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Mixing Water and Prevention through Design

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Introduction and Background

"The American Water Works Association Research Foundation (AwwaRF) is member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professional to provide safe and affordable drinking water to consumers" (AwwaRF website, 2008). In 2003, an AwwaRF project report, "Identifying and Prioritizing Emerging Safety Issues in the Water Industry," identified critical research needs related to health and safety (Puglionesi et al., as cited in AwwaRF RFP 2). The 2003 study found that the drinking water industry has more accidents and lost workdays when compared to other utility industries. U.S. Bureau of Labor Statistics (BLS) data confirms that safety performance among water utilities lags behind general industry. OSHA non-fatal injury case rates for Water Supply and Irrigation Systems in 2006 was 5.1, compared to 4.4 for Private Industry (BLS, 2007). Rates for cases involving days away from work, job transfer, or restrictions were 3.0 for water utilities, substantially higher than the 2.3 rate for private industry.

The 2003 AwwaRF report concluded that health and safety considerations are frequently not a high priority when water conveyance, treatment, storage, and distribution facilities are designed. Designing "inherently safer" systems is an approach that has gained wide acceptance in the petrochemical industry, and is an approach that much of the water industry recognizes as a strong need for its members as well. Two factors give 'prevention through design' (PtD) more urgency than in the past:

- Many of the water treatment plants and distribution systems in the U.S. are aging and are in need of major repairs, upgrades, replacement, and capacity expansion. Total capital spending toward improving this vital infrastructure is estimated to be approximately $12 billion per year with approximately annual 10% growth for at least

the next 5 years (based on a Black & Veatch survey of Capital Improvement Plans of United States Cities.) This presents a huge opportunity to reduce injury risk through hazard elimination.

- Water treatment plant operators and maintenance personnel are aging, with many nearing retirement. As this experience departs, organizational memory is lost, including skill in recognizing and avoiding hazards. Less experienced replacement workers may be more susceptible to injury from hidden hazards unless these hazards can be eliminated.

AwwaRF recognized that the earlier health and safety elements are included in the design, the greater the opportunity for building a safe facility at lower cost. With ever-changing technology, increasing standards for health and safety, and greater emphasis being placed on protecting employees and the public, there is a need to identify and communicate exemplary practices to integrate worker health and safety considerations into the design of drinking water systems. AwwaRF combined these industry needs with a few other common safety program gaps and issued Request for Proposal (RFP) 3104 titled, "Integrating Worker Health and Safety into Water Utility Operation, Management, and Facility Design."

AwwaRF Project 3104 Objectives

The research objectives for Project 3104 were presented in the AwwaRF Request for Proposal as follows:

1. Identify and evaluate best practices for integrating health and safety into the design of water utility systems.
2. Assess cost effectiveness of incorporating ergonomic design into new and existing facilities.
3. Identify and evaluate various proactive and reactive programs that promote worker health and safety.
4. Identify and quantify the costs and benefits of worker health and safety programs.
5. Identify metrics that will facilitate the evaluation of health and safety programs.
6. Identify and quantify the costs and benefits of disability management programs.
7. Objectives 1, 2 and 5 were directly applicable to PtD activities, and this paper will focus on the PtD elements of the project.

The project was funded by the EPA and awarded in December of 2005 to Black & Veatch Corporation and its research partner, Applied Safety and Ergonomics, Inc. The Final Project Report was submitted to AwwaRF in the first half of 2008. Among several safety program topics addressed, arguably the most valuable was PtD. With regards to PtD, the Report

- Discussed the current state of PtD processes in the water treatment industry
- Proposed a consensus model process for integrating safety and health considerations into facility design
- Presented a Compendium of industry "Best Practices" for hazard elimination and control, and
- Discussed the challenges and opportunities for incorporating ergonomics into the design of new and existing facilities.

This paper will discuss the unique characteristics of water utilities that affect their safety programs PtD processes. Current PtD processes used by various water utilities will be briefly described, along with the factors that drive the status quo. Finally, a vision for the future of PtD in the water industry will be presented, including the model process developed in this study and a sample of the best practices identified for reducing risk in the facility design.

