AC 2009-1973: DIFFUSING PREVENTION THROUGH DESIGN PRINCIPLES THROUGH ENGINEERING TEXTBOOKS

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Donna Heidel is a certified industrial hygienist with over 25 years' experience in the health care industry. Ms. Heidel received a B.A. from DeSales University and an M.S. from Temple University. She has spent the last 15 years of her career building a world-class, global, integrated occupational toxicology and industrial hygiene program at Johnson & Johnson, a decentralized company consisting of 230 operating companies in 57 countries. At J&J, she developed and implemented their global health hazard and control banding programs. Ms. Heidel developed the first J&J "prevention through design" (known as "safety by design") documents that included the use of engineering controls based on hazards and the exposure risks. These design standards were applied to 14 other pharmaceutical R&D and manufacturing facilities, including chemical plants (that synthesized the API) and biotechnology plants. After leaving J&J, Ms. Heidel continued to work promoting PtD efforts as a consultant to a number of large multi-national companies In August 2008, Ms. Heidel joined NIOSH to lead the PtD National Initiative.

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Defusing Prevention through Design Principles through Engineering Textbooks

…the opportunity to eliminate a hazard at the drawing board through good design is one that should be seized with both hands.[1]

Introduction

There is a growing demand on engineers by business leaders to anticipate and minimize workplace hazards early in the design process, rather than retrofit changes after workers gets hurt. Design, in this regard, can be for a facility, piece of equipment used in a process or the design of the process, system, or operation itself. It is analogous to "green chemistry," which has started to gain interest in chemistry programs as a way to prevent pollution and sustain our resources. Many decisionmakers view this preventive approach as a commonsense necessity in today's highly competitive business environment and see it as an essential element of lean production and service systems. Large and small companies worldwide have put into practice *Prevention through Design* (PtD) management practices for reducing the direct and indirect costs associated with workplace injuries and illnesses.

One significant barrier to PtD is the lack of training for most new engineers on how they can contribute to profitable enterprises by considering occupational safety and health (OSH) hazards and risks at the drawing board, and taking steps to minimize them. Senior managers from approximately forty Fortune 500 companies expressed concern over this gap in education.[2] They said time and money is devoted to training new engineers on basic company policies related to the prevention of workplace health and safety hazards. They also indicated the expensive need to retrofit equipment, systems, facilities, and operations to reduce risks that were not addressed during the design process. Today's businesses have a growing demand for engineering graduates who are knowledgeable in PtD concepts.

This paper emphasizes the importance of including PtD in engineering education. It argues that teaching such concepts does not require stand-alone courses in already full curricula. Concepts can be woven into existing textbooks through the use of examples and case studies. Authors can include PtD messages in new editions of books as they are being updated.

A brief history of PtD and its link to engineering school education is provided below. Then, the PtD National Initiative is summarized with links to more information. This initiative forms a comprehensive foundation upon which the PtD engineering textbook project is an important component. The paper presents the steps being taken to incorporate PtD concepts into selected textbooks. Finally, several case studies of PtD in action are given that represent the types of examples that could be used in engineering textbooks. It is hoped that readers of this paper will promote the PtD concept among their students and peers and request that such information be included in future textbooks used by engineering students in their fields.

History

The concept behind PtD and its linkages to engineers is not new. Beginning in the 1800s, demand for safer designs for machine guards, controls for elevators, and boilers became the norm, followed by a procession of other devices and processes created by engineers to make work environments safer. The important role of engineers was highlighted as early as 1947, by the Canons of Ethics for Engineers, which stated that:

> *He will regard it his duty to guard against dangerous elements in apparatus, structures, or plants, or dangerous conditions of operation therein, and upon observing such conditions in work with which he is associated, he will call them to the attention of his client or employer. If dangerous conditions persist with his knowledge, he is not fully relieved of his responsibilities.*[3]

Also:

> *He will make provisions for safety of life and health of employees and of the public who may be affected by the work for which he is responsible.*[3]

