PROFESSIONAL STANDARDS IN ENGINEERING PRACTICE

Michael S. Pritchard

1 INTRODUCTION

As professionals, engineers are expected to commit themselves to high standards of conduct. The Preamble of Code of Ethics of the National Society for Professional Engineers (NSPE) puts it this way:

> Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.

Although this Preamble insists that such conduct is *expected* of engineers, this is not a *predictive* statement about how engineers, in fact, conduct themselves. By and large, it is hoped, engineers do adhere to high principles of ethical conduct. However, the Preamble is a *normative* statement, a statement about how engineers *ought* to conduct themselves. This is based on the impact that engineering has on our quality of life. This impact is the result of the exercise of expertise that is the province of those with engineering training and experience. Such expertise carries with it professional responsibility.

To talk about professional responsibility in this way is to enter the arena of ethics, or morality.[1] Standards for engineers may be articulated in codes. These codes can be broad statements of principle, such as are found in engineering codes of ethics. Or they may be quite specific and prescriptive, such as building codes. Many engineering standards are also understood in terms of the "accepted practice" of engineers, whether formally stated or not. In each case we can ask what, if any, underlying moral basis engineering standards have and what these standards contribute to our understanding of the moral responsibilities of engineers.

[1]In this paper 'ethics' and 'morality' will be used interchangeably. Neither textbooks nor ordinary language exhibit patterns of use that clearly distinguish them.

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William F. May points out the seriousness of the responsibility that comes with professional expertise. Noting our growing reliance on the services of professionals whose knowledge and expertise is not widely shared or understood, May comments:

> [The professional] had better be virtuous. Few may be in a position to discredit him. The knowledge explosion is also an ignorance explosion; if knowledge is power, then ignorance is powerlessness. [May, 1998, p. 408]

The knowledge that comes with expanding professional expertise is largely confined to specialists. Those outside these circles of expertise experience the ignorance explosion to which May refers. This includes the general public, as well as other professionals who do not share that expertise. May concludes:

> One test of character and virtue is what a person does when no one else is watching. A society that rests on expertise needs more people who can pass that test. [May, 1998, p. 408]

May's observations apply as much to engineers as accountants, lawyers, doctors, and other professionals. What this means is that, in its ignorance, the public must place its *trust* in the reliable performance of engineers, both as individuals and as members of teams of engineers who work together. It is not just the public that must place its trust in the reliable performance of engineers. Engineers' employers, colleagues, and co-workers need to, as well. Thus, the need for mutual reliance and trust is pervasive. Fortunately, our common morality provides us with a resource that commends the establishment of such trust and enables us to understand, support, and critically evaluate standards for professionally responsible behavior.

Thus, a good place to begin is with a discussion of common morality. This will help set the stage for a consideration of the function and limitations of codes of ethics regarding professional standards for engineers. Next will be a discussion of regulatory standards, commonly accepted standards of practice, and the broader notion of a "standard of care," commonly invoked in judicial settings. Throughout it will be clear that engineers must rely on *good judgment* rather than merely algorithms. This will also be evident in the discussion of relationships between professional standards, on the one hand, and engineering imagination, innovation, and design, on the other. Finally, questions regarding the scope of professional standards will be considered, particularly in light of the rapidly growing international setting of much engineering practice.

2 COMMON MORALITY

Philosopher Bernard Gert observes that, regardless of our individual and cultural differences, there are some universal features of human nature that provide the basis for a system of common morality, such as our fallibility, rationality, and vulnerability [Gert, 2004]. He is careful to point out that common morality is not a system derived from his or any other philosopher's moral theory. Common morality precedes theories that attempt to describe or evaluate it. Although it does reflect general acceptance by thoughtful people, common morality does not depend on the theorizing of moral philosophers. In fact, Gert says that common morality is accepted in all philosophical theories of morality [Gert, 2004, p. vii].

Gert characterizes common morality in terms of a set of moral rules and moral ideals. He does not claim that we explicitly endorse these rules and ideals as he formulates them. Rather, his account is best understood as a rational reconstruction of basic features of our moral lives — an account that attempts to represent faithfully something implicit in our moral lives. Gert's list of rules and ideals is offered as a comprehensive representation of the central features of ordinary morality. To illustrate, Gert's moral rules are:

- Do not kill.
- Do not cause pain.
- Do not disable.
- Do not deprive of freedom.
- Do not deprive of pleasure.
- Do not deceive.
- Keep your promises.
- Do not cheat.
- Obey the law.
- Do your duty.

None of these rules is "absolute." Each has legitimate exceptions. Sometimes they even conflict with one another. However, violations of these rules require a justification that can be publicly accepted by all reasonable persons. That there can be justified departures from a moral rule is a central feature of common morality. In controversial cases, reasonable persons might not come to the same conclusions about what to do. But, given basic agreement on the facts in particular situations, shared acceptance of the moral rules can be expected to result in widespread agreement on most matters.