Methods

Project #3104 was performed in three phases. Phase 1 included development and delivery of a detailed questionnaire, data compilation, and analysis of the responses from twenty (20) water utilities. It also included facilitation of a data sharing and validation workshop.

Phase 2 of the study included case studies of five selected utilities and a second workshop. The objective of the case studies was to identify and document best practices for health and safety programs, including approaches used for integrating H&S into facility design. The case study protocol included facility tours, examination of training and other program documents, and interviews with workers, operations managers, senior executives, safety coordinators/managers, engineering managers, maintenance managers, purchasing agents, human resource managers, and union representatives. At each of the five selected utilities, among the topics discussed were:

- methods for integrating H&S into design and procurement
- level of involvement and reliance upon external engineering service providers
- lessons learned from previous capital projects
- design review methodologies
- management of change, and
- training of engineers on ergonomics, hazard recognition and prevention, health and safety program requirements, and loss prevention.

At the Phase 2 workshop, the twenty participating utilities received a briefing on the findings from Phase 1, as well as highlights from the case studies. The participants then divided into working groups to develop the elements and metrics for a model PtD process for water utility engineering projects. The resulting consensus model is intended to serve as industry best practice for integrating health and safety into the design of water utility facilities. It clearly defines stakeholders and participants for each project phase, along with the objectives to be met from project specification through commissioning. It also identified key skills and tools that were needed to achieve success.

Phase 3 involved writing the final project report. The Final Report presented the research findings, the model PtD process for water utilities, and a compendium of industry best practices. Although a number of H&S topics are addressed, much of the focus is on PtD processes.

Characteristics of Water Utilities and Their Safety Programs

Water utilities convey, treat, store and distribute water. While some perform all four functions, others only engage in conveyance, or treatment, or storage and distribution. Hazardous activities range from fighting forest fires on the slopes of protected watersheds to avoiding dog and spider

bites when reading meters; from operating heavy construction equipment to monitoring processes using highly hazardous chemicals from computerized control rooms. Some of the greatest injury potential, in terms of frequency, severity, and number of exposed employees, is associated with operations and maintenance (O&M) activities. Many of these activities are associated with work at facilities that pump and treat water. These are designed facilities and therefore the focus of PtD processes. Hazards associated installing pipelines, tending reservoirs, and reading meters are not less significant; they are just outside the purview of most facility based PtD processes.

Water utilities are typically governed either by elected water district boards, or by municipalities. In either case, the General Manager typically reports to elected officials in some capacity. Approximately 2/3 of water utilities are owned and operated by municipalities. This introduces features that are very different than profit centered businesses that comprise general industry. First, in many jurisdictions they are not subject to any regulatory oversight from OSHA. Second, they are often the only revenue generating department within city government. Since governments are generally not set up to make money, as long as the water utility does not operate at a loss or provide poor service, they do not attract much scrutiny from city hall.

Water utilities generally have very limited competitive pressure, and there is little concern about the possibility for outsourcing. If operating expenses increase, water boards and municipalities can simply raise rates to cover them. While utilities try to deliver water economically, the primary measures of performance are not financial. Rather, water quality, pressure and volume are paramount, as these factors are necessary for maintaining public safety and system reliability. Since 9-11, security has also become a significant concern.

Because of their unique financial situation, water utilities rarely have cost as a primary driver for change in the organization. Of the 20 utilities participating in this study, **none** identified cost pressure as a major business concern, although several identified ability to limit growth in operating costs as consideration in facility expansion. None of the organizations studied used cost data as a metric for safety performance, and none reported that their senior leaders expressed concern for accident costs. In fact, utilities participating in the study did not have sufficient cost data available to enable the researchers to perform an assessment of cost effectiveness. For many, the safety leaders, human resource managers, and even general managers do not receive financial data associated with injuries or accidents, aside from equipment repair costs. It was the consensus of the participating utilities that although cost data would be interesting, it would have little or no effect on their organization. Hence, the research team was unable to collect sufficient data for purposes of cost/benefit analysis, or for establishing a benchmark rate for direct/indirect costs.