Since the late 1970s, the importance of inherent or intrinsic safety, safety by design, design for safety, safe design (and similar names) surfaced, particularly in the chemical industry driven by major industrial disasters. The chemical industry today puts great importance on inherently safer design. [4, 5, 6]

In the 1980s, the United States National Institute for Occupational Safety and Health (NIOSH) initiated the Safety and Health Awareness for Preventive Engineering (SHAPE) project to create awareness in the engineering profession of the importance of OSH technical issues in engineering projects. A series of nine instruction modules were developed and made available to the public, specifically to engineering programs, on the NIOSH website.[7]

In 1995, the National Safety Council established the Institute for Safety Through Design (ISTD). The ISTD hosted a symposium in 1996 with high-level representatives from industry, government, and engineering schools to address two key questions: (1) What is the OSH knowledge an engineer should have upon completion of a baccalaureate degree? (2) How can this knowledge best be delivered? One conclusion of the symposium was that there is little room in engineering curricula for stand-alone courses on OSH; changes should be made through the existing course structure.[8]

There have been numerous articles on the lack of OSH education in engineering school curricula and many initiatives to change the situation, but most have worked with individual professors. While these approaches have had limited success, they have generally proven to be unsustainable because professors come and go and the methods used to teach OSH to engineering students were not always institutionalized by engineering programs.

There is a continuation of efforts in the United States and elsewhere to highlight the importance of basic OSH knowledge for new engineers, and the tools to apply PtD concepts after they

graduate. This focus is supported today by the first Fundamental Canon of the Code of Ethics for Engineers, which states that he or she shall:

> *Hold paramount the safety, health, and welfare of the public.*[9]

There also is a criterion for the 2009-2010 Accreditation Cycle by ABET, Inc. that requires engineers to have:

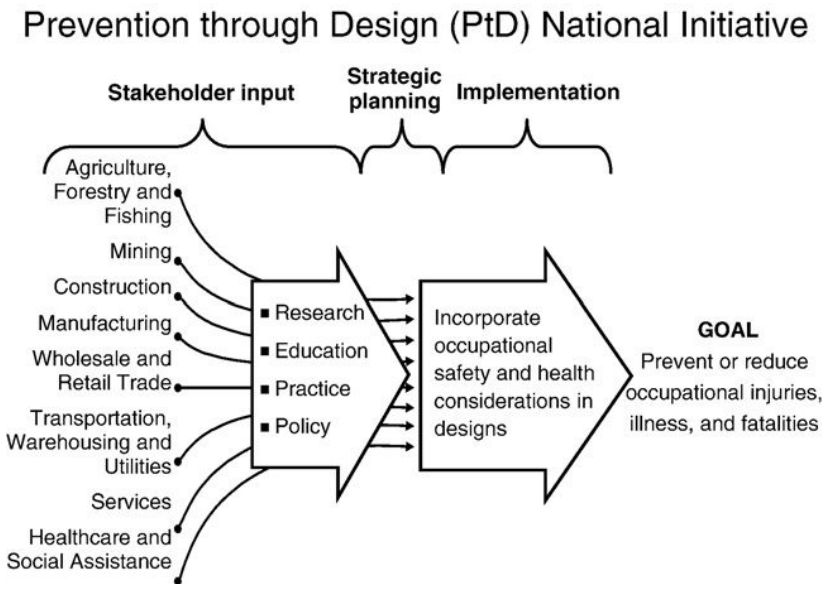
> *An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.*[10]

Although the term "employees" has been dropped from the Code of Ethics, as compared to the 1947 version, arguably because workers are an important subset of the nation's "public," the importance of engineering students to learn how to anticipate and minimize safety and health risks of their designs (for builders, users, and recyclers) appears paramount.

The engineering profession has long recognized the importance of preventing safety and health problems with the designs its members create. This meshes well with the demand on new engineers by modern industry leaders to reduce costs associated with poor design. Besides the cost of retrofitting, not designing for prevention can lead to increased chemical exposures, ergonomic hazards, explosions, fires, falls, amputations, etc.

