The Construction Superintendent's Handbook

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Contents

Preface

My hat is off to the construction superintendent, that man or woman in the field who supervises the process of creating the structures we work in, play in and live in. All too often the days are long, the problems overwhelming and the possibility of adverse weather adds another variable to the equation. But through it all work goes on and somehow it gets built.

Construction is the largest single industry in the United States, providing employment for more than 5.2 million people and generating a total industry payroll of more than $32 billion. In 1991, the new construction put in place totaled $391.4 billion, and although substantially less than the $434 billion volume experienced in 1990, it is still a very respectable figure. The people associated with this industry ought to feel that they have made, and will continue to make, a substantial contribution to their communities and to their nation.

The superintendent on a construction project is one of the key participants in the entire construction process. He or she is the individual primarily responsible for the demanding task of orchestrating the activities of a small army of specialists in order to create a structure to house both man and his machines.

The construction superintendent must be knowledgeable in a wide range of technical matters and, at times, assume the role of engineer, lawyer, traffic cop, psychiatrist, teacher, father confessor and even magician. The construction superintendent must be strong and firm when strength and firmness is required, and soft spoken and understanding when that need arises. He or she must be fair—always—and above all possess the ability to create and maintain a harmonious team that will work toward a common goal—the successful and timely completion of the construction project.

At various times during the construction process, the superintendent will be able to call upon many experts in the field for advice and assistance, but at other times decisions will have to be made on the spot, with no time for reflection or consultation with others, and hopefully, this book will come in handy during those times.

The Construction Superintendent's Handbook will assist those people striving to attain the respected position of superintendent and will also provide more than a few insights for those experienced professionals who have achieved this goal.

This book is divided into three sections with many chapters within each one of these sections.

Section 1—The Job Begins Before The Job Begins is devoted to the preparation required before construction actually commences. The process of mobilization can be a hap-hazard affair or, when given enough forethought and planning, result in a smooth start to the construction that is soon to begin. With the threat of legal action hanging over everyone's head, construction superintendents nowadays must fully understand the company's responsibilities and contractual obligations as well as those of the other participants in the construction cycle. Chapters 1 through 4 deal with these subjects and more, and will help prepare the superintendent for the construction process discussed in the next section.

Section 2—The Construction Process elaborates on the jobsite daily routine, safety, and managing effectively in Chapters 5, 6 and 7. Chapter 8 should alert the superintendent to any legal pitfalls lurking around the corner. Working on a rehab project? Chapter 9 will discuss some of the unique problems facing the superintendent when remodeling and renovating projects.

Section 3—Basic Construction Technology delves into the more common construction components encountered on the jobsite, and while not purporting to cover every phase of every component, does contain valuable information to assist in answering many day-to-day questions about building systems, products and their application.

The author has been associated with the construction industry for more than 35 years. From summer jobs in high school to time clerk, assistant superintendent, project manager and vice-president in charge of operation, he addresses subjects from the front office view as well as from the trenchs. For those professionals who stay the course, the position of Construction Superintendent promises to provide an outstanding opportunity to realize job satisfaction as well as personal financial rewards.

I

The Job Begins Before the Job Begins

1

Mobilization

There is a great deal of work that must be accomplished before that first shovel of earth is turned or that first grade stake is driven into the ground. In much the same manner that a sound superstructure needs a sound foundation, so does the actual building sequence require sound preconstruction preparation.

The first step in this process involves mobilization—establishing and organizing the field office on the construction site, whether it be a fancy 50-foot trailer or a simple 10-foot by 10-foot homasote-covered shanty.

Second, the superintendent needs to be aware of the type of construction contract that has been awarded, since different types of contracts require different kinds of administration in the field.

Third, it is necessary for the superintendent to determine what is expected of the other parties to the contract—the owner, the professional consultants, both architect and engineer, subcontractors and vendors, and home office staff and personnel.

SETTING UP THE FIELD OFFICE

A well organized field office should provide easy access to all of the "tools of the trade," those important papers, documents, plans and specifications that will be referred to time and time again over the life of the project. A field office should have more than just a desk, chair and a telephone in order to provide a proper environment in which to work. On the other hand it does not necessarily require computer terminals and fancy electronic equipment to transform it into a functional, efficient office. What it does need is ORGANIZATION.

- A plan rack or plan table large enough to permit the review of drawings without having them fall off the table.
- A file cabinet, or file cabinets, for the systematic filing of all correspondence that will be generated over the life of the project.
- A lockable closet or cabinet in which to store confidential information along with valuable equipment such as lasers, surveying equipment and power tools.
- Shelf space for manuals, books of specifications and, hopefully, this book.
- A security alarm system.

- Drinking water, toilet facilities, conference table and other such nice touchs that the budget may allow.

The Facimile Transmission Machine

The expression "fax it" has become a part of today's business vocabulary, and the fax machine is a boon to the construction industry and that sometimes lonely outpost—the field office. As more and more architects, engineers, subcontractors and suppliers install these machines in their offices, electronic mailmen can deliver critical construction documents within minutes of the time requested. Fax machines installed in a field office can save valuable time and money when used to receive or transmit:

- Field changes requested by the architect, engineer, owner, home office, or the project superintendant.
- Critical product data sheets from subcontractors and suppliers to the architect–engineer for rapid review.
- Written authorization to proceed with extra work.
- Daily job progress reports.
- Weekly payroll time sheets
- Requests for clarification or information (RFCs and RFIs) when design conflicts or problems are uncovered in the field.
- Test reports and field inspection reports.
- Accident reports
- OSHA inspection reports.

Helpful hints to consider when Setting up the field office:

1. Establish a filing system using the same divisions as the contract specification book which normally follows the format of the CSI (Construction Specifications Institute) i.e. Division 2-Sitework, Division 3-Concrete, Division 4-Masonry, and so forth. Within each of these files place the appropriate subcontract agreements, purchase orders, approved product data sheets for that trade, and small size shop drawings.
2. Set up a secondary file for all subcontract agreements and purchase orders alphabetically arranged, not only as back up for the one filed in its appropriate division, but for more rapid accessability. When change orders are issued they should be attached to their respective subcontract agreement.
3. Request that the home office furnish a subcontractor–supplier list complete with phone numbers, fax numbers and name of contact person within the organization. Tack this on the wall near the phone.
4. Post emergency numbers on the wall—hospital, paramedic, fire department, police department, after-hours phone numbers for key home office personnel and emergency numbers for key subcontractors such as plumbing and electrical.

SITE LOGISTICS

Not only is it important to consider what belongs in a field office, but it is also equally as important to determine where the field office ought to be placed on the site, and a great deal of thought should be given to the total concept of site logistics—the how and where of the entire site usage during construction.

Locating the Field Office

There are certain key considerations to be reviewed when determining the placement of the field office on the site:

Will it have to be moved as construction progresses?
Can it be located relatively close to existing electric and telephone lines so that these utilities can be quickly and inexpensively connected to the field office?
Will the location afford the best view of activity on the site?
Will there be easy and convenient access to the field office for all of the visitors that can be expected and can nearby visitor parking spaces be created easily?

Other logistical considerations:

- Location of subcontractor field offices, storage sheds and material lay-down areas.
- Location of storage areas for general contractor equipment and supplies.
- Location of temporary roadways to provide access to the construction areas and to all of the field offices and storage areas on the site.
- Areas on the site to be kept free and clear for future activities such as those for structural steel shake-down, space for crane travel and the materials they will be hoisting into place.
- Environmental factors and neighborhood concerns.
- Site security.

Location of Subcontractor Field Offices and Storage Trailers

On a construction site for a big project quite a bit of space will be required to accomodate subcontractor office and storage trailers and this is a topic that should be discussed at the first subcontractor meeting. Advance preparation of a site plan with sections set aside for the subcontractors can be passed around for comment as to the location and size of space required for each trade. Temporary utility requirements should be discussed at the same time. Will electric welding equipment be used and, if so, what will be required in the way of exact power requirements? Will any subcontractors be using pipe cutting and threading machines? What about table saws and stone or masonry cutting saws that will require electric power sources and a water source? Although most general contractor–subcontractor agreements contain provisions stipulating who will be responsible for installing these temporary utilities, the superintendent must verify that there is sufficient incoming electrical service and other utilities available to accomodate all of these demands.

If a particular subcontractor has a requirement for an unusually large amount of space this must be kept in mind. For instance, a large masonry job will require areas for brick and block storage, sand, mortar, mortar mixing area and even space for such masonry accessories as brick anchors and wall reinforcements. The mechanical subcontractor may require a large area to store and fabricate pipe or a place to store major pieces of heating and cooling equipment prior to installation in the building. All of these requirements need to be considered when planning the subcontractor's staging areas.

Location of Other Material and Equipment Storage Areas

Lumber, plywood, reinforcing steel, welded wire mesh—all of these materials will be required on most projects and they need considerations other than just space:

- Is there easy access, not only for the delivery of these materials, but for later distribution to the building?
- Do some of these materials need to be protected from the weather and therefore must be covered and/or heated during cold weather?
- Will the possibility of theft of materials be another consideration when deciding on storage area locations?
- Will there be some method by which controlled access to these areas can be created?

And last, or possibly along with all of these other considerations, thought should be given to those materials that require a storage area very early in the project but must remain in those areas until the very late stages of construction.

Too often not enough consideration is given to the storage of topsoil, which is stripped from the site as soon as excavation commences and is not used until fine grading in preparation for landscaping begins. When moved from place to place as construction proceeds, this costly material tends to disappear as erosion and comingling with general fill occurs. Carefully consider the site logistics for this sometimes forgotten material.

Location of Temporary Roadways

When areas being designated for field office, storage area and materials depots are being planned, locating and maintaining temporary roadways must also be addressed. Environmental and cost concerns will enter into the equation and attention should focus on locations where these roads can remain until they are either incorporated into the permanent site road or driveway system or can remain in place as long as possible before being relocated. Depending on where the project is located geographically, other cost considerations come into play. During spring, summer and autumn in most parts of the country, the rainy season can turn poorly constructed temporary roads into quagmires, and on those construction sites in northern climates, heavy snowfalls require frequent plowing and roads of shorter length will cost less to maintain. And on those hot, dry summer days, dust control will be of major concern and contingency plans to obtain a water truck or sources for calcium chloride will all have to be thought out beforehand.

Temporary roads accessing directly onto busy thoroughfares may require a flagman, but if consideration had been given to moving this road around the corner, the need for traffic control might have been eliminated.

Future Areas on the Site to be Kept Free for Other Operations

On large suburban building sites where there is plenty of room, ample space considerations must be given to any construction procedures that require mobile cranes—either rubber tire or tracked. The erection of a mid-to high-rise structural steel-framed building with a mobile crane will not only require a level travel surface around the building but will also require space for the tractor trailers delivering the fabricated steel, and space for a "shake-out" area. Load-bearing masonry buildings with precast concrete plank floor decks will also require plenty of room for both crane travel and flat bed deliveries of materials. Buildings with stone clad exteriors, architectural precast concrete panels or glass curtain walls generally require access completely around the entire building. Although some of these areas can be temporarily occupied by other trades, they must be vacated in time for the trades that require the access later on.

Environmental Factors and Neighborhood Concerns

Along with the hay bales and situation fences, other environmental concerns can have an impact on individual site logistic plans. Are there public watersheds or public water sources nearby that may become polluted by site run-offs containing traces of diesel fuel, deicing salts, motor oils, acid-based masonry cleaners or leaky drums of antifreeze? Will construction traffic in and out of the site impact on the already heavy flow of traffic on some major arteries near the site? And will substantial amounts of antitracking materials be required at the entrance and exits to the site to keep the public roads relatively clear of dirt and debris?

As more and more construction sites develop in and around existing commercial, industrial and residential neighbors, a construction superintendent must become sensitive to the concerns of these neighbors. Diligent dust control, constant surveillance of public roadways and walkways near and adjacent to the site and attention to noise abatement procedures all contribute to an atmosphere where the contractor is perceived as a friendly, concerned neighbor rather than an intruder.

Outraged neighbors, whether corporate or residential can cause serious disruptions to the construction process and these disruptions run the gamut from irrate phone calls to court injunctions containing cease and desist orders. On the other hand, good neighbors can become a great asset as we shall see when we discuss site security. Paying attention to environmental and neighborhood concerns is not only good practice, but it is good business.

Site Security

Employee theft in the United States for all types of businesses amounts to approximately $50 billion per year, and in 1988 construction equipment thefts made up $1.1

billion of that total. Theft of equipment is not only costly in terms of replacement value, but possibly millions more could be added because of lost productivity and scheduling delays incurred as a result of the equipment not being there when needed.

The FBI recently published some rather astounding statistics—60 percent of all employees would steal if they knew that they wouldn't get caught, and 10 percent of the company's employees are actively looking to steal something. According to a Cocaine National Helpline survey conducted a few years ago, 18 percent of all cocaine users will steal from their co-workers.

Other statistics help to create a profile of the person most likely to steal from the workplace. Men are five times more likely to steal than women and younger men, those between the ages of 18 to 22, while comprising only 12 percent of the workforce, are credited with being responsible for 69 percent of all job site thefts.

There are ways to deter theft, some more obvious that others. A well constructed steel gang box secured with a heavy chain and strong lock is one of the best places to store hand and power tools. Both large and small tools should be prominently marked with I.D. numbers in such a manner that in order to remove these numbers it will be necessary to grind or burn away a substantial portion of the tool. When gasoline- or diesel-powered equipment is stored on the site, locked gas caps are a must. Not only will they prevent a disgruntled employee from dumping sand in the tank, but they will also prevent any neighborhood kid from discovering that sugar and gasoline don't mix.

