Developing Effective Construction Documents

Lessons and Case Studies in Constructability

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Preface

I am thrilled to introduce this book to the construction industry. It is focused on helping design team members gain a greater understanding of what information a contractor needs for both the bidding and construction phases of a project and, even more importantly, why they need this information. Our discussions throughout this book will skip right past the basics of design document preparation and proceed directly to the many intricacies of a project design that are not intuitive or are easily overlooked during the design phase of a project.

Architects and engineers are experts in their trades and provide services that contractors are unable to perform. Just as contractors are not experienced in project design, architects and engineers are not trained in the intricacies of bidding and executing a project. Because design team members are not in a position to gain extensive experience in the infinite details of bidding and executing a construction project, they are not provided an opportunity to become thoroughly knowledgeable of what information the design documents need to provide to ensure accurate bids are attained.

The discussions throughout this book present an in-depth examination of how to efficiently and effectively prepare design documents in order to ensure that the general contractor, subcontractors, manufacturers, suppliers, and all other project team members clearly understand their roles for the project. Through a series of examples that are derived from extensive field experience, a greater understanding of why the general contractor and their team of subcontractors require certain information for both bidding and construction purposes will be attained. We will examine the intricacies of how the design documents can be developed to ensure accurate bids are received, change order issues are minimized, and the overall quality of the project meets the expectations of the architect and owner.

When questions arise during the course of construction the line of communication between the design team and the field crews can a laborious one. When beginning my career I often contemplated why the person with the question, namely the field worker, did not speak directly with the person who has the answer, usually the architect. As my first project progressed, I quickly realized how many people truly need to be involved with each decision made on a project and understood why the line of communication made so many stops along the way. Nevertheless, this realization has never deterred me from working to improve this communication process. Though my approaches to bettering this communication process have been varied, my primary focus has consistently centered on the only truly efficient and effective tool to achieve direct communication between the architect and the field crews—the design documents.

When a question is generated in the field it is passed from the crew member, to his foreman, to the subcontractor's office, to the general contractor's office, to the architect's office, to the engineer's office, and then the answer is sent back through this same channel. This is a great deal of work just to answer a single question, not to mention the delays incurred while awaiting the final answer. This emphasizes why significant effort in preparation of the design documents prior to bidding the project and commencing construction is paramount to a successful project. Unfortunately, in the modern construction industry architects are pressed to prepare design documents quickly and general contractors are subsequently forced to bid the projects quickly. The two most important aspects of a project that are habitually disregarded during this crucial and frantic preconstruction stage are design document quality control and thorough analysis of the subcontractor bids. Architects are rarely provided sufficient time to perform an adequate quality control review of the completed drawings prior to the bidding period. Subsequently, general contractors simply do not have enough time during the bidding period to review the bid documents, prepare their bid instructions, issue the documents to the subcontractors, await the subcontractor estimates, and then analyze the subcontractor bids. We will never have all of the time we desire for document quality control and bid analysis at the onset of a project, but we can learn to make better use of the limited time we do have.

The easiest way to answer a question or prevent a problem is to provide the answers and solutions in the design documents, i.e., answer the questions before they are asked and solve the problems before they arise. Of course it is virtually impossible to prepare a perfect set of design documents, but we can continually increase our knowledge and improve our work. The discussions in this book are presented as a series of examples, each with a purpose of demonstrating what the design documents should include for effective bidding and execution of a construction project. Further, and even more importantly, we will elaborate to discuss the reasons why such information is required.

A key premise is that this book will not narrowly focus on *what* the design documents must include. We will explore the design and construction process much more deeply by focusing on *why* the design documents must include certain information. Take the knowledge and experience written here not simply as a checklist of issues and loose ends to be aware of, but as examples. Approach this book not as teachings in *how* good design documents are prepared, but in *why* design documents are prepared the way they are. By applying the various teachings of this book to the unique challenges of your projects, the knowledge and experience you gain will be exponential.

Design documents serve two distinct purposes. First, they provide sufficient information for the contractor to construct a project. The design documents are generally referred to as "construction documents" in this regard. Secondly, they serve the purpose of bidding a project to the subcontractor community. The design documents are generally referred to as "bidding documents" in this regard. Unfortunately, a complete understanding of the difference in these terms cannot be summed up in a few short sentences. However, there are two common misconceptions concerning these terms that you should keep in mind throughout the lessons we are about to embark upon. The first misconception is that providing a good set of bid documents is the equivalent of providing a good set of construction documents, and vice versa. The second misconception is that the construction documents consist of more information and greater detail than the bid documents. In fact, these two terms are not synonymous and in many cases the bid documents actually require more information and greater detail than the construction documents. We will examine and dispel each of these errant understandings through the myriad of examples in this book.

One of the best practices I began early in my career was to set up and maintain a database that I still use today. This is a basic and rudimentary database in an MS Excel® spreadsheet that consists of separate worksheets for each individual building trade. I use this database to keep track of all the lessons that I have learned in my career and that are likely to occur on future projects. The items in this database come from a wide variety of sources, including items that have become problems on my projects, items that have become problems on other projects that I have heard about, items that I caught before they became problems, and a myriad of items that have simply come to my attention in one way or another. This database has now grown to be a tremendous tool for use in planning projects, foreseeing problems, creating quality control programs, performing constructability reviews, allocating subcontractor scopes of work, and, of course, outlining this book. I urge everyone to follow this same practice. Whenever you learn something new—write it down. My personal database consists of a different spreadsheet for each individual building trade, but your personal method may well follow a different format. The important thing is that your acquired knowledge is kept in an easily referenced form and that you continually update it every time you learn something that is worth remembering.

The construction industry is extremely complex, such that no one person could ever learn everything there is to know within their lifetime. Actually, I do not believe any one person could even learn five percent of the intricacies of this industry in their lifetime. This is why we directly employ so many subcontractors, suppliers, and other individual companies for projects, each of whom have an in-depth knowledge and expertise in their respective trade. Most of these companies will in turn hire multiple material suppliers, manufacturers, sub-subcontractors, professional services firms, and other companies. Once a project is completed, it is not uncommon for nearly one thousand different companies to have been involved from the project's conception, through design, bidding, construction, and eventual completion. This emphasizes the importance of the design documents. The only truly efficient and effective means of conveying coordinated direction to all of these parties is via the design documents.

The construction industry is full of down to earth, good people. I believe more so than any other industry. Yet our industry also has a reputation for animosity among the different project team members. These two characteristics would not seem to apply to the same group of people. There are two primary reasons for this history of animosity. The first is that the construction industry entails an inherent and tremendous financial risk for all parties, which has a tendency to create nervousness, tension, and, sometimes, defensiveness. This is especially apparent on difficult projects. By improving the design documents we can effectively manage this financial risk, which will lower tensions among the project team and aid in creating a more collaborative team environment.

The second reason is that people fear what they do not understand. For instance, subcontractors do not fully understand the architect's role and architects do not fully understand the subcontractors' roles. Because of this, architects and subcontractors do not always appreciate the effort, experience, and expertise the other brings to the project. When something goes wrong each party may wonder why the other cannot simply get it right. The truth is that there are no easy jobs in the construction industry. In this book we will discuss what information subcontractors need to perform their roles and why they need this information. We will also discuss why architects may not provide certain information and why this omitted direction must reside within the contractor's realm of responsibility. Through the discussions in this book we will all gain a greater understanding of each other's roles, responsibilities, expertise, experience, and intelligence. From which, we will all gain a greater appreciation for each other. The most successful and profitable projects are routinely also the most collaborative projects.

This book is remarkably unique in that it concentrates on the nuts and bolts of a construction project by use of countless real-life examples. This is in contrast to a general discussion of the basic philosophies and concepts of a construction project, as most books tend to provide. After a great deal of research I found no other book like it on the market and am excited to bring this unique project management tool to the industry. Whether you are an architect, construction manager, general contractor, owner, or other project team member, I truly hope this book provides a boost to your career development and wish you the very best in furthering your exciting career in the construction industry.