All moral agents, says Gert, agree that killing, causing others pain or disability, and depriving others of freedom or pleasure are morally wrong without some justification. This is in contrast to, for example, taking a walk or not taking a walk, neither of which normally requires any justification. Likewise, all moral agents agree that deceiving, breaking promises, cheating, breaking the law, and neglecting duties are in need of moral justification. Gert concludes:

> The claim that there are moral rules prohibiting such actions as killing and deceiving means only that these kinds of actions are immoral unless they can be justified. Given this understanding, all moral agents agree that there are moral rules prohibiting such actions as killing and deceiving. [Gert, 2004, p. 9]

Given something like Gert's account of common morality, the main ingredients of the codes of ethics of professional engineering societies should not be surprising. Nearly all of them identify the protection of public health, safety, and welfare as the paramount duty of engineers in the course of their engineering work.[2] They also emphasize fidelity to employers and clients, honesty in their work, restricting one's work to areas within which one has competence, the importance of confidentiality, and avoiding or minimizing conflicts of interest. In light of the Preamble to NSPE's Code of Ethics, these are just the areas of concern one would expect common morality to address.

Thus far, it has simply been assumed that engineering codes of ethics have an appropriate place in engineering practice. Given this assumption, common morality can be called upon to help formulate their provisions. However, it is important to examine this assumption itself, for serious questions have been raised about the function, limitations, and even the moral legitimacy of codes of ethics for professionals.

3 CODES OF ETHICS

There is no universally accepted account of what professions are that distinguishes them from other occupations. However, engineering exemplifies the following features that, taken together, warrant regarding it as a profession:[3] 1) Engineering requires extensive preparation in the form of training, much of which is of an intellectual character; 2) mastery of this intellectual component typically requires formal education at an institution of higher education; 3) the knowledge and skills possessed by engineers make a vital contribution to the well-being of the larger society; 4) engineers exercise a considerable degree of autonomy, or professional judgment, in providing their services; and 5) engineering societies typically claim to be regulated by ethical standards, as evidenced by their codes of ethics. The first four features relate directly to May's concern with the virtues of professionals such as engineers. However, when we turn to engineering codes of ethics, questions can be raised about both their moral status and scope.

[2] This has not always been the case. Prior to the 1970's, this was not explicitly acknowledged in the codes. A notable exception was the American Association of Engineers (AAE) code in the 1920's. This code's first principle stated, "The engineer should regard his duty to the public as paramount to all other obligations." [Taeusch, 1926, p. 102]. However, AAE itself dissolved by 1930.

[3] For a succinct discussion of features typically found in professions, see [Bayles, 1989]. For a nuanced discussion of somewhat contested questions about the status of engineering as a profession, see [Davis, 2002, Ch. 7, pp. 99-120].

Engineering codes of ethics originate in particular professional societies: for example, the American Society of Civil Engineers (ASCE), the American Society of Mechanical Engineers (ASME), the Institute of Electronic and Electrical Engineers (IEEE), and the National Society for Professional Engineers (NSPE). As suggested by their titles, these societies typically are confined within the national boundaries within which they are adopted. Even within these boundaries membership is voluntary, and only a small percentage of practicing engineers actually join. Furthermore, there is some controversy about what role engineering codes of ethics should have.

While conceding that a code of ethics may be necessary for an emerging profession to gain initial recognition, Heinz Luegenbiehl contends that engineering codes have now outlived their usefulness [Luegenbiehl, 1991, p. 137-138]. Supposedly, the codes constitute a "set of ethical rules that are to govern engineers in their professional lives." However, he argues, practicing engineers seldom consult these codes, some of their provisions are in conflict with one another and provide no guidance for the resolution of these conflicts, and the codes are coercive in intent, which challenges the autonomy normally attributed to moral agents.[4]

In reply, it could be said that the usefulness of engineering codes of ethics does not depend on their being regularly consulted by practicing engineers. If a code does a good job of identifying the basic obligations of engineers, it can be called upon when needed — for example, as Michael Davis points out, when an employer expects an engineer to do something unethical [Davis, 1991, p. 150-167]. Davis sees engineering codes of ethics as advising engineers how they should act as professionals and as conventions between professionals that enable them to cooperate in serving a shared ideal of public service better than they could if they stood alone.

So, for Davis, a code of ethics is seen as an agreement among members of a profession to commit themselves to a common set of standards that serve the shared ends of their profession. The obligation to comply with a code is an obligation to one's fellow professionals, and it is an obligation of fairness to one another — to do one's part. This gives an engineer a reason for wanting to join a professional society with a code of ethics. It also gives those already in such a society reason to continue to support it and its code, and to work at recruiting new members. An advantage for individual engineers is that, by joining, conducting themselves ethically in their engineering work is no longer just a matter of personal conscience for them. Joined with others, an engineer can appeal to his or her society's code and say, "As an engineer, I cannot do this." In professional ethics, there can be strength in numbers.

The NSPE Code of Ethics is the product of the collective reflection of its members. On Davis's view, NSPE members are obligated to comply with the code's provisions because of their agreement with each other that they will do so. However, the NSPE code is worded in such a way that it seems intended to address the ethical responsibilities of engineers as such, not solely members of NSPE. Given

[4]This is a point first argued by Ladd, [1991, pp. 130-136].

this, the standards endorsed by the code should be supportable by reasons other than the fact that NSPE members publically endorse and commit themselves to those standards. That is, the standards should be supportable by reasons that are binding on even those engineers who are not members of NSPE. Are they?

