
Implementation Guide

# Prevention Through Design for Mechanical/Electrical/Plumbing Worker Safety

SHIP Grant Program
Safety and Health Investment Projects
SafetyGrants.Lni.wa.gov
Funding and support provided by the Department of Labor & Industries

UNIVERSITY of WASHINGTON

# Authors & Research Team

**University of Washington**
Hyun Woo “Chris” Lee, PhD, LEED AP BD+C
Laura Osburn, PhD

**Oregon State University**
John Gambatese, PhD, PE(CA)

**Valley Electric**
Jamie Stuart, WSO-RSD, CESCO, CHST

**Holmberg Mechanical**
Kyle Foley, CHST, Safety Director

Cover photo: Hermanson

# Acknowledgments

**Industry Advisory Council Members**

Ed Adams, *Electrical Administrator & Operations Manager, MacDonald-Miller*

Kyle Foley, *CHST, Safety Director, Holmberg Mechanical*

Troy Hendricks, *CHST Safety Director, Holaday-Parks*

Steven Merkel, *Safety Program Director, McKinstry*

Desiree Ropel, *Safety Manager, Hermanson*

Jamie Stuart, *Vice-President – Safety/Labor Coordination, Valley Electric*

Mindy Uber, *Senior EHS Director, Skanska*

**We would like to also thank the following for their help and support on this project:**

Joel Adair, *Safety Program Manager, McKinstry*

Fernando Aguilar, *Sheet Metal General Foreman, McKinstry*

John Andrew, *EHS Specialist, Boeing*

Nick Biesold, *Senior Safety Program Manager, McKinstry*

Mark Brewster, *Director of Operational Excellence, McKinstry*

Scott Chin, *Facilities Architectural Structural Civil Committee Chair, Boeing*

Jason Conolly, *Electrical and Controls Engineering Manager, Hampton Lumbe*r

Josh Curry, *Superintendent, Valley Electric*

Jeff Doan, *Facilities Engineering Senior Manager, Boeing*

Jaymes Fleming, *Detailing Manager, Holaday-Parks, Inc.*

Daryl Fonslow, PE, LEED AP, *Principal, Electrical Engineering, Stantec, Buildings*

Joe Forest, N*ational Energy & Technical Services Safety Program Director, McKinstry*

Wilder Hoxie, Sr., *Safety Program Manager. McKinstry*

Drew Johnson, *Virtual Construction Manager, Valley Electric*

Britin Linberg, CSP, *Safety Program Manager, McKinstry*

Erjay Manjares, *Facilities Engineering Senior Manager, Boeing*

Nathan Marsh, PE, LEED AP, *Engineering Manager, Holmberg Mechanical*

Matt Nielsen, PE, LEED AP, *Senior Mechanical Engineer, McKinstry*

Brian O'Connor, *Facilities Engineering Manager, Boeing*

Jim O'Dore, *Superintendent, Valley Electric*

Mark Pollock, P. Eng., *Global Product Manager, Littelfuse*

Clemens Rossell, *Facilities Civil/Structural Engineer, Boeing*

Boyd Sylvester, *Program Manager, McKinstry*

Justin Thayer, CSP, CHST, *Director of Safety, Puget Sound Chapter, NECA*

Bob Zweifel, EE, *Sales Engineer, Littelfuse*

# Table of Contents

Photo: MacDonald-Miller

# Introduction

It is believed that mechanical/electrical/plumbing (MEP) designers and contractors in Washington State can benefit significantly from the potential application of Prevention through Design (PtD) for the following reasons:

- First, according to the Center for Construction Research and Training (CPWR), the specialty trade contractors accounted for 58% of the total fatalities in 2010. Among various construction trades studied by CPWR, MEP construction workers indicated a relatively higher rate of injuries.[1] Specific to Washington State, the Bureau of Labor Statistics (BLS) shows that the accident and injury rates for the MEP industry were relatively higher than the average of the nationwide construction industry in 2015.[2]
- Second, many MEP contractors in Washington State possess unique design–build capability, which enables them to influence design decisions and achieve a high level of coordination between designers and field personnel. Thus, they are well positioned and capable of implementing PtD effectively and efficiently, with proper education and guidance.

In response to these identified needs, this PtD Guide aims to support MEP designers and contractors in Washington State, when implementing the PtD concept to improve worker safety, by providing procedural guidelines, PtD best practices, and a protocol for effective communication and coordination between project stakeholders. This guide is intended to be used by MEP designers and contractors, as well as General Contractors (GCs) to implement the PtD process into their firms and projects. Architects, owners, maintenance personnel, and structural engineers will also find this guide useful as a tool for implementing PtD and identifying when and how to engage MEP designers and contractors during the PtD process.

This PtD Guide has the following structure:

### Chapter 1: The PtD Process: The Five Phases of PtD

This chapter provides information on the phases and steps of the PtD process from Hazard Identification to Learning. The chapter lists what stakeholders are involved in each step, as well as case studies that illustrate each phase in the process. The chapter also provides a discussion on how differences in project delivery type impact PtD implementation.

### Chapter 2: Stakeholder Engagement

This chapter discusses how to communicate the value of PtD to different stakeholders and how to identify and engage the right stakeholders at the right time in the PtD process.

### Chapter 3: Communication and Decision-Making

This chapter provides information on three key components in communication and decision-making for success in PtD implementation: communication processes that support collaboration, information technology infrastructure, and PtD documentation tools.

### Chapter 4: Changing the Industry

This section provides recommendations from industry professionals on how to make large-scale change that will help advance PtD implementation in the MEP and construction industry.

### Chapter 5: Resources

This section provides a list of resources on important safety-related codes, PtD resources, and online tools.

### References

### Appendix A: Templates

This section provides a series of PtD templates that firms can adopt or adapt to help implement the PtD process.

### Appendix B: Fact Sheets

This section provides a series of six fact sheets consisting of case studies where PtD practices were used on different projects. These fact sheets provide an array of information on how safety was addressed through design on MEP projects.

### What is PtD?

Prevention through Design (PtD) or "safety in design" is the practice where safety is considered and hazards eliminated throughout the design process.[3]

PtD "encompasses all of the efforts to anticipate and design out hazards to workers in facilities, work methods and operations, processes, equipment, tools, products, new technologies, and the organization of work. The focus of PtD is on workers who execute the designs or have to work with the products of the design."[4]

PtD is implemented through identifying hazards and assessing risks in order to anticipate, prevent, or minimize (i.e., "design out") workplace injuries, fatalities, and illnesses.[5] To do PtD successfully means considering not only the design of tools, equipment, materials, and structures, but also designing safe work processes, such as equipment installation, access, maintenance, and use.

A large body of research suggests that the design process has a strong impact on safety in construction.[6] To understand why PtD can be an extremely effective method for eliminating and controlling hazards, minimizing risks, and increasing worker safety, we can look to the Hierarchy of Controls.[7] (See Figure 0.1.) The Hierarchy of Controls represents the range of control solutions from the most effective (top) to the least effective. PtD is the most effective because

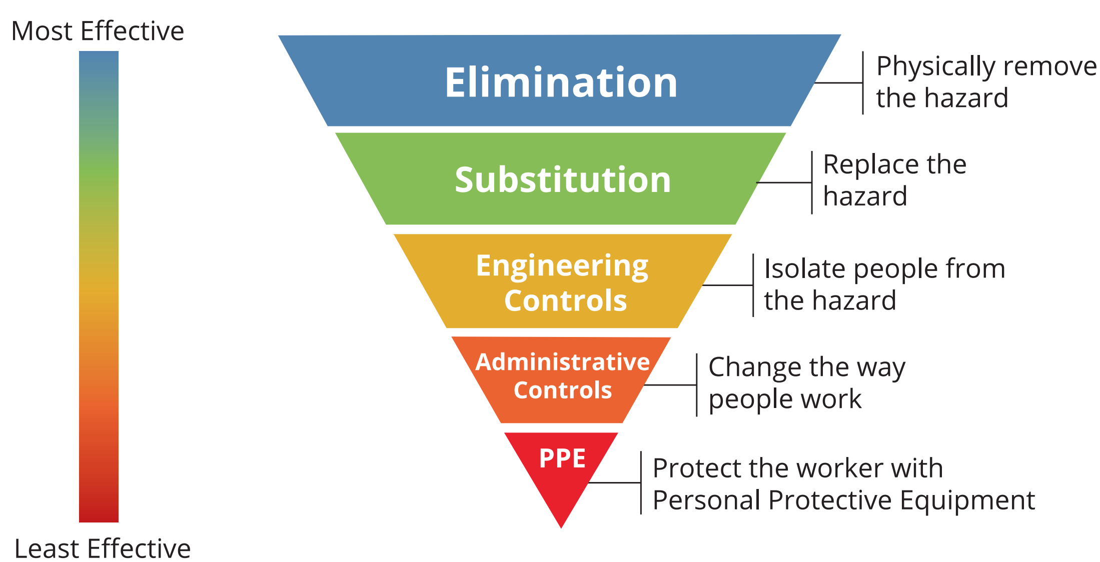



Figure 0.1. The Hierarchy of Controls (Source: NIOSH).

it aims to eliminate hazards. In other words, PtD processes, where the design approach eliminates the hazard and the need to use lower level controls, are more effective than depending on engineering, administrative controls or PPE as the primary mode for ensuring worker safety.

### Whose safety is being addressed?

Designing for safety means considering the safety and  and health of anyone who could be impacted by design throughout a project's lifecycle.[8] This means considering MEP installers, end users, as well as the safety of the general public. Implementing PtD includes thinking about the design with respect to worker access, egress, proper lockout locations, and proper tie-offs.

### The Value of PtD for MEP

PtD offers a significant value for owners in terms of lifecycle costs. There is a direct relationship between when one integrates safety during a project's lifecycle and the cost of integrating safety. (See Figure 0.2.) It is far easier and less expensive to make safety a key consideration during the planning and design process than after construction and during building operations.[9]

Photo: McKinstry

PtD, as a process that requires collaborative, interdisciplinary communication, may also enhance creativity, which can potentially lead to organizational and technological innovations.[10] In this way, the implementation of PtD can provide owners value on projects that extend beyond construction worker safety.[11]

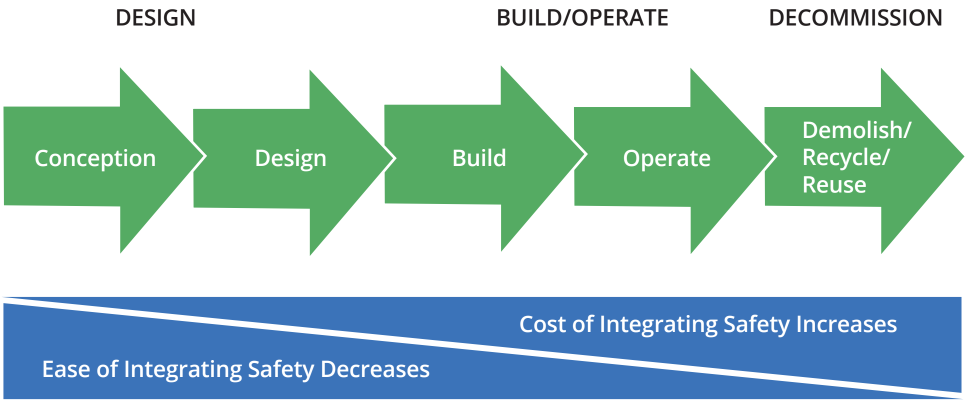



Figure 0.2. The relationship between the cost and ease of integrating safety. Figure adapted from Philip Hagan, John F. Montgomery, and James T. O'Reilly, eds., *Accident Prevention Manual for Business & Industry: Engineering & Technology*, 14th edition (Itasca, IL: National Safety Council, 2015).

Photo: Valley Electric

Chapter 1

# The PtD Process: The Five Phases of PtD

## The Five Phases

The PtD process has five key phases:

1. Hazard Identification
2. Risk Assessment
3. Design Revision
4. Implementation
5. Learning

Within each phase are a set of different tasks that are to be carried out by one or more of the following stakeholders:

- Architect
- Structural Engineer
- MEP Designer
- MEP Contractor (Safety Professional/Foreman)
- General Contractor (GC)
- Owner/Maintenance Personnel

It should be noted that the PtD process is a sequential process that is also cyclical. After PtD implementation is complete, the MEP contractor documents lessons learned within their firm and shares them with other stakeholder groups for future projects. (See Phase 5 for more.)

Phases can also be conducted in parallel depending on the project delivery process. For example, for projects using Design-Build, the boundaries between phases may be blurred because there would be more opportunities for multiple stakeholders to work closely together and collaborate on safety issues, such as assigning hazards for each component while also assigning risks for each hazard or conducting a review of a risk assessment and concurrently making design suggestions to eliminate or mitigate those risks.

While the PtD process described in this chapter consists of best practices, each organization should aim to adapt the process in the way that best fits their current practices within specific project conditions and organizational resources. For example, an MEP design-builder may be able to blur the lines between the Hazard Identification Phase and the Risk Assessment Phase as both MEP designers and MEP field personnel may have better chances to work together on projects, such as gaining safety feedback during design milestone deliveries. We expect every company to learn from this guide, customize the process that best fits their company and the project, and come up with their own practices.

### The PtD Process and Project Delivery Differences

Project delivery method is a driving factor that determines how easy it is to implement PtD practices.

More collaborative forms of project delivery, such as Design-Build and Integrated Project Delivery (IPD), will provide greater opportunity to integrate safety in design early in the design process and into construction, as the design phase often overlaps with construction in these forms of delivery. Project delivery contracts such as Plan-Spec, or Design–Bid-Build, provide fewer opportunities for MEP contractors and their safety professionals to be involved during the design phase. However, the full PtD process can still occur with Plan-Spec as there are still opportunities available, even after the initial design process is complete, through redesigning for revisions.

This guide presents two versions of the PtD process that apply to two different types of overall project delivery processes: 1) a collaborative delivery process (e.g., Design-Build) and 2) a Plan-Spec process.[12]

The phases remain the same in each version of the PtD process and have common steps, however, there are some small differences between the two processes that center on the stakeholder groups that can be involved in each step and the process through which design revisions can be made. These differences will be called out within each phase of the PtD process.

The key difference between the two versions of the PtD process is what occurs prior to entering Phase 1. (See Figures 1.1-A and 1.1-B.) On Design-Build projects, the architect and structural engineer develop the initial design and specifications that are then handed off to the MEP designer who develops the initial MEP design. Based on the developed MEP design, the MEP contractor will start the PtD procedures in the Hazard Identification Phase. However, the design itself is not necessarily complete, and it can be easier to make larger design revisions to MEP components.

In Plan–Spec projects, once the MEP designer develops the design, the design is considered complete. Then, the MEP contractor receives and reviews the design and determines whether hazards have been identified and mitigated appropriately. If yes, the MEP contractor can move immediately to Phase 4 and develop a construction plan. However, if hazards have not been identified and there are potential opportunities for creating a safer design, the MEP contractor enters Phase 1: Hazard Identification.

As noted previously in the guide, the following are suggested best practices. Firms will need to consider their own current work practices, the opportunities available on specific projects, and the resources that they have available to implement the different phases. Firms may choose to customize the following phases, if needed, and use the procedures within the phases that work best for them. ■

Photo: MacDonald-Miller

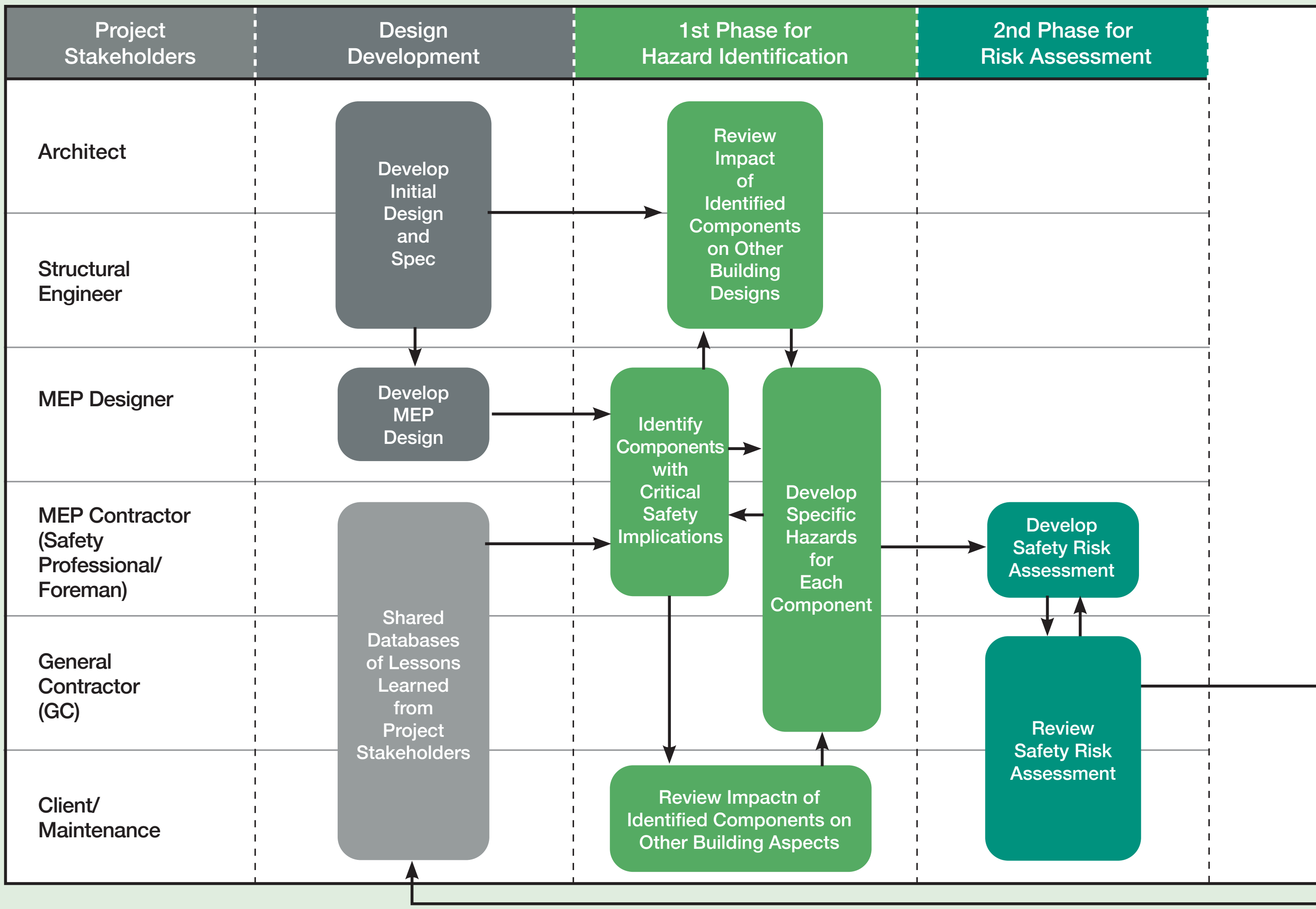
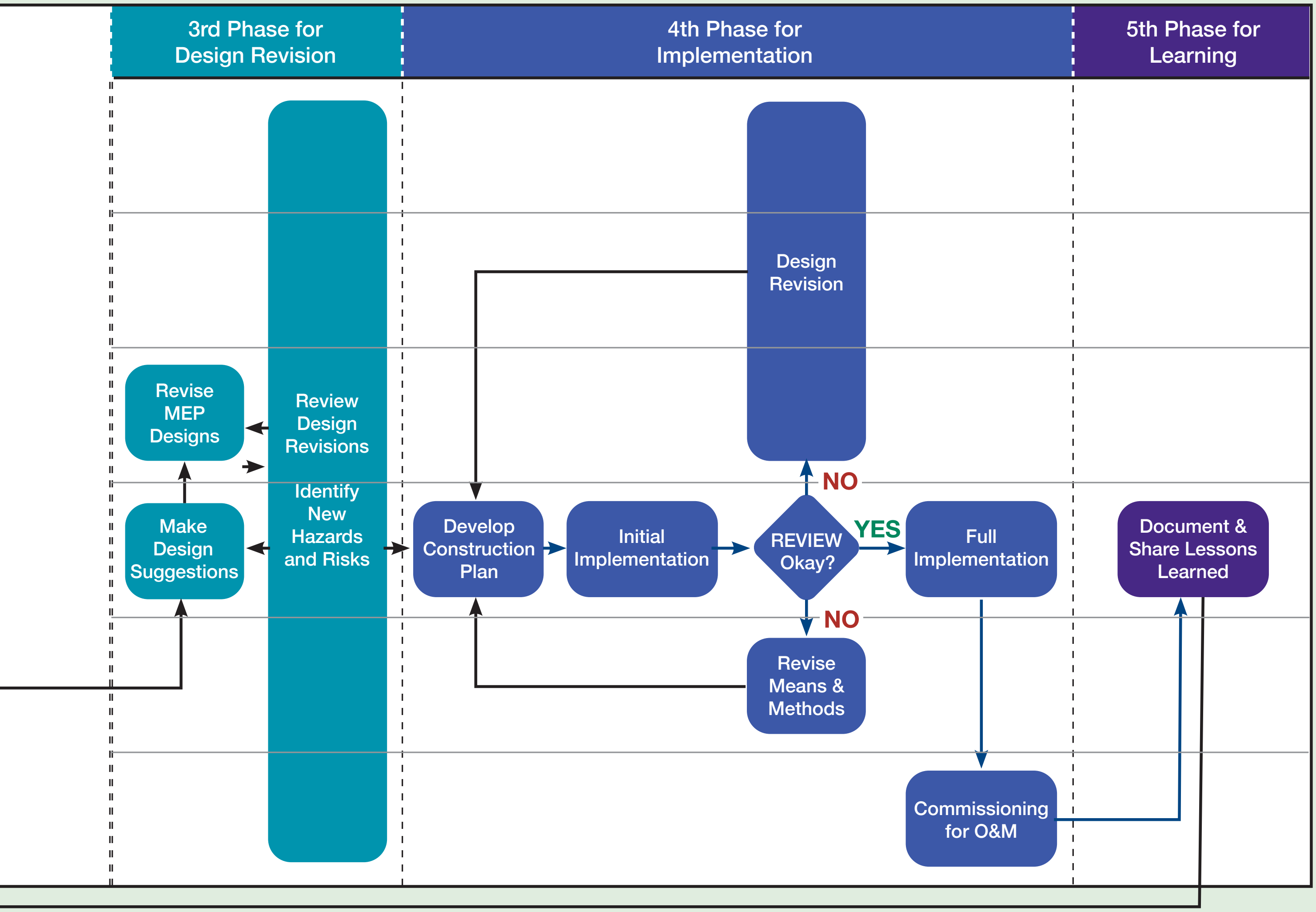



Figure 1.1-A. PtD Process Map for Design–Build.