"The only way to truly win an argument is to prevent the argument from ever occurring in the first place."—**Jason G. Smith**

Chapter 7

Miscellaneous Metals

The miscellaneous metals trade is one of the four most tedious scopes of work for a general contractor to properly allocate among the bidders and execute during construction. The miscellaneous metals, caulking, above-grade waterproofing, and flashing subcontractors have a commonality in that they are essentially responsible for the project leftovers. Effectively, other trades generally get first pick of which work they wish to complete on the project and these subcontractors will assume responsibility for whatever steel, caulking, waterproofing, and gauge metal work remains.

Ensuring the eclectic list of miscellaneous steel components is accounted for in the subcontractor bids, but not double covered, is a difficult task for the general contractor. An equally difficult task is carried out during construction in assuring none of the assorted items on these lists are forgotten.

Like most other trades, to gain a true understanding of how to effectively incorporate the miscellaneous metals work into the design documents it is essential to understand how the general contractor will allocate this work to the subcontractors. Even more so in this chapter than the others, we will discuss how the work is allocated among the subcontractors and how the design team can prepare the design documents to help ensure accurate bids are received.

Steel work on a project falls into two distinct categories: primary and secondary steel. Primary steel refers to the supporting structure of the building. Essentially, if removal of a steel member would cause the building to collapse in any way, then it is a primary steel member. Secondary steel refers to steel supports for the building components, not the building itself. Secondary steel is used for support of canopies, ceiling-hung toilet partitions, counter tops, curtain walls, window washing equipment, acoustical ceiling clouds, equipment platforms, and countless other items. Miscellaneous metals subcontractors will provide most of the secondary steel on the project, but not all of it. Structural steel subcontractors will provide all primary steel and some select secondary steel on a project.

The standard guidelines a general contractor will use in allocating secondary steel work are as follows:

A. If the steel in question is directly attached to the primary steel structure and can be fabricated in the shop to a point in which the member can be simply and quickly erected in the field, it will be most efficiently

FIGURE 7.1 This secondary steel structure is more efficiently constructed by the structural steel subcontractor than it would be by the miscellaneous metals subcontractor.

completed by the structural steel subcontractor (Figure 7.1). Otherwise, the steel is more appropriately allocated to the miscellaneous metals subcontractor.

B. If the steel in question is specifically identified in a specification section outside of MasterFormat Division 5, then it is a manufactured product more appropriately provided and installed by the trade responsible for the respective specification section. Tree grates, recessed floor mats, benches, stainless steel corner guards, and ornamental bollards are just a few examples of steel items that will not be provided by the structural steel or miscellaneous metals subcontractors.

C. Any steel designed (not just shown, but actually structurally designed) in the structural documents is usually the responsibility of the structural steel subcontractor and any steel not designed on the structural drawings generally falls under the miscellaneous metals scope of work.

DESIGN CONSIDERATIONS FOR MISCELLANEOUS METALS

1. A great deal of secondary steel work is completed on a design-build basis. The division of work between the design team and the subcontractor for this design-build work is a very hazy line and because this line is hazy architects are liable to furnish either too much or too little information. Some architects even hold that because secondary steel work is a design-build trade they do not need to reflect it in the design documents at all. In fact, the design team does have a responsibility to depict secondary

steel graphically to ensure the design documents are suitable for bidding purposes.

a. The need for secondary steel often arises for heavy items mounted on gypsum board walls and ceilings when the stud framing itself is not structurally sufficient to carry the load. Secondary steel in this case is constructed in line with the stud framing to augment its structural capacity. Coiling doors and ceiling-mounted toilet partitions (Figure 7.2) are two examples of when secondary (also commonly termed supplemental or miscellaneous) steel will be required behind the gypsum board. Coiling door and ceiling-mounted toilet partition fasteners will actually bridge though the gypsum board and fasten directly to the concealed secondary steel.

   Stud framing is also traditionally a design-build trade. A common misunderstanding is that secondary steel used to augment stud framing does not need to be depicted in the drawings because miscellaneous metals and stud framing are both design-build trades. Therefore, it is believed that the contractor should be fully responsible for whatever means are necessary to construct an adequate supporting structure. The fact is that this complicated coordination effort between the framing and miscellaneous metals bidders cannot reasonably be completed during the already hectic bidding phase of a project. It is acceptable, and efficient, for the subcontractors to perform all engineering for this work, but the bidders need some way of knowing where secondary steel is necessary during the bidding phase. The most efficient and effective

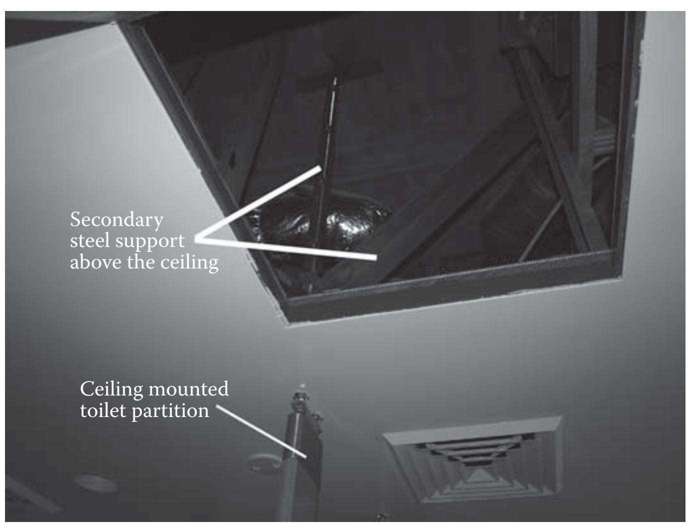

FIGURE 7.2 Secondary steel support for a ceiling-mounted toilet partition. (Photo by author, courtesy of Hathaway Dinwiddie Construction Company and the California Institute of Technology.)

method of conveying this information to the bidders is with a graphic representation of the secondary steel in the design drawings.
Architects may also hold that because stud framing engineering is the contractor's responsibility, they cannot know prior to receiving the framing shop drawings whether the stud framing will or will not be sufficient to carry the various component loads. In practice, experience has shown that there are few circumstances when the necessity for secondary steel is not obvious to a veteran architect. When borderline cases do present themselves a phone call to the structural engineer or a general contractor should resolve any questions.

The steel indicated graphically in the design drawings does not need to be sized or in any way engineered. This steel only needs to be depicted graphically so the bidders are cognizant that it needs to be included in their estimates.

It is true that if secondary steel is not depicted in the design documents the contractor will in fact still have the ability to effectively build the project. The general contractor can identify where secondary steel is necessary during the submittal process and alert the miscellaneous metals subcontractor when secondary steel needs are identified. Unfortunately, the submittal process does not occur until well after bidding is complete and subcontracts have been awarded. Without graphic depictions of the secondary steel in the design documents inaccurate bids will be received. This is another good example of the difference between a good construction-set of design documents and a good bid-set of design documents.

With few exceptions, secondary steel will be provided by the miscellaneous metals subcontractor and the item which the secondary steel is supporting will be provided by another trade. The entire component being designed must be fully coordinated by the design team and depicted in the design documents. For example, the design for ceiling-hung toilet partitions usually consists of a toilet partition specification section and simple lines on the floor plans depicting where the partitions need to be. Section details of toilet partitions are not always provided, which is generally acceptable for all toilet partition types except for ceiling-hung. Because ceiling-hung toilet partitions require secondary steel, the architect is obligated to provide a detail illustrating the above ceiling secondary steel to ensure the design documents are clear for bidding purposes. Miscellaneous metals subcontractors are experts at designing and installing secondary steel, but they are not experts at toilet partition installations. Without this detail the miscellaneous metals bidders will not realize the specific toilet partitions identified for the project will require secondary steel.

Similarly, the steel for a coiling door may not be shown on the design drawings for any purpose other than informing the bidders of its necessity. This steel will be fully engineered by the miscellaneous metals subcontractor and, because it is fully concealed within the walls, has no architectural impact to the building. Nevertheless, reflecting this steel on the design drawings for the sole purpose of identifying its existence to the bidders is a good enough reason to provide the detail.