In answering this question it is important to note that the code's Preamble makes no reference to its members creating or committing themselves to the NSPE code. Instead, it attempts to depict the role that engineering plays in society, along with the standards of conduct that are required in order for engineers to fulfill this role responsibly. Thus, this depiction is presumed to be apt regardless of whether engineers are members of NSPE.

Engineers and non-engineers alike can readily agree that engineers do play the sort of vital societal role depicted by the Preamble. What about the normative implications of that role? Here, too, engineers and non-engineers can agree, at least broadly. This is because, as already noted, the basic ethical standards endorsed by the NSPE Code of Ethics are supported by common morality.

However, even if common morality can be appealed to in support of the basic provisions of an engineering code of ethics, this does not ensure that all of its provisions will be free from controversy, or even inappropriate content. In part this is because those who deliberate about what should be included in a code can be expected to take into account not only ethical considerations, but also realities of the workplace of engineers. Most engineers are corporate employees, and corporate goals may be more or less receptive to, for example, engineering concerns about sustainable technological developments. Although some prominent engineering societies now include statements about environmental concerns, most still refrain from making any explicit statements on such matters.

One way to minimize controversy is for a code's provisions to be stated in such a way that there is broad room for interpretation. In fact, as is the case with Gert's moral rules and ideals, this is to some extent a practical necessity. Actual situations cannot be anticipated in all their relevant nuances, and *judgment* is itself one of the hallmarks of professional practice. For example, although sometimes it is clear what would constitute a failure to protect public, health, and safety, often it is not. Not actively protecting public safety will fail to satisfy the public safety standard only if there is a responsibility to provide that level of safety. But, since no engineering product can be expected to be "absolutely" safe (at least, not if it is to be a useful product) and there are economic costs associated with safety improvements, there can be considerable controversy about what a reasonable standard of safety is.

4 TECHNICAL CODES AND STANDARDS

Engineering codes of ethics typically state that the work of engineers is expected to conform with "applicable engineering standards," such as *technical* codes and standards. These codes and standards have a life of their own, in the sense that they do not depend on engineering codes of ethics for either their origin or their bindingness.[5] They have been developed and formulated in the course of time as engineering practice itself has developed. Technical codes are legal requirements that are enforced by a governmental body to protect safety, health and other relevant values [Hunter, 1977, p. 66-71]. Examples are building codes, sanitary and health codes, and fire codes. Technical standards are usually regarded as recommendations rather than legal requirements. Varying in length from a few paragraphs to hundreds of pages, they are usually written by engineering experts who sit on standardization committees.

Technical codes are often based on standards, or they may refer to standards as either a required or possible way of meeting code requirements. Standards may become mandatory by inclusion in a business contract. Standards are often seen as specifying criteria for good design practice, and as such they may be relevant in liability claims against companies or designers [Hunter, 1977, p. 66-71].

While technical codes are formulated by government bodies, technical standards (on which codes are often based) are not. Standards may be internal to a company, to a consortium of companies, or industry-wide. Industry-wide standards are usually formulated by consensus. A main reason for standardization in industry is the desire for interchangeability and compatibility. Standardization ensures that replacement parts are interchangeable with the original ones. Standardization also ensures that different products can work together or can use the same technical infrastructure.

Industry-wide standards are usually formulated through national standards institutes, like the American National Standards Institute (ANSI) and the International Organization for Standardization (ISO). ANSI is a privately funded federation of business and industry, standards developers, trade associations, labor unions, professional societies, consumers, academia, and government agencies. ANSI has accredited a number of organizations, like the American Society of Mechanical Engineers (ASME), as standards developing organizations. These standards developing organizations oversee the process of standard formulation, which involves the relevant stakeholders and which has to meet the requirements formulated by ANSI to guarantee openness, transparency, balance of interests and due process. Standards are achieved by consensus.

European standards are formulated through the CEN, the European Committee for Standardization.[6] The procedure is comparable to that of ANSI, but there are some significant differences. The process is organized primarily through the national standards bodies, which are members of the CEN. Stakeholder involvement is thus organized through these bodies. Moreover, a standard agreed upon by the technical committee for a specific standard is adopted as a harmonized European standard, or not, by a weighted vote of the national standards bodies. If a European standard is adopted, national standards bodies are obliged to withdraw

[5]The next eight paragraphs on codes and standards are, with minor alterations, the contribution of Ibo van de Poel, to whom I am much indebted for allowing the inclusion of his work.

[6]Information based on http://www.cenorm.be/cenorm/index.htm.

conflicting standards and to adopt a standard that conforms to the harmonized standard.

Apart from standards formulated through organizations like CEN, ANSI and ISO, also *de facto* standards can be distinguished. These standards are not approved by standardization organizations but are widely used and recognized by industry as being standard. Often such standards are effectuated through the market. Given this, de facto standards do not necessarily reflect the interests and values of the wider public. Industry consortia can also voluntarily agree on standards, not only to promote interchangeability and compatibility, but also in an attempt to create a de facto standard which may give an important economic advantage.