3rd Phase for Design Revision
4th Phase for Implementation
5th Phase for Learning
Review Design Revisions
Identify New Hazards and Risks
Revise MEP Designs
Make Design Suggestions
Design Revision
Develop Construction Plan
Initial Implementation
REVIEW Okay?
NO
YES
NO
Full Implementation
Revise Means & Methods
Commissioning for O&M
Document & Share Lessons Learned

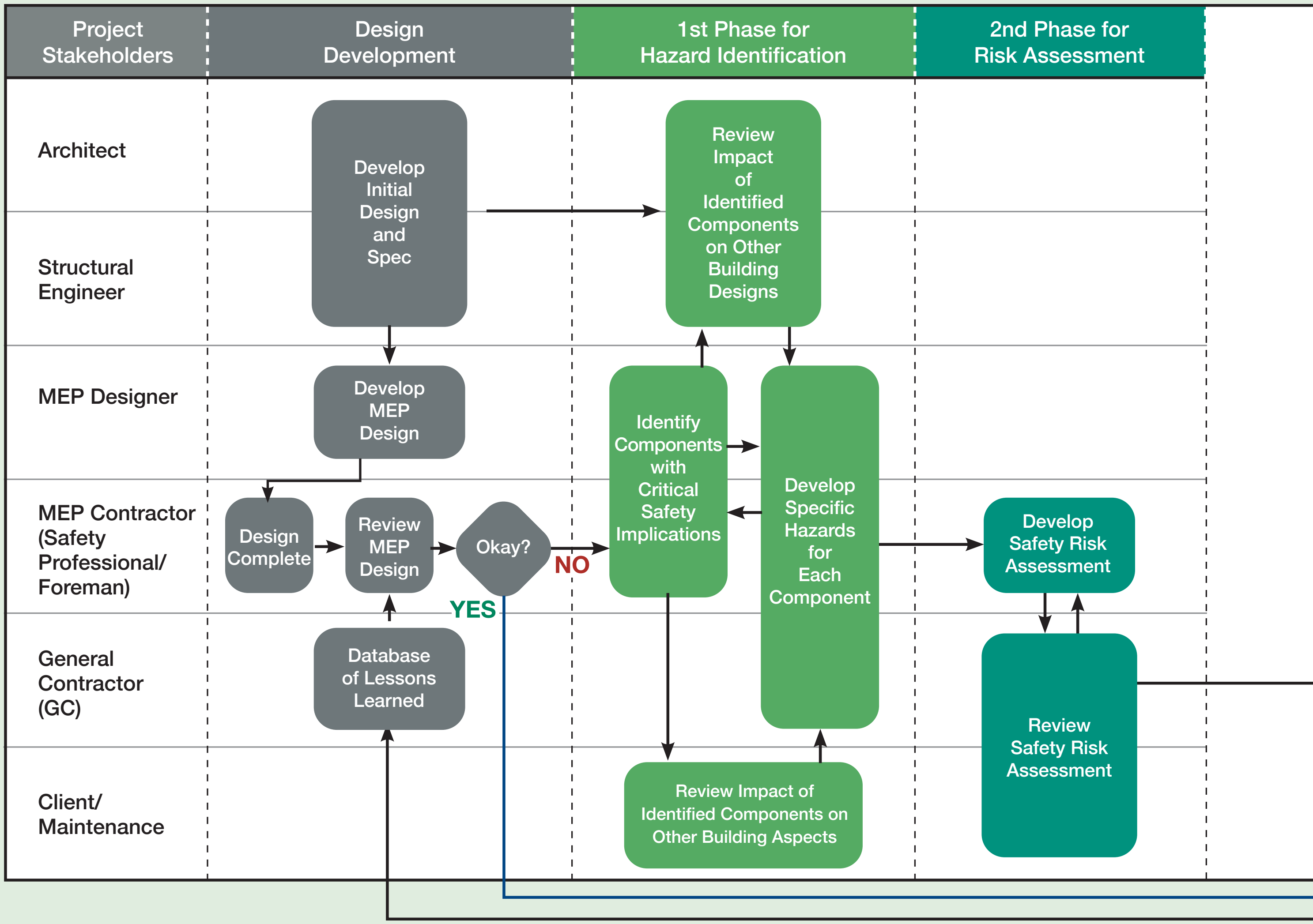
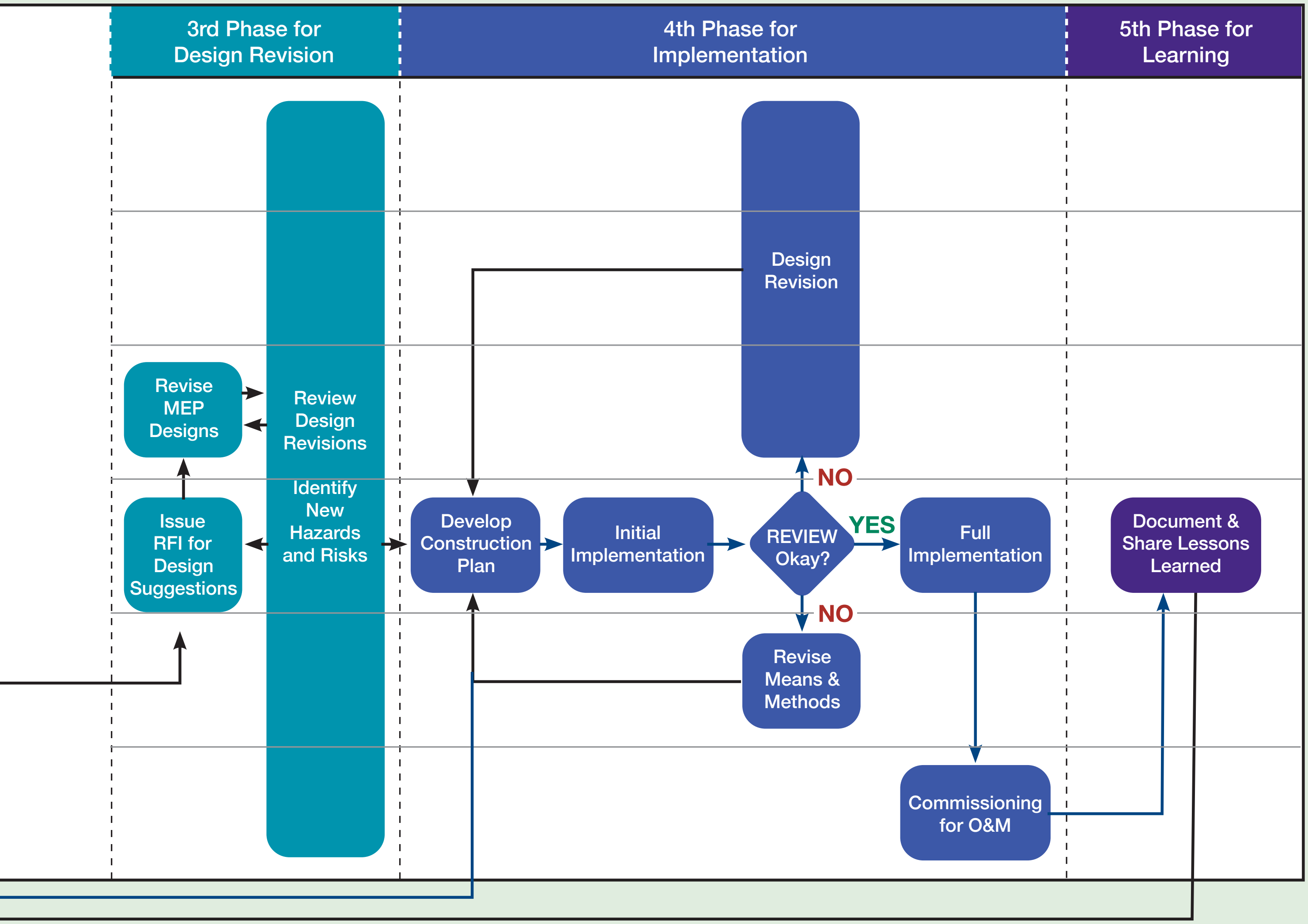
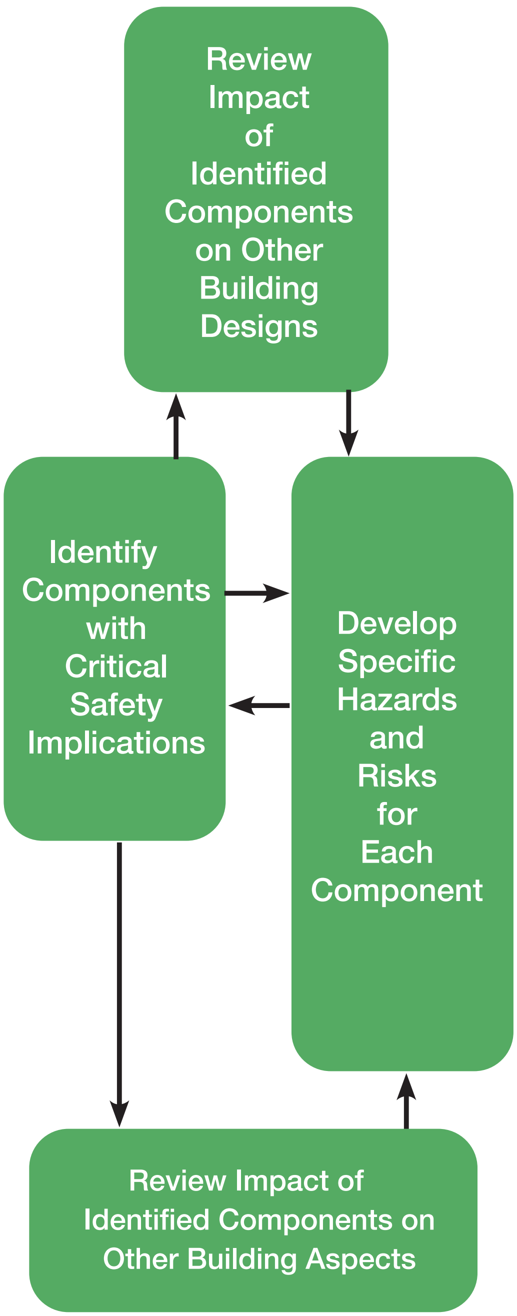



Figure 1.1-B. PtD Process Map for Plan–Spec.



3rd Phase for Design Revision
4th Phase for Implementation
5th Phase for Learning
Design Revision
Revise MEP Designs
Review Design Revisions
Identify New Hazards and Risks
Issue RFI for Design Suggestions
Develop Construction Plan
Initial Implementation
REVIEW Okay?
NO
YES
NO
Full Implementation
Document & Share Lessons Learned
Revise Means & Methods
Commissioning for O&M

# Phase 1: Hazard Identification




Hazard identification is the process of identifying and tracking hazards that could impact the safety of MEP construction workers (e.g., installers), MEP maintenance personnel, users of MEP systems, and the general public. The top four construction hazards identified by the Occupational Health and Safety Administration (OSHA) are falls, struck-by, caught in-between, and electrocutions.[13]

Examples of potential hazards that may need to be identified and tracked are places where potential falls could occur (e.g., installing ductwork, working from heights), the size and weight of materials that need to be lifted, and arc-flash hazards.

It is important to identify and track hazards so that designers can think through the potential hazards that may occur throughout the building's lifecycle (during and after construction) and determine which hazards could be removed or mitigated through changes in the MEP design or building design by applying the PtD concept.

Phase 1 has four key steps:

1. Identify components with critical safety implications
2. Review the impact of the identified components on other building aspects
3. Review the impact of the identified components on other building designs
4. Develop specific hazards for each component

### *Step 1: Identify components with critical safety implications*

Stakeholders involved:

- Design–Build: MEP Designer and the MEP Contractor (Safety Professional/Foreman)
- Plan–Spec: MEP Contractor (Safety Professional/Foreman) only

This procedure involves identifying a list of MEP components with the potential for significant safety implications. For example, switchgear can be flagged for an arc-flash hazard. If you are working on a Design–Build project, this process can be an opportunity for the MEP designer and the MEP contractor to exchange information and learn from one another about MEP design practice and potential hazards that could occur on the jobsite.

*Step 2 and 3: Review the impact of the identified components on other building aspects and designs*

Stakeholders involved:

Step 2: All project delivery types: Owner/Maintenance Personnel

Step 3: All project delivery types: Architect/Structural Engineer

Steps 2 and 3 of the Hazard Identification Phase are similar in terms of the process, but involve different stakeholder groups. For Step 2, the owner representatives, including identified maintenance personnel who will work on a component after installation for maintenance and repairs, should review the potential impact of the hazard on other non-design-related aspects of the building such as maintenance practices. For Step 3, the architect and structural engineer should review the potential safety impact of the hazard when the component has been used on other building designs such as structural or architectural components.

*Step 4. Develop specific hazards for each component*

Stakeholders involved:

- Design Build: MEP Designer, MEP Contractor (Safety Professional/Foreman), GC
- Plan–Spec: MEP Contractor (Safety Professional/Foreman) only

The person identifying hazards should refer to a list of hazard categories and document any hazards identified. Documentation of hazards can be done using a simple checklist and/or using 3D modeling tools, such as Building Information Modeling (BIM).

Take time to think through the work or workflows for MEP construction workers as well as MEP maintenance personnel. Ask yourself:

- What hazards may exist during a component's installation?
- What hazards could exist when the component is in use, or being maintained or repaired?
- What hazards could exist during potential renovations?[14]

This final step of hazard identification should also take into consideration any related safety regulations and manufacturer specs for each component. Once hazards have been identified for a component, assign the hazard to the component. ■

CASE STUDY

**Design Hazard Analysis Program**

One MEP firm has standardized its hazard identification using safety cone icons in BIM. The design lead or engineer will identify a potential hazard in the BIM model to identify safety measures that can be used on site, or opportunities to mitigate or remove the hazard through design. Where the hazard is identified, the design lead or engineer will place a safety cone icon. (See Figure 1.2.) The model or 2D drawings based on the model are then sent to the superintendent and/or project manager to develop a safer design or mitigation measures in response to the hazard. On Plan–Spec projects, the team will send a Request for Information (RFI) to the owner, architect, and GC about design suggestions to mitigate or remove any identified hazard.

Source: Valley Electric

Figure 1.2. Safety cones in BIM model identifying hazards.

# Phase 2: Risk Assessment



Photo: Enespro

Risk assessment is the process of determining and quantifying the risks of possible harm associated with each hazard throughout the building's lifecycle. It is an important step in the process as it allows risks to be quantified. This process will help to determine the hazards that need to be addressed first and to prioritize potential design changes that will need to be made in Phase 3.[15]

This phase has two key steps:

1. Develop safety risk assessment
2. Review safety risk assessment

### *Step 1: Develop safety risk assessment*

Stakeholders involved:

- All project delivery types: MEP Contractor (Safety Professional/Foreman)

Once hazards have been identified, the MEP contractor should conduct a safety risk assessment of each hazard for each MEP component. A risk assessment is based on the severity of harm that could occur and the likelihood or probability that harm could occur in order to prioritize what hazards require design changes and what hazards should be addressed first. The assessment should consider risks of specific types of MEP design, component, and equipment, which could occur during installation, as well as risks that could occur during maintenance and repair.[16] When conducting a risk assessment for each MEP component, ask yourself:

- What is the likelihood of an injury occurring due to the hazard?
- What is the likely severity of an injury that occurs?
- What types of injuries could occur during installation?
- What types of injuries could occur during a component's use, maintenance, and repair?
- What are the consequences if an injury did occur?[17]

There are a number of different tools and different methods for calculating risk. For example, a risk assessment allows the MEP contractor to give each hazard a risk level that can be calculated by multiplying the severity of an injury and the probability of an injury occurring.[18] (For an example, see Appendix A.2: Risk Evaluation Form.) Risks can also be calculated using a design risk calculator.[19] For example, the Safety in Design Risk Evaluator, or SLiDeRUlE (*www.constructionsliderule.org*) is an online calculator that can help MEP contractors (as well as designers) assess the risk of specific MEP components.

***Step 2: Review safety risk assessment***

Stakeholders involved:

- All project delivery types: GC, Owner/ Maintenance Personnel

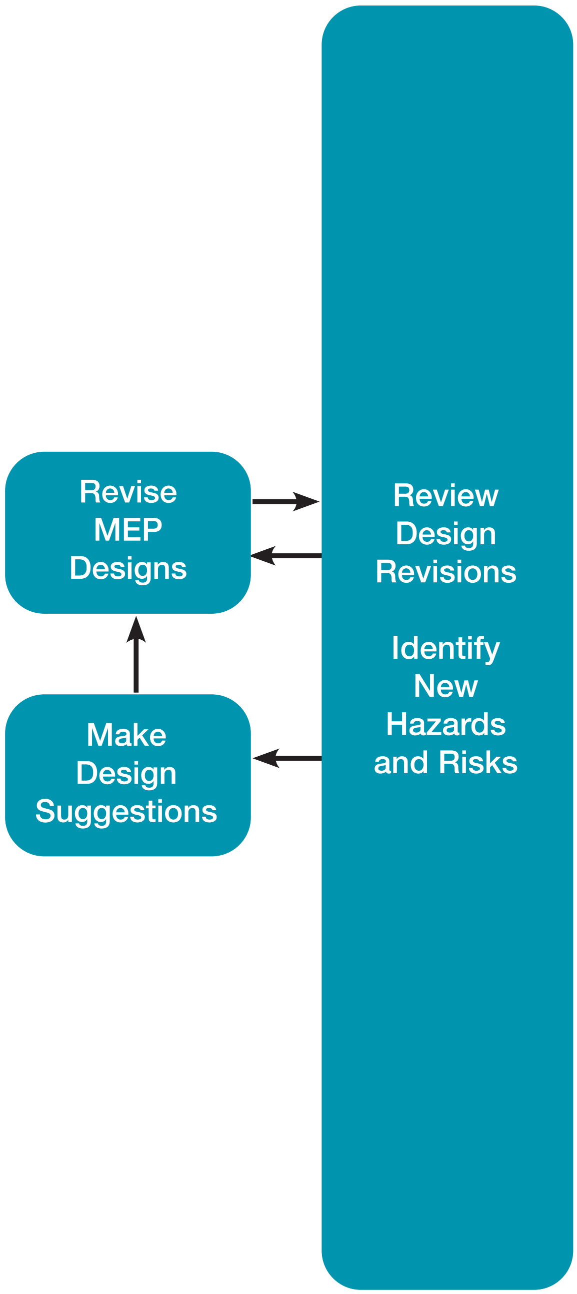
After the safety risk assessment is complete, the risk assessment should be reviewed by the GC and owner/maintenance personnel. Using tools that help both assess and document risks, such as a risk matrix, will help to convey important information across different stakeholder groups and help to generate important feedback from the GC and owner/maintenance personnel that the MEP contractor and designer will need to make any design suggestions based on the risk assessment. ■

**CASE STUDY**
**Design Safety Review Risk Assessment**

One MEP firm has been working to standardize their design safety review process using a Design Safety Review Checklist to manage and assess the overall risk of different MEP systems and determine whether design revisions may be needed. (See Appendix A.4: Design Safety Review Checklist.) The tool lists specific systems in a design and asks questions that will help spark conversations with team members to assess the risk of the design and opportunities for safer designs. In this way, the document acts as a discussion point for the company's internal risk assessment of a project, as well as providing a section where one can detail any design additions that pertain specifically to safety or design suggestions.

Photo: McKinstry

# Phase 3: Design Revision




Design Revision is the process of revising the design to eliminate the hazards identified and assessed in the prior phases. The hazards with the highest level of risk that could be eliminated through design should be addressed first. This process also includes identifying and assessing any new hazards that could occur due to new revisions made in the design. This process is important because it prioritizes eliminating hazards over other forms of control, such as changing the way people work around the hazards or the use of PPE, making the project field site safer for MEP construction workers and building operations safer for MEP maintenance personnel.[20]

This phase has three key steps:

1. Make design suggestions (Design–Build)/ Issue RFI for design suggestions (Plan–Spec)
2. Review design revisions and identify new risks
3. Revise MEP designs

For this phase, the process for Step 1 is different depending on whether you are working on a Design–Build or Plan–Spec project. While Design–Build projects allow for design suggestions to occur prior to the completion of the final design, Plan–Spec projects require using the RFI process to propose design suggestions.

### *Step 1: Make design suggestions (Design–Build)/Issue RFI for design suggestions (Plan–Spec)*

Stakeholders involved:

- All project delivery types: MEP Contractor (Safety Professional/Foreman)

The MEP contractor should make design suggestions that consider the safety of MEP construction workers, MEP maintenance personnel, and even the public. The MEP contractor (safety professional/foreman) can provide design suggestions based on their personal expertise, or by using a database of safe designs or online resources that provide safe design guides or safe design case studies.[21] For example, the Construction Industry Institute's "Design for Construction Safety Toolbox" is a software tool consisting of 430 design suggestions.[22] Appendix B of this guide also has a series of case studies on safe designs specifically for MEP workers. Design suggestions should then be documented for design review. In the case of Plan–Spec projects, documentation should be done through an RFI.