Now that we have discussed why secondary steel needs to be indicated in the design documents, we will discuss what information needs to provided by the design team. In fact, the miscellaneous metals subcontractor only needs to be informed of where secondary steel is necessary and if there are any architectural concerns that will impact its design. The following points will clarify the hazy line that divides the design work of the architect and the design work of the miscellaneous metals subcontractor.

a. As discussed above, the architect must graphically depict all secondary steel. Miscellaneous metals subcontractors understand that this steel will be shown sporadically throughout the architectural drawings and are well accustomed to sorting through all architectural drawings to locate and estimate this steel. Secondary steel does not require any special organization within the architectural drawings, but all secondary steel does in fact need to be shown in the architectural drawings. The miscellaneous metals bidders cannot be expected to find secondary steel components in civil, plumbing, electrical, or other drawing series.
b. The size, shape, configuration, and connections of secondary steel in concealed locations (within walls, ceilings, etc.) do not need to be provided in the design documents. In fact, a change order issue may present itself if the architect furnishes too much information. For instance, if the architect calls for 3/16″ welds, but the miscellaneous metals subcontractor later realizes through their engineering calculations that 3/8″ welds are necessary, a change order request may be justified. The basis of this change order request would be that deceptive information was provided in the design documents.
c. When secondary steel is exposed, its size, shape, and configuration do need to be provided by the design team. This is to ensure the design intent of the exposed steel is clearly relayed in the form of design parameters to the miscellaneous metals subcontractor. An example of when the architect will need to identify the size, shape, and configuration of steel for aesthetic reasons might be an exterior canopy with exposed steel. In this case the architect will furnish much more information than just identifying the steel shapes. To ensure the canopy meets the design intent they will also size the steel members, show the type of connections to use, and provide any other information necessary to eliminate design variables. The architect's job in this case is to ensure the canopy is engineered by the miscellaneous metals subcontractor to perfectly match their architectural intentions. In this case the architect may show that a connection is to be welded rather than bolted, but they should not identify the size of the weld. In this case the architect may call for a 4″ x 4″ tube steel member and prohibit other steel shapes, but they will not indicate the thickness of the tube steel.

d. Secondary steel connections do not need to be engineered by the design team. Quite often when architects are unsure of what does or does not need to be identified in the design documents they will indicate some random welds, bolt sizes, steel thicknesses, and other general information. This type of information is not required of the design team, as the miscellaneous metals subcontractor will just need to engineer it anyway. In fact, if the design team details the connections and the miscellaneous metals subcontractor later determines larger connections are necessary they will have sufficient grounds for requesting additional compensation on the basis of deceptive information being provided in the design documents.

Again, the design team must ensure the design intent and construction type of each building component is clear to the contractor (i.e., provision of a good construction-set of design documents). They must also ensure that all bidders are clear as to their respective roles on the project (i.e., provision of a good bid-set of design documents). If these two criteria are met the design team has done their job well.

2. Miscellaneous metals shop drawings will be submitted by the contractor intermittently during the first quarter of a project. Controlling this vast myriad of submittals to ensure all miscellaneous metals items are accounted for in them is a tedious management task for which the general contractor is ultimately responsible. A diligent general contractor manages these items by creating a log of all miscellaneous metals components. This log is then coordinated with the project schedule to prioritize the due dates and allowable durations for each items review period, fabrication, delivery, and installation. It is highly encouraged for the architect to request a copy of the miscellaneous metals log as a submittal. This submittal request is not usually made, but is an extremely beneficial tool for use in the project's quality control effort. After having designed the project, the architect naturally has an intimate knowledge of it. The architect should review this log as a courtesy to the general contractor and alert them of any components noticed to be missing. Assurance of a complete and correct log will still be the contractor's responsibility, but this review is well worth the effort for any problems it does in fact prevent. The primary purpose of the submittal process is quality control, and this is a quality control issue.
3. Baseplates for posts within a stud wall must be configured such that they reside fully within the cavity of the stud wall. For example, installation of a medium to large coiling door at a stud-framed wall is typically supported structurally with tube steel jambs and header in line with the stud framing and concealed within the wall cavity. When a square baseplate is used for the base of the tube steel jambs it will protrude out of the bottom of the wall (Figure 7.3).
4. The base condition for railings requires the architect's attention. For exterior railings it is common practice to core drill the concrete. The rails are then set in the cores and secured with hand-packed grout (Figure 7.4). Intuitively, one might think that casting sleeves into a concrete pour is a more efficient

Chapter 9

Heavy Exterior Cladding

Primary Trades: Precast Concrete, Glass Fiber Reinforced Concrete (GFRC), Masonry

Heavy exterior cladding generally describes building facade systems that require secondary steel supports because common stud framing is not structurally adequate to support its weight. These immense systems are the most difficult, and usually most expensive, of the building facade systems. This increased cost is due in large part to the considerable secondary steel framing required to support their installation.

Precast concrete is used in a variety of circumstances, one of the most widespread uses being panelized facade systems (Figure 9.1). These architectural concrete products have a much higher industry standard for quality than cast-in-place concrete work. To attain this higher level of quality, precast panels are constructed in the controlled conditions of a precast shop (Figure 9.2), typically using laminated plywood or fiberglass forms and highly skilled craft workers. Architectural precast concrete is characteristically used at exterior locations where stone or glass fiber reinforced concrete may similarly be used, including wainscot, door trim, window trim, planter walls, and benches.

Building facade systems of all types, heavy or light weight, are traditionally performed in what can be considered a design-assist manner (meaning a portion of the design work is omitted by the design team and completed by the subcontractor). Generically speaking, with this approach the architect will provide sufficient detail in the architectural drawings to convey their expectations for the appearance and waterproofing ability of the facade system, and the subcontractor will then maintain responsibility for all engineering work associated with their system. We will discuss the intricacies of this general arrangement in this chapter, especially as these intricacies pertain to the bidding process.

FIGURE 9.1 Architectural precast. (Photo by author, courtesy of Hathaway Dinwiddie Construction Company and the California Institute of Technology.)

FIGURE 9.2 Precast concrete fabrication. (Photo provided by Walters and Wolf, Inc.)

The general contractor will lead an extensive coordination effort comprising all of the various facade subcontractors and with a comprehensive goal of enclosing the building. This process is commonly referred to as exterior skin coordination. Exterior skin coordination is a vital responsibility of the general contractor, but it is also a responsibility some general contractors have a tendency to take lightly. This is a process for which the general contractor must be held fully responsible. To ensure this responsibility is not taken lightly the architect should monitor the exterior skin coordination as it progresses. Ensuring this supplemental design effort is completed satisfactorily and in a timely manner is crucial to the success of a project. Poor construction details and problematic waterproofing conditions will result if this coordination effort is completed halfheartedly or late in the project.

DESIGN CONSIDERATIONS FOR HEAVY EXTERIOR CLADDING

1. The most contentious financial issue in regard to heavy exterior cladding systems pertains to the supporting steel for panelized systems, such as precast concrete and stone. The facade subcontractors will typically provide supports to a point only a few inches behind their systems. Unfortunately, at the floor levels the primary structure of the building may be one or two feet inboard of the cladding and between floors there is no structure. Bridging the distance from the primary building structure to the support points of heavy exterior cladding requires a great deal of expensive secondary steel work.

   Secondary steel bridging from the primary steel to the facade system anchor points will in most cases be completed by the miscellaneous metals subcontractor. Miscellaneous metals subcontractors are highly qualified to perform steel-related design work, and do so regularly. But, in order to bid the project they must understand where the steel is that needs to be designed and constructed. Further, the facade subcontractors need to be cognizant of the exact points of connection between their system and the secondary steel work in order to prepare accurate bids. Accurate bids cannot be attained unless the secondary steel is depicted in the design documents.

   It is not reasonable to expect the contractor to coordinate the extent of this secondary steel work prior to bidding the project. To provide a good bid-set of design documents the design team is obligated to graphically indicate this secondary steel. Again, this steel does not need to be engineered by the design team; it just needs to be shown graphically in the various facade details. By showing this steel the facade bidders will understand where their point of connection is and the miscellaneous metals bidders will understand the extent of secondary steel work they are responsible for. Omission of this steel from the design documents regularly produces very expensive scope gaps for which the owner would almost certainly hold financial responsibility on the premise of incomplete information having been provided in the design documents.