So, it can be seen that technical codes and standards serve a number of values. They serve utility and prudential values like interchangeability, compatibility, and efficiency. They also serve moral values such as safety, health, environmental sustainability and privacy. These values are often translated in codes and standards in rather concrete terms. For example, in codes and standards for pressure vessels, the value of safety is translated into a certain wall thickness of the vessel — to avoid explosions. In a building code, sustainability may be translated in terms of certain maximum heat transfer through the windows of a building in certain circumstances.

Such translations may, sometimes, be ethically questionable, as we shall see in the ASME/Hydrolevel case discussed below. Another problematic area is safety in car design. Most crash tests for cars stress the safety of people inside the car and not the safety of people outside the car [van Gorp, 2005]. However, for those inside a car the risks are more voluntary than for cyclists and pedestrians that are hit by the car in case of an accident. Moreover, those inside the car have the advantage of using the car while cyclists and pedestrians only face the risks. Both factors, the degree of voluntariness and the distribution of risks and benefits, mean that the moral acceptability of the risks to people outside the car is more problematic than the risks to those inside the car.

This means that, from an ethical point of view, it is important to examine current codes and standards with a critical eye. Nevertheless, given the need for codes and standards in engineering practice, it seems reasonable to place a burden of proof on those engineers who would take exception to them. This would seem to be an implication of Gert's last two moral rules of common morality: obey the law and do your duty (here, your job-related responsibilities). The other moral rules can be used to evaluate whether these two rules should carry the day in problematic cases.

5 ACCEPTED STANDARDS OF ENGINEERING PRACTICE AND THE STANDARD OF CARE

In requiring engineers to conform to accepted standards of engineering practice, engineering codes of ethics insist on compliance with technical codes and standards.

These codes and standards are *regulatory* in intent. They may focus on desired *results* of engineering practice — for example, on whether the work satisfies certain standards of quality or safety. Technical codes and standards may also require that certain *procedures* be undertaken to ascertain that specific, measurable levels of quality or safety are met; or they may require that whatever procedures are used be documented, along with their results.

Equally important, engineering codes of ethics typically insist that engineers conform to standards of *competence*, standards that have evolved through engineering practice and that presumably are commonly accepted, even if only implicitly, in ordinary engineering training and practice.[7] Regulatory standards and standards of competence are intended to provide some assurance of quality, safety, and efficiency in engineering. It is important to realize, however, that they also leave considerable room for professional discretion in engineering design and its implementation. This calls for competence. There are few algorithms for engineers to follow here. Performance standards that do not specify particular procedures to be followed or materials to be used clearly leave room for professional discretion. But even more specific technical codes leave room for discretion (for example, as in the Citicorp Building illustration discussed below, whether to bolt or weld joints).[8] So, the need for engineering *judgment* should not be overlooked.[9]

Regarding safety, for example, rather than leave the determination of what counts as safe solely in the hands of individual engineers, safety standards may be set by government agencies (such as the National Institute of Standards and Technology, the Occupational Safety and Health Administration, or the Environmental Protection Agency) or non-governmental organizations (such as professional engineering societies, ANSI, ISO, and CEN). Nevertheless, standards of safety, as well as standards of quality in general, leave room for considerable engineering discretion. Although some standards have a high degree of specificity (e.g., minimal requirements regarding the ability of a structure to withstand winds of a certain velocity striking that structure at a 90 degree angle), some simply require that unspecified standard processes be developed, followed, and documented [Shapiro, 1997, p. 290].

Underlying all of these more specific efforts to articulate particular codes and standards is a broader *standard of care* in engineering practice, a standard appealed to in law and about which experienced, respected engineers can be called upon to testify in the courts in particular cases. Although the standard of care is used as a standard in law, it can also be seen as a reasonable moral standard, reflected in common morality's concern to avoid and prevent harm, suffering, and death, among other things. It also can be seen as instrumental in engineers's efforts to protect public safety, health, and welfare in the course of their work, the

[7]See, for example, the Association for Computing Machinery: ACM Code of Ethics and Professional Conduct, 2.2 Acquire and maintain professional competence.

[8]For a good discussion of the importance of judgment, imagination, and responsibility in relation to standards and codes, see [Coeckelbergh, 2006, pp. 237-260].

[9]This is a major theme of Stuart Shapiro's [1997].

paramount duty of engineers according to virtually all of the codes of ethics of engineering societies in the USA, and in most other countries as well.

Joshua B. Kardon characterizes this standard of care in this way [Kardon, 1999]. Although some errors in engineering judgment and practice can be expected to occur as a matter of course, not all errors are acceptable:

> An engineer is not liable, or responsible, for damages for every error. Society has decided, through case law, that when you hire an engineer, you buy the engineer's normal errors. However, if the error is shown to have been worse than a certain level of error, the engineer is liable. That level, the line between non-negligent and negligent error is the "standard of care."

How is this line determined in particular cases? It is not up to engineers alone to determine this, but they do play a crucial role in assisting judges and juries in their deliberations:

> A trier of fact, a judge or jury, has to determine what the standard of care is and whether an engineer has failed to achieve that level of performance. They do so by hearing expert testimony. People who are qualified as experts express opinions as to the standard of care and as to the defendant engineer's performance relative to that standard.

