Reference: Introduction to the Engineering Profession, 2nd Edition, by Burghardt

ETHICAL PROBLEMS

The drive to decrease costs may lead to some situations that create ethical problems for you. For example, at the end of each month a certain number of computers, electronic components, or tools are expected to be manufactured, shipped and very importantly, billed. The bills become an asset in the receivables column of the ledger and balance the expenses incurred in producing the product in the debit column. The same event occurs quarterly as well. Businesses, especially small ones, often require short-term loans to cover the time between shipping their products and receiving payment for the products. Banks want to be assured that sufficient payments are in the pipeline, so to speak, before they will give the company a loan, to be used in part to pay your salary. As an engineer you must be aware of business needs as well as the need to maintain product standards, not letting a product be shipped to meet quota guidelines when it falls short of quality or safety standards. Quality standards are different from safety standards: the marketplace will eventually not purchase the product if it fails to meet the quality level expected of it; however, safety standards affect not just the marketplace but all of society.

There is virtually no moral dilemma in informing your superior that a problem exists with a product, when it violates the law or creates a safety hazard. Your superior will react positively or negatively to your concern. If he or she agrees, then there is no problem. The dilemma arises when the supervisor disagrees or the company decides not to change what it is doing because it believes it is following the correct course of action. If you make your complaints known outside the company, there is a high probability that you will be fired for your trouble. Perhaps the company officials are correct; you will have sacrificed a great deal, to no benefit for society, if your interpretation of what violates the law or creates a safety hazard is in error. The NSPE offers some guidelines in this area, most importantly the following: "The engineer should make every effort within the company to have the corrective action taken. If these efforts are of no avail, and after advising the company of his intentions, he should notify the client (customer) and responsible authorities of the facts." (Opinions of the Board of Ethical Review, NSPE, 1965.) In the rest of this section we will look at some situations like this engineers have encountered and how they reacted.

THE DC-10 DISASTER

On June 12, 1972, an American Airlines DC-10 nearly crashed due to a design deficiency in the rear cargo door. The door had to be secured from the outside by the baggage handlers, and people inside the plane could not check the security of the door. Should the door open, the lower cargo hold would depressurize tremendously, the passenger floor above it would collapse, breaking the hydraulic control lines for the rear engine and the tail wings, and the airplane would likely go out of control and crash.

The American Airlines DC-10 did not crash because of several very fortunate events. The captain had, by chance, practiced on a simulator how to handle the plane if he lost control of the rear engine and rear wings. Plus, the plane was lightly loaded with only 67 passengers. When the door exploded out at 12,000 feet over Ontario, depressurizing the cargo hold and causing loss of control of the rear engines and wings, Captain McCormick correctly and coolly reacted, ascertained what the problem must be, and returned the plane to Detroit.

After an investigation, the door problem was solved by installing a one-inch peephole over the locking pins. As early as 1969, however, engineers had noted the problem and suggested changes in the design. The differential pressure problem is one that has known remedies, for instance installing vents on the floor so the pressure differential could not occur. None of the solutions were implemented. On June 27, 1972, as a result of the near crash of the American Airlines DC-10, director of project engineering Daniel Applegate of Convair, the subcontractor and designer of the DC-10 fuselage, wrote a memorandum to his supervisors, stating in part, "It seems to me inevitable that, in the twenty years ahead of us, DC-10 cargo doors will come open, and I expect this to usually result in the loss of the airplane."