According to the Associated General Contractors of America, in 1989 heavy equipment thefts and vandalism cost contractors $412,000,000. Protection against losses such as these require some rather special precautions. Equipment manufacturer J. I. Case distributes an antitheft kit to their dealers and customers, which sets forth an eleven-point program to deter potential equipment thieves:

1. Use security devices such as ignition locks, stabilizer arm locks and especially fuel shut-off valves (specifically ones that allow the equipment to move a short distance before it stops—this drives would-be thieves into a panic.)
2. Record the equipment's product identification number (PIN) and the serial numbers of all components and attachments to the equipment, and keep this document in a secure place.
3. Take photos of the equipment with particular attention to dings, dents, welds et' cetera so that these photos can be used for future identification if the equipment is stolen and recovered.
4. Plaster the equipment with large decals indicating that PIN's are hidden and a reward will be offered if the equipment thief is apprehended.
5. Don't leave parked equipment in remote areas or in unlit areas on the site. Park them in a highly visible location.
6. Light the site and park equipment in fenced-in areas.
7. Take frequent inventory of all equipment so that anything missing can be promptly reported.
8. Communicate with the local police. Let them know what equipment will be stationed on the site and how long it is likely to remain there. If they see anything moving off the site before that time, they should stop and question the driver.

9. Since 90 percent of all equipment thefts occur between 6.00 P.M Friday and 6:00 A.M. Monday, weekends require extra security measures.
10. Never, never leave keys in the equipment. It not only makes it easier to steal that piece of equipment, but also that key will quite often fit other pieces in the fleet.
11. Lock each machine whenever it is idle.

J. I. Case provides some other statistics that might be helpful in warding off the theft of equipment, by providing a list of the Top Ten pieces of equipment likely to be stolen:

1. J. I. Case 580 Backhoe-Loader.
2. John Deere 510 Backhoe-Loader.
3. Ford 445 Wheeled Loader.
4. John Deere 455 Crawler Loader.
5. J. I. Case 855 Crawler Loader.
6. Cat 734 Skid steer loader.
7. Clark 743 Skid steer loader.
8. Clark 555 Backhoe-loader.
9. Massey Ferguson 30 Backhoe-loader.
10. Cat 943 Crawler loader.

If you are working in one of the top-ten states chances of equipment theft will increase proportionately. The top-ten areas are:

1. Texas	6. Arizona
2. California	7. Illinois
3. Oklahoma	8. Georgia
4. Florida	9. Ohio
5. Michigan	10. Missouri

If your company owns a J. I. Case 580 Backhoe-loader and the construction project is located in Texas, keep a short leash on that piece of equipment.

Caterpillar™ Tractor's Answer to Equipment Theft

Caterpillar™ Tractor Company of Peoria, Illinois, is taking an active role in the prevention of equipment theft. If a piece of Cat equipment is stolen, the contractor is instructed to call the local Caterpillar™ Equipment office and give them the engine, transmission and torque convertor I. D. numbers. This information will be passed on to the Caterpillar™ Stolen Equipment File and, in turn, forwarded to the FBI, where it will be entered into the National Crime Information Center files. This file can be accessed by all law enforcement agencies and if a piece of stolen equipment shows up at any Caterpillar™ dealer, or if their service representative services any piece of stolen equipment in the field, the I. D. numbers of the stolen equipment are entered on a work sheet, and the dealer who initially registered the equipment will be quickly notified. Caterpillar™ is rightfully proud of the fact that in 1989, they achieved a 37.5

percent recovery rate on stolen equipment by using this system. Loren Bussert, a Caterpillar™ corporate security manager says, "We get an average of seven calls a day from law enforcement officials."

Good Neighbor Policies Pay Off

Paying a call on nearby neighbors and following up with a letter advising them that there will be a fair amount of equipment on the job site for a certain period of time can be the first step in enlisting their assistance. If they observe any unusual site activity on the weekends when the job is shut down, or in the evening when all workers have left, they should be asked to please call the company's after-hours representative.

Helpful hints to consider when formulating a site logistics plan:

1. Circulate a site plan to all major subcontractors indicating the areas set aside for their use. Include the location of access roads and ask them to comment on their designated spaces. Make them a part of the decision making process and they will be more receptive to the plan—and besides they just might come up with some good ideas!
2. Ask subcontractors to share in the cost of a weekend guard service or the expenses of installing bright site lights or creating fenced-in storage areas. They have as much to gain—or lose—as anyone else.
3. Visit neighbors, introduce yourself and give them a thumbnail sketch of what will be happening on the construction site and when the project is scheduled for completion. Leave your field office phone number and ask them to call if they have any problems. Sure, you'll get some crank calls, but most people will appreciate the thought. Stop back several months later and ask them "How am I doin'?"
4. Dispose of empty boxes on the site as quickly as possible. They not only add to the clutter and debris and constitute a potential fire hazard, but they also provide that dishonest employee with a container in which to sneak something off the site.
5. If an unfamiliar truck and driver appear on the job site with written instructions to pick up a valuable piece of equipment, call the owner of that equipment to verify.
6. Pay attention to noxious odors emanating from the site. If that gasoline or diesel engine is creating excessive fumes that could generate neighborhood complaints, shut it down until repaired or replaced. Site garbage should be promptly removed to avoid odors and keep the rodent population down. All part of your Good Neighbor Policy.

PROJECT START-UP CHECK LIST

Order telephone ________	Field Office Supplies ________
Pay phone for Subs? ________	Lumber marking crayons ________
Temporary power ________	Pencils, pens, pads ________
Access to Temporary Water ________	Cans of spray paint ________
Portable Toilets ________	File Folders ________
Temporary Fencing ________	Payroll forms ________
Hay bales, Siltation Fencing ________	Extra Work Orders ________
Construction Signs ________	Daily diary ________
Emergency Phone Number List ________	Backcharge slips ________
Building Permit ________	Telephone Numbers ________
OSHA Documents ________	Owner ________
EEO Documents and Posters ________	Architect/engineer ________
First Aid Kits ________	Testing lab ________
Security System Hook-up ________	Building officials ________
Personnel Equipment and Supplies ________	Subcontractors ________
________	Suppliers ________
Foul weather gear ________	Survey and Layout Equipment ________
Boots ________	________
Hand tools ________	Transit/level ________
Wooden grade stakes ________	Laser/battery pack ________

2

The Construction Contract and the Construction Documents

REVIEWING THE CONTRACT

In order to have a more complete understanding of the contractor's responsibility in any given project, a superintendent ought to be familiar with the type of construction contract that has been executed. Some of the terms and conditions in the contract may have a direct bearing on the administration of the work at the job site. A contract may contain some conditions that are at variance with those in the plans and specifications and, based upon legal precedents, the terms and conditions of the contract will take priority over those in the specifications or on the construction drawings. For example, if the contract indicates that construction time is 365 *working days* but the specifications indicate 365 *calender days* that's quite a difference since "working days" relates to a 251-day completion schedule not one of a year's duration.

It is important to analyze the provisions of the construction contract to determine which ones will have an impact on the administration of the project in the field. And not only is it important to be aware of certain provisions within the contract, but it is also of equal importance to be aware of the various types of construction contracts in general use today.

There are four basic types of construction contracts:

- The cost of work plus a fee contract (cost-plus)
- The lump sum or stipulated sum (as it is sometimes called) contract
- The cost of the work plus a fee with a guaranteed maximum price contract (GMP)
- The construction management contract (CM)

Each of these contract types have their own form of administrative procedures and requirements, many of which impact directly on the way in which a superintendent will operate in the field on a daily basis.

The Cost of the Work Plus a Fee Contract

Although an explanation of this form of contract might seem unnecessary, there are some important aspects of the cost-plus contract that warrant closer inspection. As the name implies, work under this type of contract will be paid for when substantiated costs are submitted to the owner and the contractor adds a fee to these costs. The fee is usually expressed as a percentage of submitted costs. But many of the problems associated with this form of contract relate to an interpretation of what is "cost." For instance, can the contractor include a portion of the owner's time spent administering the job or can costs include that new typewriter in the home office? These kinds of questions will be answered by reading the contract, since most standard cost-plus contract forms include a preprinted list of costs that will and will not be reimbursed:

Costs to be reimbursed:

1. Wages for labor in the direct employ of the contractor, including all fringe benefits.
2. Salaries of all personnel on the contractor's payroll who are stationed at the jobsite, whether clerical or supervisory.
3. Costs of reasonable travel, associated with the project, incurred by contractor's officers and managers.
4. Cost of all materials, equipment and supplies incorporated into the work, including all taxes and delivery costs. (Sometimes the contract will stipulate that certain tools exceeding a specific value, included in "costs" and paid by the owner, will be turned over to the owner when the project has been completed.)
5. All payments to subcontractors for work performed.
6. Cost of temporary equipment, equipment rentals, repairs to equipment and fuel costs.
7. Cost of temporary electric power and temporary water.
8. Insurance and bond costs, cost of permits and fees associated with the work.
9. Losses, expenses not covered by insurance, excluding those caused by contractor negligence.
10. Minor expenses, telephone, petty cash items, postage, stationery, supplies for the field office.
11. Costs to remove debris from the site, including dump fees.

Costs that will not be reimbursed:

1. Salaries of contractor's personnel stationed in the office. (An exception to this may be the project manager's time spent on project business while in the office.)
2. Expenses of the home office including overhead and general administrative expenses.
3. Contractor's capital expenses.
4. Costs due to negligence of the contractor or his subcontractors.
5. Cost of any item not specifically and expressly included in the Cost to be Reimbursed clause. (This is a category that must be clearly defined so that there

is an indication of what non-clear cut costs incurred in the field will be reimbursed. When in doubt submit the cost item for payment.)

So how does all of this affect the superintendent whose job it is to get that building out of the ground? Most cost-plus contracts contain a clause giving the owner the right to audit the contractor's books to verify all of the costs being invoiced. The records kept on the job site and the type of documentation forwarded to the home office will assist in providing substantiation of many of these costs. All that is required is to take a little more time at the end of the day to make appropriate notations in the daily log book, and on material receiving tickets and daily time sheets. Notations in the daily diary will document visits to the job site by the project manager and other home office personnel. A line or two concerning the purpose of the visit, topics discussed and action taken will further substantiate reimbursable time.

When the company transfers equipment or workers from another project to the cost-plus site, some form of "transfer slip" should accompany the move indicating when the worker or equipment arrived, how long they or it remained on the site and what was accomplished. Although daily time sheets may verify the worker's time another document may be needed for equipment tools or expendable supplies.

Material delivered to the job site from the company's own yard must be accompanied by a receiving ticket, and if the ticket does not contain the project name, this should be written on that ticket before sending it to the office. A brief notation with a description of what and where the material was used will be most helpful. If, for instance, two hundred 2 × 4's are ordered for temporary barricades, a note on the ticket will answer questions posed by the owner a year later when the books are being audited and this invoice is being questioned. When a professional service, such as a surveying crew, is engaged, ask the crew chief to note the activity performed that day on his worksheet and subsequent invoice.

Accurate record keeping is essential in establishing and substantiating all job-related, reimburseable costs, and remember, many questions could be raised about the validity of these costs several months or possibly a year later, and a brief note may be all that's needed to jog ones memory when asked about a certain expenditure.

Cost of the Work Plus a Fee With a Guaranteed Maximum Price— The GMP Contract

This type of contract is similar to the regular cost-plus contract in that all costs associated with the work may be audited by the owner at the end of the job, but with this form of contract there is a guarantee as to the maximum cost of the work. GMP contracts are often used when an owner is anxious to begin construction before a completed set of plans and specifications have been prepared. The general contractor will prepare an estimate based upon what the less-than-complete drawings reveal plus additional costs to cover the anticipated scope of work that may be reflected in the completed drawings and in the specifications. The GMP contract allows both owner and contractor to proceed with construction, because although work will progress on a cost-plus basis, the owner has the assurance of a "cap" on the upper limits of cost. The contractor, on the other hand will have built some form of contingency into the estimate to cover some unforseen costs, which inevitably creep into the project as the drawings are completed (a process sometimes referred to as "design creep"). An integral feature of all GMP contracts is a "savings" clause. In the event that the actual cost of the project is less than the GMP, both owner and contractor may share in these savings depending upon how the contract is worded. This monetary incentive is beneficial to both parties, and verification of all costs incorporated into the project take on another aspect—not only to substantiate the costs to be reimbursed by the owner, but also to provide a complete accounting of all costs to create the base from which savings, if any, can be calculated. So the superintendent's role in the documentation of GMP costs is as important as when administering a regular cost-plus contract.

Each item of work incorporated into the project must be clearly identified, receiving tickets must be properly marked, and equipment and labor costs documented through accurate time sheets and delivery receipts. As in the cost-plus contract, the GMP contract also includes a list of reimbursable and nonreimbursable expenses. Although the concept of a GMP contract is based on actual costs incurred plus the contractor's fee, any changes to the scope of the work should not be performed unless the guaranteed maximum price is adjusted, either upward when scope is added, or downward when items of work are being deleted. A simple scenario can be created to illustrate the effects of not changing the GMP when scope is changed.

Let's say the GMP of the project is	$3,000,000
And the contractor's fee is	300,000
Therefore "costs" ought to be	2,700,000
And let's say the project is 90 percent complete and all costs to date are	$2,500,000

Subtracting the contractor's fee of $300,000, there would appear to be a savings of $200,000. Suppose the client was to receive 75 percent of the savings, leaving 25 percent for the contractor. The owner or client would receive $150,000 and the contractor would receive $50,000. But let's change the scenario a little bit. The owner, aware of the potential $150,000 savings, decides to buy sod for certain areas around the building instead of seeding per the contract requirements—and suppose the added cost for this change amounts to $30,000.