Closely related to the lack of interest in financial measures, the researchers found different injury/illness case management strategies than are typically found in for-profit organizations. Case management is nearly always handled through an external service provider or a centralized municipal department. In many though certainly not all utilities studied, case management was primarily focused on processing the paperwork and not on aggressive return-to-work programs. Where this was the case, days-away-from-work case rates tended to be very high, even as high as 20 times the national average for general industry.

In the absence of traditional financial incentives, the research team was interested in learning what the factors drove safety initiatives in these organizations. As one very astute manager pointed out, what really gets management attention in the water industry is not cost, it is labor

availability or what is sometimes referred to as “wrench time”. It is time-consuming and often difficult for many utilities to justify additional workers because of the public perception of staffing requirements, and political appointees are sensitive to headcount. It is critical when starting any new business initiative to understand the “currency” that the organization uses to “keep score”. In general industry, the currency is dollars; in public utilities it is system reliability that matters, and reliability is totally dependent on available labor hours to maintain the system.

PtD processes not only make new systems inherently safer, they make them more efficient. This implies that to sell PtD to water utilities, the message needs to focus on keeping workers on the job and reducing the number of employees required to perform routine tasks. This message will resonate more than dollar saving and financial benefits. For example, designing confined spaces with stairs so that they do not require a permit to enter can not only make entry tasks safer, it takes fewer employees to do the task. This enables utilities to use the saved labor to accomplish more preventive maintenance, improve customer service, and perform upgrades. Although few of the utilities studied had been using this approach, safety coordinators with several utilities expressed excitement about using this “new” strategy.

Since one of the key objectives of the study was to identify best practices, five utilities were studied in depth to gain additional understanding of what drove their safety performance. Top industry performers had two characteristics in common. First, they had a General Manager or other senior manager who was passionate about not getting people hurt. In these organizations, the top leader made safety a top priority, was actively engaged in the safety process, and set clear goals and expectations. This priority did not come from their oversight board or municipal government. The public is more concerned about the safety of its water than about the safety of water department workers.

Second, top performing organizations had taken the initiative to hire top performing safety professionals to lead their processes. These professionals had typically been recruited from general industry or construction, had been formally trained in safety, and had considerable experience. In the cases studied, the combination of solid top level support and very competent leadership of the safety process had successfully changed the organizational culture over a period of several years.

It was also observed that turnover in water utilities seems to be much lower than in general industry. Many utilities are staffed by persons with close family and community ties, and the close-knit workers report that they look out for each other. Many workers reported that their family had helped run the community water department for generations. While this cohesion provides incentive for keeping each other safe, it does not seem to provide the knowledge or organizational discipline necessary to instill safe work practices.

Another challenge facing water utilities is recent technology developments. For decades, technology in the water treatment industry was comparatively stagnant, as processes for clarifying, filtering and then chlorinating water were universally applied. Recently, technologies such as ultra-filtration, reverse osmosis, and ultra-violet disinfection have introduced new equipment and processes. These processes pose both new hazards and opportunities for safer processes. However many utilities have very limited experience with such processes and are challenged to extend their legacy knowledge to these processes.

Given the lack of regulatory oversight, the absence of significant cost pressures, and reliance on having leaders with a passion for safety, it is not surprising that safety performance for the water industry lags behind general industry. However, PtD processes hold the potential for creating inherently safer worksites with reduced injury risk for those working in treatment facilities or with distribution and conveyance equipment. Selling PtD processes may require strategies that focus on benefits to operational performance rather than cost savings.

Examples of Best Practices in Water Utility Design

For those unfamiliar with PtD, the concept might seem a bit abstract. To help reader understand the benefits and techniques, the following design features are examples of industry "Best Practices" that would be incorporated into designs using a PtD process.