   Although the facade systems are design-build by nature, an experienced architect is capable of anticipating the secondary steel locations and configurations relatively easily and accurately. This estimation is generally deemed sufficient for bidding purposes. However, the architect should add a qualification to the design documents emphasizing the steel design is only a graphic depiction and the actual steel configuration, member sizes, and connection types are the full responsibility of the contractor.
2. Masonry systems require ledger angles intermittently up the face of a building. This secondary steel member commonly occurs at each floor level in order to take advantage of the floor deck for support of the angles. This component needs to be coordinated between the architect and structural engineer, especially for floor decks constructed of metal decking with a

concrete fill (termed composite decks), because ledger angles supported by the end of the structural floor decks will necessitate additional rebar and thick steel edge angles. This design coordination is often overlooked during the fast-paced design phase.

3. The design of facade supporting attachments (commonly termed clips) is an important focal point during the design team's submittal review. The design must be such that in the finished building all steel components are hidden from view. Heavy exterior facade systems will usually be fastened from the interior side of buildings, but when the cladding is hung on a concrete shear wall this is impossible, so in this case the attachments must be made from the exterior side of the building. Each project is comprised of its own unique conditions and on each project the architect must review the facade design, both in the design documents and the subcontractor's submittal drawings, with this in mind.

   For example, a relatively common practice is to recess the clips about one inch into the gap between precast concrete panels (Figure 9.3). This position is shallow enough that a welder can access it, but deep enough that a solid sealant joint can be run in front of it. An obscure quality control issue arises with this method of construction in that the smoke from the welding work may permanently stain the facade panels. This is a particular concern for precast concrete panels because of their naturally porous surfaces. The facade must be protected from this smoke. Keeping these panels clean is the financial responsibility of the general contractor, but the reality is that general contractors are likely to miss this obscure quality control issue both during bidding and during construction. Quality control is everyone's job, so incorporating an appropriate protocol into the design documents is highly recommended. Of course, this issue should also be monitored with the project's quality control program.

4. When facade systems bear at or shortly below finish grade a concrete ledge is generally found to be a more cost-effective means of support than a steel ledger angle (Figure 9.4). It must be recognized that precast subcontractors will not design or construct concrete supports for their panel systems. Though precast subcontractors are experts at concrete design and construction, they only perform concrete work in the shop and will not

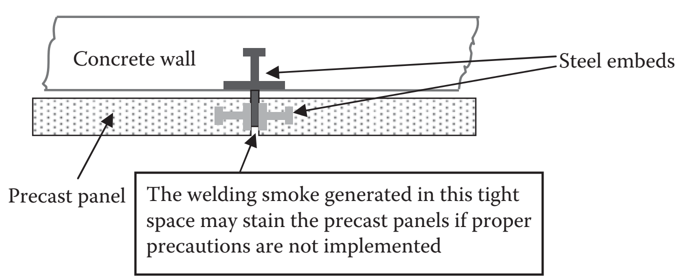

FIGURE 9.3 Precast panel clip recessed between panels.

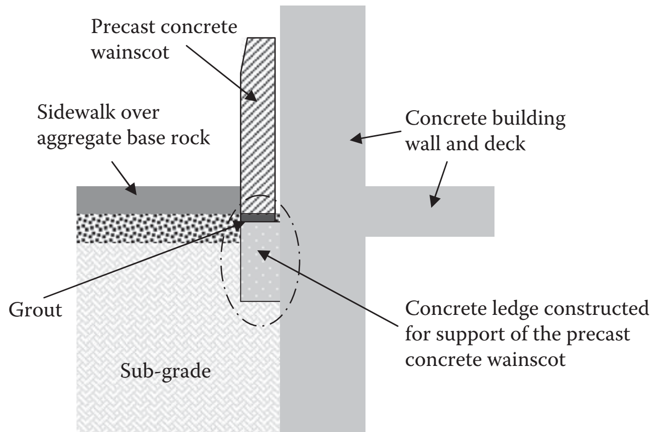

FIGURE 9.4 Precast concrete wainscot bearing on a concrete ledge slightly below grade.

extend this expertise to the field. For this reason, when project conditions deem a concrete ledge to be the most cost-effective means of supporting precast panels, these ledges should be fully designed by the structural engineer and incorporated into the design documents. This ledge will be constructed in a joint effort by the formwork, rebar, and place and finish subcontractors.

There are two common shortcuts that design teams and contractors have been known to use in an effort to reduce the cost of this ground level panel support work, but only one of these shortcuts is usually deemed acceptable. First, when the top of footing is 12 or 18 inches below finish grade it is usually found to be cost-effective for the facade panels to be constructed extra-tall such that they extend far enough below grade to bear on top of the footings. This utilization of the footings is an excellent approach because it provides for a net savings by trading the cost of an elongated facade system for the savings realized from the eliminated ledge construction. Of course, this approach may only be applicable to continuous footings and not spread footing foundations.

Secondly, if a concrete sidewalk is abutting the building it may seem like a good idea to bear the precast panels on top of it to save the cost of constructing a concrete ledge. But, it is not a good construction practice for facade components to be supported by two structures that are not interconnected. This holds true even if the facade panels are relatively light weight, which is a common misconception. Two structures that are not interconnected will incur differential settlement, so it is not prudent to bridge these structures with a facade system. Also, sidewalks will be demolished and reconstructed periodically during the life of a building and this demolition would cause the facade panels to collapse.

An additional item worth mentioning that concerns setting wainscot panels with a forklift is ensuring there is enough space between the bottom of panel and top of concrete ledge for the forks. The thickness of the forks

Chapter **21**

Mechanical (HVAC)

The mechanical work of a project (more commonly referred to as the heating, ventilation, and air conditioning, or HVAC, work) includes all equipment, ductwork, and piping for the systems that regulate air movement and/or modify the ambient air temperature. Following are some general examples of commonly encountered mechanical systems.

A. Air handling units (Figure 21.1) with variable air volume terminal boxes (Figure 21.2) (VAV boxes) are customary on commercial construction projects (Figure 21.3). This type of system derives its heat from a hydronic boiler system that is provided by the mechanical subcontractor, not the plumbing subcontractor as is often mistaken.
   a. Interestingly, pipe fitters, as the workers are called in the mechanical trade, for hydronic piping systems share the same union with plumbers. Though their formal training is somewhat different, these workers can actually be employed in either trade. However, in practice, pipe fitters rarely perform plumbing work and plumbers rarely perform pipe fitting work.

B. Residential projects, such as houses, condominiums, or apartment buildings, characteristically utilize split systems for heating and cooling. Split systems consist of a fan coil within a closet, attic, or ceiling soffit of a residence and a condensing unit on the roof.

C. The mechanical subcontractor will provide all exhaust systems, including the following:
   a. Restroom exhaust, due to odors, is required by building code to have its own dedicated duct system and exhaust fan.
   b. Laundry exhaust, due to lint collection, will also have its own duct system. This duct system, as will be discussed later in this chapter, may include integrated lint traps, in-line booster fans, or a roof-mounted exhaust fan.
   c. Commercial kitchen exhaust from the range, fryers, and other greasy cooking areas will be designed as an isolated system due to accumulation of grease in the ductwork.
   d. Parking garage exhaust is also designed as a stand-alone system.

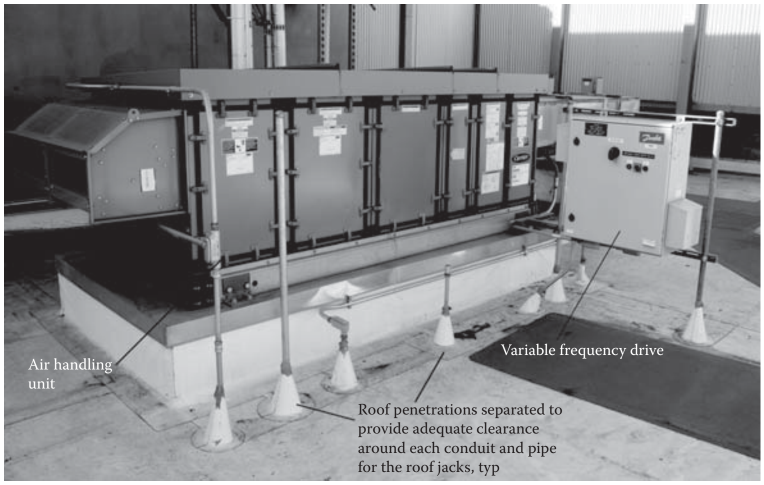

FIGURE 21.1 Air handling unit. (Photo by author, courtesy of the University of Southern California.)