For this legal process to be practicable and reasonably fair to engineers, it is necessary that there be an operative notion of "accepted practice" in engineering that is well understood by competent engineers in the areas of engineering under question. As Kardon puts it:[10]

> A good working definition of the standard of care of a professional is: that level or quality of service ordinarily provided by other normally competent practitioners of good standing in that field, contemporaneously providing similar services in the same locality and under the same circumstances. [Kardon, 1999]

Given this, we should not expect to find a formal statement of what specifically satisfies the standard. Rather, an appeal is being made to what is commonly and ordinarily done (or not done) by competent engineers.

Engineers who have responsible charge for a project are expected to exercise careful oversight before putting their official stamp of approval on the project. However, what careful oversight requires will vary with the project in question in ways that resist an algorithmic articulation of the precise steps to be taken and the criteria to be used. Two well known cases are instructive. In the first instance, those in charge of the construction of the Kansas City Hyatt-Regency hotel were charged with professional negligence in regard to the catastrophic walkway collapse in 1981.[11] Although those in charge did not authorize the fatal departure from the

[10] *Ibid.* Kardon bases this characterization on *Paxton v. County of Alameda* (1953) 119c.C.A. 2d 393, 398, 259P 2d 934.

[11] For further discussion of this case, see [Harris *et al.*, 2009, p. 252]. See also [Shapiro, 1997, p. 287].

original design of the walkway support, it was determined that responsible monitoring on their part would have made them aware of the proposed change. Had it come to their attention, a few simple calculations could have made it evident to them that the resulting structure would be unsafe.

In this case it was determined that the engineers in charge fell seriously short of accepted engineering practice, resulting in a failure to meet the standard of care. Satisfying the standard of care cannot guarantee that failure will not occur. However, failure to satisfy the standard of care itself is not acceptable. In any particular case, there may be several acceptable ways of meeting the standard. Much depends on the kind of project in question, its specific context, and the particular variables that (sometimes unpredictably) come into play.

The second case also involved a departure from the original design not noted by the chief structural engineer of Manhattan's 59 story Citicorp Building [Morgenstern, 1995, p. 49-53].[12] In contrast to the Hyatt Regency walkway, this was not regarded to be a matter of negligence. Chief structural engineer William LeMessurier was surprised to learn that Citicorp's major structural joints were bolted rather than deep-welded together, as called for in the original design. However, he was confident that the building still more than adequately satisfied the New York City building code's requirement that winds striking the structure from a 90 degree angle would pose no serious danger. Assuming he was correct, it is fair to conclude that either deep welds or bolts were regarded to be consistent with accepted engineering practice. The code did not specify which should be chosen, only that the result must satisfy the 90 degree wind test.

Fortunately, LeMessurier did not rest content with the thought that the structure satisfied the city building code. Given the unusual features of the Citicorp structure, he wondered what would happen if winds struck the building diagonally at a 45 degree angle. This question seemed sensible, since the first floor of the building is actually several stories above ground, with the ground support of the building being four pillars placed in between the four corners of the structure rather than at the corners themselves. Further calculations by LeMessurier determined that bolted joints rendered the structure much more vulnerable to high winds than had been anticipated. Despite satisfying the city code, the building was unsafe. LeMessurier concluded that corrections must be made. The standard set by the city building code was flawed. The code could not be relied on to set reliable criteria for the standard of care in all cases.

From this it should not be concluded that there is only one acceptable solution to the joint problem. LeMessurier's plan for reinforcing the bolted joints worked. But the original plan for deep welds apparently would have, as well. Many other acceptable solutions may have been possible. So, a variety of designs for a particular structure could be consistent with professional engineering standards.

The Hyatt-Regency case is a clear illustration of culpable failure. The original design failed to meet building code requirements. The design change made mat-

[12] For further details, see [Harris *et al.*, 2009, pp. 307-308]. See also [Morgenstern, 1995, pp. 49-53].

ters worse. The Citicorp case is clear illustration of how the standard engineering practice of meeting code requirements may not be enough. It is to LeMessurier's credit that he discovered the problem. Not doing so would not have been negligence, even though the structure was flawed. Once the flaw was discovered, however, the standard of care required LeMessurier to do something about it, as he clearly realized. Furthermore, it seems that foremost in mind for LeMessurier was his sense of moral responsibility for the safety of the Citicorp structure. To some extent, of course, the possibility of legal liability may have been a factor as well, but LeMessurier's account of the course of events makes it clear that his primary focus was on his moral responsibility to do his best to correct the flaw in the building that he, and only he, had discovered through his own engineering conscientiousness and initiative.

6 INNOVATION AND PROFESSIONAL STANDARDS

No doubt William LeMessurier was disappointed to discover a serious fault in the Citicorp Building. However, there was much about the structure in which he could take pride. A particularly innovative feature was a 400 ton concrete damper on ball bearings placed near the top of the building. LeMessurier introduced this feature, not to improve safety, but to reduce the sway of the building — a matter of comfort to residents, not safety. Of course, this does not mean that the damper has no affect on safety. Although designed for comfort, it is possible that it also enhances safety. Or, especially since it's movement needs to be both facilitated and constrained, it is possible that, without other controls, it could have a negative effect on safety. In any case, the effect that a 400 ton damper near the top of a 59 story structure might have on the building's ability to handle heavy winds is something that required careful attention.