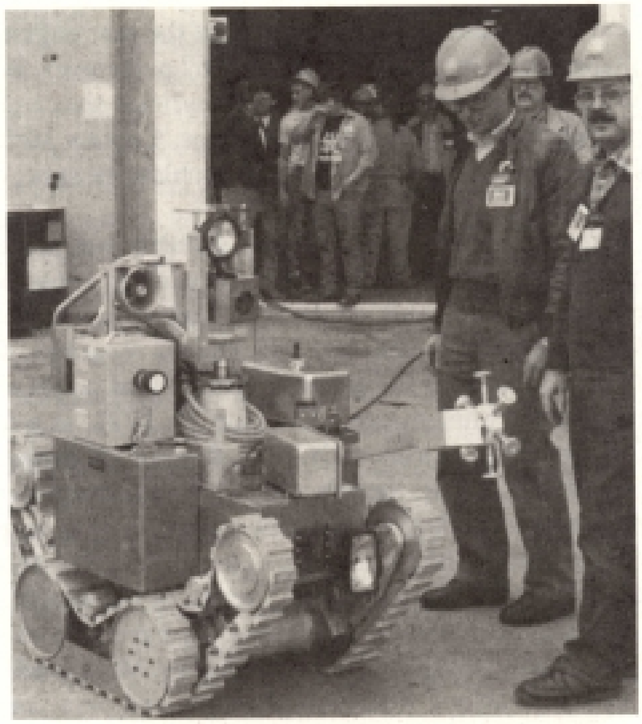
Nothing was done beyond minor changes such as the peephole, because of some unusual financial pressures at play. McDonnell Douglas Corporation was in a precarious financial situation and was counting on beating the competition with the newly designed DC-10; delay would allow a competitor's aircraft, the Lockheed Tri-Star, to be constructed. The assumption was that the market would not accommodate both planes. Convair, a subcontractor, was reluctant to press for a solution, since it was not clear who would have to pay for the design changes, costing millions of dollars. In response to Applegate's memo the general manager of Convair said that he was sure McDonnell Douglas would interpret the recommendation for change as an admission of error on Convair's part. The matter was dropped at that point.

On March 3, 1974, a Turkish Airlines DC-10 with 346 people on board took off from Paris. It reached an altitude of 12,000 feet, the cargo door burst open, the floor collapsed, and the plane crashed, killing all on board.

NUCLEAR REACTOR WELDS

The fate of engineers who persist in challenging management on safety issues outside of the company is not good in terms of job security, however beneficial it is to their mental health and self-esteem.

Carl Houston, a welding supervisor for Stone and Webster, a large engineering consulting firm, reported for work at the site of a nuclear power plant being built for Virginia Electric and Power Company (VEPCO) in early 1970. Having no specific assignment given to him, he was free to inspect various welding operations. He immediately found cause for concern. The steel pipes designed to carry reactor cooling water had welds that were substandard for a variety of reasons. Improper electrodes were being used at times; some electrodes did not receive required oven drying; and not all of the welders were properly qualified—indeed many were learning on the job. When Hous-



Robots perform tasks in environments that are dangerous for humans. This robot is used for routine inspection, monitoring, and surveillance tasks within areas of a nuclear power plant that are subjected to radiation. (Courtesy of Public Service Electric and Gas Company)

ton reported this to the manager, nothing was done to correct the problems, and he was told to take the matter no further. He did not take this advice and reported the matter to the head office of Stone and Webster, which again had no effect on remedying the problem. Carl Houston was forced to resign.

He then notified VEPCO and the Atomic Energy Commission (AEC) and still received no response. He notified the office of the governor of Virginia and the Virginia Department of Labor, still with no result. Finally, his two senators from Tennessee managed to convince the AEC to investigate his allegations. The AEC confirmed Houston's charges. VEPCO hired a consulting engineering firm, which also concluded that Houston was correct in finding welding deficiencies. Finally, the AEC required that the plant have three times the inspection frequencies of normal nuclear plants.

Houston was correct but out of a job. He suffered significant financial losses due to lack of employment and legal expenses.

BEING RIGHT IS EXPENSIVE

In the mid 1960s George B. Geary worked essentially as a sales engineer for U.S. Steel in the tubular steel products area. Though not an engineer by education, Geary had developed, through 14 years of working with U.S. Steel, a substantial background in the technology of manufacturing steel pipe. At this time the company was introducing a new product for the oil and gas industry, but Geary thought it had not been adequately tested and might rupture under high pressure. He so informed his superiors and suggested that additional testing be done before selling the pipe, thereby preventing financial loss due to personal injury and damage suits as well as loss of reputation for U.S. Steel. His immediate superiors insisted he proceed to market the pipe without additional testing, and Geary did so. He also went above his superior's head to corporate headquarters. Ultimately, a vice president thought enough of Geary's idea that he ordered a suspension of the sales effort until further tests were run.