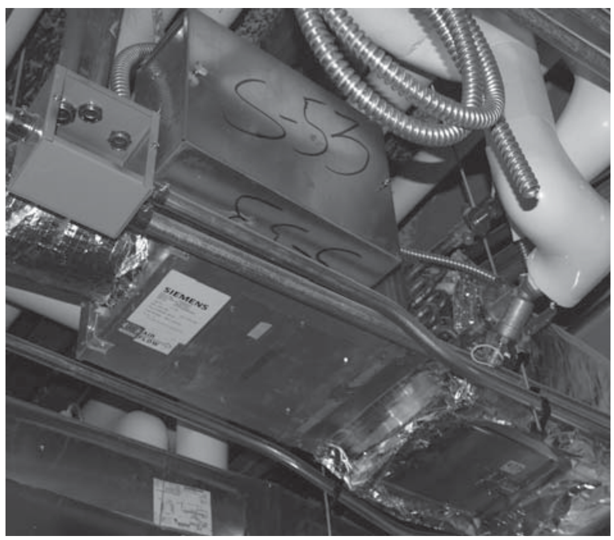

FIGURE 21.2 Variable air volume box, also termed a VAV or terminal box. (Photo by author, courtesy of Hathaway Dinwiddie Construction Company and the California Institute of Technology.)

D. Radiant heating, whether with radiators or tubing concealed in the floor or ceiling, is completed by the mechanical subcontractor's hydronic piping crew (pipe fitters). This is not the plumbing subcontractor's work as is sometimes confused. Although this system involves a considerable amount of piping and does not move air, it does control the air temperature, therefore it falls under the mechanical subcontractor's realm of responsibility.

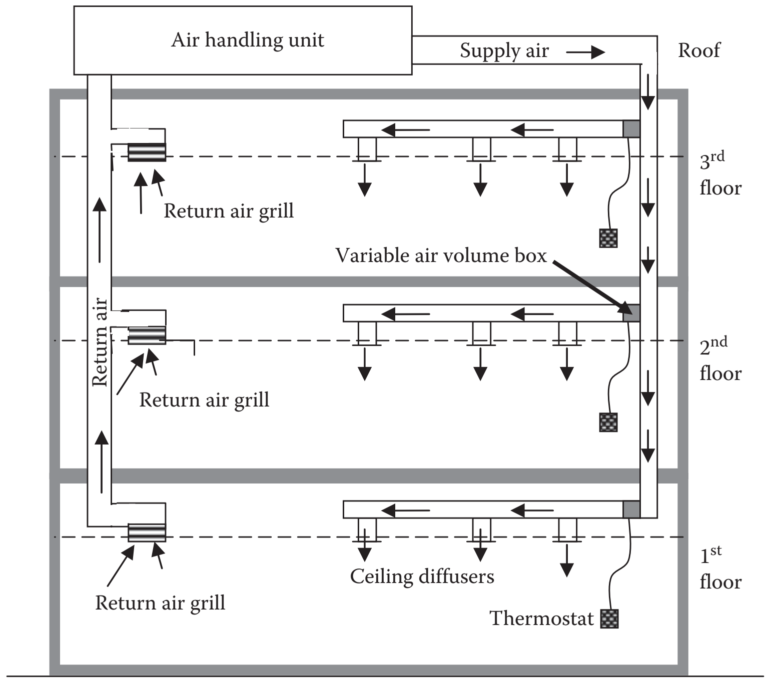

FIGURE 21.3 HVAC system. (Illustration by author and Jimmie Hinze.)

This is not a complete list of the systems a mechanical subcontractor may provide, but it is a good sampling of their responsibilities. When determining if work is to be performed by the mechanical subcontractor, the general rule is that if the system moves air, permits the movement of air, or has a primary purpose of controlling the ambient air temperature, it is most likely the mechanical subcontractor's work. There are few exceptions to this rule.

DESIGN CONSIDERATIONS FOR MECHANICAL SYSTEMS

1. Duct penetrations through a roof are a persistent source of leaks. As a general rule, penetrations should be made through a vertical surface, as opposed to a horizontal surface, whenever possible. This general advice is based upon the fact that water will shed down a vertical surface, but it will collect and pond on top of a horizontal surface. The mechanical subcontractor is traditionally delegated the flashings and sealants around duct penetrations on a design-build basis. But, because these waterproofing conditions have such a problematic history, it is a good quality control practice to provide these details in the design documents. By provision of these details, the architect maintains control over the quality of these seals and precludes the contractor from simply providing the least expensive installation possible.

Always remember, warranties usually last only a year, while buildings last for many decades.

a. Penetrations through a vertical surface are preferred. In addition to the obvious flashing and sealant elements, these details should identify the duct sloping slightly downward away from the wall. This angle will ensure water sheds away from the wall and prevent ponding on top of the duct and against the wall seal.
b. Ducts penetrating horizontally will do so through a sheet metal cap on top of a roof curb (Figure 21.4). This is one of the worst waterproofing details commonly practiced in the industry, especially when multiple ducts penetrate the same cap flashing. The seal from the duct to the cap flashing is often constructed poorly and is the genesis of many leaks.
c. A recommendable alternative that is rapidly gaining in popularity is to actually construct a sheet metal enclosure on top of the roof curbs (Figure 21.5). This is a fully waterproofed enclosure that for all intents and purposes can be considered a small penthouse. This method is especially effective for multiple duct penetrations.

2. Mechanical equipment located at the roof or attic of a multi-family residential project (apartments or condominiums) should always be positioned over corridors rather than directly over the residences. Even with well designed acoustical measures, this equipment vibration will inevitably create noise that travels into the residences. When placing equipment over a residence cannot be avoided it is a good design practice to position them

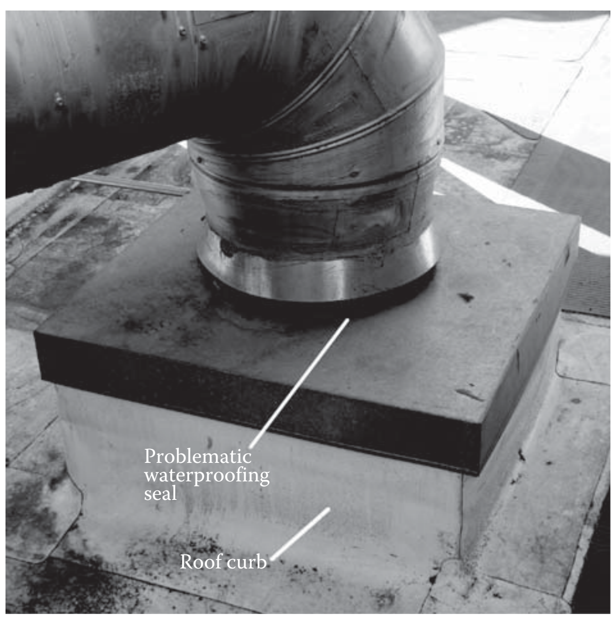

FIGURE 21.4 Vertical duct penetration through a roof cap flashing.