Supporting the structure on four pillars midway between the corners of the Citicorp building was another innovation — one that might explain why it occurred to LeMessurier that it was worthwhile to try to determine what effect 45 degree winds might have on the structure's stability. Both innovations fall within the range of accepted engineering practice, provided that well conceived efforts are made to determine what effect they might have on the overall integrity and utility of the structure. The risk of relying exclusively on the particular directives of a building code is that its framers are unlikely to be able in advance to take into account all of the relevant effects of innovations in design. That is, it is quite possible for regulations to fail to keep pace with technological innovation.

Although engineers and their employers might try to excuse failure to provide safety and quality by pointing out that they have met existing regulatory standards, it is evident that the courts will not necessarily agree. The standard of care in tort law (which is concerned with wrongful injury) is stated more broadly than regulatory standards are. The expectation is that engineers will meet the standard of care as expressed in *Coombs v. Beede*:[13]

> The responsibility resting on an architect is essentially the same as that which rests upon the lawyer to his client, or upon the physician to his patient, or which rests upon anyone to another where such person pretends to possess some special skill and ability in some special employment, and offers his services to the public on account of his fitness to act in the line of business for which he may be employed. The undertaking of an architect implies that he possesses skill and ability, including taste, sufficient enough to enable him to perform the required services at least ordinarily and reasonably well; and that he will exercise and apply, in the given case, his skill and ability, his judgment and taste reasonably and without neglect.

As Korden points out, this standard does not hold that all failure to provide satisfying services is wrongful injury. But it does insist that the services provided evidence *reasonable* care. What counts as reasonable care is a function of both what the public can reasonably expect and what experienced, competent engineers regard as acceptable practice. Given the desirability of innovative engineering design, it is unrealistic for the public to regard all failures and mishaps to be culpable; at the same time, it is incumbent on engineers to do their best to anticipate and avoid failures and mishaps.[14]

7 REGULATING THE REGULATORS

Ideally, regulatory standards are unbiased, as are the regulators. However, since the experts who help establish the standards typically are employed by the very companies whose products are being regulated, special efforts must be made to minimize the chances that they will unfairly favor their employers.

Rather than naively assume that all conflicts of interest can be eliminated, Stephen Unger suggests the following:

> [One must] ensure that the membership of decision-making committees includes a variety of people with varying biases, and to carry out the entire process in an open fashion, that is, to make the decision-making process transparent to all interested parties. Inviting comments from all concerned groups and individuals and providing appeals processes are additional methods for ensuring fair play. [Unger, 1994, p. 210]

Unfortunately, as Unger points out, his recommended process is not foolproof. A classic illustration is the case of the *American Society for Mechanical Engineers*

[13] *Coombs v. Beede*, 89 Me. 187, 188, 36 A. 104 (1896). This is cited and discussed in [Strand and Golden, 1997].

[14] For good discussions of responsibility and innovation in engineering design, see [Grunwald, 2001] and [van de Poel and van Gorp, 2006].

(ASME) vs. Hydrolevel, which was finally settled against ASME. The first half of the 19th century was marked by boiler explosions on steamboats that resulted in the deaths of thousands of Americans. ASME played the leading role in establishing uniform requirements for safe boilers. A special area of concern is boilers being heated when the water level in the boiler is insufficient. In the early 1970's the ASME code specified: "Each automatically fired steam or vapor system boiler shall have an automatic low-water fuel cutoff, so located as to automatically cut off the fuel supply when the surface of the water falls to the lowest visible part of the water-gauge glass" [American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, section IV, paragraph HG-605a].

Attempting to make competitive inroads in this area, Hydrolevel developed a mechanism that included a time delay in its fuel cutoff system, claiming that this would ensure a more reliable determination of water level in boilers whose water is in motion. ASME's BPVC Boiler and Pressure Vessel Committee was headed by prominent representatives of two companies then dominating the market. Unknown to Hydrolevel, a letter was circulated that insisted that low-water fuel cutoff mechanisms should operate immediately. By the time Hydrolevel discovered the existence of this letter, it had suffered serious market losses. Hence, it undertook an anti-trust lawsuit against the two companies and ASME. The two companies settled out of court with Hydrolevel. However, ASME protested that it had done nothing wrong, despite the fact that some of its volunteer committee members had, on their own, acted unfairly in their companies' behalf. ASME took its case all the way to the Supreme Court of the United States, but to no avail.