PtD National Initiative

The concept of PtD now cuts across all industry sectors and special editions of scientific journals have been dedicated to the topic.[11, 12] To support and strengthen the development of the PtD concept, which is maturing in many of the largest industries in the world, NIOSH launched a collaborative initiative to more broadly convey the notion. Its function is to be a positive catalyst to the creation and dissemination of business tools, case studies, demonstration projects, and good practices centered on design solutions that reduce worker injuries, illnesses, and costs. The initiative addresses PtD by industry sector and through four over-arching functional areas of practice, policy, research, and education.[13] The diagram shows the framework for the initiative. More detailed and current information is available on the NIOSH PtD website.[14]



One of the initiative's functional areas focuses on "education," and there is a paper available that summarizes current and potential future activities in this area.[15] There is also a comprehensive PtD National Strategic Plan being developed with input from stakeholders across many disciplines and industry sectors, which will be available for public comment in 2009. The NIOSH PtD website, mentioned above, is the best source for information. The textbook project described in this paper falls within the education functional area and is an important component of the overall PtD National Initiative.

PtD Engineering Textbook Project

In cooperation with an editor at a leading engineering textbook publisher in the United States, funding for a four year project was secured in 2008 by a project team at NIOSH to demonstrate how PtD concepts could be incorporated into new or existing engineering textbooks. The planned outcomes from the project are: (1) at least seven new editions of textbooks that include material on PtD published and used by engineering schools to train new students and (2) a demonstrated process that can be used by others to add PtD concepts into engineering textbooks.

The editor is responsible for more than 60 textbooks covering most of the subspecialties in aerospace, civil, chemical, and industrial engineering. Many of the books have leading or significant market shares within their areas of focus. The books are used in schools across the United States reaching thousands of students each year.

The main focus of this project is to identify authors of textbooks and create a process to weave in PtD concepts. In October 2008, the editor sent a letter to specific authors who were working on new or new editions of textbooks informing them about the project, and providing background information on the PtD National Initiative. Several authors responded positively to the letter and are currently in contact with the NIOSH team. External consultants and volunteers with textbook-specific engineering expertise are being identified to provide input to authors to weave PtD concepts into the textbooks to maximize effect and acceptance by professors and students. The broad networks of engineers who are participating in the NIOSH PtD National Initiative are the first pool of experts from which consultants for this project are being sought. Actual contributions to individual books have not yet been finalized.

In summary, this project created a unique relationship among NIOSH, a leading engineering textbook publisher, engineering textbook authors, and outside experts to incorporate PtD concepts into popular engineering textbooks as they are being written or updated. The project will develop a model that could be used by other publishers. The beneficiaries will be engineering professors and their students who use the new textbooks, and the companies that hire the new graduates with increased knowledge of PtD.

It is expected that the NIOSH relationship with the editor will remain strong after the funding cycle ends because of its long-term potential impact on PtD (by putting more informed engineers into the marketplace) and the relative low cost to maintain the connection. NIOSH is seeking to expand the project through collaborations with other textbook publishers and authors. The goal would be to catalyze other groups capable of replicating and improving on the project, ideally

without the need for direct NIOSH involvement or resources in the future. If PtD incorporated into textbooks gives a competitive edge to authors and publishers, others may join the effort.

PtD Examples

The PtD Textbook Project is just getting underway and many decisions as to how PtD principles and examples will be integrated into engineering textbooks are still being considered. The following section highlights several examples where PtD played an important role in reducing the risks of injuries and illnesses for workers. These examples are not intended to show specific examples that will actually be used in any engineering textbook. Presently, authors interested in working with NIOSH are being identified and external experts with subdiscipline engineering expertise are being contacted. As such, the form and content of new PtD text for any of the textbooks have not been finalized. However, NIOSH and the project team is willing to work with all authors interested in including PtD principles and examples in future engineering text books.