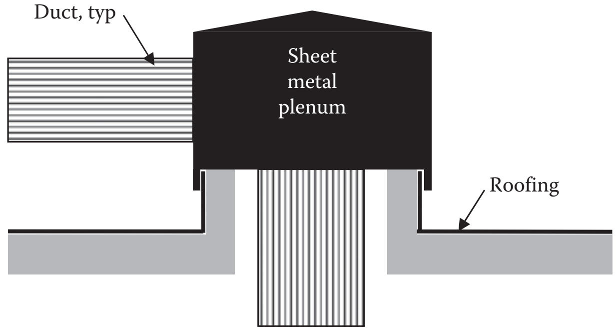

FIGURE 21.5 Horizontal duct penetration through a sheet metal plenum.

over bathrooms, kitchens, and other areas where the noise will not be as noticeable. Installing equipment over bedrooms should be avoided at all costs. This is an imperative design coordination effort between the architect and mechanical engineer.

3. When developing their design, mechanical engineers routinely take the acoustical performance of mechanical equipment into consideration. The mechanical engineer is charged with the duty of ensuring the acoustical performance of the equipment is within the acceptable project levels. But, what is not regularly considered is how the equipment may perform 20 or 30 years into the life of the building. As equipment ages it will begin to operate louder and produce greater vibrations. This projected equipment aging should be accounted for with appropriate acoustical measures in the initial project design.
4. The general contractor will orchestrate the MEP subcontractors in coordinating how their systems are routed through the building, underground, in the attic, and on the roof. This is known as the MEP coordination process. Through this process they will devise the most economical manners to install the MEP systems, but these may not be the methods best suited for the project. For this reason the design team is encouraged to impose restrictions on the MEP installation with regard to maintaining clear paths of travel for maintenance workers through the attic and on the roof. In some locations maintaining clear paths of travel will require the subcontractors to route their piping and conduit on racks approximately seven feet in the air rather than on the floor or roof (Figure 21.6). Not only will this produce an additional cost for the rack structures, but the overhead work entails a greater labor effort for the MEP crews than the same work at a comfortable and efficient working height. These pipe racks and additional labor will not be included by the bidders unless they are specifically directed to do so.

   These steel rack structures will usually be provided by the respective MEP subcontractors, not the miscellaneous metals subcontractor as is often mistaken. Because of this division of work these racks must be depicted on the mechanical, electrical, and plumbing drawings.

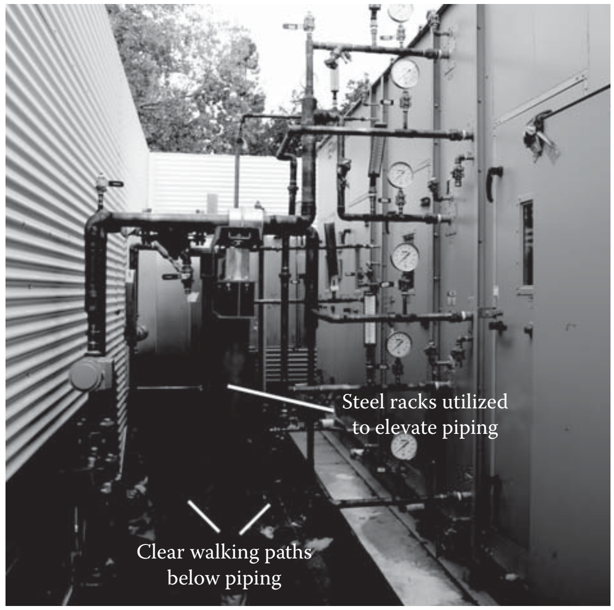

FIGURE 21.6 Hydronic piping supported above the walking path. (Photo by author, courtesy of Hathaway Dinwiddie Construction Company and California State University, Northridge.)

5. Sub-ducting is a method used to eliminate the need for smoke dampers on lateral exhaust ducts at a shaft (Figure 21.7). The concept is for small lateral exhaust ducts to penetrate the primary exhaust duct and run up inside it for a specified dimension, generally about 22 inches. This method is only employed with roof-mounted exhaust fans set for continuous operation. Also be aware that sub-ducting is allowable in many municipalities, but not all.

   The reason sub-ducts are necessary is to prevent any cross contamination of smoke from below making its way into a lateral duct. Tests have proven that smoke being pulled upward through the duct by a roof-mounted exhaust fan may, in reality, travel laterally into a non-sub-ducted branch duct, but it will not travel downward 22 inches through a sub-duct and then laterally into a branch duct.

   One of the most practical uses of sub-ducts is for dryer exhaust on a multi-family residential project, such as a condominium tower. Smoke dampers are required to prevent the movement of smoke between two different smoke control zones, so they are used when a duct has openings in two or more different smoke control zones. In the case of a condominium building, each residence will be considered a separate smoke control zone. A significant problem is presented in that smoke dampers cannot be used for dryer ducts because the lint will accumulate over time and clog them. For this reason, when sub-ducting is not allowed, the dryer ducts

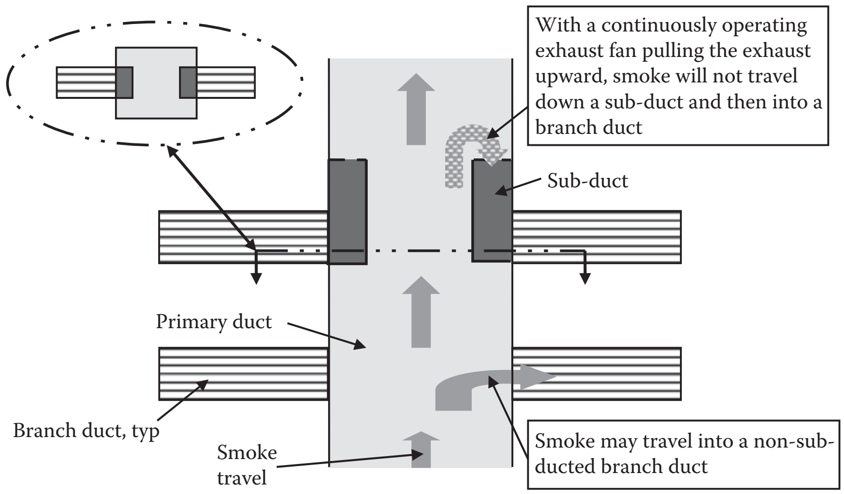

FIGURE 21.7 Sub-duct system.

must be routed individually from each residential unit, as they cannot open to another residence (i.e., another smoke control zone). When the dryer ducts are independently run all the way to the roof it involves a tremendous amount of ductwork. With the sub-ducting method of design this ductwork, and associated cost, is dramatically decreased.

6. To reduce the amount of ductwork and quantity of exhaust fans on a residential building the design team may choose to route the dryer and bathroom exhaust from each individual unit out the face of the building. This is a cost-effective approach, but serious considerations as to the positions of these exhaust ports on the building facade must be taken. A building with 300 units, each with two bathrooms and one laundry room, could have as many as 900 exhaust ports on the exterior of the building (Figure 21.8). The architect should be heavily involved in this portion of the mechanical design.
7. Dryer ducts are limited in their length to point of discharge from the building, unless they are routed to a continuously running exhaust fan. This length varies among different municipalities and is dependent on the number of bends in the duct, but is typically around 15 to 20 feet. This distance is so short due to the excessive lint accumulation inherent with these ducts. They must be short enough that a maintenance worker can effectively clean them out. There are two measures that may be implemented when a dryer duct exceeds the maximum allowable length:
   a. Lint traps in line with the duct may be added. These will collect lint in a filter screen midway along the duct and are typically maintained via a ceiling-mounted access door. The only negative attribute of these devices is the unattractive access door in the ceiling. The architect would be prudent to identify the access door locations on the reflected

FIGURE 21.8 Exhaust ports on building facade. Note that the exhaust ports shown in this photograph are different sizes, corresponding to the different duct sizes. To create uniformity, the architect could require that all ports are identical in size. This would entail upsizing the smaller exhaust ports to match the larger ones. The ductwork size would not need to be increased; only the exposed shroud.

ceiling plans, rather than leaving this layout to the contractor's discretion. This will help ensure they are placed in the least distracting locations possible.

b. A dryer booster fan may be added to force the exhaust air through the duct. These in-line fans are generally located in the laundry rooms, just a few feet from the dryers. This force is great enough to prevent the lint from settling in the duct and jettison it from the building. Booster fans are furnished and installed by the mechanical subcontractor, and therefore they must be depicted on the mechanical drawings. These fans must also be coordinated with the electrical drawings, but in a somewhat unique manner. Unlike most other devices, the electrical circuit to these fans will not be derived directly from an electrical panel. They are actually wired to contacts on the back of a dryer. These contacts provide 110 V power to the fans, which in essence serves a second purpose as the controls circuit. These contacts will power the fan while the dryer is on, but shut down power to the fan when the dryer is off. This obscure circuit needs to be depicted on the electrical drawings.