- Elimination of permit required confined spaces
- Careful placement of valves to facilitate access and maintenance using neutral postures and lifting equipment
- Minimizing the need to perform elevated work
- Material handling systems for dry chemicals to eliminate manual handling of 50 lb. bags
- Designed clearances to improve accessibility for maintenance workers
- Provisions for mechanically lifting and maneuvering valves, pumps and fittings
- Control system design to eliminate operator errors
- Installation of remote valve controllers and metering systems
- Standardized valve vault designs that provide accessibility, and which facilitate use of mechanical equipment for handling pipe, valves and fittings
- Installation of weather protection for walkways and maintenance platform.

Current PTD Processes in Water Utilities

A few statistics from the AwwaRF study highlight the current state of PTD among water utilities.

- Half (10) of the participating utilities (n=20) reported that safety does not receive focused attention on most engineering projects.
- 15% indicated that Safety provided oversight on engineering projects.
- Only 50% of respondents (6 of 12) stated that safety-focused design reviews are always or often conducted on internally designed capital projects, and 43% (6 of 14) always or often conducted them on externally designed projects.

Workshop participants affirmed that PtD was a significant need for water utilities, especially given the high levels of capital spending anticipated to maintain and expand water conveyance, treatment and distribution systems over the next twenty years. Several utility representatives stated that assistance with PtD processes was the single biggest incentive for their participation in the AwwaRF study.

PtD processes among water utilities, as well as among companies in general industry, are diverse. On one extreme is total reliance on the engineer or designer to incorporate safety and health concerns in the design without any oversight or review. On the other, some organizations make a concerted effort to involve safety professionals, workers, and operations and maintenance managers in design related activities throughout the project, including safety and health specification development, multiple design and constructability reviews, formal risk assessments, and commissioning inspections. Although not formally studied, it appears that the diversity in PtD processes results from several factors, such as:

- Size of the organization
- Availability and use of external design contractors
- Expertise of both the engineering and safety department personnel
- Senior leadership expectations and directives, and
- Engineering culture within the utility.

The AwwaRF study also assessed the health of PtD processes in water utilities currently engaged in large capital expansion and improvement projects, and arrived at three general impressions. A paragraph on this topic from the Final Project Report summarizes the findings.

First, it was found that engineers focus on answering the question, “Will it work?”, even to the point of not considering the safety and maintainability question, “Will we be able to work on it?” Second, operating costs associated with safety procedures, such as the increased costs associated with personal fall arrest systems and confined space entries, are not considered in design. Third, water utilities generally do not have a process for collecting operational and maintenance experience with respect to design features, so informal methods are relied upon to keep from repeating design deficiencies. Without effective feedback or active involvement by operations, maintenance and safety personnel, engineers repeat mistakes from one project to the next.

To better understand why PtD is not more fully integrated into engineering processes, participating water utilities were asked to identify barriers and constraints for PtD processes. Lack of time allocated for this purpose, lack of available manpower, and lack of time available were most commonly cited as barriers. Ensuing discussions at the study workshops and during case studies revealed that although safety coordinators recognized the need for and value of PtD, many felt that implementation would require a concerted effort to change the priorities and culture of the engineering functions, and of the senior leaders who drove them.

Further, utilities reported three significant gaps in skills that would need to be addressed for PtD to be successful:

1. Safety coordinators who were not educated in either engineering or industrial technology would need technical training to be able to interact effectively with engineers.
2. Engineers often needed additional safety training to appreciate and understand concerns raised by safety coordinators and workers.

3. Workers participating in design reviews and similar activities needed some basic training in how to read and understand engineering drawings, and to relate these to physical structures and equipment.

Simulation software can partially compensate for the third deficiency, but many design contractors do not use this tool, and many organizations are reluctant to pay design firms to develop virtual models.

As a group, water utilities rely heavily on engineering firms for design services. This poses unique set of challenges for ensuring adequate consideration of health and safety in design. External contractors often do not have the opportunity for daily interaction and feedback from operators and maintenance personnel. They tend to be too far removed from daily operations to understand the ramifications of design features, such as the added organizational burden imposed by permit-required confined spaces and elevated work. They are rarely exposed to accident narratives with sufficient detail to learn how design changes could have prevented incidents or reduced risk. Contractors also find it more difficult to solicit feedback on design alternatives from workers and supervisors, so decisions and assumptions are made that often result in increased risk and operating costs.