In effect, the Supreme Court found ASME to be negligent in overseeing how its special committees operate in enforcing standards that can have a large impact on the economic success or failure of companies. The Court's majority opinion said, in part:[15]

> ASME wields great power in the nation's economy. Its codes and standards influence the policies of numerous states and cities, and as has been said about "so-called voluntary standards" generally, its interpretation of guidelines "may result in economic prosperity or economic failure, for a number of businesses of all sizes throughout the country," as well as entire segments of an industry. [Beardsley, 1984, p. 66]

As a result of the Court's ruling, ASME introduced a number of substantial changes in its procedures. Charles Beardsley sums up the changes:

> The most striking changes affect the Society's handling of codes and standards interpretations. All such interpretations must now be reviewed by at least five persons before release; before, the review of two people was necessary. Interpretations are available to the public, with replies to nonstandard inquiries published each month in the Codes and Standards section of ME or other ASME publications. [Beardsley, 1984, p. 73]

[15] [Harris *et al.*, 1009, p 254]. Cited from [Beardsley, 1984].

In addition, ASME requires all staff and volunteer committee members to sign a conflict of interest disclaimer, and ASME provides them with copies of its code of ethics and a publication that discusses the legal ramifications of the standards. So, essentially, in an effort to reduce bias, ASME implemented the guidelines Stephen Unger suggests.

ASME's response to its adverse legal ruling is instructive. Rather than retreat from establishing and enforcing codes and standards, it introduced changes to improve its procedures. What remained intact was its rejection of the idea that everything should be left solely to the discretion of individual engineers or the firms for whom they work. There was no wavering from its commitment to uniform codes and standards regarding matters of safety and quality; and it continued to accept its responsibility to help frame and enforce them.

8 DESIGN

The Hydrolevel case is instructive in another way. Hydrolevel came up with a departure from the more usual way of ensuring safety. This was challenged by its competitors. Initially, at least, Hydrolevel met with failure. However, in fact, its mechanism might well have satisfied reasonable standards of safety. The point here is that there is likely more than one way to satisfy safety standards, especially when stated broadly. Arguably, the ASME standard was interpreted too narrowly by Hydrolevel's competitors. But if there is more than one way to satisfy safety standards, how are designers to proceed?

If we are talking about the overall safety of a product, there may be much latitude, a latitude that, of course, provides space for considerations other than safety, as well (e.g., overall quality, usability, cost). For example, in the late 1960's, operating under the constraints of coming up with an appealing automobile that weighed under 2000 lbs. that would cost consumers no more than $2000, Ford engineers decided to make more trunk space by putting the Pinto's gas tank in an unusual place.[16] This raised a safety question regarding rear end collisions. Ford claimed that the vehicle passed the current standard. However, some Ford engineers urged that a protective buffer should be inserted between the gas tank and protruding bolts. This, they contended, would enable the Pinto to pass a more demanding standard that it was known would soon be imposed on newer vehicles. They warned that, without the buffer, the Pinto would fail to satisfy the new standard, a standard that they believed would come much closer to meeting the standard of *reasonable care* enforced in tort law.

Ford decided not to put in the buffer. It might have been thought that satisfying the current safety standard ensured that courts and their juries would agree that reasonable care was exercised. However, this turned out to be a mistaken view. As noted above, the courts can determine that existing technical standards are not

[16] For further discussion of the Pinto case, see Case 27, "Pinto," in [Harris *et al.*, 2009, pp. 266-267].

adequate, and engineers themselves are sometimes called upon to testify to that effect.

Given the bad publicity Ford received regarding the Pinto and its history of subsequent litigation, Ford might regret not having heeded the advice of those engineers who argued for the protective buffer. This could have been included in the original design, or perhaps there were other feasible alternatives during the early design phases. However, even after the car was put on the market, a design change could have been made. This would have involved an expensive recall, but this would not have been an unprecedented move in the automotive industry.

These possibilities illustrate a basic point about regulatory standards, accepted standards of engineering practice, and engineering design. Professional standards for engineers underdetermine design.[17] In principle, if not in practice, there will also be more than one way to satisfy the standards. This does not mean that professional standards have no effect on practice. As Stuart Shapiro points out:

> Standards are one of the principal mechanisms for managing complexity of any sort, including technological complexity. Standardized terminology, physical properties, and procedures all play a role in constraining the size of the universe in which the practitioner must make decisions. [Shapiro, 1997, p. 290]

For a profession, the establishment of standards of practice is typically regarded as contributing to professionalism, thereby enhancing the profession in the eyes of those who receive its services. At the same time, standards of practice can contribute both to the quality and safety of products in industry. Still, standards of practice have to be applied in particular contexts that are not themselves specified in the standards. Shapiro notes:

> There are many degrees of freedom available to the designer and builder of machines and processes. In this context, standards of practice provide a means of mapping the universal onto the local. All one has to do is think of the great variety of local circumstances for which bridges are designed and the equally great variety of designs that result.... Local contingencies must govern the design and construction of any particular bridge within the frame of relative universals embodied in the standards. [Shapiro, 1997, 293]

Shapiro's observation focuses on how standards of practice allow engineers freedom to adapt their designs to local, variable circumstances. This often brings surprises, not only in design but also in regard to the adequacy of formal standards of

[17]Mark Coeckelbergh makes a distinction between *prescriptive* and *goal-setting* regulations, with the latter providing more room for autonomy in decision-making for engineers [Coeckelbergh, 2006]. However, even highly prescriptive regulations allow room for discretion, as there may be more than one mechanism, set of materials, or method that can satisfy even a fairly specific prescription. Coeckelbergh's general point is that increasing responsibility goes with the increasing autonomy that comes with the absence of specific external determination of what, specifically, is required.

practice. As Louis L. Bucciarelli points out, standards of practice are based on the previous experience and testing of engineers. Design operates on the edge of "the new and the untried, the unexperienced, the ahistorical" [Bucciarelli, 1994, p. 135]. Thus, as engineers come up with innovative designs (such as LeMessurier's Citicorp structure), we should expect formal standards of practice themselves sometimes to be challenged and found to be in need of change. All the more reason why courts of law are unwilling simply to equate the standard of reasonable care with current formal standards of practice.