If these added costs are incorporated into the project *without* increasing the GMP, the mathematics change as follows:

GMP remains at	$3,000,000	
Contractor's fee remains at	300,000	
Contract "costs" are	2,700,000	
Actual costs become	2,530,000	
Actual savings becomes	170,000	
Owner's share of savings	127,500	
Contractor's share of savings	42,500	(Contractor just forfeited $8,000 in savings)

But if the GMP had been increased by the cost of this added work, even though actual project costs could have incorporated these costs and still remain below the guaranteed maximum price, the savings figures would look like this:

Original GMP	$3,000,000	
Change Order No.1—Sod	30,000	
Adjusted GMP	3,030,000	
Contractor's fee	300,000	(For ease of explanation we won't increase the contractor's fee, but in actuality it would increase by virtue of the change order.)
Cost of Work Estimated	2,730,000	
Actual costs	2,530,000	

Savings remain at $200,000 and the contractor's 25 percent portion remains at $50,000.

So it is important to remember that, even though a GMP concept is cost of the work not to exceed a specified amount and any savings generated would allow the inclusion of extra work without exceeding the maximum price, if there are true scope changes, the GMP must be adjusted to reflect these changes.

The savings clause in the GMP contract can also be applied to value engineering proposals submitted by the general contractor and subcontractors. Since the general contractor will share in any savings, it behooves him to constantly search out ways to increase savings without jeopardizing quality of construction. For example, if the tile subcontractor is able to make a "buy" on a slightly different color bathroom floor tile, he should be encouraged to submit both cost reductions and samples for approval. If the client accepts the tile, and a $3,000 savings is being offered, the contractor would share in these savings. Contractors who have success with GMP contracts are able to offer the client savings through the value engineering process, and the superintendent should be alert to any such potential cost savings from the beginning of the project to its end.

The Lump-Sum or Stipulated-Sum Contract

The lump-sum contract is the form used in almost all competitively bid projects, and when awarded a lump-sum contract, the contractor is obliged to perform all of the work included in the plans and specifications for a specified or lump sum dollar amount. If the contractor's costs for the completed project are substantially less than those in his estimate, he would make more profit than initially anticipated, but conversely, if the project's final costs exceed those in the estimate, less profit will be realized. Although this might appear to be a very straight forward approach to the construction process, incomplete or poorly prepared or coordinated bid documents can result in varying interpretations as to exactly what is included in the lump sum price. So even though the lump-sum contract stipulates that the contractor will perform *all* of the work detailed in the plans and specifications, when construction begins, there may be many disagreements between client, consultants and the contractor as to just what work is to be performed.

Both project superintendent and project manager need to carefully review the lump-sum contract documents to determine whether the plans and specifications contain information that is complete. If there are unclear or missing details, they should be noted so that clarification can be obtained from the architect and/or engineer. A check of dimensions, both architectural and structural, need to be made to ensure that everything checks out and the column spacing on the structural drawings is the same as that indicated on the architectural, mechanical and electrical drawings. Although it is the responsibility of the architect to confirm dimensions and coordinate drawings, the contractor has an obligation to check the drawings for errors, inconsistancies and omissions. Provisions in the general or supplementary conditions of the specifications will many times hold the contractor responsible for problems created by his failure to report dimensional discrepancies to the designers.

When and if variations are uncovered or missing details or incomplete details are found, the project manager should be notified immediately so that a request for information or clarification (RFI, RFC) can be sent to the architect. During the early phases of construction the superintendent should be alert to any questions concerning scope that may be raised by subcontractors as they gear up for their work. If their questions cannot be answered by a thorough review of the plans and specs, these concerns should be raised at the next job meeting, if time permits, or via a formal RFI or RFC if the concern is immediate.

The Construction Manager Form of Contract (CM)

Some sources state that the Wicks Law enacted in New York state in 1921 was the impetus behind the creation of the construction manager concept. The Wicks Law mandated that four prime contracts—one for HVAC, one for electrical, one for plumbing and one for general construction—are to be awarded for all contracts issued by public agencies in New York State when the value of the work exceeds $50,000. Under this concept none of these "primes" had overall responsibility for project coordination, so another supervisory layer had to be added for that purpose, and that was the role filled by the construction manager. As ungainly as it seems, the Wicks Law is still in effect in New York today and just as hotly contested as it was back in the '20s. By the mid-1960s the role of the construction manager had expanded greatly as more and more complex projects began to be designed and constructed. The CM began to get involved in the project during the design stage so that owners could use the expertise of a contractor who would bring cost estimating experience and other skills to the table to assist in guiding the project through the design-budget process. Today's CM is employed to act as the owner's agent and oversee the project either through the design stage or the construction stage or, in some cases, through both stages. When the pure form of construction management is used, subcontract agreements are issued in the owner's name, and the CM reviews and approves monthly payment requests. Checks to subcontractors are issued directly to them by the owner.

The CM is reimbursed for specific expenses incurred while administering the contract, and CM fees are derived in several different ways:

- A professional fee generally computed as a percentage of the cost of the construction work
- A fixed fee
- Direct expenses marked up to include overhead and profit (referred to as "reimbursables")

Reimburseable expenses usually are confined to the cost of on-site supervision and clerical help, including all field office expenses, project management and other supervisory costs (field engineer, project super, assistant super), and secretarial and accounting personnel stationed at the jobsite.

Construction management in the 1990s can be further defined as a CM "at-risk" or a CM "not-at-risk." The at-risk CM will be required to guarantee the ultimate cost of the project in much the same way that a conventional general contractor agrees to a lump sum price, while the not-at-risk CM does not guarantee a final cost, operating more or less as though a cost plus contract is being administered. The CM concept has gone through many mutations over the years and it is not uncommon to find general contractors nowadays performing work with GMP contracts but calling themselves construction managers since they provide preconstruction design services (usually on a no-cost basis) in order to obtain the contract for construction.

THE CONTRACT PLANS AND SPECIFICATIONS

The Plans

Prior to the actual start of construction and after the contract has been reviewed and important points noted, a thorough review of the contract plans or drawings must take place. But first of all it is important to ensure that these drawings represent the "contract set." Quite often on competitively bid projects, changes will occur as the architect reviews and clarifies, or even changes certain details as contractors bidding the job request clarifications or point out deficiencies in the drawings as they assemble their bids. The architect's changes, clarifications and so forth are then issued as addendums either in the form of written instructions, small scale drawings, or even full size drawings so it is important to have the correct set of drawings at the job site.

The Contract Set of drawings

Once a contract for construction has been awarded some architects may see fit to issue a completely new set of drawings incorporating all of the changes that took place during the bidding process, and in the title block, a new drawing issue date will be inserted often followed by the notation "contract set." Other architects may issue 8 ½ × 11 size pages incorporating some of the minor drawing changes, and if that is the case, it is important that these sketchs are assembled into the set of contract drawings. This can be accomplished by merely taping the sheets over the details they supercede. By taping only one edge, it is easy to compare new details with the ones they replaced, and by marking the appropriate addendum numbers alongside the sketches, the origin of the changes can be identified.

As the project progresses and possibly more and more clarification–addition–change sketchs are issued by the architect and engineer, the designer may decide to issue a completely new set of drawings that would incorporate all of these changes. This new set of drawings will have a new issue date in the title block and will be known as "conformed" drawings. When this occurs, and these new sets of drawings are distributed, a quick review should be made of these conformed drawings to confirm that all of the previous changes, but no additional changes, have been incorporated onto this new issue. Once that fact is established, roll up the old drawings, prominently mark them "Superseded" and file them away.

If during the course of construction, full-size individual drawings are revised and reissued, they should be incorporated into the contract set directly ahead of the drawing or drawings they replace. Mark the old drawings "VOID" in large letters so there is no confusion over which drawing is valid. From time to time it is advisable to review the updated contract drawings list with all subcontractors to ensure that everyone is working with the same set of current, updated drawings.

The Contract Specifications

Just as drawings are sometimes revised, so are the specifications, either during the bidding process or after the contract is awarded. An addendum issued by the architect may contain changes to three or four specification sections all printed on one page. It then becomes necessary to incorporate each change into its applicable section. In order to do so, cut out each specification change and tape it directly over the superseded sentence or paragraph. Tape only one edge so it can be lifted and compared with the superseded sentence or section. Alongside the taped-on portion write the addendum number from which it had been clipped. By separating each section of the specifications book with a divider and tab, and placing them in a loose leaf binder, it becomes easier to locate a specific section quickly, and when an entire page has to be replaced it is much simpler when a binder is used. Be sure to prominently mark all superceded pages in the book in big, bold letters: "VOID."

Checking the Plans and Specifications for Completeness and Accuracy

In today's construction marketplace, projects are more complex than ever before, and in today's fast paced construction climate, architects and engineers are under pressure from clients to produce plans and specifications in the shortest possible time. Unfortunately this process may produce plans and specs that have not been thoroughly checked for completeness or coordinated with respect to structural, architectural, and electrical components. This places a heavy burden on the contractor, project manager and project superintendent.

Plans and specifications have to be carefully reviewed to determine whether everything will "fit" and that there is sufficient information with which to build the building. There are boilerplate statements in most "Instructions to Bidders" documents and in the general or supplementary general conditions that state, "If the contractor discovers missing or incomplete details or conflicting items of work, he is obliged to call them to the attention of the architect for clarification. Failure to do so will result in the architect disallowing any claims for extra costs." Even though this disclaimer is included in most construction documents, the architect does owe the contractor a set of drawings that are reasonably complete and contain sufficient details so that the project can be built. Notwithstanding disclaimers inserted by the designers, the contractor must review the plans and specifications carefully in order to uncover or discover any shortcomings. Whether they are cause for a claim requires quite a bit of investigation, but the first order of business is getting the job out of the ground and avoiding problems that may be caused by a less than thorough review of these documents.

Helpful Hints when Making that Initial Review of the Contract Drawings

1. Add all of the dimensions on the site plan including back yard, side yard, front setback and the actual footprint of the building. Does everything fit? Do the individual dimensions add up to the overall dimensions?
2. Check a few random storm and sanitary pipe inverts. Are they compatible with the inverts at the building and those at the points of connection? Will all lines flow with the proper pitch?
3. If any site utilities cross over each other, is there sufficient coverage for each?
4. Do sidewalks, driveways, platforms pitch away from the building correctly?
5. Do inverts for mechanical lines on the mechanical drawings coincide with those on the site plan? Check water, storm, sanitary and also electrical conduits.
6. Add dimensions across column lines on the structural drawings to determine if they reconcile with the overall dimensions. Do the column spacings on the structural drawings coincide with those on the architectural plan?
7. Do the structural floor-to-floor heights relate properly to the finish floor-to-floor dimensions on the architectural drawings?
8. Compare duct riser and elevator shaft locations and sizes on structural, architectural and mechanical plans.
9. Verify that location and size of louvers on mechanical drawings correspond with the size and location on both architectural and structural drawings.
10. Concrete pads, either housekeeping or equipment, may be detailed on the architectural drawings but not shown on any other drawings. Review all applicable plans.
11. Will the proposed ceiling heights and underside of structural beams allow for above ceiling installation of mechanical and electrical items of work? (If mechanical and electrical subcontractors are required to submit coordinated drawings that will also uncover any potential problems.)
12. Does the reflected ceiling plan accurately show the same placement of electrical fixtures, sprinkler heads and ceiling diffusers as the applicable mechanical and electrical drawings?
13. Check a few floor plans to determine if the individual room dimensions, including partition widths, add up to the overall floor dimensions as shown on the drawing.

14. Spot check various partition types to determine if they correspond with large-scale details. Are shaft wall and fire-rated partitions so noted?
15. Is the finish schedule and door schedule complete or are some items not complete? Are there any discrepancies (i.e., does the schedule stipulate a hollow metal door frame, but the corresponding detail reveals a wood frame)?
16. Carefully read the notes on the structural drawings as they relate to concrete. Is the type of concrete listed for each use? Does this schedule conflict with any other notes on other drawings? Do these notes contain instructions for construction joint placement, shoring requirements, time frame required to strip forms?
17. Review the notes on the structural steel drawings, if that is the form of structure required on the project.

Review the Contract Specifications

1. Prior to the first appearance of any trade on the site, review their applicable specification section and note any key elements that need to be reviewed with that trade's foreman.
2. When a specification section contains a paragraph with the heading "Related Work in Other Sections," check those other sections for information.
3. Are there duplications of work contained in the specifications? A common occurance is listing hardware for aluminum exterior doors in both the "Hardware" section as well as the "Architectural Metals" or "Glass and Glazing" section. If such duplication does exist notify the project manager.
4. When the project architect or engineer's office is located in another state, read the general conditions portion of the specifications along with the special conditions for mechanical and electrical trades *very carefully*. Trade practices in one state may vary from those in another state. For instance, practices in an adjacent state may direct the mechanical and electrical subcontractors to provide trenching and backfilling for their work, but in the state in which the project is being built, these operations may have been historically assigned to the general contractor. Other specification provisions such as clean-up, temporary light and power requirements and stand-by trade issues may also vary from state to state.

No matter which form of construction contract is being administered, a superintendent needs to thoroughly review the plans and specifications, not only to ensure that they are complete, but also to scrutinize them for any constructive suggestions or changes. With the years and years of hands-on experience that most superintendents possess, they may be able to suggest a more reasonable or expeditious approach to a particular construction problem or detail. An experienced superintendent may be able to suggest cost-cutting measures or less expensive ways to achieve the architect's end goals. Value engineering suggestions originating from subcontractors should also be solicited and analyzed, and if worthwhile passed on to the home office for further review. Most owners and architects appreciate these kinds of suggestions, and they help to establish the "team" effort at the onset of the project that if continued will develop that harmonious relationship that is the hallmark of most successful construction projects.

The A.I.A. General Conditions to the Construction Contract

American Institute of Architects Document A201—General Conditions of the Contract for Construction is included in most construction contracts, either as an attachment to the contract itself or by inclusion in the specifications book. Although often overlooked as just "boilerplate," it is, an important legal document that contains some rather important points that both contractor and superintendent should understand. It should be read, at least once, from start to finish and refered to from time to time. A few of the more important issues discussed in the latest 1987 edition of the A201 document are listed below.