### *Step 2: Review design revisions and identify new risks*

Stakeholders involved:

- All project delivery types: Architect, Structural Engineer, MEP Designer, MEP Contractor (Safety Professional/Foreman), GC, Owner/Maintenance Personnel

> **CASE STUDY**
> **A Model for Collaborative Review**
>
> In one MEP firm, the Safety Program Director had the opportunity to experience a design review meeting that encapsulated the collaborative nature of the PtD process. The Safety Program Director was invited to a meeting about a heat exchange system that had some safety concerns. At the meeting were the lead detailers, lead engineers, a plumbing superintendent, and their firm's executive sales director. Together, using a 3D model of the system and images of engineering schematics as focal points for discussion, they were able to identify safety and health concerns about the system for both MEP workers and future maintenance personnel. They were also able to discuss what the construction plan might look like and map out the follow-up process. The sales director was able to communicate the safety concerns and possible design revisions to the GC and owner team. All of these comments were then documented on the actual plans of the project and provided to the engineers and detailers for future design modifications.

A structured review process of all suggested design revisions should be conducted for all the proposed design changes. This process could involve internal reviews with the design team (e.g., architect, structural engineer, MEP designer) followed by design reviews with other team members, such as the GC and owner/maintenance personnel.[23] Regardless of how the design review process is structured on a project, all project stakeholders should be involved in the process so that they can provide expertise and input about the design change and any potential impacts it might have, including identifying new hazards that the design change may create. Reviews can compare multiple design alternatives and should focus on the features of the new design, including safety implications during installation, manufacturer specs of changes to equipment, compliance of the design with local building codes and permits, and potential operational and maintenance hazards.[24] Project teams can use a Design Review checklist to help the team focus on the design's potential impacts to safety during the review. (For an example, see Appendix A.5: PtD Design Review Checklist.) All review comments, recommendations for revising the design, and any final design decisions should be documented for the MEP designer. (See Chapter 3 for more on PtD documentation tools.)

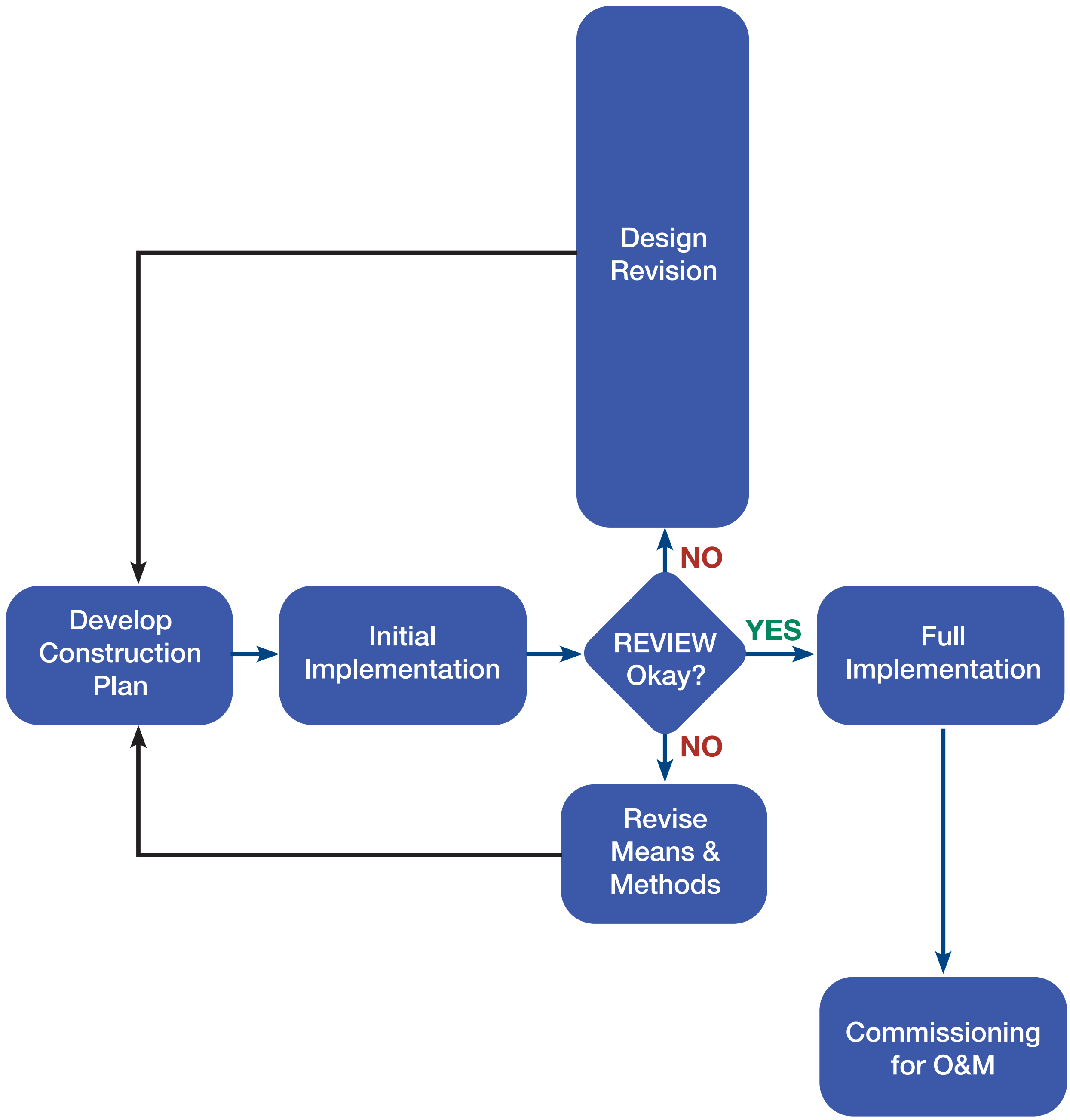
### *Step 3: Revise MEP designs*

Stakeholders involved:

- All project delivery types: MEP Designer

After gathering feedback and design decision-making from the design review process, the MEP designer should revise the MEP designs accordingly. ■

# Phase 4: Implementation



The Implementation Phase involves selecting and implementing the means and methods for safe installation of MEP equipment and materials, construction equipment that may be needed for installation, and safe coordination and sequencing of MEP trades. This process is an important part of ensuring that MEP equipment and materials installation can be carried out safely as well as identifying any potential, as yet unforeseen hazards that could impact MEP design or the means and methods for implementing the MEP design.

This phase has six key steps:

1. Develop construction plan
2. Initial implementation
3. Review construction plan after initial implementation
4. Revise design and/or means and methods
5. Full implementation
6. Commissioning for Operations and Maintenance (O&M)

### *Steps 1-5: Developing, reviewing, revising, and implementing the construction plan*

The first five steps concern developing a construction plan that is reviewed for safety and then fully implemented on the construction site. For all project delivery types, the MEP contractor should lead the development of the construction plan and how the plan would be implemented, and then review and revise the plan as needed. If the construction plan is deemed safe for MEP workers, then the MEP contractor can proceed to full implementation of the plan. If the review does not appear safe due to unsafe design and/or unsafe means and methods, then the plan requires revisions in terms of design and/or means and methods. The project team's designers (architect, structural engineer, MEP designer) should be involved in any design revisions required to ensure worker safety, and the GC should make any revisions to means and methods to ensure that MEP installation and sequencing of the trades can be done safely. The revised construction plan should then be reviewed again by the MEP contractor before moving to the full implementation stage.

### *Step 6: Commissioning for O&M*

Stakeholders involved:

- All project delivery types: Owner/Maintenance Personnel

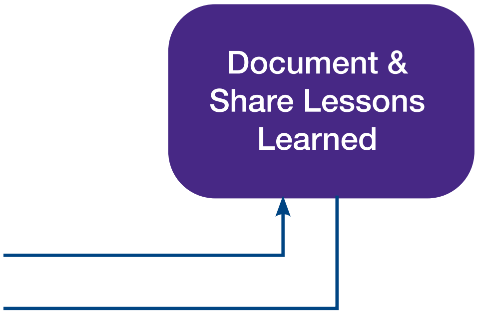
During the commissioning phase of the project, the owner/maintenance personnel can conduct a safety review of each MEP system and note any remaining hazards that require control measures and that those control measures are installed and operating as planned.[25] ■

### CASE STUDY
### Creating and Reviewing | A Construction Work Plan

One firm has a standardized process for ensuring safety in the construction process. The work plan determines how MEP equipment will be installed, tools and equipment required for installation, and sequencing of activities. The plan is then submitted and reviewed by the firm's superintendents, project management, and health and safety team. After review, they can begin to implement the plan in the field.


Photo: Enespro

# Phase 5: Learning




The Learning Phase consists of the MEP contractor developing and sharing a database of PtD lessons learned that can influence future projects. This step is an important part of PtD as it can help the MEP contractor's company, as well as future project teams and owners, improve how they implement PtD processes on the next project as well as gather information on safe design solutions.[26]

This phase has two key steps:

1. Document and share lessons learned
2. Using a shared databases of lessons learned from previous projects

***Steps 1 and 2: Document and share lessons learned and using a shared database of lessons learned from previous projects***

The MEP contractor should document all PtD lessons learned on the project. This step can include documentation of PtD processes throughout the design and construction process (what worked and what could be improved upon) as well as potential design solutions to specific hazards.

Once all lessons learned are documented and placed in a database, they should be shared within the MEP contractor's firm, as well as with the GC. On Design–Build projects and other collaborative forms of project delivery, the database of lessons learned can be shared to the owner as well as designers on the project.

On future Design-Build projects, the database should be used by the MEP contractor, GC, and owner/maintenance personnel to improve hazard identification, assess the risk associated with hazards, and choose design revisions as well as how the PtD processes (the four first phases) are carried out on a project. For those working on future Plan–Spec projects, the MEP contractor and the GC would be the key stakeholders who can use the lessons learned database after the design is complete. ■

### CASE STUDY
### Passing on Learning

A Virtual Design and Construction (VDC) Manager from one firm with over twenty years of experience in the role has picked up a lot of experience and expertise on how to design things safely and efficiently, learning from both project successes and mistakes. For specific types of mechanical design work, he trains his team, many of whom often do not have in-the-field experience, about common hazards with installing ductwork and safe design solutions. (For more on this case study, see Appendix B.2: Fall Protection: Designing Shafts for Worker Safety.)

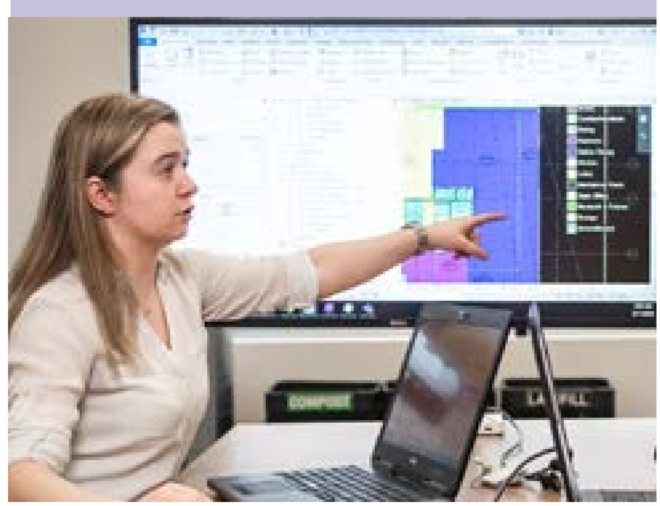


Photo: McKinstry

Photo: Valley Electric

Chapter 2

# Project Team Engagement

PtD requires extensive interaction with various project team stakeholders beyond MEP contractors and MEP designers.

Owners, maintenance personnel, architects, structural engineers, and GCs all need to be engaged in different phases and in different steps of the PtD process. Critical success factors for PtD include getting buy-in on the importance of implementing the PtD process and ensuring that everyone has the information they need at the right time so their expertise can be used to achieve safe design outcomes.

## Getting buy-in from owners, architects, and GCs

At the outset, MEP safety professionals will need to communicate the value of the PtD process or the value of specific design options that would eliminate hazards related to specific activities or projects. How to achieve this will largely depend on which stakeholders to talk to, their goals on the project, and their own organization's values.

In particular, when communicating to owners and end users of a project the importance of PtD and safer designs, MEP safety professionals could tie PtD to the long-term liability and costs of the building's maintenance. Safety incidents can be costly, and owners could be held partially liable for the losses incurred. PtD can produce savings for the owner if safe designs benefit not only MEP installers during construction, but MEP maintenance personnel as well. For example, installing permanent anchors into a ceiling for ductwork installation may not only benefit the person installing the ductwork, but also maintenance personnel who later need to maintain the ductwork.

Likewise, safety may be a goal of a specific project or a key value in an architect, owner, or contractor's organization. In these cases, MEP safety professionals can communicate how PtD implementation and PtD processes for MEP workers align with the project's or organization's own values.

Overall, the key lies in effective communication and building relationships of trust between stakeholders.

*It's conversations. It's coaching. It's influence. It's relationships. That all plays a key part. And the push for more safety when actually building the job. It's just getting them to think up front and spending the money up front, and the systems needed to do that.*
*—MEP Safety Director*

It is important to understand what the needs and goals are of different stakeholders and then to reflect those needs and goals when engaging in conversations about PtD implementation and safe design with owners, architects, and GCs.

### Getting the right people at the right time

"Getting the right people at the right time" is a common expression for the need to identify who has the expertise needed to make a decision and having them in the room when a decision needs to be made. In the PtD process, there is a need to determine the right stakeholders needed in each phase. The PtD process described in Chapter 1 outlines key stakeholders required for each step, but there may also be other stakeholders, such as specific trades (e.g., concrete, structural steel, drywall, roofing), that may also need to be in the room to provide their expertise on specific hazards, risks, design options, or the implementation plan.

The first step is to identify the person who will have the role and responsibility as the point person for different PtD phases and steps. A question to answer is: Who will be the responsible parties from the architecture, structural engineering, and GC team as well as from the owner side during the different phases of the PtD process?

The second step is to determine who has the needed information for specific issues that arise in the PtD process. Different people will have different sets of expertise that will be useful at different points on the project. The key considerations are:

- Where are you in the process?
- What specific issue or information requirement needs to be addressed?
- Who has the needed information or is the point person to direct you to who has the needed information?

It is also important to assess different stakeholder's knowledge on health and safety decision-making.[27] An MEP contractor may want to give engineering detailers or engineering designers guidance for when they should contact a safety professional for input on a design, with a question such as, what types of hazards should they look out for and what items may need review by safety professionals? Provided in Table 2.1 are a few examples of when MEP safety professionals may want to engage stakeholders and reasons why their engagement is important.


Photo: McKinstry

Table 2.1. Examples of when to engage stakeholders in PtD.

| WHEN TO INVOLVE | WHO TO ENGAGE | WHY |
|---|---|---|
| ▪ Identifying components with critical safety implications (Phase 1)<br>▪ Developing specific hazards for each component (Phase 1) | ▪ MEP detailers | ▪ To provide input into hazards on project, to learn about MEP design strategies. |
| ▪ Reviewing impact of components on other building aspects (Phase 1) | ▪ Maintenance personnel | ▪ To gain input on safety issues concerning equipment placement, access, and what safety apparatuses to install. |
| ▪ Reviewing impact of components on other building designs (Phase 1) | ▪ Architect and structural engineer | ▪ To gain input on safety issues concerning equipment that has been used on other building designs. |
| ▪ Making design suggestions (Phase 3) | ▪ MEP contractors | ▪ To make design suggestions that consider MEP worker safety. |
| ▪ Reviewing design revisions (Phase 3) | ▪ Architect, structural engineer, MEP designer, MEP contractor, GC, owner/ maintenance personnel | ▪ To provide feedback on design options on potential equipment installation hazards, shaft sizes, and safety.<br>▪ To learn about other design concerns and needs. |
| ▪ Developing construction plan (Phase 4)<br>▪ Revising means and methods (Phase 4) | ▪ Other trades and GC | ▪ To gain input on sequencing and safety between trades. |
| ▪ Conducting construction plan meetings (Phase 4) | ▪ Contractor, MEP designer, architect, structural engineer, owner/maintenance personnel | ▪ To provide safety feedback and to gain familiarity with construction plans. |

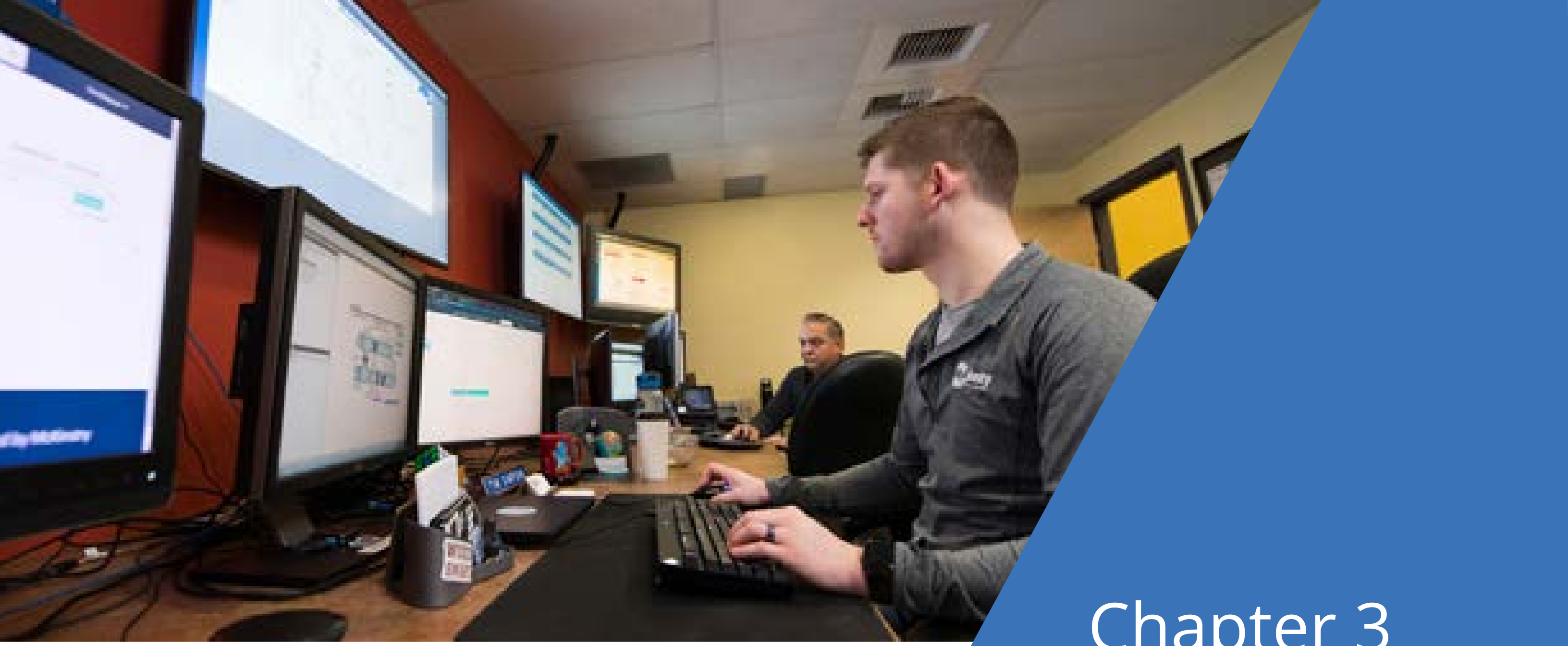


Photo: McKinstry

Chapter 3

# Communication and Decision-Making

Communication is critical for successful implementation of the PtD process.[28] The free flow and ongoing documentation of communication and information ensures that:

1. Hazards and risks are assessed and tracked, and this information is integrated into safe design options.
2. Design options are not only reviewed but that review comments will be considered and integrated into design revisions.
3. Any changes made to the design that affect safety will be shared when developing the construction plan and during its implementation.

Having established communication infrastructure, processes, and tools will also ensure that any lessons learned during the PtD process on past projects, including what design options and forms of implementation were successful or unsuccessful, will be documented and will inform future projects.

Communication is also key for ensuring that information about hazards, risks, design options, implementation, and lessons learned are shared in a timely manner when the information can have the most impact on design. For example, when those with construction/safety experience can communicate potential hazards to MEP designers about design changes—such as providing designers with a list of components that may have potential hazards, or meeting with designers to discuss the potential hazards of specific components—MEP designers will have greater insights about the safety implications of different design decisions. Likewise, if MEP designers are able to talk with the GC or MEP safety professional about any potential hazards that have been eliminated via design—as well as hazards that may still appear during construction as a result of the design—prior to the development of the construction plan, that will help those in the field know what to expect and how to best prepare for potential hazards when developing their implementation plan.

Project teams should consider three components for establishing successful communication for PtD implementation:

- Communication processes that support collaboration
- Information technology infrastructure
- PtD documentation tools

### Communication processes that support collaboration

Clear, collaborative communication is key for sharing information in a way that will lead to well-informed decision-making. Each individual stakeholder must be able to not only share their knowledge and ideas but make them meaningful to others to achieve safe-design decision-making and implementation in the field. This means that you will need to communicate your expertise in a way that demonstrates that you understand the needs and goals of both the project, and the informational needs and organizational goals of different project team members.

The processes used to support collaborative communication between stakeholders may depend largely upon the type of project delivery. More collaborative forms of project delivery will likely include greater opportunities for face-to-face meetings and information sharing between MEP contractors, MEP designers, and other stakeholder groups. For example, on Design-Build projects during the Hazard Identification Phase, MEP contractors, MEP designers, and the GC should meet and work together to develop specific hazards for each component. This involvement is different than Plan–Spec projects, where only the MEP contractor would engage in this step. Plan-Spec projects are more likely to have this type of collaborative, cross-stakeholder engagement only during the design review process after bidding and may depend more on providing documentation to other stakeholders for the exchange of information and ideas.