8. Mechanical units that produce both heating and cooling are very popular in residential construction. These mechanical units are normally located directly beneath windows and introduce fresh air into the residences through louvers. The louvers are regularly the same width as the windows and positioned immediately below them in an architecturally pleasing manner.

   The heating component of these units is usually a hydronic (hot water) system, which may require shut off valves, temperature gauges, and pressure gauges immediately adjacent to the mechanical unit. The use of through wall units such as these presents an aesthetic problem on the interior of the residence in that the piping connections are typically located on the sides of the units and these units are not routinely manufactured with a concealed space to house the piping components. These piping components will be an eyesore in a residence when not properly concealed. The architect and mechanical engineer should collaborate to specify window units that have an internal space for these piping components or design a custom enclosure.

9. Conflicts between baseboard heater locations and furniture layouts are seemingly unavoidable. This is especially true considering the fact that furniture layouts periodically change throughout the life of a building. However, the design team can take steps to minimize these conflicts by positioning baseboard heaters in unlikely furniture locations. For example, large furniture is seldom placed directly beneath a window, so the space directly under a window is an excellent baseboard heater location. Another optimal baseboard heater location is along kitchen island casework facing a living room, as these locations rarely have any more than a couple of bar stools placed in front of them.
10. Valves, terminal (VAV) boxes, dampers, and other items requiring periodic maintenance should always be located within about 18 inches above the ceiling. It is most economical for above ceiling items to be placed directly beneath the structural deck to reduce the extent of the supporting structures, but for projects with significant distances from the deck to the ceiling (this distance can be five or six feet is some cases) this can create a maintenance problem. For maintenance purposes, items mounted above the ceiling must be positioned such that they can be safely accessed from a ladder. Ladder access is limited through a T-bar ceiling grid or access door in a gypsum board ceiling, as ladders will not fit through them. Deciding whether to perform their work unsafely or to disassemble the ceiling system is not a decision maintenance workers should ever be faced with.

    A similar maintenance concern involves items located above a restroom ceiling that necessitate periodic maintenance. Access doors should never be located over the stalls (Figure 21.9), as the toilet partitions and water closets make it impossible to safely stand a ladder. It is advisable for the mechanical engineer to explicitly prohibit this practice in the design documents. As a good management practice, potential maintenance problems such as this should be examined during the submittal review process and monitored with the project's quality control program.
11. It is always best to locate valves, terminal boxes, dampers, and other items requiring periodic maintenance over corridors rather than over rooms, especially offices. This is important for two reasons. First, it is preferable to perform maintenance work without disturbing office occupants. And secondly, it is much easier to clean up in a corridor. Maintenance work generates dust, ceiling tile fibers, and other messes that are easily controlled in a corridor with a drop cloth and a vacuum. On the other hand, in an office this cleanup can be extensive with the myriad of items customarily found on the shelving, desks, and other furniture.

    Corridor ceiling spaces can become very congested with utilities, especially on biotechnology and hospital projects. To minimize this congestion

FIGURE 21.9 Access doors should not be placed in locations where they are not safely accessible, such as directly over toilet stalls.

mechanical subcontractors will want to install terminal boxes and as many other peripheral components as possible outside the corridor space. In many cases the corridor congestion will leave no other choice, so exceptions to this general criterion will need to be granted. It is a good design practice to require all items that require periodic maintenance to be located in the corridor unless otherwise specifically approved by the design team. With this approach the contractor will make their best effort to locate all items in the corridors and the architect will maintain full control over which items are allowed over the rooms. The ultimate goal of this approach is to minimize the quantity of items located over rooms.

12. Fan coils and other condensate-producing equipment mounted above the ceiling will require both primary and secondary drip pans with drain lines plumbed to the sanitary sewer system. Condensate-producing equipment is regularly manufactured with integral primary drip pans and many can also be provided with factory-equipped secondary drip pans. Equipment without an integral secondary drip pan will require an auxiliary drain pan custom fabricated and installed by the mechanical subcontractor. The plumbing subcontractor will always provide the drain line regardless of whether the drain pan is integral or auxiliary.

    When conflicts prohibit these drain lines from achieving a constant slope a small condensate pump becomes necessary. Most condensate-producing equipment that is commonly found above ceilings is offered by the manufacturers with an optional condensate pump. It is most cost-effective for the pump to be furnished as an integral feature of the equipment; therefore the mechanical engineer should incorporate this option into the equipment specification when deemed necessary.

    Of course, when the specified equipment does not offer an integral pump as an option an auxiliary pump will need to be identified in the equipment schedule. Interestingly, when the condensate pump is auxiliary it will actually be reflected in the plumbing equipment schedule and furnished by the plumbing subcontractor. This is because auxiliary pumps are generally categorized as plumbing components and are positioned in-line with the condensate drain piping. Auxiliary pumps will also require an individual electrical connection be identified on the electrical drawings, whereas the integral pumps are internally wired to the equipment.

13. Valves, meters, gauges, and other mechanical, electrical, and plumbing items located within gypsum board walls and ceilings necessitate access doors. Access doors are unattractive and can blemish the interior architecture of a building. However, there are proactive measures the design team can implement to minimize this impact to the building decor:
    a. Surface-mounted access doors are the least expensive type of access door and, because of this cost advantage, will be the contractor's product of choice. The design team may wish to specify more attractive access doors for use in architecturally significant areas. More attractive models include access doors with edges designed to be taped with the gypsum board, so as to present a frameless appearance, and models designed to receive a gypsum board inlay in the door, so the door itself can be finished to match the wall.
    b. A recurrent error with regard to access doors is when both high and low grade models are identified in the specifications, but the design documents do not indicate where each of these models are to be used. Subcontractors will be prone to using the less expensive product throughout the entire project unless specifically directed where the higher grade models are required.
    c. Access doors are furnished by the subcontractor whose work they are accessing and installed by the framing subcontractor. With a myriad of different parties furnishing access doors, ensuring the higher grade access doors are provided by each of them is a persistent quality control problem. Inexpensive surface-mounted access doors are used so routinely throughout the industry that subcontractors will furnish them as a standard operating procedure without even taking the time to read the access door specification. Because access doors have their own specification section and are not traditionally mentioned in each individual trade section, the reality is that few subcontractors will recognize the upgraded access door products. To combat this unfortunate trend, the design team is encouraged to add quality control notes to the drawings, make an effort to address this requirement during the various submittal reviews, and, of course, monitor the access door installations with the project's quality control program.
    d. Even though access doors are specified by the architect in Division 8, mechanical, electrical, and plumbing engineers each have a habit of adding a redundant access door specification in their respective MasterFormat Specifications Division. These duplicate specifications frequently go unnoticed by the architect during the design phase and

are regularly found to conflict with the Division 8 specification. This error occurs on an astoundingly high percentage of projects and can be avoided by simply eliminating the redundant specification sections.

e. The contractor is routinely required by the specifications to provide composite drawings that reflect all access door locations, but in reality these submittals are not always provided. The architect should not allow this important submittal to fall along the wayside of the project.
f. Determining access door locations is primarily the contractor's responsibility, but it is not solely the contractor's responsibility. A diligent architect will thoroughly review the mechanical, electrical, and plumbing drawings for this coordination purpose prior to issuing the design documents. During this review the architect should make an effort to identify locations access doors will blemish the interior design and work with the MEP engineers to relocate the problematic equipment, terminal boxes, valves, gauges, and other items to more discrete locations.
g. Whenever practical, access doors should be shared in an effort to reduce their total quantity. For instance, the corridor of a residential building may be littered with access doors because each individual utility at each individual residence will have a shut-off valve and in some cases might even have a meter. The architect should be heavily involved with the access door arrangement in areas where a substantial quantity of access doors is expected. This involvement will begin during the design phase and continue through the contractor's MEP coordination process.