Article 2—Lists the responsibilities and rights of the owner, which include the obligation to provide the contractor with a survey of the property containing its legal limits and the location of existing utilities. This article gives the owner the right to correct any deficiencies in the work if the contractor fails to do so within seven days after receipt of written notice.

Article 3—Pertains to the contractor, and should be read in its entirety. It states that the contractor shall not be liable for damages resulting from any errors or omissions in the plans and specifications except if the contractor fails to notify the architect in writing. The contractor is not responsible for ascertaining that the plans and specifications conform to applicable laws, building codes and the like, but the contractor must advise the architect if they do not. This article contains instructions pertaining to shop drawings and the contractor's responsibility for deviations from the contract documents. A provision in this article allows the owner to clean the premises and back charge the contractor if the builder does not keep the premises clean.

Article 4—Sets forth the architect's obligations and states that he has no control over construction means and methods and techniques since these are solely the contractor's responsibilities. The method by which contractor claims are to be presented is included in this article along with the conditions that constitute the basis for these claims. When weather conditions are the basis for a claim, the contractor must be able to provide accurate records to substantiate that those conditions were abnormal and could not have been reasonably anticipated.

Article 5—Relates to subcontractors and allows the architect the right to object to the hiring of any subcontractor if a reasonable objection can be presented.

Article 6—Stipulates that the owner may perform certain portions of the work with his own forces or he can award separate contracts in connection with other portions of the work. (This could cause a problem for the contractor if the owner's selection of a subcontractor creates a jurisdictional dispute with those subcontractors hired by the general contractor.)

Article 7—Discusses changes in the work and the preparation of change orders along with costs that can be included in the cost of work covered by a change order. When architect and contractor cannot agree on the cost of the change-order work as presented, procedures in this article explain how the contractor is to perform the work while keeping accurate records of all costs for resolution after the work has been completed.

Article 8—Deals with the subject of Time and Dates—the time when construction commences, the date when substantial completion is reached and extensions of contract time due to delays.

Article 9—Sets forth instructions for applications for payment and the conditions that must be met in order to establish substantial completion, partial occupancy and final completion of the project.

Article 10 and 11—Relate to safety, insurance and bond requirements.

Article 12—Directs the contractor to promptly correct any rejected work. The contractor shall bear the costs to correct defective work and will also be charged for additional costs incurred for architectural services and expenses relating to any testing and inspection services that may be required. Warranties issued during construction are to be extended from the time the contractor was directed to correct any work and the time when these corrections were completed. Or the owner may choose to accept the defective work and receive a credit.

Article 13—Defines the responsibility for testing procedures and the party obligated to pay for them.

Article 14—Contains the conditions whereby the contractor or owner may terminate the construction contract.

3

Subcontract Agreements, Purchase Orders and Project Manning

Do It with Our Own Forces or Sub It Out?

That question might be answered quite differently depending upon whether the contractor operates under union collective bargaining agreements or as open shop or merit shop contractors. While union contractors can tap the local hiring hall for trained and skilled workers, merit or open shop contractors must depend upon their own training programs, vocational training schools, word of mouth or other forms of advertising in order to augment their forces.

The Changing Face of the Work Force

Skilled labor in either case is a diminishing commodity today. There are less people entering the work force today and the existing work force is aging. In 1980 there were 30 million 18-24 year olds actively employed, but it is anticipated that this productive pool of labor will shrink to 25 million by 1995 as older workers retire earlier and almost 66 percent of the new entrants into the work force in the last decade of the Twentieth Century will be women, minority and immigrant labor. According to the Business Roundtable, an organization of America's top executives, the construction industry alone requires 263,000 new and replacement workers each year, but only 50,000 or so have actually sought employment in that field.

The division between union workers and non-union workers is also changing. Since World War II, union membership has declined from a high point of 33 percent of all non-farm workers to 16 percent in 1990. The Northeast, long a bastion of union construction has seen open shop operations increase dramatically. In Boston, Massachusetts, in 1989, the unions claimed their share of the market had slipped from 75 percent to 55 percent and according to nonunion sources, the union market share outside of the Boston metropolitan area slid to 30 percent.

With fewer people entering the work force and more older, experienced workers leaving it, properly trained workers will be at a premium and it is likely that both union and nonunion shops will vie for diminishing pools of skilled labor and companies will have to offer the proper incentives in order to maintain a skilled and productive workforce. This will probably result in more and more general contractors relying upon specialized subcontractors to perform work that they may have undertaken previously with their own forces.

SUBCONTRACTING THE WORK

Many superintendents are of the opinion that they cannot exhibit the same degree of control over subcontractors as they can over their own forces and although this may be true to a certain extent, managing subcontracted work requires slightly different techniques. To deal effectively with subcontractors, a superintendent must be completely familiar with the subcontract agreement and the obligations contained in that agreement.

Each general contractor has its own tailor made subcontract agreement and while the language and legalese may vary from contract to contract, the intent of certain provisions remains the same. Most subcontractor agreements contain provisions that fall into four basic categories:

Scope of work contained in the contract.
The time frame in which the work is to be performed.
Obligations of the subcontractor and obligations of the general contractor.
Method and time of payment for services rendered.

Scope of Work

It is not enough for a contract agreement to direct the subcontractor to perform the work in "accordance with the plans and specifications." The scope of the work is probably the most controversial part of the agreement. The subcontract agreement should list all drawings that include information relating to the scope of work and each drawing identified including the date of issue. Too often a subcontractor will indicate that he only reviewed and accepted what is now an outdated drawing.

Merely stating "the specifications" as a reference point in the contract may create another problem since the subcontractor may have to abide by certain terms and conditions in other sections of the specifications. Quite often the general or supplementary conditions in the front portion of the spec book contain requirements for "as builts," guarantees and warranties, project close-out procedures and other obligations that the subcontractor will be responsible to fulfill.

All addendums to the contract or bulletins issued after the construction contract was executed as well as any other revisions to that contract must be made a part of the subcontract agreement. Miscellaneous agreements concluded during subcontract negotiations should be clearly spelled out in the scope of work section of the agreement. In the event that the subcontractor's initial proposal contained a detailed list of inclusions and exclusions that were accepted as-is or changed slightly, this list should also be included in the subcontract agreement as an exhibit to the contract. It is difficult for a subcontractor to state at a later date that certain portions of work were excluded when their initial proposal included those items, and they were not deleted during negotiations.

Time Frame in Which the Work Is to be Performed

The often heard phase "time is of the essence" is more than just an expression—it is a legal term that means that work must be pursued continuously and without interruption because not to do so will result in severe financial implications to all concerned parties. Most subcontract agreements include a date on which work is to start, a completion date, a reference to the general contractor's schedule and a "time is of the essence" clause. Another clause found in many subcontract agreements requires the subcontractor to staff the job in order to maintain adequate job progress as defined by the general contractor and if he fails to do so sets forth the steps that can be taken by the general contractor in order to maintain adequate job progress. A few excerpted paragraphs from one general contractor's agreement will illustrate the point.

> "The subcontractor shall commence work within three days after notice from the General Contractor and shall continuously prosecute the work with due diligence so as not to cause any delays or interference with the completion of the project. If said work is not being performed with due diligence and the general contractor shall be the sole judge, the subcontractor upon three days notice from the general contractor agrees to supply the required equipment, materials and workers necessary to expedite the completion of the work. If the subcontractor fails to do so, the general contractor without any further notice may engage other forces to perform the work and charge the subcontractor's account for that work."

Another version of this provision is as follows:

> Should the subcontractor fail to prosecute the work or any part therefore with promptness and diligence, fail to supply a sufficiency of properly skilled workers or materials of proper quality or fail in any other respect to comply with the contract documents, the contractor shall be at liberty, after seventy-two hours notice to the subcontractor to provide such labor or materials as may be necessary to complete the work and to deduct the cost and expense thereof from any money then due the subcontractor. The contractor shall be at liberty to bar the subcontractor from the job site and take possession for the purpose of completing the work, all materials, tools, scaffolding, ways, works, apparatus, machinery, equipment and appliances and contract with any other persons to finish the same."

Take a look at your company's subcontract agreement and see if these kinds of time-related provisions are included.

Obligations of the Subcontractor and Obligations of the General Contractor

These kinds of provisions are many and varied but generally include the following:

- Subcontractor must abide by all applicable federal, state and local laws and ordinances.

- Subcontractor must provide insurance coverage in amounts and types included in the specifications.
- Subcontractor will not engage in any discriminatory hiring practices and will abide by the provisions of Executive Order 11246 (an Equal Opportunity document).
- Subcontractor warrants that all materials and equipment is new and in good condition.
- Subcontractor shall at all times keep the premises neat and orderly and clean on a regular basis. (Some contracts require the sub to clean on a daily basis.)
- General contractor is to provide a construction progress schedule and issue updates as required.
- General contractor has the right to direct the subcontractor to make changes in the work with an adjustment to the contract sum.
- General contractor shall issue written work orders to cover changes in the work or extra work.
- General contractor can terminate the contract for cause. (And the reasons for termination are included in another part of the agreement.)
- General contractor has the obligation to expedite the work as rapidly as possible.
- General contractor must be notified, in writing, of subcontractor's intent to sublet any portion of the work, and must give permission to do so.

Method of Payment for Services Rendered

There are several provisions in the subcontract agreement addressing payments, and they can be categorized as follows:

- The schedule of the regular monthly payment, including a date when the subcontractor's requisition is to be submitted to the general contractor, and when the subcontractor can expect payment in return.
- A provision relating to retainage, how much will be withheld each month, when retainage will be reduced and under what conditions release of retainage will occur.

The circumstances under which the general contractor can withhold all or a portion of monies due:

1. To pay for defective work not corrected by the subcontractor after such a request was made.
2. To compensate the general contractor for any losses incurred due to the subcontractor's delayed or faulty performance.
3. To cover the cost of a bond required to be posted by the general contractor due to a lien filed against the subcontractor by a supplier or second tier subcontractor.
4. To pay debts incurred by the subcontractor when they declare insolvency.

Although the subcontract agreement provides the general contractor with certain powers to ensure that job progress is maintained, a subcontractor that does not respond to the superintendent's repeated requests for additional manpower or for more materials and equipment may be having financial problems.

Danger Signs that Hint of Subcontract Financial Problems

- Has the subcontractor manned the job adequately until just recently but now repeated calls for more manpower are ignored eventhough it is obvious that considerable work remains to be done? Since labor must be paid on a weekly basis, as opposed to materials that don't require payment for 30 days or more, cash flow problems may manifest themselves first in work crew cut backs
- Does the subcontractor seem to run out of normal day-to-day supplies like nails, screws, taping compound, small pipe fittings, electrical tape and connectors? This could mean that the local supply house has suspended credit and the sub must limp by until another source can be developed.
- Are shop drawing submissions for key equipment late and are repeated requests for critical drawings met with "We'll get them in two weeks" only to have the same conversation in another two weeks? Shop drawings are issued only after an order has been placed and if the subcontractor's credit is poor, his normal sources of supply may be reluctant to accept an order and therefore the subcontractor has to search for a new vendor. Unusually long delays in purchasing critical equipment may also be caused by a subcontractor searching for a better deal without taking into account the effect that these delays will have on the project's schedule. If this seems to be the case, the subcontractor should be given written notice that the delay in the submission of key shop drawings may seriously effect the schedule, and if that does happen he may be held accountable for costs related to these delays. That will usually get results.
- Is the subcontractor receiving partial shipments of commodity type items such as steel studs, gypsum wallboard, framing lumber and plywood? This could mean that a credit limit has been placed on his account because of slow or nonpayment of outstanding bills.
- Has the subcontractor recently requested that joint checks be issued, naming his supplier as well as himself on the check? When a manufacturer is unsure of receiving prompt payment they will sometimes advise the subcontractor that shipment will not be made unless a joint check is issued. Approval for a joint check arrangement must be obtained in writing from the subcontractor.

Reviewing the Subcontract Agreement with the Subcontractor is a Good Practice

Before a subcontractor begins to work on the construction site it is a good idea to review the plans and specifications included in his scope of work and then, in turn, review the scope of work with the subcontractor's foreman. Although one might think everything is crystal clear, there may be some misunderstandings in the subcontractor's mind that need to be clarified before work begins. Some of the more common misunderstandings are listed below:

Subcontractor: Did not review any drawings other than those pertaining to his trade eventhough his contract refers to those drawings. The steel subcontractor might not have reviewed mechanical or electrical drawings that contained ladders, rails, door frame channels, supports. The mechanical sub may not have looked at electrical drawings that showed different power requirements for his equipment.

Subcontractor: Did not review general, supplementary, or special conditions to the contract that direct him to provide temporary light and power (in the case of electrical sub) or to cut and patch, or to excavate and backfill.

Subcontractor: Did not acknowledge receipt or acceptance of any addendums issued during the bidding process and now disclaims responsibility for same.

Subcontractor: Did not furnish unit prices as requested nor was he advised of any unit prices the general contractor included in the contract with the owner that he is now expected to accept.

Subcontractor: Did not fully understand any alternates to be priced and either did not include them in his proposal or he may have estimated them improperly.

Subcontractor: Did not include cost of permits, fees, utility company charges as directed by the specifications.

Subcontractor: Based contract price on the Bid Documents not the Issued For Construction Documents.

Subcontractor: Did not include insurance coverage as specified.

Subcontractor: Was not aware that state sales tax should have been included (or excluded!).

Subcontractor: Did not understand retainage requirements and now doesn't agree with them.

Subcontractor: Was not aware of the project schedule and therefore did not include labor costs beyond current wage scale, nor was escalation costs for materials included.