Regardless of the project delivery type, meetings with PtD stakeholders provide an opportunity for exchanging knowledge and generating innovative ideas for PtD decision-making. Meetings also ensure that all internal project team members, including MEP contractors, understand PtD decisions and any implications those decisions have for their work. Before a meeting, you can prepare by thinking of questions you may have in advance about the topic or any documentation you received prior to the meeting. Types of meetings could include:

- Design review meetings with all project stakeholders.
- Risk assessment review meetings between the GC and owner.
- Meetings with the MEP safety team about recent design changes to provide feedback on the design.

## Making Expertise Meaningful

In the fall protection system case study, Catwalk on a Trestle, an MEP safety professional had extensive knowledge about safety products and structures that could eliminate fall hazards. (For more on this case study, see Appendix B.5.) With this knowledge, the MEP safety professional believed that a catwalk was the best option. Knowing that the owner would be concerned about the extra costs involved in building and installing the catwalk, the safety professional was able to integrate these concerns into a case for adding the catwalk: that the catwalk would have a greater return on investment since it would save later costs of installing temporary scaffolding for maintenance personnel. In this case, the safety professional made safe design meaningful to the owner in terms of cost savings.

Photo: iStock.com/Chunyip Wong

- GC weekly team meetings to discuss design changes on a project.
- Meetings with different trades to review a design change or to discuss potential hazards.

### Information technology infrastructure

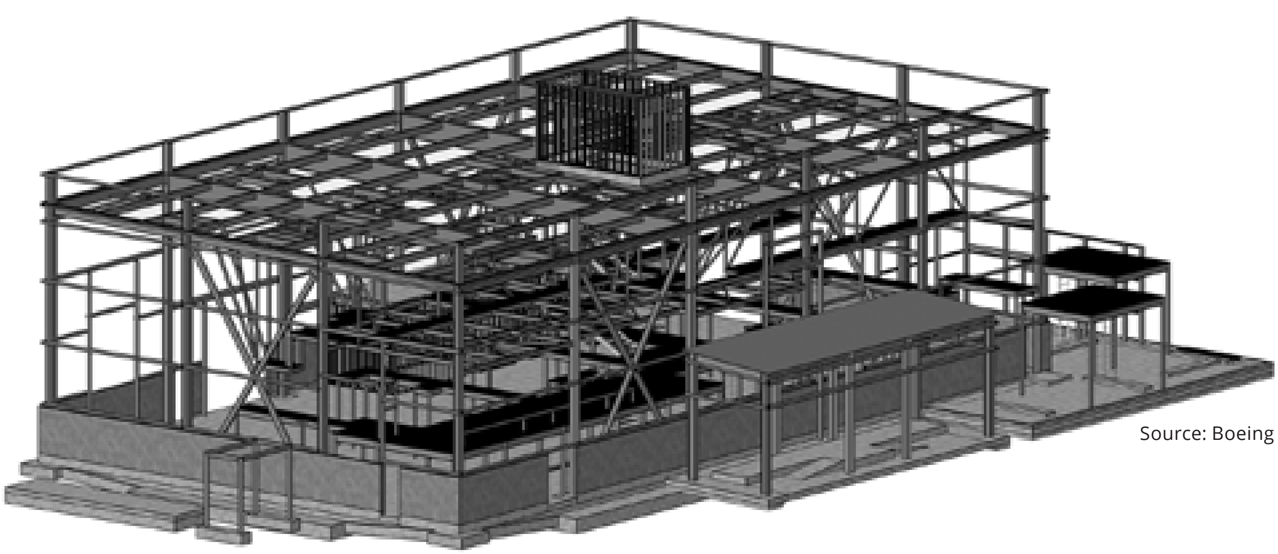
PtD requires that stakeholders can share and access information about hazards, risks, designs, and construction plans. Making decisions about what IT tools (e.g., software and hardware) will be used for each phase of the PtD process in advance will help ensure that there are standardized systems in place on how information should be shared and documented internally and between stakeholders. This will avoid difficulties down the road with MEP coordination on clash detection, and interoperability issues with different software programs and data types, with other project team members. There are many different methods for sharing and tracking information, and each organization will need to determine the tools that fit best with their current practices as well as the tools that fit best for the project. It is important to make sure that different PtD stakeholders are using the same or compatible software to facilitate a seamless exchange of information.

*Keep the stakeholders involved in the discussion throughout the project. It's a two-way street. Get everybody together, get everybody in the room, and start bringing everybody's ideas together and talking about it.*

*—VDC Manager from an electrical firm*

In particular, 3D and 4D BIM can be a useful collaborative tool in the PtD process for identifying hazards and visualizing design suggestions. For example, you can use 3D BIM models during the Hazard Identification Phase to identify potential fall hazards, working spaces, and working clearances. You can also track hazards in the model with notes about the specific safety issues involved and possible design options. 4D BIM can be used to identify any hazards that may occur during the fabrication and installation of MEP equipment, as well as identifying hazards that may occur during construction sequencing.[29]

3D BIM models can also be used as a focal point for discussion during design review meetings or to explore alternative design options during the Design Revision Phase or the Implementation. (For an example, see Figure 3.1 below.) When reviewing



Source: Boeing

Figure 3.1. A 3D BIM model used to design a catwalk system for maintenance safety.

design revisions. MEP designers can use the model as a focal point to help different stakeholders imagine alternate design options. For example, MEP designers could provide the owner's maintenance personnel with a model that would help them imagine the spaces they would work in and provide the MEP designer with feedback on safety concerns with the design. It can also be a useful tool for getting owner buy-in on specific design options that would eliminate hazards for MEP installers and maintenance personnel.

One method for ensuring that all project team members have access to the same 3D or 4D BIM model is to use BIM 360, also called "BIM in the cloud." BIM 360 is a collaborative platform where the model is kept in a cloud server, and different PtD stakeholders can access the most recently updated model. Whether the model is kept in the cloud, or on specific firm servers, the effective use of the model as a collaborative tool will rely on having a set of shared standard practices across the project team as well as open communication and a collaborative culture. You can learn more about best practices for using BIM from the guide, "Building Strong Teams: A Guide to Effective AEC Communication and Collaboration with BIM."[30]

### PtD documentation tools

Documentation is important to ensure that there is a record of decision-making and to track critical information obtained during each phase of the PtD process. Common forms of documentation on projects include smartsheets, memos, and agendas. There are also forms of documentation that are specific to the PtD process and can be used or adapted by. These include:

- ***Hazard Identification Checklist***
  A list of common hazards on a project. The checklist can include space for comments as to the hazard's location and any additional information. If one of those hazards will be present on a project, it is checked and indicates a need for risk analysis and possible design revision.
- ***Risk Assessment Forms and Worksheets***
  Risk assessment forms help evaluate the level of risk that is associated with each hazard. You

## VR for Encouraging Greater Safety in Design

Some researchers have found the use of Virtual Reality (VR) to be an effective method for helping designers to better appreciate the safety implications of their designs. One study has demonstrated that designers and construction workers were able to use VR to examine different design and construction scenarios together. The study found that this process helped the designers appreciate the safety implications of specific designs and could be an effective method for encouraging design changes that would improve safety.[32] While not everyone can afford to purchase the latest VR tools for PtD collaboration, MEP designers, architects, GCs, and MEP safety professionals can still use 2D and 3D visualizations together to identify hazards in design, explain their impact on safety, and generate design suggestions together.

Photo: iStock.com/sturti

can use risk matrices to establish risk levels of different hazards through assessing the severity of the consequences of a hazard with the level of likelihood that the hazard would occur.[31] This process helps establish the hazards with the highest risks on a project to help prioritize what hazards to focus on in the Design Revision phase.

- ***Design Review Checklists***
  Design review checklists are used as a means of providing design ideas that can remove specific hazards.
- ***Design Review Forms***
  Multiple types of design review forms can be used to evaluate different design options, including any potential new hazards and risks that may emerge from new designs. The forms help MEP designers gather much needed feedback on design suggestions from across stakeholder groups. ■

*We always had everybody at the meeting and everybody would be focused. We would all make notes on the prints and then we'd all have discussions about the comments that were captured on the prints so that we could have interaction to discuss whether or not it was a good process or not a good process.*

*—Safety Program Director*

## Creating Incentives for Completing Paperwork

Completing forms is important for tracking information. However, when workers are stretched for time, it can be difficult to get everyone to fill out the proper paperwork. One firm began to use an incentive process where everyone who completed their Design Hazard Analysis forms would be able to participate in a raffle and win a prize.


Photos: iStock.com/PeopleImages, MacDonald-Miller

Photo: Valley Electric

Chapter 4

# Changing the Industry

PtD is an effective method for eliminating and mitigating MEP safety risks and hazards that can result in MEP construction and maintenance personnel injuries and deaths.

While each firm can implement PtD on its own or work with a project team to implement PtD on a specific project, there is a need for widespread change across the industry. While large-scale changes to professional practices are difficult, changes can occur both through the promotion of PtD implementation in local and national MEP professional organizations, as well as in each firm making their own internal changes to their practices and in support of their worker's own professional development in PtD. The following are four recommendations for changing the industry.

### Share lessons learned using an open-source database

The Learning Phase in Chapter 1 includes the creation of a lessons learned database consisting of hazards, risks, design solutions, PtD documentation, and other items used on projects for PtD, which MEP contractors and designers can create and use on future projects. The database is also intended to be shared with GCs or owners on future projects. However, this step in and of itself does not allow for sharing lessons learned across MEP firms.

There are many challenges to making an open-source database of PtD lessons learned on specific projects, such as the competitive nature of the industry and concern over intellectual property in regards to design solutions. Therefore, we recommend the creation of shared lessons learned databases that would be located within local-level professional organizations, such as local chapters of the National Electrical Contractors Association (NECA), the Mechanical Contractors Association (MCA), the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), and the Associated General Contractors of America (AGC). To accomplish such a task would require that the national leadership of these organizations promote an open-source repository of PtD lessons learned, as well as support for the creation and ongoing maintenance of data-bases by local leadership. This will also require that local professional organizations or their national leadership provide the resources needed to keep these repositories updated and accessible. We suggest that next steps for following this recommendation would be a meeting amongst local NECA, SMACNA, AGC, and MCA leadership about the possibilities of creating such a resource and the process for creating and maintaining such a resource.

### Provide PtD and safety training within firms, on projects, and in local professional organizations

Training is key for improving the safety of MEP workers through the design process. Designers (e.g., MEP designers, architects, and structural engineers) would benefit from safety training on common hazards, such as the OSHA 10 safety training. This type of training would give designers a stronger sense about safety issues regarding MEP equipment access and installation. All stakeholders would benefit from training on PtD processes as well. Training can occur either on a single project, such as early in concept design, within individual firms, or through professional organizations such as NECA, SMACNA, AGC, and MCA.

### Encourage PtD workshops

Along with training, professional organizations, such as NECA, SMACNA, AGC, and MCA, could work together to provide PtD workshops for implementing PtD processes within firms and on projects. Workshops on PtD would also be a beneficial practice on individual projects, particularly Design–Build and other collaborative delivery projects where workshops can take place early in the design stage to have the largest impact.

### Promote safety culture

Safety is often discussed more during the construction phase than the design phase. Safety is also far more than code compliance: it is about thinking through the hazards and risks that MEP workers may encounter, from construction to decommissioning. Part of making industry-wide change is promoting awareness about PtD and the importance of MEP worker safety to designers (such as architects and structural engineers) and owners. Building awareness on multiple projects can help change the broader industry culture so that safety is valued across project stakeholders and ensure that safety is addressed early and often during design. Some methods for helping to promote a safety culture would include integrating MEP safety professionals (e.g., MEP contractors, foremen, safety professionals) early on during design to provide input to designers and owners on safety decision-making. Promoting safety culture also requires ensuring that your own firm has a strong safety culture and encouraging your firm to hold workshops and trainings on PtD. ■

Photo: McKinstry

Photo: iStock.com/Davizro

Chapter 5

# Resources

## MEP Safety-Related Codes

### General Safety

***Title 29 Code of Federal Regulations (CFR), Part 1926, Safety and Health Regulations for Construction***

*www.osha.gov/laws-regs/regulations/standard number/1926*

General federal requirements for health and safety in construction.

***WAC 296-155 Safety Standards for Construction Work***

*lni.wa.gov/safety-health/safety-rules/rules-by-chapter/?chapter=155*

Washington State general requirements for construction safety.

### Fall Protection Systems

***Title 29 Code of Federal Regulations (CFR) Subpart M***

*https://www.osha.gov/laws-regs/regulations/standard-number/1926/1926SubpartM*

Outlines the federal requirements and criteria for fall protection on construction sites.

***WAC 296-880 Unified Safety Standards for Fall Protection***

*lni.wa.gov/safety-health/safety-rules/rules-by-chapter/?chapter=880*

Washington State requirements for fall protection systems.

***ANSI/ASSP Z359 – Fall Protection and Fall Restraint Standards***

*www.assp.org/standards/standards-topics/fall-protection-and-fall-restraint-z359*

Standards that address fall protection equipment and systems.

### Electrical Systems and Fire Safety Codes

***NFPA 70: National Electrical Code 2020***

*catalog.nfpa.org/NFPA-70-National-Electrical-Code-NEC-Softbound-P1194.aspx*

Electrical Code for safe-work practices. Information on requirements for arc energy reduction and on how to meet these requirements during design and installation.

***Standard for Electrical Safety in Workplace, 2021 ed, ANSI/NFPA 70E***

*www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code =70E*

Requirements for reducing exposure to electrical hazards. Provides a six-step process for design and installation of electrical equipment to mitigate and control arc-flash hazards.

## Online PtD Resources

### General Resources

***Preventing Falls from Heights through the Design of Embedded Safety Features—National Institute for Occupational Safety and Health (NIOSH) (2014)***

*www.cdc.gov/niosh/docs/wp-solutions/2014-124/default.html*

Document on PtD designs that can prevent fall-related injuries and fatalities. Design solutions include embedded roof anchor points, embeds for guardrail support, and straps embedded in concrete.

***Prevention through Design—NIOSH (2016)***

*www.cdc.gov/niosh/topics/ptd/default.html*

NIOSH's Prevention through Design National initiative. Defines PtD and the PtD approach. Contains guidance, publications, and training materials, as well as news and events, and other online PtD resources.

***Prevention through Design—Mike Toole (2021)***

*designforconstructionsafety.org*

Information on the PtD process, history of PtD, and challenges for implementation. Also provides an extensive set of resources on PtD readings and links to design tools and international guidelines.

### PtD Guides

***Prevention through Design (Z590.3)—American Society of Safety Professionals (ASSP) (2020)***

*www.assp.org/standards/standards-topics/prevention-through-design-z590-3*

ASSP/ANSI standard to incorporate PtD into design decision-making. The standard and a PtD technical report are available for purchase.

***Prevention through Design (PtD) to Make Solar-Ready Houses Safe for Solar Workers—Hyun Woo Lee, John Gambatese, and Yohan Min (2020)***

*www.cpwr.com/wp-content/uploads/2020/06/SS2020-PtD-for-Solar-Ready.pdf*

Final report on study to develop a PtD design checklist and BIM models for new solar-ready houses. Appendix includes a PtD checklist.

***Applying Prevention through Design (PtD) to Solar Systems in Small Buildings—Hyun Woo Lee, John Gambatese, and Chung Ho (2017)***

*www.cpwr.com/wp-content/uploads/publications/PtD-Solar-Solar-Systems-in-Small-Buildings.pdf*

A PtD protocol for the design and installation of solar energy systems for small residential buildings. The guide introduces seven PtD attributes with related design and installation issues, including roof materials, roof slopes, panel layouts, roof accessories, fall protection systems, lifting methods, and electrical systems.

***Prevention through Design (PtD) in the Project Delivery Process: A PtD Sourcebook for Construction Site Safety—John Gambatese (2019)***

*designforconstructionsafety.files.wordpress.com/2019/09/ptd-in-the-project-delivery-process.pdf*

This guide focuses on how to implement PtD at each stage of an IPD project. The guide has form templates that can be adapted for different phases of a project as well as PtD case studies.

### PtD Tools

***Construction Hazard Assessment Implication Review (CHAIR)—WorkCover NSW (2001)***

*https://www.safedesignaustralia.com.au/wp-content/uploads/2018/10/CHAIR_Safety_in_Design_Tool_WorkCoverNSW.pdf*

Tool developed by Australian safety professionals that brings multiple project stakeholders together to reduce hazards through design. Provides details on the CHAIR process and case studies where CHAIR was implemented.

***Design for Construction Safety Toolbox, version 2.0—Construction Industry Institute (2010)***

*www.techstreet.com/cii/standards/cii-ir101-2?gateway_code=cii&product_id=2088668*

A software tool consisting of 430 design suggestions. Can be used during the Design Revision Phase.

***OSHA's Hazard Identification Training Tool—OSHA***

*www.osha.gov/hazfinder/*

A game-based training tool on workplace hazard identification. Audience is both workers and owners. There are multiple safety scenarios with the tool, including one for construction.

***Safety in Design Risk Evaluator (SLiDeRUlE)—John Gambatese, et al. (2015)***

*www.constructionsliderule.org/*

An online calculator that assesses the risk of specific MEP components. The calculator was developed by researchers in the School of Civil and Construction Engineering at Oregon State University.

Photo: Valley Electric

# References


1 The Center for Construction Research and Training (CPWR), *The Construction Chart Book: The U.S. Construction Industry and Its Workers*, 5th Ed (Silver Spring, MD: CPWR, 2013).

2 "Labor Statistics (BLSI)," Washington State Department of Labor & Industries (L&I), accessed June 21, 2021, *lni.wa.gov/claims/for-employers/workers-compensation-injury-data/labor-statistics-blsi*.

3 Sophie Barrett, *Safe Design in Practice: For Designers of Structures*, (Safe Design Australia, 2014); Georgi Popov, Leigh Ann Blunt, James McGlothlin, Deborah Young-Corbett, John N. Zey, and Pamela Heckel, "Education: Integrating PtD into Undergraduate Curricula," Professional Safety 58, no. 3 (March 2013): 44–49.

4 "Prevention through Design," National Institute for Occupational Safety & Health (NIOSH), Centers for Disease Control and Prevention (CDC), 2016, *www.cdc.gov/niosh/topics/ptd/default.html*.

5 Georgi Popov et al., "Education."

6 Helen Lingard, Payam Pirzadeh, James Harley, James Harley, and Ron Wakefield, "Safety in Design" (Centre for Construction Work Health and Safety Research, RMIT, 2014); John A. Gambatese, Alistair G. Gibb, Charlotte Brace, and Nicholas Tymvios, "Motivation for Prevention through Design: Experiential Perspectives and Practice," *Practice Periodical on Structural Design and Construction* 22, no. 4 (November 2017); Ross W. Trethewy and Maria Atkinson, "Enhanced Safety, Health and Environment Outcomes through Improved Design," *Journal of Engineering, Design and Technology* 1, no. 2 (February 2003): 187–201; Helen Lingard, Lance Saunders, Payam Pirzadeh, Nick Blismas, Brian Kleiner, and Ron Wakefield, "The Relationship between Pre-Construction Decision-Making and the Effectiveness of Risk Control: Testing the Time-Safety Influence Curve," *Engineering, Construction and Architectural Management* 22, no. 1 (January 19, 2015): 108–24; Ali Karakhan, Sathyanarayanan Rajendran, and John Gambatese, "Validation of Time-Safety Influence Curve Using Empirical Safety and Injury Data—Poisson Regression" (Construction Research Congress, New Orleans, LA, USA, 2018), 389–99.

7 "Hierarchy of Controls," NIOSH, CDC, 2015, *www.cdc.gov/niosh/topics/hierarchy/default.html*.

8 John Gambatese, "Prevention through Design (PtD) in the Project Delivery Process: A PtD Sourcebook for Construction Site Safety" (Oregon State University, January 2019).

9 Philip Hagan, John F. Montgomery, and James T. O'Reilly, eds., *Accident Prevention Manual for Business & Industry: Engineering & Technology*, 14th edition (Itasca, IL: National Safety Council, 2015).

10 Michael Behm, John Culvenor, and Kelvin Genn, "Safe Design: A Source for Innovation in the Built Environment," *Practice Periodical on Structural Design and Construction* 22, no. 4 (November 2017).

11 For an example of an owner's guide implementing PtD, see Gambatese, "Prevention through Design (PtD) in the Project Delivery Process."

12 Design-Build project delivery is a collaborative process where an owner contracts design and construction services as a single entity often called the design-contractor or design-builder. This can allow for the designer and the contractor to collaborate on recommendations to the owner and on final design decision-making. Plan-Spec is a sequential method where there is little to no overlap between the designer and contractor. Plan–Spec is also known as Design-Bid-Build.

13 "OSHA Quick Card: Top Four Construction Hazards." (OSHA) Occupational Safety and Health Administration, U.S. Department of Labor, 2006, *www.osha.gov/sites/default/files/publications/construction_hazards_qc.pdf*.

14 Sophie Barrett, *Safe Design in Practice: For Designers of Structures* (Safe Design Australia, 2014).

15 Ibid.

16 Ibid.

17 Ibid.

18 Bruce Lyon, Georgi Popov, and Elyce Biddle, "Prevention through Design for Hazards in Construction," *Professional Safety*, September 2016, 37–44.

19 Gambatese, "Prevention through Design (PtD) in the Project Delivery Process."

20 Anjali Lamba, "Practice: Designing Out Hazards in the Real World." *Professional Safety*, January 2013, 34–40.

21 Gambatese, "Prevention through Design (PtD) in the Project Delivery Process." This guide also includes case studies of safe designs.

22 Construction Industry Institute, *Design for Construction Safety Toolbox* (version 2.0), 2010, *www.techstreet.com/cii/standards/cii-ir101-2?gateway_code=cii&product_id=2088668.*

23 Gambatese, "Prevention through Design (PtD) in the Project Delivery Process."

24 Bruce Lyon, David Walline, and Georgi Popov, "Moving Risk Assessment Upstream to the Design Phase," *Professional Safety*, November 2019, 24–35; Gambatese, "Prevention through Design (PtD) in the Project Delivery Process."