14. When a supply or return duct is mounted flush with the face of wall a louvered grill is mounted in front of it. Unfortunately, when looking up at one of these grills the inside of the duct is visible. This is an architectural concern, but very easily hidden. The most common practice used to hide the visible silver duct surface is to paint the interior of the duct black within the visible zone. This way the only thing a person will see behind the louvered grill is a black surface mimicking darkness. A second method used for interior grills is to turn the grill upside down. Because the latter method presents a different architectural appearance and will direct the airflow up instead of down, some architects and mechanical engineers disapprove of this practice.
15. Mechanical engineers do not always indicate thermostat locations on their drawings, but they should. Instead, a note may be added to the drawings for the contractor to submit thermostat position drawings for design team approval prior to installation. One reason for this deferred responsibility is that these locations are unlikely to have a cost impact, so deferring this effort to the contractor's MEP coordination effort may appear to be an efficient and riskless approach. But, whether or not an element of work has a cost impact is not the differentiating characteristic between the design responsibilities of the mechanical engineer and the contractor. The differentiating characteristic is whether or not the issue has an impact on the appearance or function of a building. If an item has an impact to the appearance or function of the building it should be included in the design documents. Generally, the party responsible for making a decision is also responsible

for performing the respective design work. In this case the mechanical engineer is responsible for the decision as to where thermostats are located, and therefore they also hold the design responsibility. When the contractor locates the thermostats they are simply guessing where the mechanical engineer would prefer them, which is not an efficient approach.

16 Climate control zones may be minimized as a cost-saving effort, but this method of cost reduction can also lead to problems. For instance, consider a cluster of offices that are all controlled as a single zone. Assume this cluster includes five offices, a small open work area, and a medium-sized conference room. In a zone such as this the thermostat is traditionally placed in the office belonging to the highest ranking person. In this case, when the conference room is full of people their body heat will raise the temperature. Because the thermostat is not located in the conference room the mechanical system will not recognize this overheating. The conference room will become very hot, while the office with the thermostat remains at perfect temperature. In scenarios such as this it may be prudent to reorganize the climate control zones, provide additional zones, or reposition the thermostats.

17. Mechanical work involves a significant amount of low voltage controls work, which is reflected in the mechanical documents, not the electrical documents. The mechanical subcontractor normally provides the low voltage controls work via their own specialized low voltage electrical subcontractor. These controls can be simple, such as in a condo tower where most controls are simple wall-mounted thermostats tied to their respective fan coil. They can also be quite complex, such as for a high-end commercial building where each piece of equipment, terminal box, temperature gauge, zone thermostat, air flow sensor, pressure sensor, and so on will be wired to a central computer. This is termed a building management system (BMS). The BMS allows the building maintenance staff to monitor, and sometimes even control, the mechanical system components remotely. This expensive management system is particularly common and useful for large campuses such as universities and major industries.

    Additionally, the systems of other subcontractors, such as generators, domestic water pumps, and elevators, are also customarily monitored by the BMS system. The sensors, meters, and other devices for these nonmechanical systems will be furnished and installed by the subcontractor responsible for the respective system. The mechanical subcontractor will then provide conduit, wire, and terminations for the low voltage controls circuits to incorporate these points into the BMS system. Naturally, the mechanical subcontractor will also program the BMS system to recognize and monitor these points. Because of this joint responsibility, the design documents must clearly identify the devices in the mechanical controls drawings and the respective system series of drawings. For example, a pressure gauge in the domestic water system must be reflected on both the plumbing and mechanical drawings. These devices are generally depicted on single line diagrams in both series of drawings.

18. Commissioning of the mechanical system is described in most specifications as being performed by a third-party commissioning firm not affiliated with the mechanical subcontractor. In fact, most large mechanical subcontractors have a wholly owned subsidiary firm that performs commissioning work and, despite the specifications, employ this subsidiary as their third-party commissioning agent. These subsidiary firms are often given a completely different name than the parent company, seemingly so the association with the parent company is not readily apparent. The fact that this company is not a true, unbiased, third party is rarely noticed. This is not an easy issue to catch, so researching the corporate structure of the proposed third-party commissioning firm is an effort that should be included in the architect's quality control program.
19. Wherever a low voltage circuit begins a step-down transformer will be required. This will convert the 110 V power provided by the electrical subcontractor to a lower voltage, usually 24 V. This transition from medium to low voltage is the dividing line between the electrical and mechanical subcontractor's scopes of work, but this transformer is not always reflected in the design documents. When this transformer is not shown on either the electrical or mechanical drawings a bidding error will occur, as neither subcontractor will include it. It is most appropriate for this transformer to be furnished by the mechanical subcontractor, and therefore it is preferable for it to be reflected on the mechanical drawings.
20. Many air handling units and other large mechanical equipment are provided by the factory with an integral 110 V electrical receptacle. This should be coordinated with the electrical engineer so they do not needlessly indicate another convenience receptacle in the vicinity. This coordination effort has proven especially beneficial at the roof level, where it may eliminate the need for multiple electrical circuits.

Chapter 22

Electrical

The electrical scope of work is arguably the most technical of all the major trades. Electrical design documents are schematic in nature and require an educated and experienced subcontractor to complete the work in, essentially, a design-assist manner.

The electrical subcontractor will traditionally be held responsible for the majority of low voltage electrical work on a project. However, the electrical subcontractor will not normally self perform all of this work. Some of the larger electrical subcontractors do in fact maintain special crews to perform low voltage work, but most will actually employ several lower tier specialty subcontractors for these systems. Some of these low voltage specialty subcontractors include the fire alarm, telecommunication, security, and audio/visual trades. Low voltage subcontractors will provide their own wiring, but they cannot provide conduits, wire molds, or other raceways due to union jurisdictions. They commonly rely on the electrical subcontractor for this work. It is because of this unique arrangement that the general contractor will usually place these low voltage trades under the guidance of the electrical subcontractor. This is a very efficient, collaborative, and encouraged practice.

There are two apparent drawbacks to the electrical subcontractor employing these lower tier trades. First, the electrical subcontractor will add a markup percentage to the lower tier subcontractors' quotations. Secondly, the electrical subcontractor will commonly take bids for each low voltage trade from only one or two companies, with whom they have an established working relationship. As a result, they may not receive the lowest bids available. These drawbacks are overshadowed by the importance of the electrical subcontractor working in close cooperation with the low voltage subcontractors. This working relationship begins during the bidding phase and continues throughout the construction process. When contrasted with the drawbacks, the net worth of the coordination and management acquired through these arrangements are in fact purchased at a significant bargain.

DESIGN CONSIDERATIONS FOR ELECTRICAL SYSTEMS

1. The electrical engineer maintains primary control over the general project electrical devices, such as receptacles and lighting. They are also trained to look for routine items requiring power that are added to the design

documents by other design disciplines, such as air handling units, plumbing equipment, coiling doors, food service equipment, residential appliances, and water fountains. These common, large and/or obvious items are rarely missed by electrical engineers.

In contrast, the electrical engineer is liable to overlook the various obscure electrified components that are added to the design documents by the architect or other design team members. Some examples of project components requiring an electrical connection that an electrical engineer may fail to notice without a diligent interdisciplinary design coordination effort include:

a. The irrigation controller, which will only be shown on the landscape drawings (Figure 22.1).
b. An even more obscure item than the irrigation controller itself is its rain sensor. This is a water conservation device that signals (normally with a wireless connection) the irrigation controller when it is raining so the sprinklers shut down to take advantage of Mother Nature's courtesy watering. The rain sensor may be mounted to the side of the irrigation controller, but is more commonly located at the roof. When located at the roof it will require its own independent 110 V power source. Roof mounting is generally preferred to ensure trees, building eaves, and other items do not obstruct the rain sensor.

   When power for this device is reflected on the electrical drawings a subsequent, and frequently encountered, error is tying it to the same electrical circuit as the irrigation controller. This is not appropriate

FIGURE 22.1 Irrigation controller with an integral rain sensor.