It is not yet known in what final form PtD concepts will be introduced by authors in engineering textbooks. The types and formats of new materials will vary between books and authors. For example, one author of a fluid mechanics book that is working with the project team is developing subtle PtD examples that convey specific learning objectives in different sections of the book. Another author working with NIOSH wrote a standalone chapter on PtD for an environmental engineering book on water and waste water delivery systems. He is also including case studies of PtD in practice. The project team is encouraging creativity among the authors, and respecting the fact that the books are their own intellectual property.

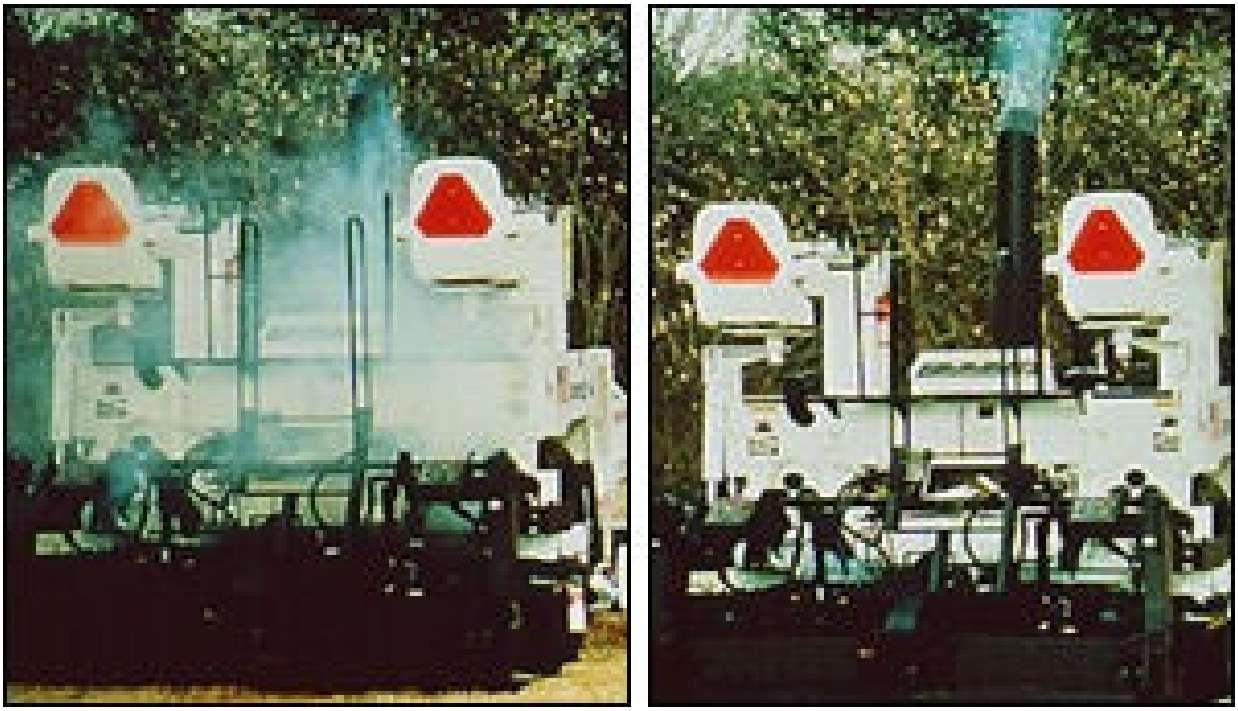
Some of the case studies given below are the result of retrofitting improvements to designs that were already in use by industry. Ideally, the best changes are made in the initial design phase and thus any negative consequences avoided. The last example is different from the rest in that it is guidance for structural engineers on how to create an “erector friendly column” to prevent construction worker injuries. The actual look and content of the materials added to future engineering textbooks under this project will be different than those given below.