25 Gambatese, "Prevention through Design (PtD) in the Project Delivery Process."

26 Ibid.

27 Lingard et al., "Safety in Design."

28 Lingard et al., "Safety in Design;" Andrew R. Atkinson and Rebecca Westall, "The Relationship between Integrated Design and Construction and Safety on Construction Projects," *Construction Management and Economics* 28, no. 9 (September 2010): 1007–17.

29 Gambatese, "Prevention through Design (PtD) in the Project Delivery Process."

30 Carrie Sturts Dossick and Laura Osburn, "Building Strong Teams: A Guide to Effective AEC Communication and Collaboration with BIM" (Seattle: Center for Education and Research in Construction, University of Washington, and Skanska Inc. 2015), *cm.be.uw.edu/wp-content/uploads/sites/29/2017/09/pub_UW_Skanska_AECcom_Report_2015_web.pdf*.

31 Rafael Sacks, Jennifer Whyte, Dana Swissa, Gabriel Raviv, Wei Zhou, and Aviad Shapira, "Safety by Design: Dialogues between Designers and Builders Using Virtual Reality," *Construction Management and Economics* 33, no. 1 (January 2, 2015): 55–72.

32 Fred Manuele, "Prevention Through Design: Addressing Occupational Risks in the Design and Redesign Process," *Professional Safety*, October 2008, 28–40; Bruce Lyon, Georgi Popov, and Elyce Biddle, "Prevention through Design for Hazards in Construction."

# A.1: Design Hazard Analysis Checklist

This checklist is used by MEP designers (Virtual Construction personnel) during Hazard Analysis to identify hazards on a project and is a part of a larger Design Hazard Analysis form. The form lists common hazards on a work site and provides space for indicating the location of the hazard. If one or more hazards are checked, then the form is sent to an MEP firm's safety department and the general foreman/superintendent. This then triggers decision-making as to whether the hazard can be engineered out of the project.

| Design Hazard Analysis Checklist | |
|---|---|
| **Project Name:** | |
| **Project Number:** | |
| **VC DHA Number:** | |
| **Hazard Location / Model View:** | |
| **DHA Triggers:** | **Yes:** |
| Trench over 4 Feet in Depth | |
| Fall Hazard over 4 Feet on Walking/Working Surface (45 inches or more in all directions) | |
| Fall Hazard over 4 feet during form and rebar work | |
| Fall Hazard over 4 feet while working above the height of a guardrail | |
| Fall Hazard over 6 feet | |
| Fall Hazard near floor hole/opening | |
| Fall hazard near wall opening | |
| Fall hazard near impalement hazard (such as: rebar, exposed steel, etc.) | |
| Fall hazard within 15 feet of an unproteced side/edge | |
| Roof work exposing employees to unprotected fall hazard | |
| Aerial Lift needed to complete work | |
| Scaffolding needed to complete work | |
| Confined Space Work anticipated | |
| Conflict with existing energized electrical systems | |
| Crane/Boom Truck needed to complete work | |
| Work will be conducted within 20 Feet of energized high voltage lines | |
| Work will be conducted over/near open waterway | |
| Work will be conducted in/near active traffic lane | |
| **Submitted By:** | |
| **Submitted To:** | |

*Source: Valley Electric*

# A.2: Risk Evaluation Form

This form is used to list hazards and evaluate their safety and health risks based on probability, severity, and exposure. Personnel using this form can then indicate their recommended control for each hazard.

**Risk Evaluation Form**

| **Project Title:** | **Project No.:** | **Assessment by:** | **Date:** |
|---|---|---|---|

**Instructions:** This form is used to evaluate a project feature based on the safety and health risks due to the hazards associated with the feature. The project feature can be associated with any part of the planning, design, construction, operations, maintenance, and/or decommissioning/recommissioning of the project.

1. Enter the worker safety and health hazard(s) associated with the project feature.
2. For each hazard:
    a. Enter the probability (1 = low, 3 = medium, 5 = high) of an injury occurring as a result of the hazard.
    b. Enter the likely severity (1 = low, 3 = medium, 5 = high) of an injury that occurs.
    c. Enter the extent of exposure (1 = low, 3 = medium, 5 = high) of the workers to the hazard.
    d. Calculate the risk associated with the hazard: Risk = (Probability)*(Severity)*(Exposure)
    e. Based on the magnitude of risk, identify the type(s) of control(s) selected to mitigate the risk.

| **Description of Project Feature:** |
|---|

| **Hazard(s)** | **Probability (A)** | | | **Severity (B)** | | | **Exposure (C)** | | | **Risk (A)*(B)*(C)** | **Recommended Control(s)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low (1) | Medium (3) | High (5) | Low (1) | Medium (3) | High (5) | Low (1) | Medium (3) | High (5) | | Eliminate | Reduce | Inform | Protect |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

*Source: John Gambatese, "Prevention through Design (PtD) in the Project Delivery Process: A PtD Sourcebook for Construction Site Safety" (Oregon State University, January 2019).*

# A.3: Safety in Design Review Form

This is another hazard identification and risk analysis form that can be used at any phase of a project.

**Safety in Design Review Form**

| **Project Title:** | **Project No.:** | **Assessment by:** | **Date:** |
|---|---|---|---|

**Instructions:** This form is used to evaluate a project feature based on the safety risks due to the hazards associated with the feature. The project feature can be associated with any part of the planning, design, construction, operations, maintenance, and/or decommissioning/recommissioning of the project.

1. Enter the safety hazard(s) associated with the project feature.
2. For each hazard:
   a. Enter the probability of an injury occurring as a result of the hazard (1 = low, 3 = medium, 5 = high).
   b. Enter the likely severity of an injury that occurs as a result of the hazard (1 = low, 3 = medium, 5 = high).
   c. Enter the extent of exposure of the workers to the hazard (1 = low, 3 = medium, 5 = high).
   d. Calculate the risk associated with the hazard: Risk = (Probability)*(Severity)*(Exposure)
   e. Indicate the type(s) of control to mitigate the risk (place an "X" in the appropriate column). One or more types of controls may be needed or desired.
   f. Identify recommended actions for how for each type of control to mitigate the risk.

| **Description of Project Feature:** |
|---|

| **Hazard(s)** | **Probability (A)** | **Severity (B)** | **Exposure (C)** | **Risk (A)*(B)*(C)** | **Applicable Control(s)** | | | | **Recommended Action(s)** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Eliminate | Reduce | Inform | Protect | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

*Source: Skanska USA Commercial Development, PtD Workshop, 2018. Form can also be found in John Gambatese, "Prevention through Design (PtD) in the Project Delivery Process: A PtD Sourcebook for Construction Site Safety" (Oregon State University, January 2019.*

# A.4: Design Safety Review Checklist

The Design Safety Review checklist is a collaborative discussion tool that helps identify hazards associated with different MEP systems, assess their risk, and find opportunities for safer designs. There are also sections for listing specs and diagrams.

**DESIGN SAFETY REVIEW CHECKLIST**

| | |
|---|---|
| Project Number: | See Kickoff |
| Project Name: | See Kickoff |
| Project Status/Deliverable: | See Kickoff |

| | |
|---|---|
| Authority Having Jurisdiction: | See Kickoff |
| Code Cycle/Year: | See Kickoff |
| Link to QC Folder: | See Kickoff |

*Link to matching Design Guide:*

| *Item Number* | *Topic* |
|---|---|
| | **GENERAL** |
| 101 | Are there opportunities to use a less direct pipe/duct route which would make service easier or safer? |
| 102 | Discuss how the proposed systems will be tested. This conversation will likely reveal opportunities to influence the design. |
| 103 | |
| 104 | |
| 105 | |
| 106 | |
| 107 | |
| 108 | |
| 109 | |
| 110 | |
| | **SYSTEM SELECTION** |
| 201 | Steam system |
| 202 | Refrigerant piping |
| 203 | Fuel oil piping |
| 204 | Hazardous exhaust |
| 205 | For all of the above: |
| | What happens if there is a system leak? Are some spaces more dangerous than others for such a leak? |
| 206 | Domestic water and cooling towers: has the legionella risk been managed? |
| 207 | Domestic hot water: are the proper temperature mixing valve ratings present for scald protection? |
| 208 | Are safety relief valves present on all systems which may see heat gain, whether this is by mechanical equipment or exposure |
| | on a roof? As an example, per this rule, an air-cooled chiller will drive the need for a safety relief valve in the chilled water sys |
| 209 | Natural gas: are shutoff valves included for all end uses? Are timer-controlled valves present for cooking equipment in elderly |

*Source: McKinstry*

# A.5: PtD Design Review Checklist

This checklist can be used by project teams to review different aspects of a project's design. The items listed in checklists like these can be adjusted and be used at different phases of a project.

**PtD Design Review Checklist**

A. Electrical/instrumentation controls can create safety hazards for construction workers if they protrude into passageways, or are hard to operate, hidden, or inaccessible.
   1. Position controls and control panels away from passageways and work areas.
   2. Indicate on the contract drawings the location of existing equipment and electrical shut-off switches. Allow the constructor access to these locations for emergency situations.
   3. Include the name, address, and telephone number of the local electrical power supply company on the contract drawings for quick reference in emergency situations.

B. A lack of safety alarms, switches, and component identification can lead to safety hazards for construction workers in emergency situations.
   1. Provide safety switches, pull cords, alarms, etc. which are clearly displayed, standardized, and easily identifiable.
   2. Provide disconnection switches which are readily accessible.
   3. Review from a safety aspect the possible misuse of the electrical/instrumentation control systems.
   4. Ensure that all electrical circuits are sufficiently identified throughout their length.

**Grounding**

A. Electrical systems must be adequately grounded to prevent electrical shock of construction workers.
   1. Ensure that all equipment is adequately grounded and protected against lightning.
   2. Provide grounding circuits to all 480 volt lighting fixtures.
   3. Ensure that the withstand rating is adequate for the available fault current.
   4. Ensure that the interrupting rating is adequate to protect all equipment.

**Location**

A. Locating electrical/instrumentation systems overhead can create fall, electrical shock, and other safety hazards for construction workers.
   1. Route cable trays above pipelines to minimize the chance of electrical shock due to leaking pipes.
   2. Minimize the amount of overhead work.
   3. Do not place overhead wiring close to windows or equipment. Locate overhead lines to minimize contact.

B. Electrical and instrumentation system enclosures and surroundings can affect the safety of construction workers.

*Source: J.C. Hollingsworth, "Design for Construction Worker Safety," Field Research Project, MS Occupational Safety Management, Department of the Built Environment, Indiana State University, Terre Haute, IN, May 2011. The checklist can also be found in John Gambatese, "Prevention through Design (PtD) In the Project Delivery Process: A PtD Sourcebook for Construction Site Safety" (Oregon State University, January 2019).*

# A.6: Design Alternative Evaluation Sheet

This form can be used to evaluate specific design options and their alignment with project goals. This form could be used as a discussion tool where design options can be discussed and selected as a team.

**Design Alternative Evaluation Sheet**

| | |
|---|---|
| **Project Title:** | **Project No.:** |
| **Assessment by:** | **Date:** |

**Instructions:** This form is used to evaluate the impacts of a design option with respect to project goals.

3. Enter the performance goals established for the project.
4. For each project goal, enter a weighting factor that signifies the importance of meeting the goal to overall project success. Use a common weighting scale for all goals (e.g., 1 = low; 10 = high).
5. For each goal, rate the impact of the design option on the goal. Use a rating from -5 (negative impact) to +5 (positive impact). Shade in the appropriate cell to indicate the level of impact.
6. Calculate the total weighted impact for each goal by multiplying the weighting factor by the impact rating.
7. Calculate the total weighted impact for the design option by summing the impacts to each goal.
8. Provide comments regarding the selected weighting factors and ratings, if desired.

| |
|---|
| **Design Option Title and Description:** |
| **Description of Occupational Safety and Health Issue(s) of Concern:** |

| No. | Project Goals | Weighting Factor (A) | Impact Rating (B) -5 0 +5 | Weighted Impact (A) x (B) | Comments |
|---|---|---|---|---|---|
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | ☐☐☐☐☐ ☐☐☐☐☐ | | |
| | | | **Total** | | |

*Source: John Gambatese, "Prevention through Design (PtD) In the Project Delivery Process: A PtD Sourcebook for Construction Site Safety" (Oregon State University, January 2019. This is a modified version of the form found originally in Hecker, S., Gambatese, J., and Weinstein, M., Editors (2004). Steven Hecker et al., eds., Designing for Safety and Health in Construction: Proceedings from a Research and Practice Symposium (Eugene, OR: University of Oregon Press, 2004).*

# B.1: Arc-Flash Hazards: Designing for Arc-Flash Safety

### What is an arc flash and why are arc flashes dangerous?

An arc flash is the uncontrolled release of light and heat through the air produced by an electrical explosion or discharge that occurs when a high-voltage gap exists.[1] Arc flashes can reach up to 10 feet or more and releases significant light, pressure, sound, and heat (up to 35,000 Fahrenheit). 80% of arc-flash accidents are caused by human error and hence preventable. Arc flashes can be fatal and are responsible for multiple types of injuries including:

- Head and body injuries
- Vision and hearing loss
- Inhalation of gases
- Severe burns

### What are the regulations and standards that impact arc- flash safety?

The 2020 National Electrical Code (NEC) and the 2021 Standard for Electrical Safety in the Workplace (NFPA 70E-2021) provides information on requirements for arc energy reduction and information on how to meet these requirements during design and installation. For electrical engineering designers, the most important sections are:

- **NEC 2020 Article 240.87 (A):** This section states when documentation for methods to reduce clearing time is required for arc energy reduction. Documentation needs to show that "the method chosen to reduce clearing time is set to operate at a value below the available arcing current."[2] Also the documentation must include requirements for performance testing an arc energy reduction protection system.[2]

- **NEC 2020 Section 110.16:** States that electrical equipment needs to be marked according to the Arc-Flash Hazard Warning labeling requirements in 110.21(B).[3] (See Figure B.1.1 for example.) Labeling is incredibly important as it is the first level of warning (signage) for the electrician. If the labeling requirements are followed by the electrician, then PPE requirements can help energized work be done safer and/or eliminated depending on what work is required to be done.[4]

---

1 Kathleen Kowalski-Trakofler, Edward Barrett, Charles Urban, and Gerald Homce, "Arc Flash Awareness: Information and Discussion Topics for Electrical Workers" (Pittsburgh Research Laboratory, Pittsburgh, PA: National Institute for Occupational Safety and Health (NIOSH), January 2007), *www.cdc.gov/niosh/mining/userfiles/works/products/videos/arcflash/afa.pdf.*

2 National Fire Protection Association (NFPA), NFPA 70: National Electrical Code 2020, 2019.

3 Ibid.

4 Ibid.

Photo: Littelfuse

- **NFPA 70E Standard for Electrical Safety in the Workplace:** The current version of the NFPA 70E provides a six-step process for design and installation of electrical equipment to mitigate and control arc-flash hazards.[5]

For calculating arc-flash energy, refer to:

- **IEEE 1584-2018 Guide for Performing Arc-Flash Hazard Calculations** (industry standard)[6]

### What is a safe design to prevent or mitigate arc flash?

There are multiple solutions when designing for arc-flash safety. Determining which solution depends on multiple design factors and costs. All of these designs require talking to the end user on the project who will be responsible for the product's maintenance. Table B.1.1 shows some of the possible safe designs for arc-flash safety.

Of these solutions, arc-flash relays provide effective incident energy reduction and are easy to install into new equipment or existing switchgear.

### What factors should I consider when developing a safe design with arc-flash relays?

The following factors are important considerations when creating a design with arc-flash relays:

- Reaction time needed for relay to detect an arc
- Clearing time required for the associated protective device to clear the fault
- Trip reliability through trip redundancy and health monitoring
- Ease of installation
- Sensor flexibility
- Required software
- Sensor design
- Avoidance of nuisance tripping
- Whether the relay can interconnect to multiple units
- Zone tripping[7]


Source: Graybar

Figure B.1.1. Example of Arc-Flash Hazard Warning Label.

Photo: Littelfuse

5 NFPA, *Standard for Electrical Safety in Workplace*, 2021 ed, ANSI/NFPA 70E (Quincy, Mass: NFPA, 2020).
6 IEEE Standards Association, "IEEE 1584-2018: IEEE Guide for Performing Arc-Flash Hazard Calculations," IEEE, accessed May 17, 2021,
7 Littelfuse, "Key Considerations for Selecting an Arc-Flash Relay" (Littelfuse, Inc., 2019), *https://www.littelfuse.com/~/media/protection-relays/white-papers/littelfuse_white_paper_pgr8800_arcflash_relay.pdf.*

Table B.1.1. Safe designs for arc-flash safety

| DESIGN SOLUTION | HOW IT WORKS | COST | DESIGN FACTORS | POTENTIAL ROI |
|---|---|---|---|---|
| Two sections of switchgear and/or maintenance bypass switch | Can de-energize one while directly working on the switch gear and doing maintenance work. | $$$$$ | Amount of space in the room, depending on size of service.<br>Double costs of installation. | Eliminates potential injury/fatality and downtime associated with arc-flash equipment damage. |
| Arc resistant switchgear | Does not reduce hazard but redirects flash away from worker. | $$$$ | Adds cost to gear package. | Mitigates external hazards of arc flash. |
| Arc-flash chute | Moves hazard up and away from worker. | $$$ | Adds cost to gear package. | Mitigates external hazards of arc flash. |
| Infrared (IR) windows and scanning of gear | IR Windows eliminates a need to open equipment; infrared scanning scans for faults without removing the cover to expose anyone. | $$ | IR windows adds cost to gear package. | Maintenance can be completed with limited PPE. |
| Maintenance mode switch | Modifies the overcurrent protective device trip curve to provide a lower instantaneous trip current than is used during normal operations. | $$ | Relies on human factors.<br>Trip unit limitations may not allow the Instantaneous.<br>Current to be set low enough. | Does not require additional space in the equipment room.<br>Minimal cost if the power distribution system specified trip units. |
| Arc-flash relays | Identifies arc flash and subsequently trips the main breakers. | $$ | Can be used for retrofits.<br>May be disruptive to selective coordination. | Doesn't damage all the gear if there is an arc incident. |

### Who do I need to talk with to design with arc-flash relays?

It is important to talk with the following people as part of the design of arc-flash relays:

- Electrical contractor and designer
- Client/maintenance
- General contractor
- Arc-flash relay vendor
- Fire safety professional

### Technical details about Littelfuse arc-flash relays

- Arc-flash relays like the ones in Figure B.1.2, detect the high-intensity light an arc-flash gives off and rapidly initiates a trip at the circuit breaker.
- Typically used in switchgear, motor control centers, generators (between the generator breaker and the generator), and panels where voltages are greater than 300 V.
- Have a solid-state redundant trip circuit for fast response time
- Arc-flash relays (Littelfuse AF0100) can be installed in less than 30 minutes

Littelfuse arc-flash relays are just one type of arc-flash relay product. Other manufacturers also make products that may work well in other situations depending on the project's needs and specifications.

*That's where your company's philosophy and approach really matter. Because if this system works, nothing happens. It's not very exciting. It's not like you get to spend a bunch of money on something that if it works, you make more product. So it takes commitment in your management team and your executive team to be willing to spend some money because we said, "safety by design—we're going to design it to be inherently safe."*

*—Electrical and Controls Engineering Manager*

Photo: Littelfuse

Figure B.1.2. Arc-flash relays.

### CASE STUDY

A Hampton Lumber electrical engineer has had many years of experience working with arc-flash safety. The engineer knows the hazards of arc flash well, having worked in a previous company that had experienced a fatality from an arc flash. When the engineer started at Hampton, he worked with the members of the Hampton Engineering Group and helped establish Hampton's safety by design culture.

As a company that has embraced safety by design, as a general rule, the electrical engineer's team would use arc resistant electrical distribution equipment. This equipment was originally designed for medium voltage use, but now could be used for low voltage motor control centers, which is where fault currents are the highest and most dangerous. These types of designs are intended to fail in predictable ways.

However, on one project at a lumber mill, the engineer needed to install arc-flash protection near an electrical fire pump. (See Figure B.1.3.) They soon found that they could not design equipment that would physically contain arc flash and meet the code requirements for the electric fire pump system. While the NEC requires that an arc-flash-safe design does not melt wiring or create additional fires and hazards, there is an exception for fire pumps. In the case of fire pumps, you cannot protect the wire from melting and have to run to failure. This requirement meant that in the case of an arc flash, there would be so much fault current potentially available for a very long time, that it would be impossible to find an arc-resistant enclosure that would meet their safety by design needs.

The team discussed for some time what a safety-by-design approach would look like, but kept hitting dead ends. They considered using an approach that relied more on PPE and training on body positioning near the equipment. However, they understood this approach was prone to human error and did not eliminate or mitigate the hazard well enough to fully protect an electrical maintenance worker. Since the company was dedicated to safety by design, they continued to look for other solutions.

The electrical engineer continued with his firm's focus group on the issue and together—in conversation with vendors, the local electrical inspector, and in informal discussions with members of the IEEE electrical safety group—developed a design using arc-flash relays provided by Littelfuse. (See Figure B.1.4.) This design could contain an arc-flash blast through limiting the duration of the arc flash. This design would also allow the system to run to failure, except if an arc flash is detected through the relay's fiber optic detectors. This capability meant that the system could have very long clearing times over current protection that the NEC requires for electrical fire pumps, but maintain the company's principle of safety by design, by shortening the time the current is flowing into the arc flash. Hampton would use the arc-flash relay design again in future projects with similar electrical design challenges. Figure B.1.5 summarizes the PtD implementation process as applied to the case study.

Photo: Jason Conelly

Figure B.1.3. The old splitter bus system that required retrofitting. The large panel on the right is the fire pump controller.