The most progressive safety and health program studied in the AwwaRF research project was owned by Metro Vancouver, which supplies and distributes water to the Vancouver, BC metropolitan area. This organization had developed a comprehensive management system approach that included an excellent PtD process as well as an evolving ergonomics component. Metro Vancouver's benchmark process is marked by a very competent staff of SH&E professionals, solid senior leadership, and significant regulatory oversight. Among several "best practices" observed in its PtD process were the integration of ergonomics and process metrics.

Ergonomics poses a fundamental challenge for most water utilities. Professionals with degrees in ergonomics or closely related fields were found in only 3 of 18 (17%) utilities responding to the survey. Engineering contractors rarely employ ergonomists, and ergonomic consultants are not widely used by this industry, aside from basic training services.

The need to prevent musculoskeletal disorders (MSDs) is readily apparent, however. Using data provided by 14 water utilities, the researchers found that sprains and strains accounted for just over 50% of the total of all injuries, but cumulative trauma injuries accounted for approximately 3%. Physical exertion was identified as the most problematic activity class, both in frequency and severity as measured by number of cases and average time lost. The two body regions most frequently injured were the back/neck and arm/shoulder. This suggests that reducing exertion demands through focusing on ergonomics in process design will reduce the risk of acute trauma MSDs.

A fundamental tenet of management is "*What gets measured, gets done*." One of the gaps identified in the AwwaRF study is the absence of PtD metrics. Examples of PtD process metrics include level of employee participation in design reviews, percent of planned design reviews held, number of safety related change orders, and level of safety training for engineers. For a PtD process to be successful, organizations will need to adopt metrics to drive it. While Metro Vancouver and a few other utilities are beginning to incorporate PtD metrics, the push needs to include many more organizations. Vancouver's process is yielding dramatic reductions in

confined space entries, elevated work, and other high risk activities. This strategy inherently results in better labor utilization as well, the all-important ‘currency’ for water utilities.

Future of PtD

One of the deliverables from the AwwaRF study is a model PtD process for the water treatment industry. The research project included a second workshop during which representatives from participating utilities, the Project Advisory Committee, and the research team collaborated on the development of a PtD model. The proposed PtD Process Model has four primary phases for integrating safety and health during capital project design and delivery. It also calls for the concurrent development of operating and maintenance procedures, and includes suggested metrics to help drive the process. The process phases are identified as follows:

1. Project specification and safety scoping
2. Intermediate design review
3. 90% review
4. Commissioning inspection.

The drafters developed objectives, recommended participants, identified process barriers, described activity mechanics, and proposed metrics for each phase. More detailed discussion of the process phases may be found in the Final Project Report.

One technological development that will likely have a major effect on PtD processes is the availability of 3-Dimensional (3-D) simulation software. Large engineering firms such as Black & Veatch have the capability to create 3-D virtual facilities that enable viewers to “tour” the planned project at will. This software facilitates participation by workers and management personnel in design reviews without having to have skill in reading blueprints. Participants can “walk” through a virtual process or facility and see a computer generated image of what the planned facility would look like. As clients become more aware of the availability of this powerful tool, it is likely they will choose to include it in project design specifications. Simulation software can help design teams quickly identify interferences, difficult access points, confined spaces, and work that will need to be performed at elevation.

Because utilities do not have competitors in the same sense that manufacturers do, they have one important opportunity that is rarely available in General Industry. Utilities can freely help each other and openly share technology. For example, two years before bringing a major new treatment facility on-line, Vancouver hired a staff of operators and sent them to work and learn at another utility that employed water treatment technology that was similar to the facility being planned and built. This provided Metro Vancouver with a team of experienced personnel who could participate fully in the design safety reviews and construction reviews that are integral to the PtD process. This same team developed a full set of safe operating and maintenance procedures prior to completion of construction, as well as accompanying training modules.

Finally, as suggested above, metrics must play an important role in encouraging PtD process development and implementation. PtD can effectively reduce injury risk, but the process will only be robust and effective if the designer team is held accountable for achieving this objective.

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