION IN EDUCATION

An indication of how easily engineering work can injure and/or kill was included, somewhat obliquely, in a series of management case studies given to six student classes over ten years ago (previously reported in [6]). The cases were written, principally, to test the students' reaction to decision-making in management problems, and presented one per week through ten weeks of the semester. Each was, in effect, an engineering-management short story, action divided between a factory and the company's head office, but each week's case led on to the next week, in a serialised format.

This was part of the series' decision-making nature, each *next week* showed the decision made *last week* was not *quite right*, that is, not *completely wrong*, but not optimal in the light of new information; the idea behind this being to show that a manager's decision-making is based only on what is known at the time.

Giving such management problems to students was believed to be legitimate because these students were attending part-time, while working in at least semi-supervising or junior-management positions, and had a good grasp of the cases' management concepts.

Through two consecutive semesters (repeated three times, hence, six classes) a series of minor accidents, some taken from real-life situations, was woven into the management problems, up to the end of the second semester when a fatality occurred. This followed Heinrich's concept that a series of such relatively minor events can be an indicator that a serious event is in the offing [7].

While most students answered the management problems well, very few students in either semester paid attention to the accidents which had the potential to be serious. However, when a fatality occurred in the nineteenth case-narrative, which was given to the second class, there was a sudden acknowledgement by most that previous events were leading up to this and should have resulted in earlier preventative action.

At the second semester's end the students could see, and understand, they were guilty of failing to grasp what was going on in the fictitious factory presented through the case study series and were committing an *error of omission*. This exercise demonstrated that managers in engineering situations must look at what destructive events can happen, before they do, and take care they do not occur. Whether that has been followed up in teaching since then is unknown but is believed to be doubtful.

SOME SUMMARY THOUGHTS

The engineers involved in the industrial cases would have had the best of intentions but may have been mis-directed by more senior, more influential, people (which certainly happened in the Challenger case), but their work-output and decisions (whether directed or spontaneous) led to injuries or fatalities.

The students who worked through the case studies did not realise that engineering situations can injure and kill or at least damage property, until they were shocked by a fatality, which, of course, was too late, if it had been real life rather than fiction. At that time, in that particular university, this author knew of no mention of industrial safety in any courses. The tentative follow-on conclusion is that there has been little, if any, follow-up in teaching safety, and there should be, because we engineers can kill (or merely injure) people.

The nearest to that has been a recent invitation (accepted) to present a lecture about *risk* to engineering students. The occasion went off very well but it left the author with a nagging feeling that (despite the best of intentions) what he presented was a rather sanitised topic, about pros and cons, neat considerations of probability, possibility and credibility, not about damaged property, injuries and bodies, which are the *dirty washing* of engineering.

CONCLUSIONS

One conclusion from the above is, simply, that if one tracks back from an injury-event related to a manufactured item one may find an engineering person is, or engineering people are, involved, somehow, not necessarily as a direct cause, but related via design history, decision-making, executive action ... *somehow ... somewhere.*

The conclusion from the use of management case studies to encourage safety-thinking in students was that the few classes, who worked through those cases, realised engineering situations can injure and kill or at least damage property.

Overall, the aim of this article has been to remind *us* that although we do not pull the trigger on a fire-arm, or wield a knife or axe, some of our output, the things we build, the devices we operate, can be equally as deadly as those implements. And then, having accepted that engineering academics should be explaining that is so to our students, and providing at least mention of how the profession's work output can be made safer. It is difficult because it is a side of the profession about which no-one wants to think. But it is there. It needs to be recognised, revealed, and covered by discussion and teaching.

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BIOGRAPHY

Ronald Bentley Ward arrived in Sydney, New South Wales, on 6th October, 1928. He attended early schools in inner suburbs, then, Sydney Technical High School, still recognised as the one for engineers and scientists, which was in the 1940s located close to the city, now in a southern suburb. After passing the Leaving Certificate in 1945, he worked as an apprentice, then, as a tradesman toolmaker at the Commonwealth Aircraft Corporation from 1946 to 1954. He, then, moved from aircraft engine manufacture to chemicals and worked with several firms in engineering positions up to 1979 when he opened his own consulting firm, specialising in project management. In 1984, he became a lecturer at the New South Wales Institute of Technology, which became the University of Technology, Sydney, and retired from that position in 2001. While working in industry, he completed a trades course in fitting and machining, the Associateship Diploma (Mechanical Engineering) of the Sydney Technical College, Bachelor of Engineering at the University of New South Wales, and Master of Business Administration at Macquarie University. During the years at the University of Technology he returned to the University of New South Wales to research a thesis on the relationship between hazards and management practices in the chemical industry and was awarded the degree of Doctor of Philosophy in 1995. He has published three books, one text on communication, another on engineering management, and a third book outlining some engineering oddities, plus well over a hundred-and-forty papers on education, engineering, accidents, management and speculative topics, over a hundred-and-twenty expert witness reports. He has also written a series of one hundred-and-ten fictional case studies, and two as-yet-unpublished novels. All of these exemplify his interest in engineering as a profession, and the need of a broad education at the undergraduate level, where topics other than those purely technological should be included and presented in a manner to suit those students. He has lived in Sydney suburbs all his life, and travelled interstate and overseas many times to conferences with his wife, Brenda. He has maintained his connection with engineering education by continuing to write and publish, and by having been accepted in 1998 as a Visiting Fellow in the Faculty of Engineering of the University of New South Wales. He thanks WIETE for the invitation to submit this article for the Global Journal of Engineering Education.