Photo: Jason Conelly

Figure B.1.4. The installed arc-flash protection relay.

This case demonstrates the importance of establishing a safety-by-design culture within a firm. The firm was willing to put in the time and resources to seek out a new safety-by-design solution. This case also demonstrates the importance of seeking out expertise on hazards and design solutions from multiple places, including internal firm experts, personal networks from national organizations like the IEEE, and vendors.


Figure B.1.5. PtD Implementation Process of Case Study B.1.

# B.2: Fall Protection: Designing Shafts for Worker Safety

## Why are falling hazards due to mechanical shafts dangerous?

Shafts in buildings are spaces where mechanical ducts, electrical cabling, and piping are installed. When the shafts are vertical and extend from one story to the next, openings in the floor slabs are created to allow the shafts to pass through the floor. Working on top of a floor slab adjacent a shaft opening exposes workers to the risk of being hit by objects that may fall from above, as well as fall and swing fall hazards until the designed ducts and piping are in place and the opening is covered or protected. Fall and swing-fall hazards can lead to disability or death, with falls being the leading cause of death in construction. The larger the shaft opening, the more likely it is for a fall hazard to exist. In general, fall protection associated with work around shaft openings includes railings around or protective coverings over the openings. In addition, workers installing duct and piping in the shaft are often tied off using a fall restraint system ("yo-yo") with a harness. (See Figure B.2.1.) Despite these fall protection measures, a shaft opening is still very dangerous to work around.

## What are the regulations and standards concerning fall protection?

Title 29 Code of Federal Regulations (CFR), Part 1926, Subpart M details the requirements and criteria for fall protection on construction sites. Fall protection is required for heights of 6 feet or more above a lower level or at less than 6 feet when over a dangerous piece of equipment. Subpart M also states the criteria that employers should use to determine whether fall protection is required and to provide workers with fall protection systems that meet those criteria.

Washington State's WAC 296-880 *Unified Safety Standards for Fall Protection* describes the requirements for protecting workers when working at elevation and provides standards for fall protection. The standards have stricter requirements than Occupational Health and Safety Administration (OSHA) 29 CFR 1926 Subpart M. In the WAC 296-880 standards, fall protection is required for heights of 4 feet or more above the ground or lower level. Fall protection systems are also required regardless of height where there are holes employees could fall into or "open-sided floors, walkways, platforms, or runways above or adjacent to dangerous equipment."[1]

1 Washington State Department of Labor & Industries, *Unified Safety Standards for Fall Protection*, WAC 296-880 (2020), *lni.wa.gov/safety-health/safety-rules/rules-by-chapter/?chapter=880.*

Photo: Jaymes Fleming

Source: Jaymes Fleming

Figure B.2.1. Construction workers over shaft opening.

Both 29 CFR 1926.501(b)(4) and Washington State's WAC 296-880-40015 describe requirements for covering holes and openings at construction sites.[2] 29 CFR requires that guardrail systems, fences, barricades, or covers should be placed at the edge of a well, pit, or shaft that is 6 feet or more.[3] Other requirements include strength requirements for hole covering, and that they must be secured and color coded, marked with the word "hole" or "cover" to ensure that workers are aware of any potential safety risk and hazard. There are also additional weight requirements for barriers around the openings and screens used to cover openings.

### What is a safe design to eliminate falling hazards related to shaft openings for ductwork?

One way to design for safety for shaft openings is to work with a structural engineer to reduce the size of the shaft to match the size of the duct and/or number of pipes needed for each floor. By doing so, the need for any covering or guardrails is minimized. (See Figure B.2.2.)

### What factors should I consider when preventing fall hazards through design?

- Required number and sizes of ducts per floor
- Required number of pipes and their sizes per floor
- Required fire protection around ducts and pipes, if any

### Who do I need to talk with when designing a shaft to fit ductwork?

- Architect
- Structural engineer
- Mechanical/electrical designer

Source: Jaymes Fleming

Figure B.2.2. Duct and piping.

2 Occupational Safety and Health Administration (OSHA). "Title 29 Code of Federal Regulations (CFR) Subpart M 1926.501 - Duty to have fall protection." Accessed April 23, 2021. *www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.501*; Washington State Department of Labor & Industries, *Unified Safety Standards for Fall Protection*.

3 OSHA "Title 29 Code of Federal Regulations (CFR) Subpart M 1926.501 - Duty to Have Fall Protection."

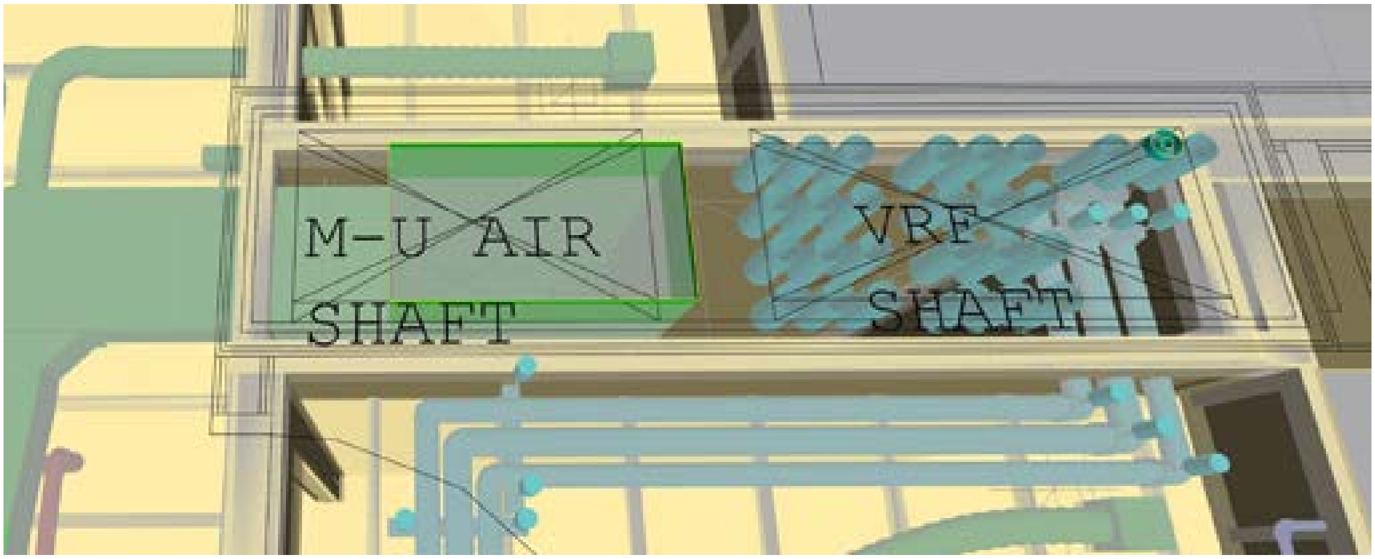
## CASE STUDY

A detailing manager (also known as a Virtual Design and Construction [VDC] manager) at a mechanical firm models mechanical systems at a high level of detail for construction projects. During this process, they look at ways of creating efficiencies and designing for safety using Building Information Modeling (BIM), a 3D design software tool. When modeling during the design phase, the detailing manager pays attention to shaft work that would expose MEP installers to falling hazards and considers how to minimize time on ladders and lifts, and the size and shape of materials.

Determining the size of a shaft designed for ductwork and piping requires communication between the mechanical engineer, architect and structural engineer about the opening size needed to get the ductwork and piping to go through the building. It is a common design practice that the architect's and structural engineer's 2D drawings create spacious openings to fit the largest ducts and greatest number of pipes. On the architectural and structural drawings, these shaft openings often remain the same size on each floor. Until the ducts and pipes are installed, large shaft openings inadvertently create falling hazards for workers.

However, systems usually reduce in size as they branch off to feed different floors. Reducing the shaft size as the systems reduce can help to reduce the total hours and number of personnel that need to be exposed to work inside the shaft when placing supports for systems. This is because a smaller shaft size allows for easy attachment to the slab. Reducing the shaft size also means that once the systems are installed, the hazard is removed and railings or coverings are no longer needed.

Therefore, when the detailers encounter this type of work, they determine whether or not such a large opening is needed on each floor and if it is not needed, how to reduce the opening size to prevent falling hazards. The detailer suggests making smaller holes for the piping and an individual shaft for the duct. They also models the shafts in BIM so that they reduce in number and size as they move from the




Source: Jaymes Fleming

Figure B.2.3. This image shows a M-U air shaft and VRF shaft designed in BIM. The original architectural and structural plans had designed the shaft size to encompass both the M-U duct and VRF piping. However, the detailer was able to create a separate shaft.

mechanical room (usually at the top of a building), towards the lower floors where the duct requirements are smaller and there are fewer pipes needed. (See Figure B.2.3.) Matching the size and shape of the floor openings to the size and number of ducts/pipes prevents having large, gaping holes in the floor slabs that are easy to fall through. Figure B.2.4 summarizes the PtD implementation process as applied to the case study.

This case demonstrates how BIM can be used to identify hazards and mitigate or eliminate them through design using 3D modeling. This case also demonstrates how understanding the design practices of different stakeholders (e.g., architect and structural engineer in this case) can help MEP designers better understand why certain practices occur and innovative ways of creating new designs that improve safety for construction workers. ■

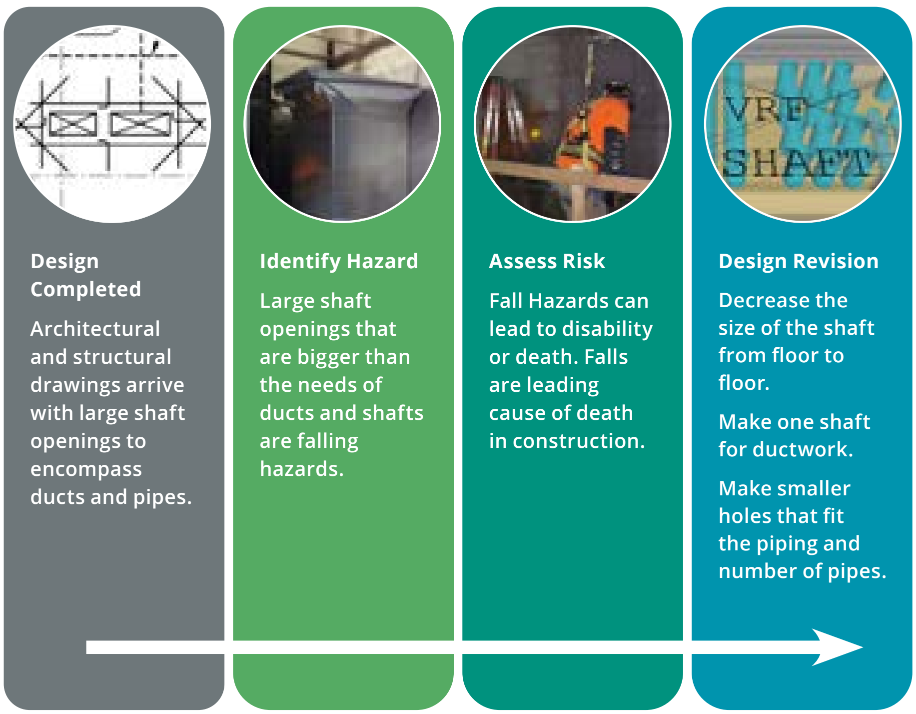



Figure B.2.4. PtD Implementation Process of Case Study B.2.

# B.3: Fall Protection Systems: Anchors and Lifelines

### Why is conducting installation and maintenance on a rooftop dangerous?

Fall hazards can lead to disability or death. According to the Occupational Health and Safety Administration (OSHA), falls are one of the leading causes of death in the construction industry, with 33% of all fall fatalities occurring from rooftops.[1] Installing and maintaining MEP equipment on a rooftop can lead to slips, trips and falls due to a number of causes, including:

- Wet surfaces or weather hazards (e.g., snow, ice)
- Hitting your foot against an object (e.g., tripping over a vent, pipe, uneven surface)
- Losing your balance (e.g., sloped roof)

### What are the regulations and standards that impact safety with rooftop work?

Washington State's WAC 296-880 *Unified Safety Standards for Fall Protection* has stricter requirements than Title 29 Code of Federal Regulations (CFR) Subpart M, where fall protection is required for heights of 4 feet or more above the ground or lower level. Fall protection systems are also required regardless of height where there are holes employees could fall into or "open-sided floors, walkways, platforms, or runways above or adjacent to dangerous equipment."[2]

### What is a safe design to prevent slips, trips, and falls from a rooftop?

There are multiple forms of fall protection systems, but a lifeline system in combination with anchors can be a useful system on a rooftop that is mostly covered by other equipment (e.g., solar system), where slips, trips, and falls could easily occur. A lifeline and anchor system can be used as a fall arrest system, which will stop you in the process of a fall, or as a fall restraint system, which will keep you a safe distance from the edge of a rooftop.

### What factors should I consider when developing a lifeline and anchor system for a rooftop?

- Weight capacity
- Leading edge
- Manufacturer specs for the system

---

1 Scott Breloff, Elizabeth Garza, Scott Earnest, Alan Echt, Christina Socias-Morales, and Jeanette Novakovich, "Stand-Down for Falls in Its 7th Year: Fatal Falls Are Falling," *NIOSH Science Blog*, August 10, 2020, *blogs.cdc.gov/niosh-science-blog/2020/08/10/falls-stand-down-2020*.

2 Washington State Department of Labor & Industries, *Unified Safety Standards for Fall Protection*, WAC 296-880 (2020), *lni.wa.gov/safety-health/safety-rules/rules-by-chapter/?chapter=880*.

Photo: iStock.com/France68

- Inspection timeframe and frequency, including what components will require further inspection
- Local weather conditions that could affect the rooftop's safety for installers and maintenance
- Cost

### Who do I need to talk to design a lifeline and anchor system for a rooftop?

- MEP contractor and designer
- Client/maintenance
- General contractor (GC)
- Structural engineer/architect

### Technical details about Safeguard Industries' horizontal lifelines

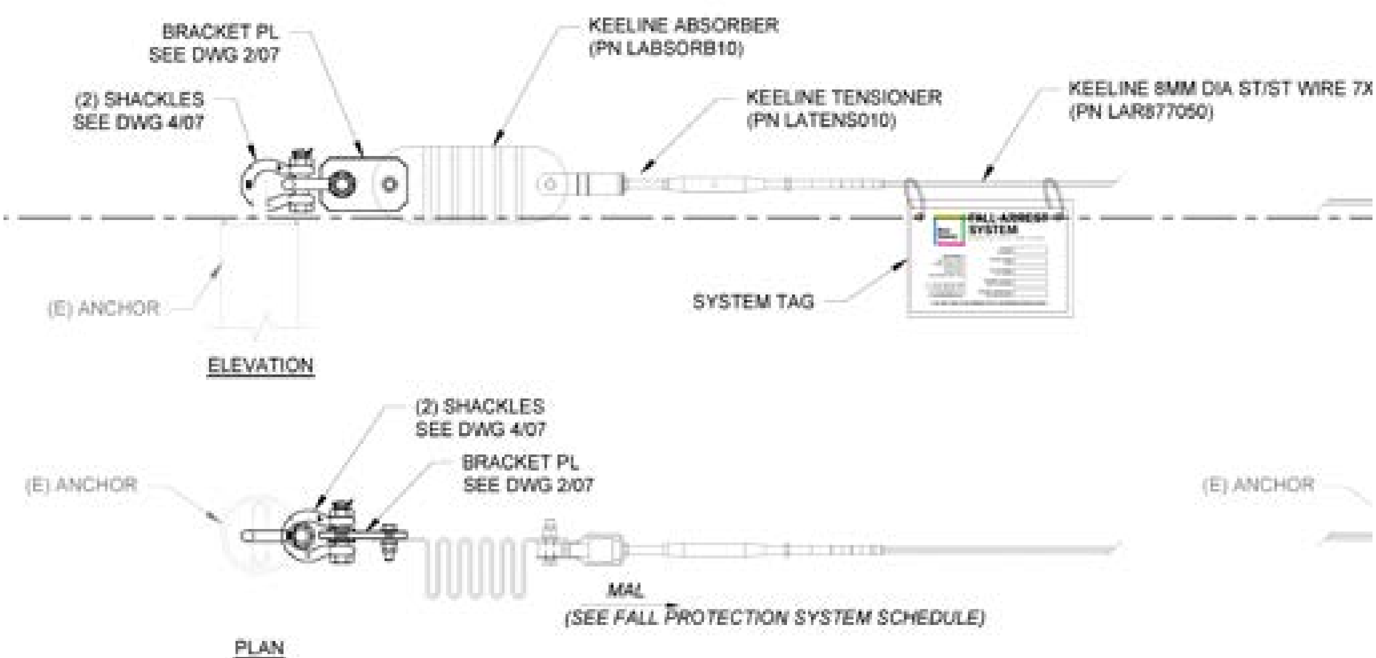
- Linear anchoring devices to allow workers to move along the whole length of their fall protection systems, without needing to disconnect and fixing points of the anchorage.
- Normally includes energy (or shock) absorbers that prevent deformation of the line or failure of anchors due to (1) the geometry of pulling across the horizontal lifeline and/or (2) arresting the fall. (See Figure B.3.1.)

Safeguard Industries' Horizontal Lifelines are just one type of lifeline product. Other manufacturers also make lifeline products that may work well in other situations depending on the project's needs and specifications.

### Technical details about rigid roof anchors

- Rigid anchors are a point of attachment and integral to any fall arrest system. (See Figure B.3.2.) They are designed to resist a force generated in any fall. The one shown in Figure B.3.3 can resist forces of up to 5400 lbs in any direction. The anchor alone is designed for only one person to be attached to the anchor at any time.
- The anchor shown in Figure B.3.3 has a hot dipped galvanized steel exterior with an SSI forged D-ring and a cavity filled with polyurethane insulation.

Safeguard Industries' rigid roof anchors are just one type of lifeline product. Other manufacturers also make rigid roof anchors that may work well in other situations depending on the project's needs and specifications.

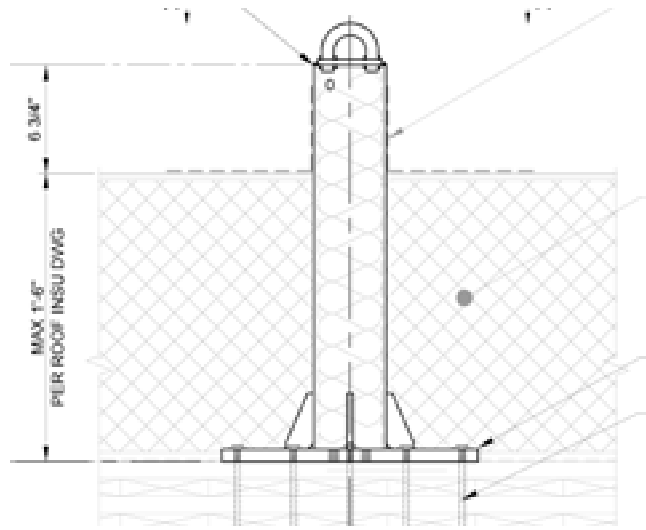



Source: Safeguard Industries

Figure B.3.1. Horizontal lifeline system shop drawing for Catalyst Building.

Source: MSA Safety

Figure B.3.2. Rigid Roof Anchors.



Source: Safeguard Industries

Figure B.3.3. Safeguard Industries' shop drawing for the Catalyst Building.

## CASE STUDY

The Catalyst Building in Spokane, Washington, is a part of the South landing Eco-District. The building was designed to be the largest zero-carbon, net-zero buildings in North America and was constructed with cross-laminated timber (CLT) panels and generates 300,000 kwh/year through its rooftop solar PV arrays. The building was a collaborative effort between Katerra, McKinstry, Avista utilities, Michael Green Architecture, Eastern Washington University, the McKinstry Ascension team (energy side), and the Emerald Initiative (an independently owned development group affiliate of McKinstry).

In terms of safety, the initial safety system design was based off of the original plans from the construction side of McKinstry, assuming a wide-open roof. This made it easy to envision a fall protection plan using a system consisting of davit pedestals with a davit base frame in conjunction with rigid anchors. The davits would be installed every 30 feet and the anchors every 15 feet. The safety system was more than adequate for construction of the building. Future maintenance workers would be able to easily attach and reattach to the davits and safely walk around the wide-open roof space.

While the building was under construction, McKinstry's safety plans were passed to the GC as the project was about to be handed over to the energy and maintenance company. The energy team then drew up their plans for the solar panel design and installation. It is at this point that the drawings for the roof's design changed dramatically from a wide-open space to a space completely covered in solar panels that would cover up the anchors, blocking access and egress routes. This meant that maintenance workers using tie-off points now had limitations as to where and how they could walk along the roof. If maintenance workers had to detach from each anchor and walk along the perimeter only, they could slip, trip, and fall, particularly if the roof is covered in snow or ice, common conditions for the Spokane area in winter.

One member of the energy team identified the new slip, trip, and fall hazards for future maintenance workers conducting maintenance on the solar panels. They alerted the rest of the energy team and the GC. McKinstry's safety professionals were then pulled into the conversations with the energy team and GC about the need for a new safety system. Initially, the group suggested a guardrail system. However, the guardrail option was considered too costly to implement and too late in construction to develop.

The safety professionals then suggested that since there were so many tie-off points on the roof with the anchors, there could also be a lifeline system put into place. The lifeline system would have a cable in place between the anchors along the perimeter of the building. This would prevent a maintenance worker from having to attach and reattach from each anchor, not only improving the safety of the system, but also improving efficiency in maintenance as a worker would not have to attach and reattach every 15 feet along the top of the building.

The team purchased the lifeline system from Safeguard Industries and had them install the horizontal lifeline system along the perimeter of the roof to maintain the solar panels. (See Figure B.3.4.) The system is pass-thru and designed for two users to be attached at once. This eliminated the risk of a maintenance worker having to disconnect from one post to connect to another to do their work. Figure B.3.5 summarizes the PtD implementation process as applied to the case study.