Subcontractor: Took exception to certain items in the plans and specs at bid time, but did not notify the general contractor.

Subcontractor: Assumed that "or equal" materials or equipment would be acceptable and priced the job accordingly.

Subcontractor: Did not know requisition cycle and now requires a different payment schedule.

Subcontractor: Was not advised that materials stored off-site could or could not be requisitioned.

Subcontractor: Did not know that the construction contract limited the amount subcontractor could add to change orders as overhead and profit and will not comply with that requirement now.

In all dealings with subcontractors they should be treated like members of the "team" and not as adversaries. Only when all else fails should the threat of contract cancellation or legal action be raised.

4

Job Procedures and Policies

The construction industry is a high-risk business where rewards can be great and, conversely, losses can be devastating. Control over costs in the field becomes one of the project superintendent's most important responsibilities.

ESTABLISHING A COST REPORTING SYSTEM

In Chapter 2, the cost-plus a fee contract and the guaranteed maximum price contracts were discussed and the importance of accurately tracking costs stressed. But no matter which type of construction contract is being administered, recording and controlling all job costs remains essential.

Field Reporting and the Estimator's Data Base

A company's data base of construction costs is the heart of their estimating system, and the information in this data base must be added to and upgraded constantly in order to retain that competitive edge when bidding jobs.

Costs are obtained from subcontractor's, suppliers, cost estimate manuals and from work performed by the company's own forces in the field. For those general contractors who maintain concrete crews or masonry crews or carpentry and drywall crews, reporting the cost of their work is critical in tracking actual costs as opposed to estimated costs. But before this can be done, a system to segregate and identify each work task must be in place, and this will require assigning a code number to every phase of the work task.

The first step in the establishment of a cost-code reporting system starts with the task of assigning numbers to each standard component of construction. Within the construction industry there are two generally accepted work task numbering systems; The Uniform Construction Industry Code, known as UCI, and the more widely accepted Construction Institute's MASTERFORMAT format. The CSI numbering system is the one that most architects use when preparing specification manuals and begins with the broad categorization as follows:

Division 1—General conditions or requirements
Division 2—Site work
Division 3—Concrete
Division 4—Masonry
Division 5—Metals
Division 6—Carpentry
Division 7—Roofing, insulation, waterproofing
Division 8—Doors, windows, glass and glazing
Division 9—Finishes
Division 10—Specialties
Division 11—Equipment
Division 12—Furnishings
Division 13—Special construction
Division 14—Conveying systems
Division 15—Plumbing, HVAC, sprinklers
Division 16—Electrical
Division 17—Control systems

A typical CSI cost-code number may contain as many as ten digits; the first two digits (generally the first digit is a zero) identify the major division, the third, a major subdivision, the next three numbers identify a major classification of work and the last four digits identify a specific operation. A typical CSI concrete cost code—032 138 0500—would identify the following task:

03—Concrete major division
2—Form work major subdivision
138—Form work pertaining to beams and girders
0500—Form work pertaining to an exterior spandrel twelve inches wide.

For most general contractors a ten-digit cost code is not necessary, and one containing just five digits is all that is required, (using the same scenario as before, a five numbered code for a concrete spandrel girder becomes "03135").

03—(Cast-in-place concrete)
1—Forming operations
3—Girders
5—Girders between twelve inches and eighteen inches

Once a system of cost codes for work tasks has been established it will be used by the Estimating Department during the preparation of the estimate. When an estimate results in a successful bid and a contract award, all of the cost codes for field operations will be distributed to the superintendent, either preprinted on the weekly time sheets or on a copy of the estimate for field use, or on a separate cost-reporting sheet. But no matter which form it takes, the purpose is the same: to report man-hours and the quantity of the task performed. The end result of all of this paperwork is to be able to create unit costs that accurately reflect the cost of performing a task. No matter how the data is reported, it will be converted into costs per unit of work when quantities of work are reported on a weekly basis.

Mr. John Doe, carpenter, was working on concrete wall forming last week, and the efforts of his labor will eventually appear in the data base when the week's payroll has been processed.

John Doe—Carpenter Journeyman—Hourly wage rate	$18.50
Fringe benefits	5.50
Total hourly cost	$24.00

For the week ending November 21, 1991, Doe worked forty hours on the same task, concrete wall forming, Code 03278 (forming eight-feet high foundation walls). The quantity reported for the week was 283 square feet of surface area (which means forms installed on both sides).

The computations for unit costs will be as follows:

40 hours × $24.00 per hour =	$960.00
Total area formed	283 square feet
Unit cost/square foot cost	$3.39 per square foot to form 8-feet high foundation wall.

OTHER JOB-RELATED COSTS REPORTED AS GENERAL CONDITIONS

The composition of general-condition or general-requirement costs vary from contractor to contractor. Some contractors will include a project superintendent's salary and the project manager's salary in corporate overhead while other general contractors will include these costs in their general conditions. Many of these general condition costs are time related as opposed to task, or work-completion related. Temporary sanitary facilities, telephone expense, office and storage trailer rentals are but a few. Not all of these general-condition expenses listed below are under the direct control of the superintendent, but for those that are, proper reporting and control of the related expense is important.

Typically general conditions expenses will include:

Project coordination—project manager and assistant project manager
Project superintendent and nonworking foreman
General superintendent (usually not full time, but has time apportioned to several projects)
Time keeper
On-site clerical/secretarial/accounting staff
Job security costs
Safety program costs and costs for OSHA requirements
Trucking materials via contractor's trucks
Debris control, including cleaning costs, dumpster rentals and dumping fees
Temporary utilities—water, electricity, gas, sanitary control, telephone
Field office rental, repairs, supplies
Storage trailers and temporary fencing
Reproduction costs—cost of blueprints
Travel costs—to owner's, architect's, engineer's place of business, visits to subcontractors or suppliers
Temporary signage

Cranes, hoisting equipment for both crews and materials
Small tools
Provisions for weather protection, temporary enclosures and temporary heat for same.
Traffic control, dust control, snow plowing costs
Project closeout costs including cost to complete punch list items, prepare "as-built" drawings and assemble other closeout procedures.

Proper allocation of those costs directly within the control of the superintendent remains an important part of his job. Since general-conditions cost estimates can range from a low of 4 percent of total project cost to a high of 10 to 11 percent, all items in this category must be accurately reported so that they can be monitored and controlled diligently. A contractor's estimate of general-conditions costs can be a major factor in determining whether a competively bid job is won or lost.

Receiving and Controlling Materials at the Job Site

When construction materials are received at the job site, the following questions need to be answered:

1. Was a purchase order issued for these materials, and is there a copy on the site?
2. Are the correct materials being delivered?
3. Is the quantity correct?
4. Are there any damaged materials and, if so, does an insurance claim need to be filed?

Only the job superintendent or his appointed representative should be designated to check, receive, and sign for materials.

Unless shipments are carefully checked for both quality and quantity, the contractor may be paying more than he should. If 2 × 12 fir joists were ordered, but 2 × 12 HemFir joists were delivered, the cost differential (fir being more costly than HemFir) can be considerable, and since fir joists have more structural strength, the substitution of a lesser grade could have serious consequences under certain circumstances.

When quantity and quality have been verified in the field, it is helpful to office personnel to have a legible, recognizable signature on the receiving ticket. If a cost-code system has been established for materials, the proper code should be entered on the receiving ticket and a brief note as to the use of the material will also be of value.

Weather Sensitive Materials

There are certain kinds of paint, for instance, that freeze at 32 degrees F or must be kept above 40 degrees F, and when these kinds of paints are delivered in the dead of winter, the superintendent should determine whether a heated truck has made the delivery or otherwise ascertain that the material has been delivered in good condition.

Ready-mix concrete is another material that is sensitive to temperature extremes. Affected by both hot and cold weather, the superintendent should be alert to the time the truck left the batch plant and how long the concrete has been in the truck before it is discharged. Most ready mix suppliers stamp their delivery tickets with the time the truck departed the plant, and travel time along with waiting time to unload may be cause to reject the shipment during either very cold or very hot weather.

THE IMPORTANCE OF GOOD COMMUNICATION AND DOCUMENTATION ON THE JOB SITE

During the course of a project, hundreds or even thousands of instructions are issued—some written and some verbal. Lines of communication must be established early in the project. Should all inquiries to the owner, architect and engineer go through the office? Will subcontractors be allowed to communicate directly with the design consultants and, if so, what form of confirmation will be required by the general contractor? And how should the project superintendent bring all of his questions to light?

The Regularly Scheduled Job Meeting

The job meeting is probably the best way to communicate since subcontractors and design consultants can get together and inspect actual field conditions requiring clarification. Printed minutes of these meetings provide the documentation after items have been discussed and decisions have been made. Each construction company has its own format for holding job meetings. Some companies prefer to have a separate meeting with the owner's representative, architect and engineer, followed by a subcontractor's meeting while other companies feel it is better to have one meeting in which subcontractors, owner's representatives and design consultants attend.

In either case, it is important for the project superintendent to attend these meetings. Some superintendents tend to shy away from attending job meetings, but that's a mistake. Job-meeting minutes are no substitute for being there. Sometimes discussion takes place in the meeting that doesn't appear in the minutes or sometimes the writer of the minutes interprets what has been discussed in a manner different from original intent.

Many job meeting minutes end with the statement, "The meeting minutes represent the writer's interpretation of events as they transpired. If there are objections to any statements contained therein, they are to be submitted, in writing, prior to the next scheduled meeting."

Plan ahead so that attendance at job minutes can be scheduled. Job meetings should have an agenda, and each item should be addressed quickly and thoroughly. Questions and answers should be prepared beforehand so that the meeting flows along rapidly. After the first job meeting the format for subsequent meetings will be to:

- Review topics discussed at the previous meeting, and
- Introduce new topics for discussion.

Topics to be discussed at job meetings should include:

- A review of job progress to date, and possibly a review of anticipated future progress.
- Comments on the quality of work.

- Discussion of problem areas.
- Requests for clarification of vague or missing details.
- Review of materials, equipment to be approved.
- Answers to questions from previous meetings.
- Results of recent inspections, test reports.

Preparing for a Job Meeting

In order to keep these meetings as short as possible, all participants should have prepared a list of questions that need to be addressed and have answers to the questions that arose at the previous meeting. A superintendent should keep a daily list of questions or items to be discussed at the next job meeting. If there are questions about plan or specification clarification, a thorough review of the plans and/or specs should be made beforehand to ensure that the answers are not lurking in some obscure place on the drawings or in the specifications.

Questions from subcontractors, as they arise during the course of the work week, should be noted, and if the subcontractor or supplier should attend the meeting, they should be notified in advance.

Documentation of Field Related Matters

Job meeting minutes should be distributed promptly to all parties that attend the meeting or have an interest in what was discussed or resolved at those meetings. These meeting minutes become a part of the project's file and provide documentation of items discussed and resolved. However there are other forms that are useful in providing documentation of questions arising from the field.

The Request for Information (RFI) and the Request for Clarification (RFC)

It is rather easy to create an RFI or RFC file if the company has not previously used one. Prepare a simple form that is numbered sequentially (see Figure 4-1 and 4-2). These forms can be used when questions arise from subcontractors and require answers from the general contractor or from the design consultants. These forms can also be used when the general contractor needs to obtain information or clarification from a subcontractor or owner/architect/engineer.

The RFI and RFC, when numbered sequentially will provide a system for filing, locating and retrieving both questions and answers throughout the life of the project.

The essential parts of these forms are:

1. Date issued,
2. Sequence number,
3. Party to whom it is directed,
4. Inquiry complete with plan/specification section being questioned to include sketches or data sheets,

REQUEST FOR INFORMATION

RFI No.__________

DATE:__________

PROJECT NAME: ____________________________

LOCATION: ________________________________

TO:

****

TRANSMITTED BY:

RESPONSE REQUIRED BY:

****

REQUEST FOR INFORMATION AS FOLLOWS:

****

SENDERS SIGNATURE

Figure 4-1 A Typical Request For Information (RFI) form.

5. Individual generating the inquiry and the person or place where responses should be sent,
6. Response time requested, that is, by return phone call or fax, by express mail, at next job meeting.

A list of outstanding RFIs and RFCs should be included in every job meeting as a way of ensuring that all parties are aware of what is and what is not outstanding. This list

REQUEST FOR CLARIFICATION

FRANK MERCEDE & SONS, INC.
860 CANAL STREET
STAMFORD, CT 06902
TELEPHONE: 203/967-2000
FAX: 203/353-8737

RFC NO.____________________

DATE:____________________

Project name: ____________________________

Location: ____________________________

____

RFC Directed To:____________________________________

____

Respond To:______________________________________

REQUEST FOR CLARIFICATION AS FOLLOWS:
****

____
Senders Signature

Figure 4-2 A Typical Request For Clarification (RFC) form.

also creates documentation for any potential delays because of the contractor's inability to get a timely response from the owner or his consultants.

CHANGE ORDERS—HOW THEY SHOULD ORIGINATE, BE PROCESSED AND CONTROLLED

Rarely is a project completed without changes being made to the initial scope of the work, and this process is one of the major sources of disputes among owners, contractors and subcontractors. But it doesn't have to be that way if the proper steps are taken when changes are being discussed or when they are being implemented. Changes in the work can result from one the following conditions:

1. Changes in the scope of the work initiated by the owner, architect or engineer to add or delete items of work before or during the course of construction.
2. Changes initiated by the contractor or subcontractors because of real or perceived errors, omissions or inconsistancies in the contract set of drawings and/or specifications.
3. Changes initiated by the owner, Architect/Engineer, general contractor or subcontractor when there are differing interpretations as to their respective contract obligations.
4. Changes to the scope of work because of unforeseen subsurface conditions or extra work required after exposing previously concealed conditions or during an emergency.