On July 13, 1967, George Geary was fired. U.S. Steel even tried to prevent him from receiving unemployment compensation while he was looking for a new job, saying he was discharged for willful misconduct. Nearly a year later, the Pennsylvania Board of Review concluded that he had the welfare of the company in mind and could not be charged with willful misconduct; thus he was entitled to unemployment compensation. He tried suing U.S. Steel for wrongful discharge but lost in a closely decided case, split 4 to 3.

It seems that it takes a heroic effort to fight a company decision, even in matters of safety. This certainly could be a moral dilemma some of you will face. It is an unusual situation that will reach the dramatic instances detailed above, but not an impossible one. Engineering societies have proposed that legislation be enacted to prevent firing an engineering when his or her acts are consonant with the ethical obligation of a professional to hold paramount factors relating to public safety, health, and welfare. This legislation is making slow progress in terms of judicial trends and legislative initiatives.

Another more dramatic proposal is that if an engineer's judgment is overridden by a manager, and the engineer formally objects, arguing that this would create a serious danger to human safety or health or perhaps lead to serious financial loss, and if the manager persists in his or her decision, responsibility for the consequences rests with the manager. The manager would be legally liable if in the future such danger or loss occurred. As of now a manager has no legal responsibility for actions associated with decisions in these areas. Liability would tend to reduce the temptation to make decisions for immediate gain, such as meeting deadlines and cutting costs. Furthermore, it would make managers responsible for their actions whether or not they still worked for the company when the real effect of the decision, such as a plane crash or other disaster, occurred.

While this idea has been proposed by others, the process of drafting such legislation would be formidable; perhaps society needs initiatives in this area. It again points to the fact that engineers have to become more politically and socially aware as well as technically competent.

A POSITIVE SIDE TO PERSEVERANCE

The previous examples illustrated some of the negative forces you may confront as a practicing engineer, but it is important to note that speaking out as a concerned citizen does not usually result in dismissal actions.

In 1977 James Creswell, an inspector for the Nuclear Regulatory Commission (NRC), was assigned to inspect the start-up conditions at a new nuclear generating station, Toledo Edison's Davis-Besse facility. During the low-power testing a sudden and significant generation of heat occurred due to failure in the main feedwater system. The reactor operators did not receive clear information as to what was happening within the plant, because of faulty instrumentation and control systems. The operator assumed a valve was stuck in the open position and closed down the emergency core cooling pumps.

A similar mishap had occurred at a nuclear generating station in California, though the cause was completely different; misinterpretation of information and insufficiently clear information from the instrumentation and control systems caused operator error that could have resulted in a major catastrophe. Fortunately, none occurred at the Davis-Besse plant, for it was operating at 9-percent power and the actual valve failure was detected after 22 minutes, a relatively short time.

Creswell was disturbed that luck should be a factor in the safe operation of nuclear reactors and for over a year communicated his views to all parties concerned—the NRC, the utility, and the manufacturer of the power plant. No party was interested. He persisted. Finally, he took a day's leave and at his own expense traveled to meet two receptive NRC commissioners in Maryland. They listened and subsequently requested that NRC staff members answer the questions Creswell raised. As the memo was being typed, the Three Mile Island disaster occurred.

Unlike Davis-Besse, Three Mile Island had been operating at 96-percent power and the failure of the relief valve to close had taken over two hours to detect. This combination of operator errors created an explosive situation, in part because of deficiencies that Creswell had noted. He later received a $4000 award from the NRC. While his concern did not prevent this tragedy, his efforts and concerns for public safety were recognized. In the final analysis, his perseverance paid off.

HOLDING THE LINE

Probably everyone is familiar with the explosion of the Challenger space shuttle. The simple fact is the shuttle flew against the advice of engineers, particularly Roger Boisjoly and Arnold Thompson. They stated that the anticipated cold weather conditions in which the shuttle was scheduled to fly could create a situation where the rocket booster seals would fail. That is exactly what happened, causing a fatal explosion.