PtD Example 1: Mechanical device reduces risks to workers[16]

Mechanical lifting devices reduce risk of back injuries to health care workers and improve patient safety and comfort

The hazards associated with lifting present significant risk to health care workers in the U.S. Lifting without the assistance of mechanical devices can also compromise the safety and comfort of patients. A NIOSH study evaluated the effectiveness of a safe resident lifting and movement intervention in six nursing homes. After investing $158,556 for patient lifting and handling equipment and worker training, lost workday injuries fell by 66%, restricted workdays dropped 38%, and workers' compensation expenses were reduced 61%. The initial investment for the lifting and handling equipment and worker training was recovered in less than three years based on post-intervention savings of $55,000 annually in workers' compensation costs.

PtD Example 2: Industry-wide equipment design change protects workers' health[17]



Before and after photos of asphalt fume emissions from highway-class pavers

More than half a million workers in the U.S. face exposure to fumes from asphalt, a petroleum product used extensively in road paving, roofing, siding, and concrete work. Health effects from exposure to asphalt fumes include headache, skin rash, sensitization, fatigue, reduced appetite, throat and eye irritation, cough, and skin cancer. In the mid-1990s, The National Asphalt Pavement Association (NAPA) collaborated with industry partners to address concerns about the hazards of asphalt fumes for paving-site workers. This partnership resulted in U.S. industry-wide effort to design, lab-test, field-test, and validate engineering control modifications to highway-class paving machines to remove fumes from the vicinity of workers. The industry partners signed a voluntary agreement to include these ventilation controls on every new U.S. -manufactured highway-class paver.

PtD Example 3: Designing-out existing noise hazard to protect miners' hearing[18]

The coating the chain conveyor and flight bars with a heavy-duty, highly durable urethane decreases noise exposures

Overexposure to noise remains a widespread and serious health hazard to workers in many U.S. industries. Hearing loss is permanent and can lead to poor verbal communication and the inability to recognize warning signals. Workers who experience hearing loss can also suffer from increased stress and fatigue. In underground coal mining, the operation of continuous mining machines - which cut and gather coal - pose a significant risk to miners' health. These machines contain an onboard conveyor consisting of a chain with flight bars that drag the coal along the base of the conveyor system. The chain creates excessive noise as it makes contact with the metal base and the coal. Mine operators working in proximity of the machine are at risk of permanent and irreversible hearing loss. An innovative Prevention through Design solution calls for coating the chain conveyor and flight bars with a heavy-duty, highly durable urethane. The redesigned chain conveyor and flight bars decreased noise exposures of continuous mining machine operators by 3 dB(A). The redesign also increased the chain life by a factor of three, more than off-setting the 20% cost increase of coating the chain.

PtD Example 4: E-stop on fishing vessels reduces risk of serious injury or death[19]

A capstan -type winch with fishing lines wound around.

A fishing vessel captain demonstrating the use of an emergency-stop (e-stop) mounted on the winch.