By whichever means the change-order work is initiated, the superintendent must:

- Receive written confirmation or authorization that the change order work is to proceed.
- Receive the necessary documents in order to identify and implement these changes, such as sketches, written description of the work, bulletins issued by the architect and so forth.
- Be advised of the method by which all costs associated with the change-order work shall be documented—lump sum or time and material.

Confirmation of Authorization to Proceed

When change-order work proceeds, according to the textbook approach, the architect will have submitted a request for the change-order proposal to the contractor, who, in turn will have submitted a written cost proposal. The architect would then review the proposal and, if accepted, issue a formal change order to the contractor. Only then would the work begin. But this rarely if ever happens.

In most cases, verbal requests are made by the owner or the Architect/Engineer and a verbal response is made by the contractor. Some negotiations might then take place and the contractor would be authorized to proceed with the work while the paperwork catchs up and a formal change order is issued. But this approach is fraught with dangers and misunderstandings that often lead to disputes and lawsuits.

Barring the receipt of a formal, written change order, the superintendent should have some form of written approval to proceed with the work, and this should be forthcoming from the contractor's office. There are conditions under which a superintendent must be able to originate or authorize extra work, such as when a job-site emergency arises, but generally some form of written authorization should be generated in the field to document this authorization and provide a record of just what was authorized.

A frequently used form for this kind of situation is the Field Order or Field Authorization Report (see Figure 4-3). This form can be used to initiate a change-order request to a subcontractor or the owner, or the architect or engineer, and this form can also be used as a written record of a verbal order. A copy of the order should be sent to the party that will perform the work, and the party requesting the work (if other than the general contractor), a copy is retained in the field and a copy should be sent to the office.

Authorization to Proceed When the Exact Nature and/or Cost of Work Is Unresolved

Many times when change-order work is being authorized, it is difficult to determine costs beforehand. This kind of situation will occur when repairs may be required to existing structures or when unforeseen subsurface conditions are encountered. If a cost plus agreement can be obtained, documentation of costs becomes a critical matter, and unless a representative of the party authorizing the cost plus work is on the site to verify all costs as they are incurred, some system of cost substantiation must be established.

This is best accomplished by having daily tickets prepared for all labor and materials provided for the work. Each ticket should contain a detailed description of work performed, hours worked, materials and equipment used. An agreement should be reached before work commences that these tickets are to be presented to the owner and/or his representative on a *daily basis* and any questions regarding daily tickets are to be addressed immediately.

The Forced Account—Construction Change Directive

A forced account is simply a method of tracking and presenting costs of change-order work when contractor and owner can't agree beforehand on the proposed cost of the change-order work. When work proceeds on a forced account basis, the owner agrees to reimburse the contractor for all substantiated costs plus overhead and profit. Although this seems rather straightforward, the forced account method is used when contractor and owner can't agree on the price before the work begins, so there is every reason to believe that the contractor and owner won't agree on the actual cost of the work when it has been completed! Documentation for forced account work must be extremely thorough.

Field Instruction

Date: ______________________ **Order Number:** ______________________

Job Name: ______________________ **Job Number:** ______________________

1. **This Field Instruction (F.I.) is issued for the purpose of:**

   __ **Requesting an estimate**
   __ **Directing work be performed**
   __ **Directing work be stopped**
   __ **Other** ______________________

   A general description of the work situation involved here is as follows:

   ____

   Signed: ______________________

IF IN THE SUBCONTRACTOR'S OPINION THIS F.I. INVOLVES WORK WHICH INCREASES THE CONTRACT AMOUNT, OR TIME OF PERFORMANCE, HE SHALL NOT PROCEED UNTIL SECTION 2 OR 3 IS COMPLETED BELOW.

2. The Contractor and Subcontractor acknowledge this F.I. will result in an increase/decrease/no change to the Subcontractor's Contract Price. The Subcontractor is hereby directed to proceed with the work on the following basis:

   __ Detailed estimate is accepted in the lump sum amount of $______________
   __ Time and material plus overhead and profit as called for in the Subcontractor/Contractor Agreement
   __ Unit Price
   __ The approximate estimate is accepted with supporting details and exact price to follow within 7 days.

   Amount of approximate estimate $______________

   __ Other

   Signed: ______________________

   Signed and Accepted: ______________________
   Subcontractor Rep.

3. The Contractor hereby directs the Subcontractor to perform the Work described above at no change in Contract Price on the basis that the Work is included in the original Contract.

   Signed: ______________________

4. The Work will not be performed.

5. The final amount of this F.I. which will be processed as a Change Order is:

   Signed: ______________________ $______________

Note: Whenever time and material work is to be performed, daily work tickets must be presented to the Project Superintendant for signature. Failure to do so may result in rejection of payment request.

COPY: Office Subcontractor Field

Figure 4-3 A Typical Field Order.

The "construction change directive" is a term created by the American Institute of Architects in their 1987 version of the General Conditions to the Construction Contract (A.I.A. Document A201). This directive is nothing more than a written notification from the architect to the contractor directing the contractor to proceed with the change-order work, and since the cost of this work cannot be agreed upon before it starts, the contractor is to submit an itemized lists of costs when the work has been completed. The costs to be included for reimbursement under the construction change directive are:

- Costs of labor, including all fringe benefits,
- Cost of materials, supplies, equipment, including cost of transportation to get them to the site,
- Rental cost of machinery and equipment, but not including hand tools,
- Cost of bond premiums, insurance, permits, fees and taxes, and
- Cost of supervision and field office personnel directly involved with the work.

Added to these costs will be the contractor's overhead and profit. There again, if contractor and owner or architect can't agree upon a fair and equitable cost beforehand, will agreement on the final cost under the "construction change directive" be any easier? As with any other time and material work, documentation must be assembled and presented after the work has been completed. Bills, invoices, receiving tickets for materials and rental equipment are to be included along with daily labor tickets and payroll. Further documentation in the form of photographs and videotapes should be considered when earthwork, unforeseen subsurface work, or reworking existing structures is being performed under the construction change directive.

AS-BUILTS AND OTHER CLOSEOUT DOCUMENTS

The time to begin preparing for the project closeout is when the project is just getting started. That's the time to review the specifications to determine what kind of documentation will be required when the project has been completed. These project closeout requirements should be carefully read and highlighted, and all trades having any involvement in closeout documentation should be notified even though their contracts include those provisions.

Particularly when site work is in progress, the proper location and invert elevations of all underground utilities will be required, and it is encumbant upon the superintendent to make sure that whoever is responsible for logging this information is doing so. Some specifications require air tests, or exfiltration tests on various kinds of underground piping,and if provisions have not been made to have these tests performed, the party responsible for providing these tests must be notified immediately.

Whenever tests such of these are conducted, as a back-up to the formal test report submission issued by the engineer, testing service or inspector, the superintendent should place an entry in the daily dairy or log book indicating where and when the test took place, who was present at the time, the results of the tests, if known, and any verbal acceptances or rejections issued at the time.

Some architects and engineers insert a provision in the specifications stipulating that they will be inspecting the progress of as-built drawings during the course of construction, and if these drawings, in their opinion, are not being prepared properly, they will recommend that the owner withhold all or a portion of the current payment due the contractor. Attention to "as-builts" is often paid too late and they are one of the prime reasons that owner's withhold final payment when they are not submitted at the end of the job.

CHECKLIST OF COMMON CLOSEOUT REQUIREMENTS:

1. As-built drawings—site and utility work, foundations, structure, plumbing, HVAC, sprinkler and electrical.
2. Inspection reports—issued by government inspectors, consulting engineers, testing laboratories.
3. Test results—concrete, steel, soils analysis and soils compaction, balancing reports for liquid and air.
4. Operating and maintenance manuals.
5. Removal of all temporary construction, temporary utilities, and in particular temporary lighting above the new ceilings.
6. Product guarantees and warranties.
7. Service contracts.
8. Elevator code compliance and inspection certifications.
9. Final cleaning of the building and premises.
10. Copy of Certificate of Occupancy.
11. Attic stock, which may include bricks and decorative block, floor coverings, ceiling tiles.
12. Panes of replacement glass.
13. Unused containers of paint along with list of manufacturers and color selection identification numbers.
14. Complete list of all subcontractors, suppliers including addresses, phone numbers and contact person.

II

The Construction Process

5

Establishing the Daily Routine

A great deal of the project superintendent's work day is filled with the responsibility of ensuring that the proper trades are working on the job site with sufficient manpower and materials to maintain job progress. Phone calls and questions asked by subcontractors require more time, but somewhere in this busy schedule time must be set aside for the other important matters that are an integral part of the daily routine.

- Monitoring the construction schedule
- Preparing daily paperwork:
  - Payroll forms
  - Material delivery receiving reports
  - Tool and equipment inventory control
  - The daily diary or daily log
- Shop drawing review
- Quality control
- Safety

THE CONSTRUCTION SCHEDULE

Preparing, monitoring and updating the construction-progress schedule is one of the keys to controlling today's increasingly complex construction projects. It is a tool, like many others available to the superintendent, that needs to be kept in good working order and used frequently to be effective.

There are two basic forms of construction schedules in general use in the construction industry today: the Gantt chart and the critical path method format. A third, less frequently used scheduling form is the PERT chart (project evaluation and review).

The Gantt Chart

Named for its originator Henry Gantt, most people refer to this form of schedule as the bar chart, a rather straightforward approach to project scheduling familiar to most construction people (see Figure 5-1). The bar chart lists activity items or events vertically and the calender period in which these events will take place horizontally across the top of the schedule. Bar charts are relatively quick and simple to prepare

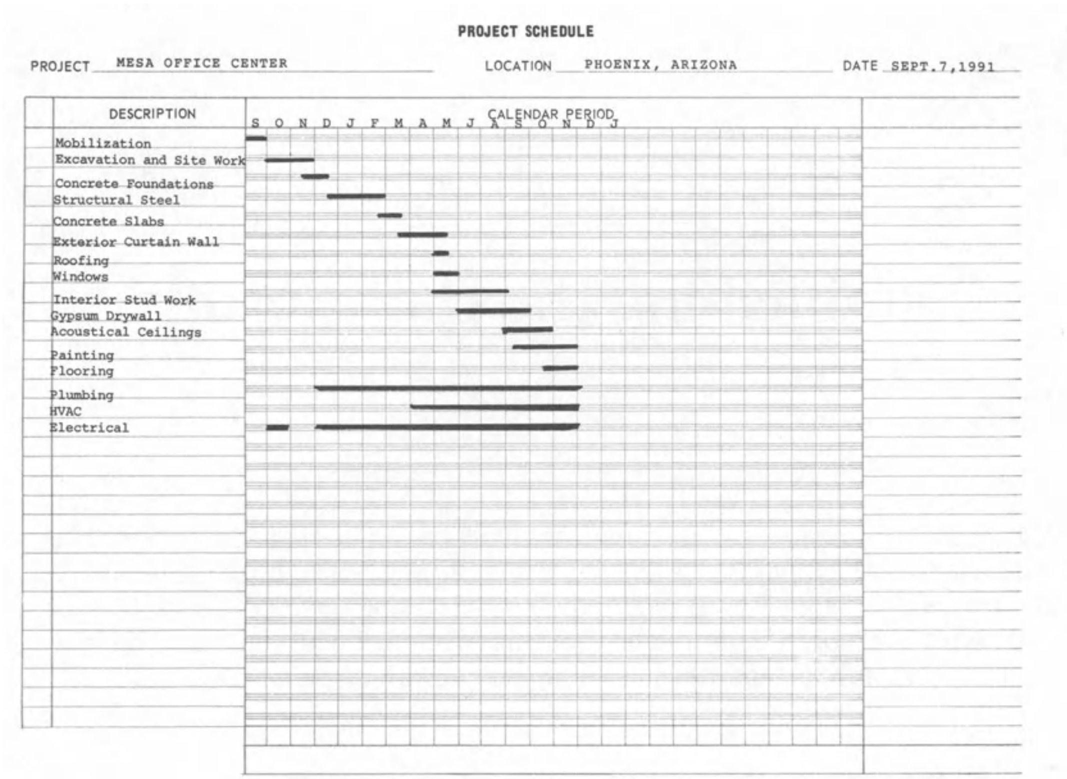


Figure 5-1 The Gantt or Bar Chart.

and monitoring can be performed by tracking actual progress for each construction activity with a colored pen or pencil line above or below the "scheduled" progress.

From time to time a new schedule must be prepared that incorporates any revisions or adjustments and tracks actual versus estimated time. Outdated schedules should be kept until the project has been completed since they may have to be referred to from time to time to show how and why the schedule changed. Although the Gantt or bar chart shows the relative interdependency of one item of work to another, a better display of one activity's progress, or lack thereof, upon another is more graphically shown in the critical path method (CPM) schedule.

The CPM Schedule

The CPM is a graphic display of all of the efforts critical to the timely completion of a project and the path that must be followed in order to obtain that timely completion. Duration times for each element of construction are included and the effect of a late or early start of one element upon another is vividly portrayed (see Figures 5-2 and 5-3).