This case demonstrates that even when conducting safety in design early in the design process, as was the case for the initial fall protection system, later design revisions, such as the addition of the solar system, can lead to other safety hazards that need to be identified and addressed, not just for those installing equipment, but for those who will provide the maintenance. This means that after the initial design is complete and implemented, new design additions could mean a new iteration of hazard identification, risk assessment, safety design revisions, and implementation. ■

Photo: McKinstry

Figure B.3.4. Lifeline system on Catalyst roof.

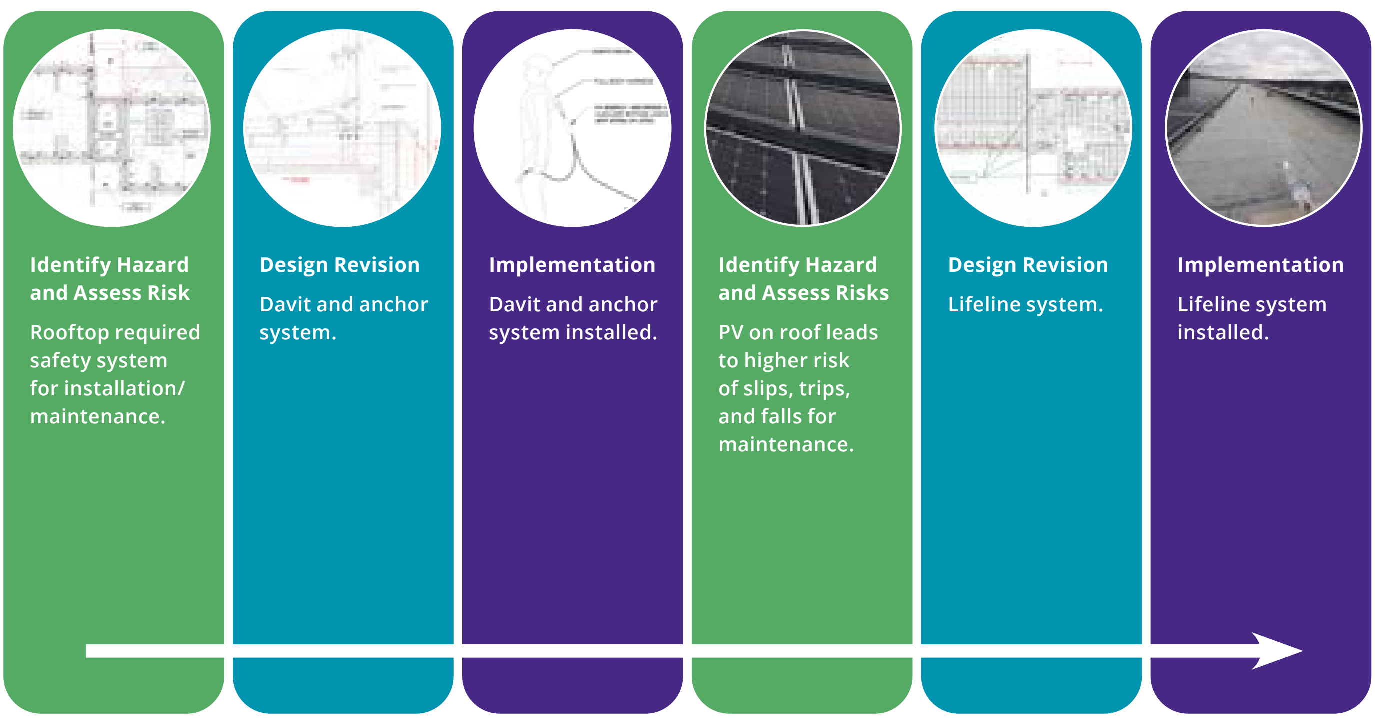



Figure B.3.5. PtD Implementation Process of Case Study B.3.

# B.4: Fall Protection Systems: Cast-In-Place Anchors

### Why are fall hazards dangerous?

Fall hazards can lead to disability or death. According to the Occupational Health and Safety Administration (OSHA), falls are one of the leading causes of death in the construction industry, accounting for one-third of all construction site fatalities.[1] Working at heights can lead to falls and swing fall hazards.

### What are the regulations and standards concerning fall protection?

Title 29 Code of Federal Regulations (CFR) Subpart M details the requirements and criteria for fall protection on construction sites. Fall protection is required for heights of 6 feet or more above a lower level or at less than 6 feet when over a dangerous piece of equipment. Subpart M also includes the criteria that employers should use to determine whether fall protection is required and to provide workers with fall protection systems that meet those criteria.

Washington State's WAC 296-880 *Unified Safety Standards for Fall Protection* describes the requirements for protecting workers when working at elevation and provides standards for fall protection. The standards have stricter requirements than Title 29 Code of Federal Regulations (CFR) Subpart M. In the WAC 296-880 standards, fall protection is required for heights of 4 feet or more above the ground or lower level. Fall protection systems are also required regardless of height where there are holes employees could fall into or "open-sided floors, walkways, platforms, or runways above or adjacent to dangerous equipment."[2]

### What is a safe design to prevent falling hazards?

There are multiple forms of fall protection systems, including fall protection anchors, concrete straps, guardrails, nets, and tie-off cables. Cast-in-place anchors can prove more durable and longer lasting than nylon straps poured into concrete.

1 Scott Breloff, Elizabeth Garza, Scott Earnest, Alan Echt, Christina Socias-Morales, and Jeanette Novakovich, "Stand-Down for Falls in Its 7th Year: Fatal Falls Are Falling," *NIOSH Science Blog*, August 10, 2020, *blogs.cdc.gov/niosh-science-blog/2020/08/10/falls-stand-down-2020*.

2 Washington State Department of Labor & Industries, *Unified Safety Standards for Fall Protection*, WAC 296-880 (2020), *lni.wa.gov/safety-health/safety-rules/rules-by-chapter/?chapter=880*.

Photo: McKinstry

### What factors should I consider when preventing fall hazards through design with cast-in-place anchors?

- Locations for anchors (e.g., near mechanical shafts, along leading edges)
- Manpower needed at a specific location
- Whether one or more workers will need to tie-off to a single anchor
- Whether there is a swing fall hazard if a worker falls when attached to the anchor
- Structural strength of concrete and distance to concrete edge
- Future maintenance needs
- Inspection timeframe and frequency, including what components will require further inspection
- Cost

### Who do I need to talk to when designing fall protection using cast-in-place anchors?

- MEP contractor and designer
- Client/maintenance
- General contractor (GC)
- Structural engineer/architect

### Technical Details about Ace Anchor

- Type A anchorage connector
- Minimum permitted service temperature: -30° F
- 5,000 lb. MBS (minimum breaking strength)
- Materials: zinc-plated steel. Components include ACE Anchor, D-ring plate cover, and plate cover screws

### Installation and Use

1. Select mounting location for anchors. When poured and fully cured, concrete must be at least 6″ thick, be reinforced, and have a compressive strength of at least 3,000 psi.
2. Install anchors on wall or slab, and secure with (4) 3/16″ diameter nails or screws. (See Figure B.4.1.)
3. Pour concrete around the secured anchor stem. (See Figure B.4.1.) Concrete must be fully cured prior to use.
4. Attach complete and compatible personal fall arrest system to the anchor connection point. (See Figure B.4.2).

Guardian Fall Protection’s Ace Anchors are just one type of cast-in-place anchor product. Other manufacturers also make anchor products that may work well in other situations depending on the project’s needs and specifications.

Photo: Guardian Fall Protection

Figure B.4.1. Ace Anchor.

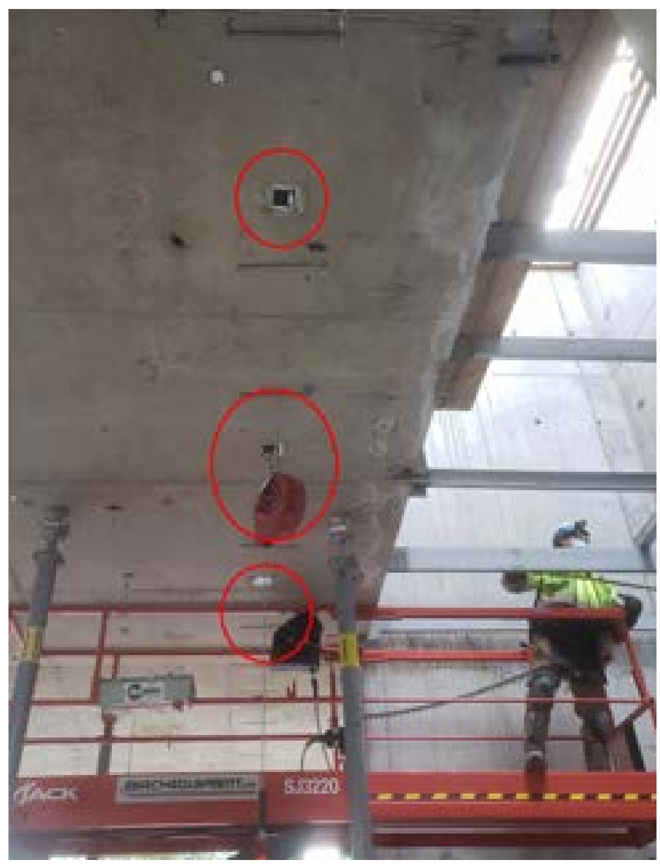


Photo: Guardian Fall Protection

Figure B.4.2. Ace Anchor.

## CASE STUDY

McKinstry has been using cast-in-place nylon straps as a key part of their fall protection system for MEP installers and maintenance personnel. However, during one project in Bellevue, the McKinstry superintendent noticed that many of the straps were being cut and damaged during the process of pouring concrete, something that he had seen occur on past projects over the past 15 years as well. Looking for a safer fall protection product, he found Guardian cast-in-place zinc-plated steel anchors with a D-ring plate cover. While the anchors were slightly more expensive than the straps, the superintendent felt that the installation efficiency and durability of the anchors compared to the straps would make up for the cost.

On a later project, Building Cure, the same superintendent identified that future workers on the construction site would need preset fall protection anchors. While construction had already started, the areas that would need anchors had not yet begun to be constructed and were still in design, so the superintendent brought over the idea of using cast-in-place anchors to his project manager to ensure the safety of MEP installers. Recognizing that future maintenance personnel would also gain benefit from the anchors, the superintendent and his project manager provided a redline drawing to the facility's maintenance personnel that showed the locations of the MEP equipment that would need to be serviced and the locations of the anchors that they believed were needed to install MEP equipment. This plan included using two anchors together in one area to mitigate any potential swing fall hazards. Maintenance personnel provided their own input on the anchor locations and brought it to the GC as a submittal.

These same cast-in-place anchors were used again on subsequent projects using the same process. The superintendent works with maintenance personnel and the GC to determine the location and number of the anchors in the design. The anchors are placed in every location where there could be a potential fall, such as around mechanical shafts and leading edges when work has to occur on the exterior of a building. (See Figure B.4.3.) Around mechanical shafts, the anchors are placed in several areas to ensure a worker can reach the back and front of a shaft. In high-rises, the anchors are placed on every floor. The distance between each anchor is determined by the structural strength of the concrete and distance to the concrete edge. The anchors also

Photo: McKinstry

Figure B.4.3: Ace Anchor in ceiling near shaft.

*The safety factor comes into the job site way before you even get any material on site. We look at areas of potential hazard, a lot of it will be the shaft areas, leading edges. And then we go back to the GC and we present to them and say, "hey, we're going to be needing some type of fall protection in these areas." And we collaborate amongst each other.*

*—General Foreman*

come in two types: one rated at 5,000 lbs. to hold a single worker, and one where two workers can tie-off, rated at 10,000 lbs. Figure B.4.4 summarizes the PtD implementation process as applied to the case study.

Collaboration is key when designing for safety. In this case, maintenance personnel were key players working with MEP safety professionals to provide their insights into the locations of cast-in-place anchors, ensuring the anchors could be used well after the building was constructed. However, working together in this way does not mean that this collaboration is only able to take place when using forms of collaborative project delivery, such as Design-Build. Safety in design can occur on a plan spec project using the submittal process. This case also demonstrates that a part of safety in design is to carry over lessons learned from prior projects about safe products that will impact not only the safety of MEP workers, but the safety of maintenance personnel as well. ■

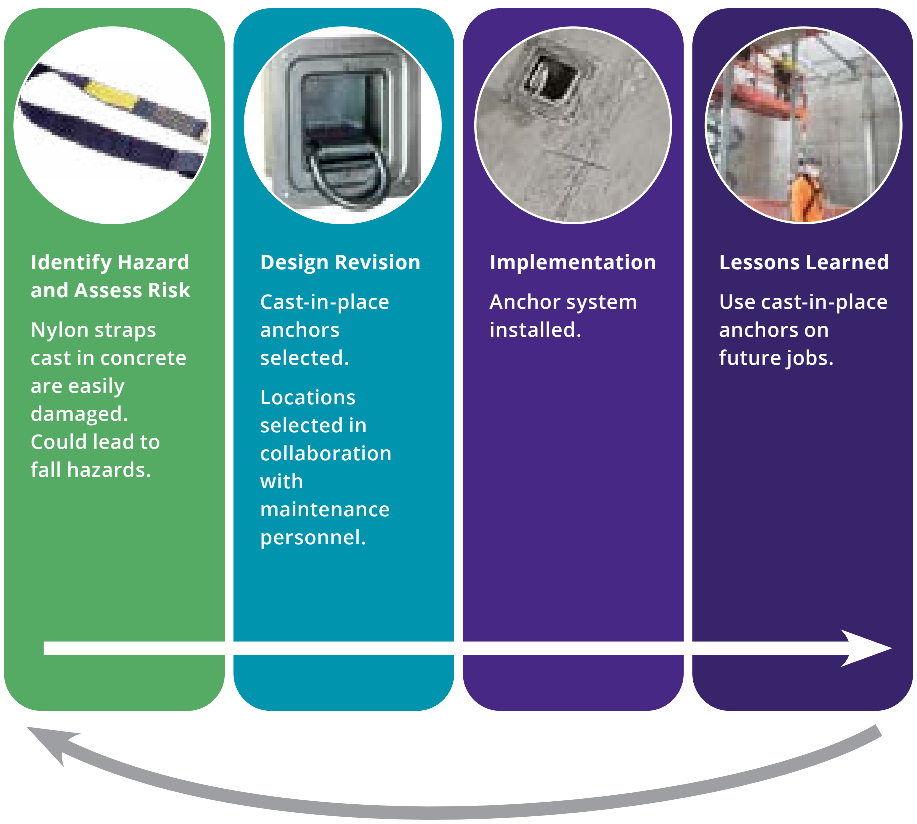



Figure B.4.4. PtD Implementation Process of Case Study B.4.

# B.5: Fall Protection Systems: Catwalk On A Trestle

### Why are fall hazards from a trestle dangerous?

Working on a trestle at height exposes MEP workers (installation and maintenance) to fall hazards. These hazards can lead to disability or death, with falls being the leading cause of death in construction.

### What are the regulations and standards concerning trestles and fall protection?

Section 1926.501 of the Occupational Health and Safety Administration (OSHA) requires employers to provide fall protection systems, such as guardrails or safety nets.[1] Trestles fall under the requirements of OSHA's 1926 Subpart L for scaffolds, as detailed in the Section 1926.451 requirements.[2] In WA state, Chapter 296-874 of the Washington Administrative Code (WAC) provides additional requirements for scaffolds, including those under WAC 296-874-40038.[3]

Title 29 Code of Federal Regulations (CFR) Subpart M details the requirements and criteria for fall protection on construction sites. Fall protection is required when working at heights of 6 feet or more above a lower level or at less than 6 feet when over a dangerous piece of equipment. Subpart M also states the criteria that employers should use to determine whether fall protection is required and to provide workers with fall protection systems that meet those criteria.

Washington State's WAC 296-880 *Unified Safety Standards for Fall Protection* describes the requirements for protecting workers when working at elevation and provides standards for fall protection. The standards have stricter requirements than Title 29 Code of Federal Regulations (CFR) Subpart M. In the WAC 296-880 standards, fall protection is required when working at heights of 4 feet or more above the ground or lower level. Fall protection systems are also required regardless of height where there are holes employees could fall into or "open-sided floors, walkways, platforms, or runways above or adjacent to dangerous equipment."[4]

---

1 Occupational Safety and Health Administration (OSHA), "Title 29 Code of Federal Regulations (CFR) Subpart M 1926.501 - Duty to Have Fall Protection," accessed April 23, 2021, *www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.501.*

2 OSHA, "1926 Subpart L," United States Department of Labor, accessed May 25, 2021, *www.osha.gov/laws-regs/interlinking/standards/1926%20Subpart%20L*.

3 Washington State Legislature, "Chapter 296-874 WAC," Washington State Legislature, June 2, 2020, *apps.leg.wa.gov/wac/default.aspx?cite=296-874*.

4 Washington State Department of Labor & Industries, *Unified Safety Standards for Fall Protection*, WAC 296-880 (2020), *lni.wa.gov/safety-health/safety-rules/rules-by-chapter/?chapter=880*.

Photo: iStock.com/pamspix

Oregon Administrative Rules, Chapter 437, Division 2, Subdivision B, Walking-Working Surfaces, describes requirements for fall protection systems, including guardrails on runways (also called catwalks) when working at heights of 4 feet or more. Oregon Administrative Rules, Chapter 437, Division 3, Subdivision L provide requirements for scaffolding, including information on requirements for guardrail systems.[5]

### What is a safe design to eliminate fall hazards and prevent falling from trestles?

There are multiple forms of fall protection systems depending on the design of a trestle, its purpose, and whether it will be a temporary or permanent structure. A catwalk with a complete guardrail system (toeboard, midrail, and toprail) is an effective safety solution that can prevent falling. It also eliminates the need for harnesses, connection points, and fall protection equipment, (e.g., lanyards, self-retracting lifelines).

### What factors should I consider when eliminating fall hazards from a trestle using a catwalk?

- The weight that will be placed on the trestle while in use
- Who will need to use the trestle throughout the project's lifecycle
- The impacts on safety for those who will need to work on the trestle
- The cost of installing a catwalk versus the cost of temporary scaffolding
- The cost effectiveness of a safe design

### Who do I need to talk to when designing a catwalk on a trestle?

- The structural engineer to ensure the trestle can withstand the weight of the safety system
- The client to demonstrate the benefits of the safety system
- The contractor to understand the costs of installing the safety system

## CASE STUDY

A project team working on a manufacturing building project was designing a trestle that would hold pipes intended to span between two buildings. The project team planned to preload the trestle with pipes so that the workers did not have to crane the pipes to the trestle and then work them down through the trestle to install them. When they set the trestle, the pipes were going to be put into place and then connected.

During the design phase, the safety professional suggested that they also install a catwalk with toeboard, mid-rail, and top-rail. The safety professional felt that when workers had to climb up in the trestle, they would have to figure out how to tie off to prevent falling. If a walkable platform was added to the system, then installers and maintenance technicians could just walk around the trestle safely and easily, and the workers would not have to tie-off using fall protection.

The client did not want to add the catwalk at first. The safety professional talked to the structural engineer to make sure that the trestle could support the catwalk system for the extra weight the system would have on the trestle. The safety professional also had to determine the cost of installing the safety system prior to putting it into the trestle and compare it to the cost of having temporary scaffolding that would be required for installation as well as the cost of safety for maintenance workers if the catwalk system was not there.

The safety professional presented to the client this information about costs and how much safer it would be for the individuals working in the trestle to not have to tie off every two minutes to move from one section to the next section. The client decided that it would be best to create the catwalk inside the trestle. (See Figures B.5.1 and B.5.2.) Since this project was completed, several more pipes have been added to the trestle and, since the client had paid for the

5 Oregon Secretary of State, "Oregon Occupational Safety and Health Division - Chapter 437," accessed May 25, 2021, *secure.sos.state.or.us/oard/displayChapterRules.action?selectedChapter=74.*

Photo: Joe Forest

Figure B.5.1. Trestle side view.


Photo: Joe Forest

Figure B.5.2. Trestle view from ground.

catwalk upfront, it eliminated the need for building temporary scaffolding in its entirety. The catwalk has also made it easier and safer for future maintenance. Figure B.5.3 summarizes the PtD implementation process as applied to the case study.

This case demonstrates the importance of building a case for safety during design review with owners. MEP designers should make sure to provide information on a safety system's technical details, safety potential, as well as the safety system's return on investment (ROI). In this case, the catwalk was the most cost-effective design measure due to both eliminating costs incurred from possible safety incidents, as well as removing the costs of having to build temporary scaffolding to protect MEP workers when more piping needed to be installed in the trestle in the future. This case also demonstrates the importance of involving safety professionals in the design of projects. Safety professionals are able to foresee incidents that could be prevented and then provide that input throughout a project's development. ■

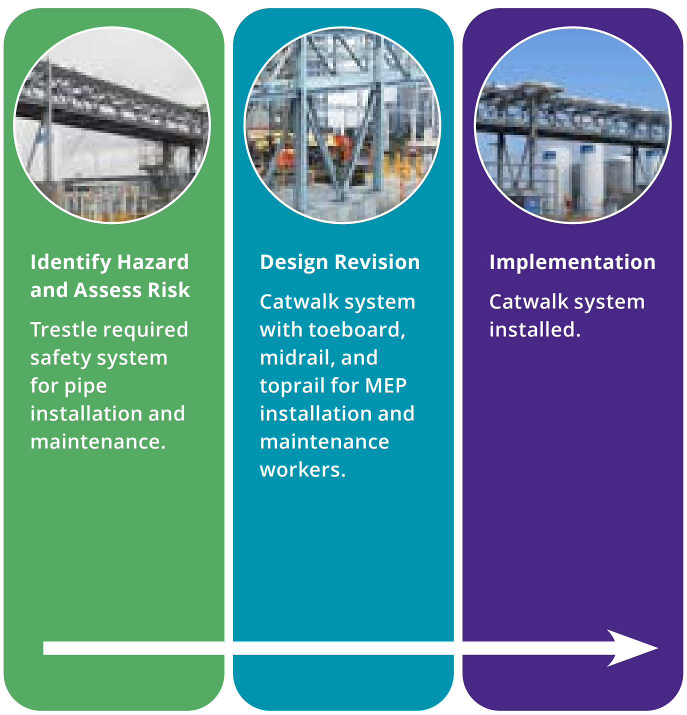



Figure B.5.3. PtD Implementation Process of Case Study B.5.