Bucciarelli makes another important point about design. Design changes are often made during the process of implementation; that is, design itself can be seen as a work in process, rather than as a final plan that precedes and guides implementation. This is illustrated in the fictional case study *An Incident in Morales*, a video developed by the National Institute for Engineering Ethics.[18] While implementing a design for a chemical plant in Mexico, the chief design engineer learns that his budget is being cut by 20%. To fall within the new budget, some design changes are necessary. Next the engineer learns that the effluent from the plant will likely cause health problems for local residents. The current design is consistent with local standards, but it would be in violation of standards across the border in Texas. A possible solution is to line the evaporation ponds, an additional expense. Implementing this solution provides greater protection to the public; but, as it turns out, this comes at the expense of putting some workers at the plant at greater risk because of a money-saving switch to cheaper controls within the plant — another design change. So, a basic question facing the engineer is, given the tight budgetary constraints, which standards of practice take priority? The moral of the story is that, from the very outset of this project, the engineer failed to take sufficiently into account signs of trouble ahead — including warnings from senior engineers at another facility that taking certain shortcuts would be unwise (if not unethical).

9 THE SCOPE OF STANDARDS OF PRACTICE

Some standards of practice are clearly only local in their scope. The New York City building code requirement that high rise structures be tested for wind resistance at 90 degree angles applied only within a limited geographic region. Such specific code requirements are local in their origin and applicability. Of course, one would expect somewhat similar requirements to be in place in comparable locales in the United States, as well as in other high rise locales around the world. This suggests that underlying local codes, particularly those that attempt to ensure quality and safety, are more general standards of safety and good engineering practice.

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[18] *An Incident at Morales: An Engineering Ethics Story*, developed and distributed by the National Institute for Engineering Ethics, the Murdough Center for Engineering Professionalism, and the Texas Tech University College of Engineering (2003). This video is available from the National Institute for Engineering Ethics, Box 41023, Lubbock, Texas 79409-1023. (Email: Ethics@coe.ttu.edu.)

One test of whether we can meaningfully talk of more general standards is to ask whether the criteria for engineering competence are only local (e.g., New York City civil engineers, Chicago civil engineers, Kalamazoo, Michigan civil engineers). The answer seems clearly to be no within the boundaries of the United States, especially for graduates of accredited engineering programs at United States colleges and universities.

However, as Vivian Weil has argued, there is good reason to believe that professional standards of engineering practice can cross national boundaries [Weil, 1998, p. 303-314]. She offers the example of early 20$^{\text{th}}$ century Russian engineer, Peter Palchinsky. Critical of major engineering projects in Russia, Palchinsky was nevertheless regarded to be a highly competent engineer in his homeland. He also was a highly regarded consultant in Germany, France, England, the Netherlands, and Italy. Although he was regarded as politically dangerous by Russian leaders at the time, no one doubted his engineering abilities — either in Russia or elsewhere.

Weil also reminds readers of two fundamental principles of engineering that Palchinsky applied wherever he practiced:

> Recall that the first principle was: gather full and reliable information about the specific situation. The second was: view engineering plans and projects in context, taking into account impacts on workers, the needs of workers, systems of transportation and communication, resources needed, resource accessibility, economic feasibility, impacts on users and on other affected parties, such as people who live downward. [Weil, 1998, p. 306]

Weil goes on to point out that underlying Palchinsky's two principles are principles of common morality, particularly respect for the well being of workers — a principle that Palchinsky argued was repeatedly violated by Lenin's favored engineering projects.

At the outset of this chapter, it was noted that the codes of ethics of engineering societies typically endorse principles that seem intended to apply to engineers in general rather than only to members of those particular societies. Common morality was suggested as providing the ground for basic provisions of those codes (for example, concern for the safety, health, and welfare of the public). Whether engineers who are not members of professional engineering societies actually do, either explicitly or implicitly, accept the principles articulated in a particular society's code of ethics is, of course, another matter. However, even if some do not, it could be argued that they *should*. Weil's point, a point accepted in this paper as well, is that there is no reason, in principle, to believe that supportable international standards cannot be formulated and adopted. Furthermore, this need not be restricted to abstract statements of ethical principle. As technological developments and their resulting products show up across the globe, they can be expected to be accompanied by global concerns about quality, safety, efficiency, cost effectiveness, and sustainability. This, in turn, can result in uniform standards in many areas regarding acceptable and unacceptable engineering design, practice, and products.

In any case, in the context of an emerging global economy, constructive discussions of these concerns should not be expected to be only local.

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