CPM scheduling has been used by contractors for many years, but because of the complexity of plotting all of the detailed information and updating it on a regular basis, only those contractors with computers and programmers used this scheduling method until quite recently. Now with the availability of inexpensive personal computers and scheduling software packages offered by a number of companies, CPM scheduling is becoming more widespread among small- and medium-size contractors. As more and

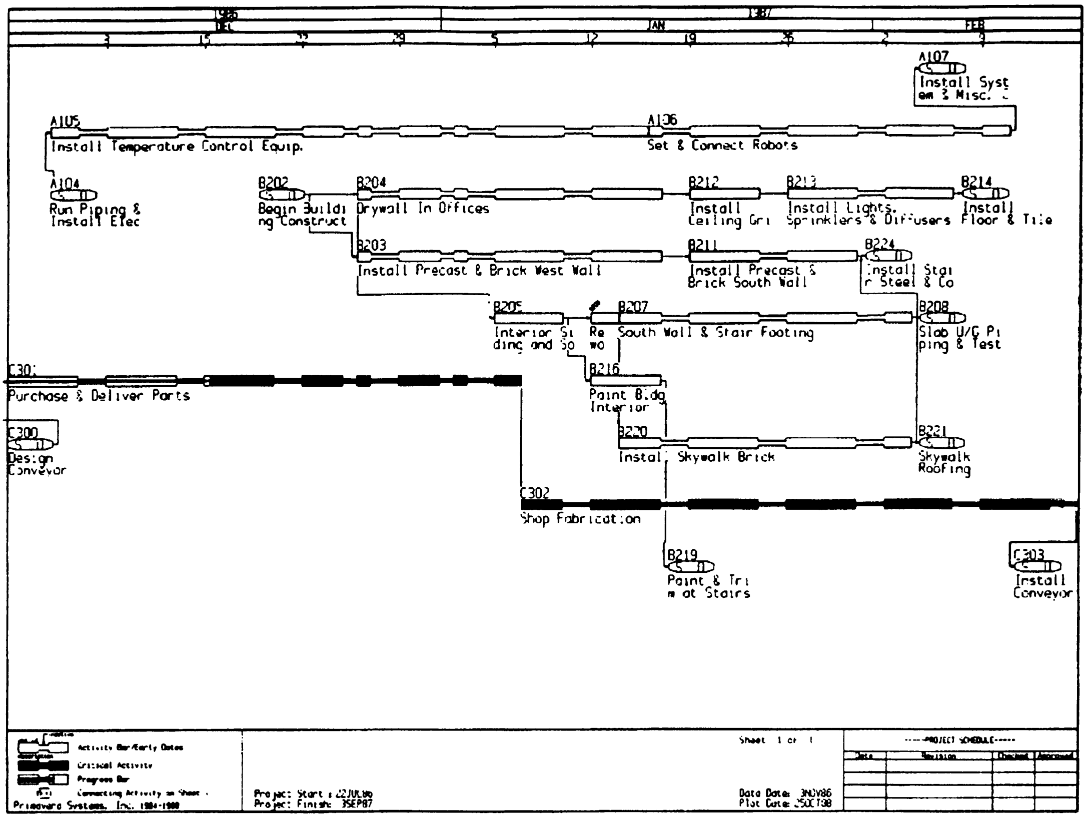


Figure 5-2 A CPM Chart with Oblong Nodes Depicting Work Tasks.

more owners in their bid documents are requiring contractors to provide CPM schedules prior to the submission of their first application for payment and at various times during actual construction, familiarity with this form of scheduling becomes very important. Some CPM schedules include activities for shop-drawing submissions and include a time frame for shop-drawing review along with the anticipated delivery of equipment after approval of the shop drawings. Although some CPM schedules are so complicated that they may be difficult to comprehend, by becoming familiar with some basic CPM terminology and format concepts these schedules will become less formidable.

Basic CPM terminology:

Activity flow—the sequence of work from one task to another.

Order of activity—an indication of which work task or event precedes or follows another.

Duration—the time is takes to complete a task or event.

Nodes—graphic representations of specific work tasks displayed on the CPM chart as round, rectangular or hexagonal boxes containing a number identifying work tasks and possibly including other information such as "early start," "late start" and "float time."

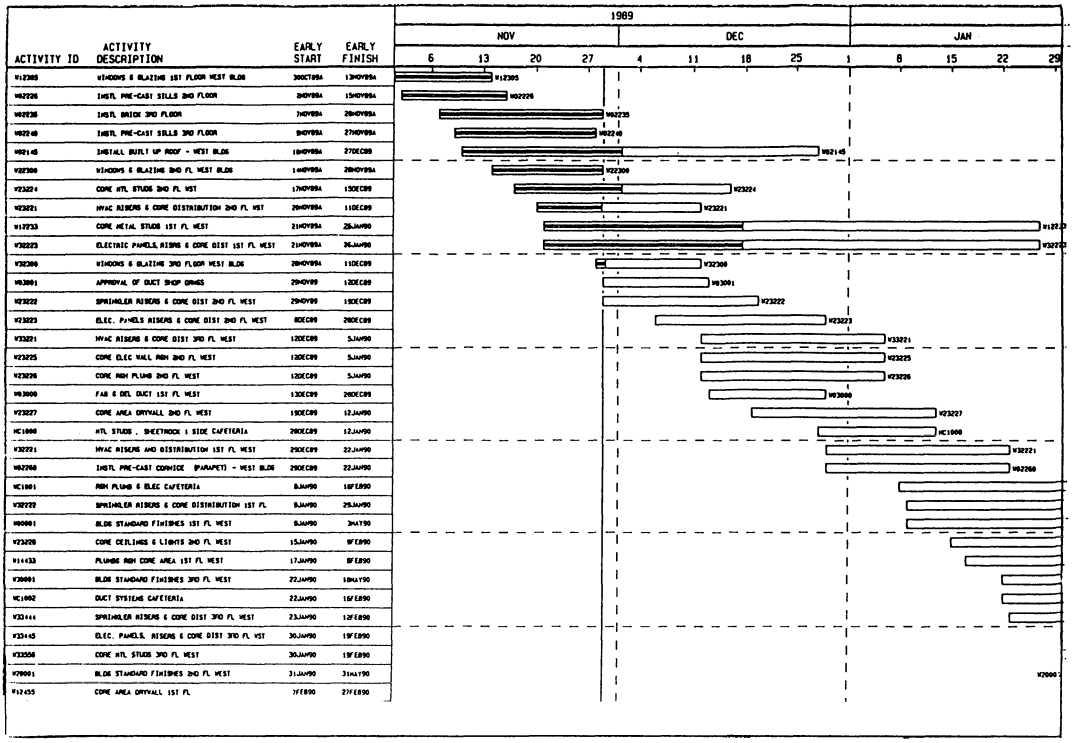


Figure 5-3 CPM Chart in Bar Chart Format Showing Early Start–Early Finish.

Early start—a date earlier than originally anticipated for the start of an activity.
Late start—staring a work task or event later than originally anticipated.
Early completion—completing a task or event earlier than originally scheduled.
Late completion—completing later than initially scheduled.
Float time—contingency time alloted to a specific task or series of tasks to compensate for unforeseen delays that inevitably occur in construction projects.

A Word About Float Time. Very few things planned by man come off as originally scheduled. Whatever form of construction schedule is going to be prepared, additional time must be included to allow for weather delays, late equipment and material deliveries and other such contingencies. CPM terminology for these kinds of unforeseen construction delays is called "float," and who owns this float time can be a source of confusion and potential disputes unless qualified early on, preferably in the construction contract. Does the contractor "own" the float, and can he use all of the delay time that it represents in order to substantiate a timely completion? Or does the owner "own" the float time, its purpose being to allow him to delay making critical decisions during the construction period without affecting the scheduled completion time? This kind of question becomes rather important when a construction contract contains a liquidated damages clause and the contractor wants to use the float time to offset some delays and avoid the penalties that these delays will cause. If the owner is of the opinion that the contractor does not own the float, these delays may result in a penalty.

Float time is also important when the potential for a bonus is available to those contractors who complete the work before the date indicated in the construction schedule. Since these schedules generally contain float time and a contractor may complete the project on time without using any of the contingency or float time, he may have actually completed the project ahead of schedule and be eligible for a bonus if he owns the float time. However, if the owner is of the opinion that the float time does not belong to the contractor, an on-time completion may not qualify for the bonus.

CPM Schedule Updates. A CPM schedule presentation will highlight the interdependency of one work activity on another, and when one work task starts beyond the late start date or finishes after the late completion date, all other subsequent activities will be affected. Periodic updates are necessary, and these updates can take place in the field on a weekly basis or biweekly basis when subcontractor meetings or regular job meetings take place. With the appropriate information logged in the field and passed on to the office, a computerized update can be accomplished rather rapidly.

The Thirty Day Look-Ahead

At times a superintendent hardly has a moment to plan for the next day much less think about what may be required in thirty days, but this kind of "look-ahead" will help to avoid the crisis that could occur without advance planning. The thirty day look-ahead is a method of projecting project requirements one month ahead, which in turn starts the process of identifying the materials and equipment that will be required in order to maintain or increase productivity and scheduling requirements.

When the superintendent has obtained a listing of shop-drawing submission dates and corresponding equipment-delivery dates, advance planning can begin. Since most materials and equipment drive the construction schedule, without firm commitments for delivery dates, it is almost impossible to plan effectively. The thirty day look-ahead process should begin before any earthwork or excavation begins. Depending on how much time is required to rough grade the site and prepare a building platform, two critical materials will be needed—ready-mix concrete and reinforcing steel. The first look-ahead should address these two items. Has a subcontract been awarded for concrete work or will it be performed with the company's own forces? In either case a ready-mix concrete supplier must be selected so that concrete mix designs can be obtained, sent to the engineer for approval and returned to the supplier approved or for resubmission. A brief look at the structural drawings and a review of the concrete specifications should unearth any other required submissions such as the need to submit shop drawings indicating the location of control joints, expansion joints, forming methods, pour sequences and so forth.

Reinforcing steel, if required, must be promptly purchased so that any required shop drawings can be prepared by the supplier, submitted to the engineer for approval and returned to the vendor so that cutting, bending and fabrication can be scheduled. Since it is doubtful that all reinforcing shop drawings can be prepared at the same time, the superintendent should establish a priority based on his needs. Will continuous footing steel be required first, followed by steel for interior spread footings, followed by east foundation wall steel and then south wall steel? This kind of prioritizing should be passed along to the reinforcing steel detailer and fabricator as quickly as possible.

As additional thirty day look-aheads are formulated, all of the traditionally long lead items will be identified. Hollow metal doors and frame deliveries can create problems if they are not ordered promptly, and all finish hardware questions must be resolved so that an order can be placed at the same time since the two products are so interdependent. The preparation and review of hollow-metal shop drawings has always been a time consuming process and this needs to be factored into the equation.

And although footings are just being placed and it appears that the roofing installation is far off in the future, it is not too early to begin thinking about the location and dimensioning of all roof penetrations and openings. Will roof scuttles and hatches be required? Any skylights to be installed? What about HVAC equipment that will have to be located, roof openings coordinated and dunnage requirements finalized? Once again, the thirty day look-ahead keeps these items clearly on the horizon and creates an awareness for action—not next week or next month, but NOW!

The Importance of Good Communication and the Look-Ahead. The most effective use of the thirty day look-ahead can be attained when a good line of communication exists between the field and the home office. As future requirements are being developed in the field the project manager and/or purchasing agent must be made aware of these future demands and their priorities. Purchasing may have to be sequenced in such a manner that materials and equipment will be on the job when needed. It would not make much sense to concentrate on purchasing floor tile or carpeting before finalizing negotiations with an electrical or mechanical subcontractor. When a look-ahead is generated by the project superintendent and communicated to the office, additional costs to expedite materials may be avoided, and stress levels should be lowered a notch or two.

By effectively planning the requirements of the project through a device such as the thirty day look-ahead, there should be a marked decrese in the problems associated with:

- Embedded items in concrete work;
- Lack of proper concrete accessories such as chairs for wire mesh, water stop, expansion joint materials, curing compound materials;
- Areaway and trench drain frames required to be set into cast-in-place concrete;
- Sleeves, conduits, box-outs in concrete foundation walls;
- Waterproofing, dampproofing materials for concrete foundation walls;
- Properly sized and located concrete slab openings for pipe, duct risers, elevators; and
- Dimensional verifications of concrete and masonry openings to accomodate windows, louvers, and speciality doors.

When preparing the look-ahead, consider the following traditional delivery requirements for certain critical items:

Galvanized hot dipped concrete embedments	6–8 weeks
Structural steel	2–4 months to detail, approve, fabricate
Curtain walls	5–6 months to detail, approve, deliver
Architectural precast concrete panels	2–4 months to detail, approve, manufacture
Hollow-metal doors and frames	3 months for drawing preparation, approval, manufacture and delivery
Elevator equipment	5–6 months for shop drawings, approval, cab deliveries
HVAC equipment	4–6 months for drawings, approvals and deliveries
Electrical equipment switchgear	8–10 weeks
Lighting fixtures	2–4 months
Fire pumps	3–4 months

PREPARATION OF DAILY REPORTS

Payroll

The thought of being confronted by a few angry workers on payday is usually the only incentive a superintendent needs to process daily and weekly payroll forms promptly. Workers on the company payroll that have been transferred from one project to another must be accounted for and travel time charged to either project. If no company policy exists that deals with which project is to assume this travel time, one should be established to avoid either double charging workers time or not charging either project, therefore underreporting the workers actual total hours. Proper assignment of work-task codes was discussed in the previous chapter, and every effort must be made to be as accurate as possible when assigning cost codes on daily labor reports.

Material and Equipment Delivery Receipts

Receipts for material and equipment deliveries should be processed in a timely manner and not be allowed to accumulate on the job site. These receipts should note any missing or rejected items and contain a signature that is readily recognized by the office staff. When a superintendent delegates authority to someone else to receive materials on the site, the superintendent should initial the ticket as well. Some construction company accounting departments will not issue payment to a vendor unless a properly acknowledged receiving ticket has been received from the field, so it is important that these receipts be handled properly and promptly.

Tool and Equipment Inventory Control

Some contractors prefer to own their own equipment such as compressors, compactors, concrete cutting and coring machines and various kinds of pumps, while other builders prefer to lease or rent these kinds of equipment. Whichever method is used, a record of daily equipment should be maintained either to create a data base of repairs and maintenance, in the case of the contractor who owns the equipment, or to substantiate down time and rental-rate adjustments for those contractors who rent or lease equipment. This record of daily equipment usage can be incorporated into the daily log or diary or recorded on a simple form, but in either case should contain the following information:

Project name, location and date;
Type of equipment in use;
Where the equipment is being used on the site and how it is being used;
Number of hours in use daily and nonuse hours because of breakdowns/malfunctions;
Type and quantity of fuel consumed;
Preventative maintenance performed—if any;
Repairs performed (to be accompanied by receipts for parts and labor); and
Repairs required or maintenance due.