*During the design phase, I suggested that they put in a walkable surface with toeboard, midrail, and toprail. They didn't want to do it at first, until I showed them the cost of what it would take for scaffolding to be installed during this workflow, and also how safe it would be for the individuals working up into the trestle to not have to tie-off every two minutes to move from one section to the next. And they ended up going with the pipe rack with the walkable surface inside.*

*—Safety Program Director*

# B.6: Fall Protection Systems: Catwalks for Maintenance Safety

### Why is working at height dangerous?

Working at height exposes MEP workers (installation and maintenance) to fall hazards. These hazards can lead to disability or death, with falls being the leading cause of death in construction. Working at heights can also be dangerous for those working below as untethered tools could fall from heights and injure workers at lower levels.

### What are the regulations and standards concerning fall protection and catwalks?

Section 1926.501 of the Occupational Health and Safety Administration (OSHA) requires employers to provide fall protection systems, such as guardrails or safety nets. Requirements and criteria concerning catwalks fall under Title 29 CFR Part 1910, Subpart D for Walking-Working Surfaces.[1]

In Subpart D, 1910.22 details the maintenance, loads, access and egress requirements and criteria for walking-working surfaces. In addition, 1910.29 (b) concerns the requirements for guardrail systems that should be used on catwalks, including criteria pertaining to midrails, toprails, and the use of screens.

Washington State has adopted the federal codes for catwalks which are listed under WAC 296-24-735 *Walking Working Surfaces*. Information on general requirements can be found under WAC 296-24-73505.[2]

### What is a safe catwalk design to eliminate or prevent fall hazards?

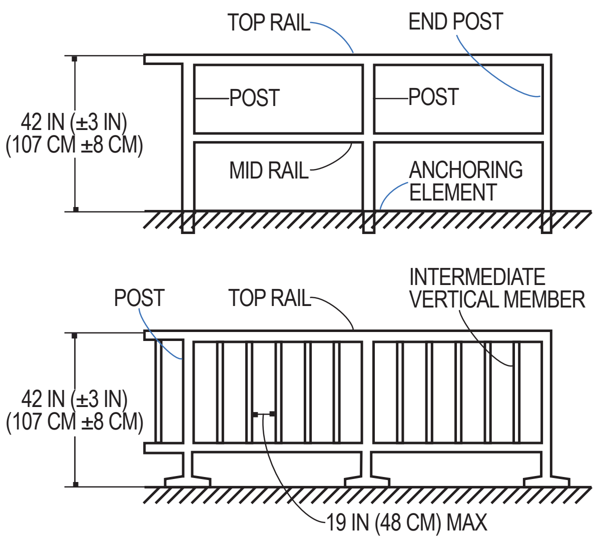
A catwalk with a complete guardrail system (toeboard, midrail, and toprail; see Figure B.6.1) is an effective safety solution that can prevent falling and provide maintenance workers access to equipment at heights. Catwalks eliminate the need for harnesses, connection points, and fall protection equipment, (e.g., lanyards, self-retracting lifelines).

---

1 Occupational Safety and Health Administration (OSHA), 1910 Subpart D, "Walking-Working Surfaces," United States Department of Labor, 2019, *www.osha.gov/laws-regs/regulations/standardnumber/1910/1910SubpartD*.

2 Washington State Legislature, "WAC 296-24-735: Walking Working Surfaces," 2020, *apps.leg.wa.gov/wac/default.aspx?cite=296-24-735*; Washington State Legislature, "WAC 296-24-73505: General Requirements," 2020, *apps.leg.wa.gov/wac/default.aspx?cite=296-24-73505*.

Photo: iStock.com/petcharaPJ




Source: OSHA

Figure B.6.1. Guard Rail Systems figure from 29 CFR 1910.29 (b).

Photo: iStock.com/PakkalinC

### What factors should I consider when eliminating fall hazards using a catwalk?

- Access from the catwalk for equipment maintenance workers and the associated risks to perform maintenance activities
- Potential preventative maintenance type and schedule
- Who will use the catwalk throughout the project's lifecycle
- Accessibility to equipment
- The weight that will be placed on the catwalk while in use
- Safety checklist and code compliance
- Egress from the catwalk
- Ability to modify equipment design to leverage use and placement of the catwalk
- Other fall protection measures
- Structural and seismic loads, materials, durability and constructability
- Walkway width
- Codes and regulations
- Potential equipment or materials that could interfere with the catwalk design
- Where to locate kick-plates and where to tether tools
- Options for protecting workers who use a ladder on the catwalk to access overhead work

### Who do I need to talk to when designing a catwalk?

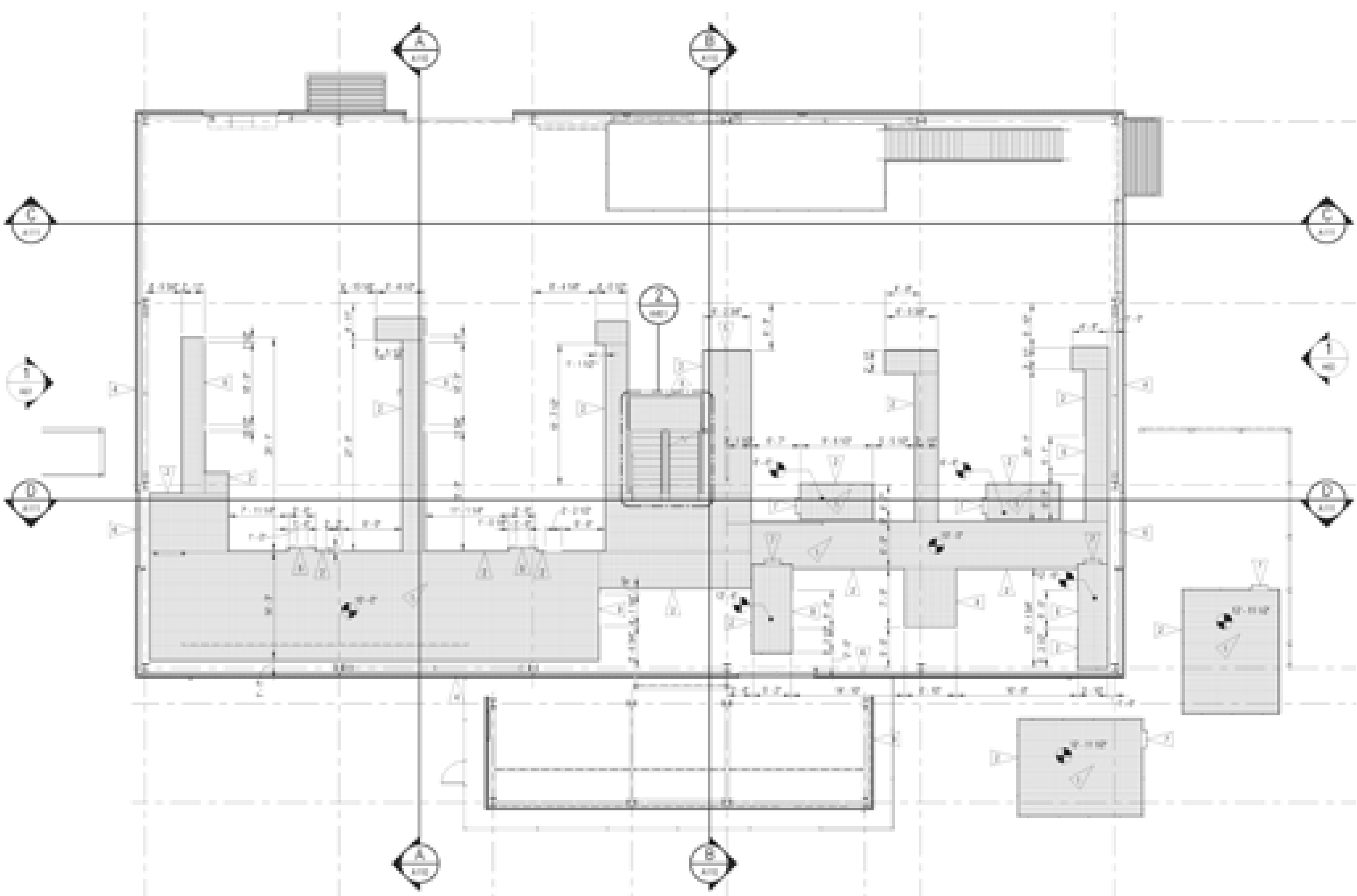
- Architect
- Mechanical and electrical engineers
- Design consultants
- Subcontractors
- Maintenance workers
- Safety professionals
- Equipment manufacturers
- General contractors (GCs)

## CASE STUDY

Boeing's capital projects have a strong culture of designing for safety. Their engineering and safety philosophy is to design out as many hazards as possible and provide a more passive solution for safety versus solutions that require administrative controls or use of PPE. For example, Boeing would prefer designs that use guardrails instead of anchor points that would require training, inspection, and specialized equipment for a maintenance worker to perform a job safely.

One of Boeing's recent projects is a new boiler building. While many of their boiler buildings do not have catwalks, this building required a catwalk because various pieces of MEP equipment—boilers, fire protection devices, HVAC equipment, and electrical components such as panels, controls, gauges and lighting—would be required in the building at various levels. Therefore, the design of the catwalk system was an essential part of the overall project design from the beginning. (See Figure B.6.2.)

Because maintenance and serviceability are critical in their facilities, it was important to design a catwalk system that would provide safe access to these critical components, allowing maintenance personnel to safely perform their work. They wanted a design that would improve upon maintenance and cleaning, worker safety and accessibility, safe equipment installation and removal, hazard avoidance, the elimination of injury and incidents, and ease of moving parts to different locations for servicing.



Source: Boeing

Figure B.6.2. Platform plan for boiler facility.

The design process involved a collaborative team that included facilities engineers and maintenance staff. Their design process began with a statement of work, and associated engineering criteria. The statement of work included the requirement for fall protection design, such as catwalks, anchors, or access to the equipment via lifting devices.

The Boeing engineering team along with the maintenance staff discussed these requirements in pre-design meetings prior to writing the statement of work. The Boeing engineers, project managers, and construction managers worked closely with maintenance staff and outside design consultants to determine the proper means for safe design. The design criteria they considered included, what equipment needed to be maintained, the weight bearing capacity of the catwalk, walkway width, and structural and seismic loads. The criteria also included whether equipment could be modified to work better with the placement of the catwalk, such as the relocation of valves, gauges, panels, controls, or utilities. In this way the equipment would be more easily accessible via the catwalk and would prevent the need for maintenance workers to have to stretch, climb, crouch, crawl, or use PPE.

Photo: iStock.com/pamspix

A stakeholder list was then created that identified all the pertinent parties needed for the catwalk's design. These included engineers, Environmental Health and Safety (EHS) personnel, maintenance staff, manufacturer representatives, and when necessary, GCs. From there, these key stakeholders collaborated with other key project team stakeholders to identify potential maintenance work required, frequency to maintain equipment assets, and accessibility.

As the process evolved, potential hazards and risks were identified in the beginning of the project and continued throughout the design, and even through construction and commissioning. In most cases the facilities personnel were involved and created a list of potential hazards and how the hazards should be addressed or mitigated through the design. The integrated facilities team continuously assessed risks and evaluated design solutions. Some of the design considerations for the catwalk included ease of movement on the catwalk, toeboard to prevent parts and tools from falling over edges, increased load capacity, stairs instead of ladders when possible, and proper lighting and egress. (See Figures B.6.3 and B.6.4.) In this particular facility, ladders and lifts were not safe or feasible, so other design considerations were implemented, such as stairs and gates.

The project team then identified the specific equipment and incorporated manufacturer equipment information into a 3D Building Information Model (BIM). (See Figure B.6.4.) The catwalks were then designed around the equipment and then assessed and reevaluated for validation with regards to safe access. The 3D model helped the team to determine equipment accessibility, equipment location, potential future modifications or expansion, and possible modifications to the manufacturer's equipment to enable safe access and best interface with the catwalks.

At 60–90% of the design phase, after the catwalk's initial design was complete, the team used the 3D model to identify clashes and obstructions between the catwalk and other MEP components, such as

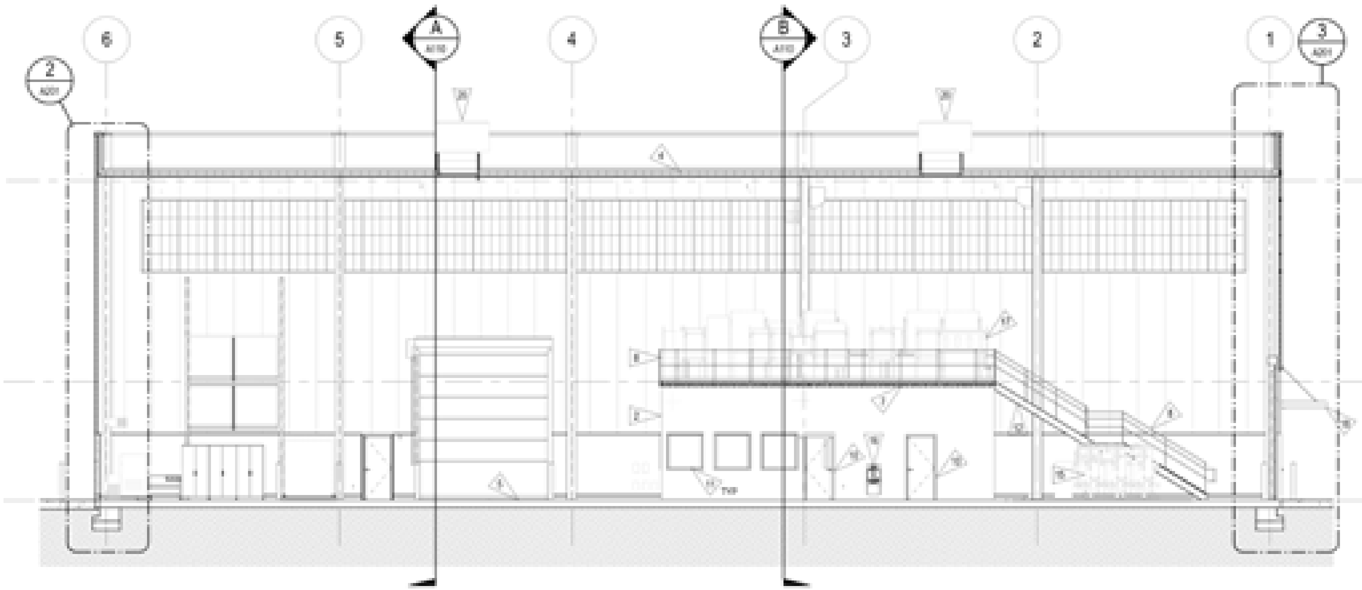



Figure B.6.3. Blueprint of the building section looking east. This view shows a stairway leading to a catwalk.

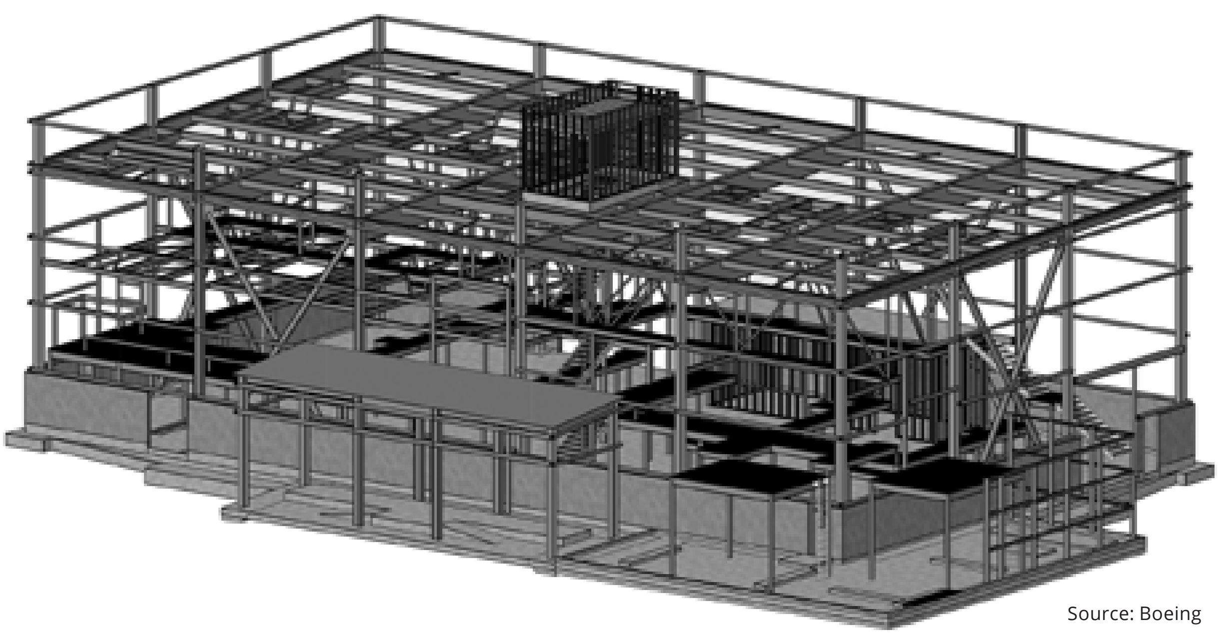



Figure B.6.4. 3D model of building looking southwest. This model shows several stairways leading to different catwalk levels.

gauges and valves. If these obstructions remained, then maintenance personnel would have to move the catwalk every time they needed to access the equipment. In response, the team identified the problem areas and provided mitigation strategies, such as moving valves out and away. Figure B.6.5 summarizes the PtD implementation process as applied to the case study.

This case demonstrates that designing for MEP maintenance worker safety is an important part of safety in design. This process means that designers need to consider not only equipment installation during construction, but equipment access, use, and designing for the safe use of tools. One key method for integrating MEP maintenance worker needs into the design is the early identification and involvement of maintenance professionals and safety staff as key stakeholders in the PtD process, including design-decision making. This case also demonstrates that PtD is a process that should begin early, with hazard identification and risk assessment integrated into the design and construction process. ■

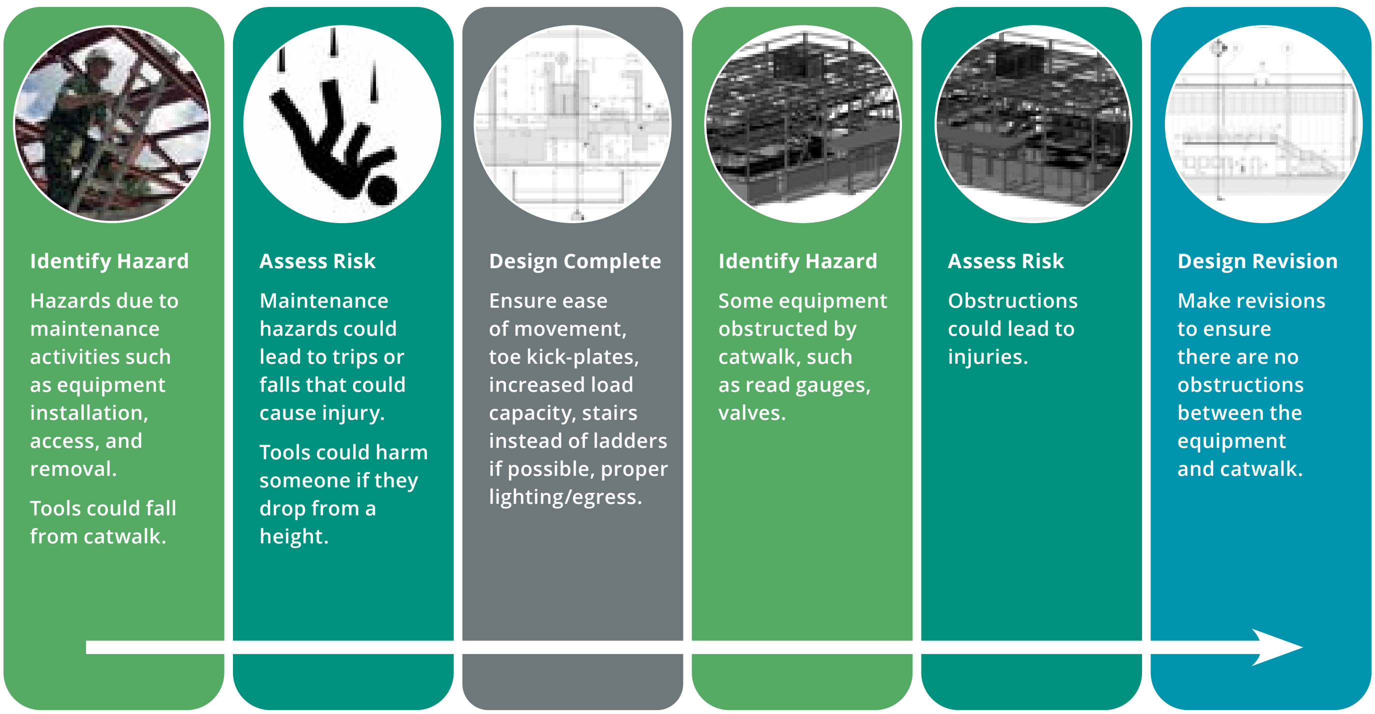



Figure B.6.5. PtD Implementation Process of Case Study B.6.



Photo: Hermanson


Photo: iStock.com/Vladimirovic