Higher management in Morton-Thiokol and NASA overruled their advice. Boisjoly and Thompson could not prove that it would happen, only that it might happen, and it was important to Morton-Thiokol and NASA to have the shuttle fly.

Following the disaster, Roger Boisjoly testified before the federal investigative commission. There was a great deal of sentiment against him, and he was able to keep his job in part because of Congressional pressure, though his status within Morton-Thiokol suffered. He offered these words of advice to engineering students at MIT the following year: "I have been asked by some if I would testify again if I knew in advance of the potential consequences to me and my career. My answer is always an immediate yes. I couldn't live with any self-respect if I tailored my actions based upon potential personal consequences."

This addresses a fundamental reason many engineers practice their profession. It contributes directly to their sense of value, their level of happiness. Aristotle noted that happiness is self-realization, not contentment. Having an easy life, according to Aristotle, is not the path to happiness; rather, using your abilities, your talents, skills, and interests, to their fullest yields the path to happiness. Continuing along this line of reasoning, it follows that the more complex and challenging the situation in which you use your abilities, the greater your happiness. Certainly the undergraduate engineering curriculum is one of the most, if not *the* most, challenging and complex academic paths available. There is a great deal of satisfaction in undertaking this challenge in school and in your pursuant career—one reason many intelligent people find engineering very rewarding.

4.5 DESIGN CHANGES

Changes are often made in the execution of a design. As an engineer in charge of a project or product, you must make sure that the changes do not affect the product or project integrity. A case in point where the changes affected the project was in the construction of the elevated walkways in the Hyatt Regency Hotel in Kansas City, Missouri. Two elevated walkways, shown in Figure 4.1, spanned the lobby. In July 1981 a dance contest was in progress and over a

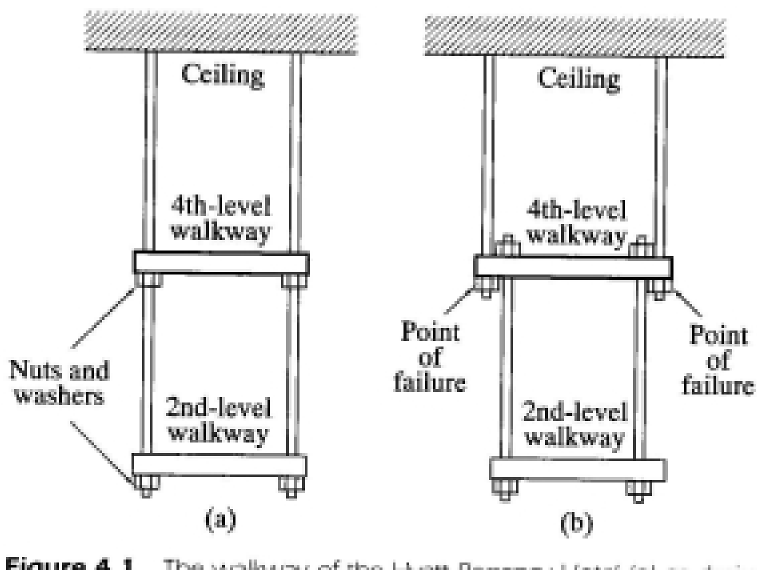


Figure 4.1 The walkway of the Hyatt Regency Hotel (a) as designed and (b) as constructed.

thousand people were on the overhead walkways, watching the participants below, with some of the observers dancing as well. The walkways were not constructed as designed but had loads twice that of the original design. The walkway supports failed, and 111 people were killed and 188 injured. Several factors led to the failure of the walkway, compounding the effect of any one factor. They included the dynamic load caused by dancing, a welded seam that had to be load-supporting, and the possible omission of some load-bearing washers.

The combination of all these events caused the failure, and the constructed walkway was of a different and poorer design than the original. Thus, not only when changes are made should all safety considerations be reviewed, but the product or project as constructed must be inspected to make sure it conforms with the design specifications.