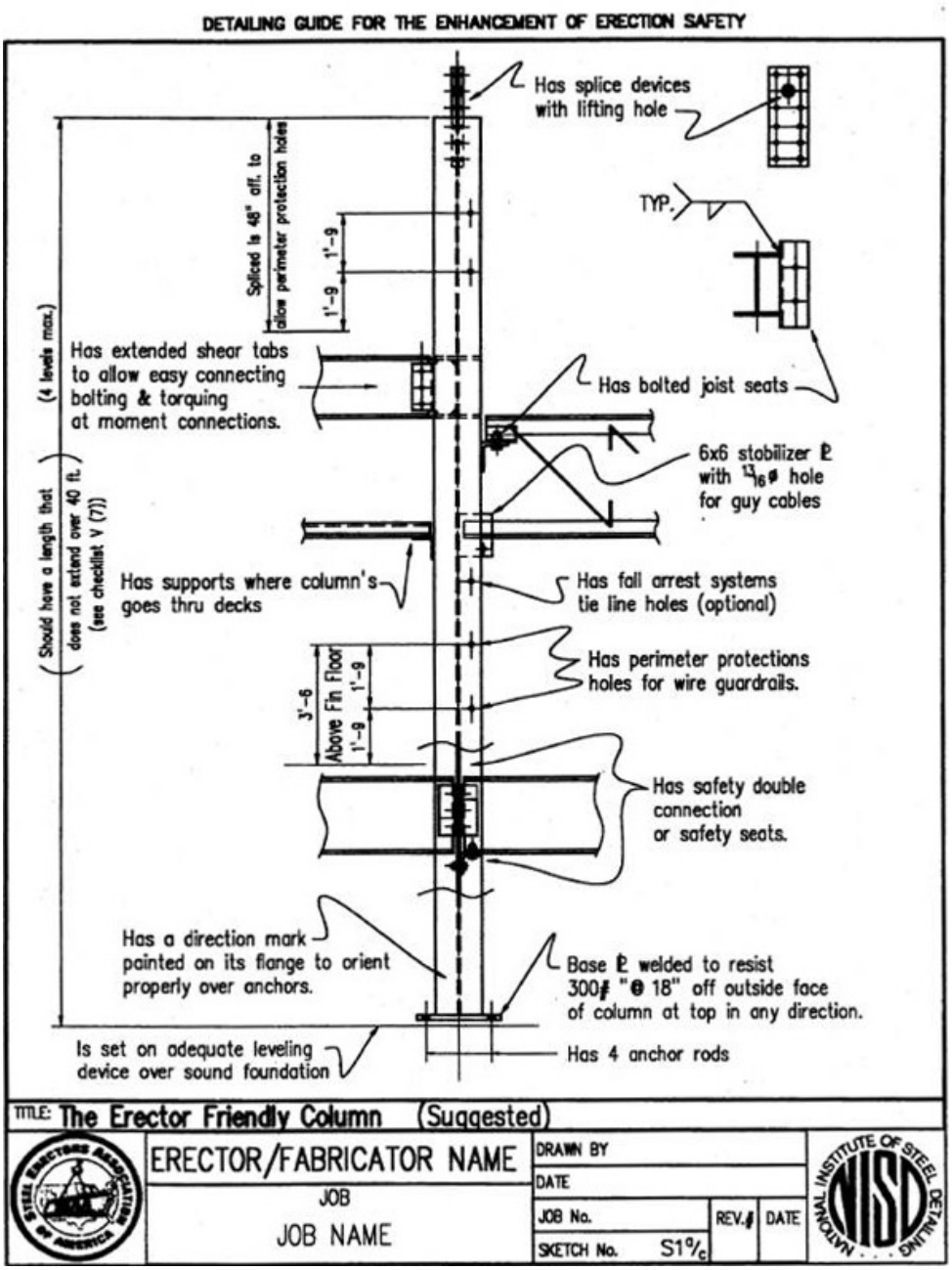
Commercial Fishing is the most dangerous occupation in the United States. Its occupational fatality rate – 142 per 100,000 workers – is 36 times higher than the average fatality rate for all U.S. workers. Fatal deck injuries, caused by unsafe machinery and equipment, remain a significant problem in the industry.

In Alaska, deck injuries result in approximately 12% of all commercial fishing fatalities and 67% of severe, hospitalized injuries. Entanglements – especially those associated with powerful, capstan-type winches used to reel in large fishing nets – pose a significant threat to deck workers in the commercial fishing industry.

The capstan winch is usually mounted in the center of the deck. The winch's drum rotates while the crew works on deck. Fisherman who lose their balance or are inattentive can become caught in the fishing line as it winds around the drum. The winch provides no entanglement protection and the controls are usually out of reach of the entrapped person.

A unique "Prevention through Design" solution – an emergency-stop ("e-stop") system situated on the top of the winch - addresses the serious machinery hazard posed by a capstan deck winch. When pushed, the emergency switch arrests the drum's rotation in less than 180 degrees rotation, sufficient to limit serious entanglement injury. Vessel owners who have the e-stop installed on their winches recommend it enthusiastically to other fishermen.

PtD Example 5: The erector friendly column[20]



This image is from a collection published jointly by the National Institute of Steel Detailers and the Steel Erectors Association of America that identifies the specific decisions structural engineers can make to improve the safety constructability of their designs.[21]

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