These kinds of records will prove useful when:

1. Adjusting rental bills to reflect down time because of malfunctions or breakdowns;
2. Deducting the cost of actual repairs and/or fuel from rental equipment when these items are included in the rental rate;
3. Recording the cost of equipment operations for the estimating data bank; and
4. Evaluating performance and reliability of equipment when considering repurchase.

Keeping Track of Hand Tools and Small Power Tools

Productive workers need the proper tools, maintained in good working order, and quality tools can be expensive, so there should be a system in place at the job site to keep track of the small arsenal of tools that the contractor provides to all workers. Controlling small tools will not only ensure that they are on hand when needed but also that they are in proper condition and will function efficiently and safely.

Small hand tools and small power tools should be kept in one central location on the job site, either in a shed or in a secure place within the field office.

To establish a system of distribution and accountability, it is necessary to obtain an inventory of all tools in use. If at all possible an identification number should be assigned to each tool and marked or stamped on it. This I.D. number, description of the tool and manufacturer will form the basis of the inventory list. When tools are kept at the company's yard and this initial inventory list is to be created, each superintendent will have to prepare a list of tools on their particular job site on a particular day and send the list to the contractor's yard where the master list will be prepared.

Job site assigment and control of hand tools and small power tools can be accomplished in a number of ways. Workers can "sign" tools out and in on a form or by making entries in a log book. The question usually arises as to whether the worker should return each assigned tool at the end of the day or return it only when he is finished with it. If no company policies exist, the superintendent has to establish his own procedures. A system of brass tags can also be initiated in order to keep track of tools. A small board can be prepared with the worker's name on the left side, and a tag stamped with the tool I.D. number or a plastic tag with the tool number handwritten on it is placed on a hook opposite the workers name when he picks up his tool. When the tool is returned, the tag is removed. Verification of tools assigned to each worker on a weekly basis should keep things in order.

Tracking Tools from One Project to Another—The Transfer Slip

A simple form such as the one shown in Figure 5-4 is all that is needed to track tools and equipment that are being transferred from the company's yard to a project or being transferred from one project to another. One copy of the completed form should remain on the site where the tool had been originally stored, another copy should be sent along with the tool to its new location, and a file copy should be sent to the central storage yard or warehouse.

When a tool has malfunctioned or is in need of repair, any such remarks ought to be included on this transfer slip. And if the tool is considered too dangerous to use, it should be "red tagged" and sent directly back to the yard, even if another job superintendent has requested it.

TRANSFER CARD

EQUIPMENT – MATERIAL

Eq. No.	Item Description Model. Serial #	From Date	From Location	To Location	Remarks Repairs, etc.
				BY	

Figure 5-4 A Transfer Slip for Equipment and Materials.

Sharing Equipment and Tools with Other Parties on the Job Site

Every superintendent would like to be cooperative with other tradesmen on the job, and a favor usually begets a favor—except when it comes to the use of potentially dangerous machinery and equipment. Today's construction atmosphere is charged with situations where negligence claims can arise at any time, and today's friend might become tomorrow's legal adversary. A piece of equipment operating improperly or recklessly can easily injure, maim or kill, and insurance investigators and lawyers will quickly attempt to place the liability on a guilty party.

There is a way to be cooperative while limiting the possible effects of a lawsuit and that is to have the borrower or temporary user of the company's equipment sign a "hold harmless" form such as the one contained in Figure 5-5. Although this form applies to the use of scaffolding, it can be easily modified to suit other uses, and since this kind of form has strong legal implications, it is best to have the company's attorney review any such form before placing it in use. It is also wise not to permit someone else to use the company's equipment without first having signed such an agreement.

THE DAILY LOG OR DAILY DIARY

No one knows when they will be called on to accurately recall events from last week, last month or even last year. This is one of the primary reasons for maintaining an accurate accounting of each day's activities on the construction job site. A bound book of daily job site activity will prove useful for any number of reasons:

1. To substantiate events that happened or did not happen on the site.
2. To provide a log of events for historical purposes.
3. To provide documentation to support a claim or to refute a claim.
4. To record an unusual construction activity or procedure for future reference.
5. To provide information that will add to the company's data base.

Certain basic information should be recorded in the daily log, and any other information that might assist in recreating that day's events will also be beneficial. The minimum data that the daily log should contain is:

1. Weather conditions for the day including temperature readings (preferably early morning, mid-day and afternoon).
2. Lists of all subcontractors working on the site and their respective crews' sizes.
3. Record of material and equipment deliveries.
4. Record of all visitors to the site identified by name, affiliation, purpose of visit and length of visit.
5. Employees of company stationed at the site that day.
6. Brief description of the work activity—that day and areas in the building and on the site where work was being performed.

SCAFFOLDING AGREEMENT

WHEREAS, ______________________________ desires to use the
(Subcontractor)
scaffolding of ______________________________ at the
(General Contractor)
______________________________ and
(Project Name)

WHEREAS, ______________________________ will not permit such use
(General Contractor)
unless this Agreement of Indemnity is executed by ____________________,
(Subcontractor)

NOW THEREFORE, in consideration of ______________________________ allowing
(General Contractor)
______________________________ to use such scaffolding,
(Subcontractor)
______________________________ agrees as follows:
(Subcontractor)

Does indemnify ______________________________ against any loss of
(General Contractor)
liability arising directly or indirectly from the use of said scaffolding,

including any liability or claimed liability on the part of ____________
(General
____________ because of any damage to person or property (including
Contractor)
death) and will defend and save ______________________________ harmless
(General Contractor)
against any expense, including all legal fees and disbursements. This

Agreement of Indemnity is absolute and shall not be minimized or affected by

any negligence or claimed negligence on the part of ____________________
(General Contractor)

IN WITNESS WHEREOF, ______________________________ has caused this
(Subcontractor)
Agreement to be executed this ______ day of ________________, 19____.

BY: ______________________________
(Subcontractor)

TITLE: ______________________________

Figure 5-5 A Hold Harmless form—This One Applies to Scaffolding.

7. Notation of any unusual or noteworthy events that took place that day.
8. Record of any accidents or safety violations noted, even if separate reports had been filed.
9. Record of any inspections made, by whom, and results if known.
10. Any work stoppages, labor disputes, jurisdictional disputes, visits by union delegates/business agents.
11. Notation of job progress or lack of progress with comments to support either statement.

12. Record of any verbal requests for information or verbal instructions received from owner, design consultants, subcontractors or home office personnel.

The purpose of the daily log is twofold—to record in seminarrative form a record of activities so as to create a history of the project and, not necessarily secondarily, as a defense against future claims or to support a future claim. The daily log will be one of the first documents to be requested when certain kinds of disputes arise. Delay claims due to unusually severe weather conditions and delay claims caused by strikes and other disturbances beyond the contractor's control will be supported by entries in the log. And conversely, if no such entries have been recorded, these types of claims will be more difficult to prove.

The real value of a complete and comprehensive log book can only be appreciated when some type of claim arises a year or two after the project has been completed and the company attorney begins to question the superintendent about the facts surrounding the claim. Sitting in the lawyer's office with a less than complete daily log book, trying to recall events of time past will vividly drive home the need to create a proper log book—but by then it will have been too late!

SHOP DRAWING REVIEW

Shop drawings help to fill in many of the missing details on construction drawings, and they must be given the attention they deserve. Shop drawings should be reviewed by the job superintendent for completeness, correct quantities, dimension verification and general compliance with the specifications. A superintendent's input when shop drawings are being processed can be very important. A standard size product may not fit into a nonstandard opening, and either product or opening may have to be changed. Field conditions may require further changes or modifications and if these kinds of changes are made on the shop drawings instead of in the field after the wrong product has been delivered, both time and money will have been saved. When shop drawings are received in the home office, the superintendent should obtain a copy for review. These drawings must be clearly marked "preliminary" or "not approved" so as not to become confused with the final, approved version. When the approved shop drawing has been received from the architect or engineer it should also be reviewed to ensure that any comments made by the design consultants comply with the contract requirements and don't add more scope or contain other changes that may increase the cost of the product.

Some common pitfalls to avoid when reviewing shop drawings:

Hollow-metal doors frames	Verify all door swings and throat opening dimensions. Compare schedule with door schedule. Compare with requirements in hardware schedule. Will frames require different types of anchorage than ones shown? Will frames in masonry opening fit into standard masonry coursings? Are door undercuts compatible with thickness of flooring materials?

	Are borrowed lights sized properly for the walls in which they are to fit? Are the glass stops sized to proper glass thickness?
Finish hardware	Are hardware locations and cut-out dimensions same as shown on hollow metal and wood door shop drawings?
	Are the hardware finishes the same as specified?
	Are any floor recesses required for concealed closures or sills?
Doors	Overhead, sliders, roll-ups—is size of opening adequate?
	Are fastening and blocking details acceptable? If electrically operated, are characteristics correct?
Windows	Will they fit into the designed rough openings?
	Are the blocking and fastening details adequate?
	Is there sufficient space in the opening to allow for shimming?
	Will the exterior sill and interior stool fit properly, and can they be adequately fastened to the structure?
	Will the installation result in a weather-tight fit?
Structural steel	Are all floor slab and roof openings properly coordinated with architectural, mechanical and electrical drawings, both location and size?
	Are elevator shaft openings correctly located and sized?
	Are elevator entrance sill conditions and divider beam details okay?
Architectural precast concrete	Are methods of attachment compatible with structure in type, size and location?
Elevators	Do shaft size requirements—front-to-back, side-to-side—correspond with structural steel dimensioning?
	Has framed opening been provided in roof steel for any required elevator hatches?
	Will machine room equipment fit into space shown on drawings?
	Are floor-to-floor travel heights correct?
	Are electrical characteristics correct?
	Are rail anchorage points in the right location?
HVAC	Check electrical characteristics of equipment—same as on electrical drawings?
	Does equipment require starters by electrician or HVAC sub?
	Verify that size and depth of any cabinet/wall heaters will fit in wall.
	Are special finishes required on radiation covers, cabinet heaters?
	Will construction or final filters come with the units?
	Are louver sizes same as shown on architectural drawings and will fit in rough openings provided for them?
	Are louver sizes consistent with masonry coursing?
Electrical	Verify fixture designations and fixture count.
	Will fixtures fit into space alloted for them?
	Will adequate clearance be provided around switchgear and in electric closets containing distribution panels?

Miscellaneous—toilet partitions	Are wall-to-wall dimensions correct? Has blocking of proper type and location been installed? If ceiling hung, who installs support steel?
Toilet accessories	If recessed, are openings consistent with accessory dimensions? Has blocking been installed at correct location?
Kitchen cabinets	Are overall dimensions in accordance with wall locations? Are blocking requirements indicated?

Taking a little more time to thoroughly review shop drawings will pay off in more productive time spent during the installation stage and will also result in a much higher quality project.

QUALITY CONTROL

Quality control is as much a state of mind as it is an inspection and measuring process. Unless there is an awareness of the proper way to perform certain construction tasks, quality control has little chance of succeeding. Quality control ought to begin as each trade commences work on the site. A thorough review of the subcontractor's agreement and the appropriate specification section should alert the superintendent to what is to be expected of each trade. By thinking quality and stressing quality during walk-throughs and at subcontractor meetings, work crews will become more aware of minimum acceptable quality levels. Only then can an atmosphere be created where quality becomes as important as production—because they really do go hand in hand.

Standards of quality are generally a part of the construction specifications, which contain not only products deemed acceptable but also installation instructions. Even though these instructions sometimes only refer to various engineering standards or publications. For instance, the concrete specification section in Division 3 frequently refers to ACI (American Concrete Institute) standards and will state that "Placing concrete shall comply with ACI 301—Chapter 8—Paragraph 8.3" or finish slab tolerances shall be Class BX as defined by ACI 117-3, paragraph 2.2. The architect assumes that the superintendent has the full set of expensive ACI books in the job trailer—which is not the case. It appears that one of the few times these ACI standards are explained is after the fact, when work is rejected for being substandard. Although architects and engineers ought be more specific in stating quality levels instead of excerpting from a trade or professional organization book of standards, the contractor is nevertheless held responsible for all specified standards.

Other specification sections may be much clearer and concise in their quality requirements. Specification sections such as Division 6 will contain rather specific quality requirements so the superintendant needs to become familiar with them. Rough carpentry requirements for blocking and plywood usually stipulate wood species, wood treatment and grades required for various usages such as:

- Wood to be in contact with concrete, masonry or plaster—preservative treated lumber.
- Wood to be used where fire resistivity is required—fire retardent lumber.

- Plywood used where exposure to the exterior or where relative humidity levels are frequently above 85 percent—"X" grade plywood with exterior adhesives.

  Or simply:
- Kiln dried lumber in lieu of air dried.
- Douglas Fir in lieu of HemFir or vice-versa.

Other specification sections may contain complete instructions for inspection of surfaces prior to the application of a coating of one sort or another and the coating application instructions themselves may be included in great detail. Many Division 7 specification sections pertaining to waterproofing materials are in this category. For instance, a specification for fluid-applied waterproofing on concrete might be as follows:

Inspection of the subsurface—The coating manufacturer's representative is to inspect the subsurface and submit a certification that it is compatible with their product and the condition of the subsurface is acceptable.

Repair of the substrate—Instructions are included for cleaning off debris, patching cracks, filling voids and honeycomb along with instructions to grind down high spots.

Application of the waterproofing—Installation is to be in accordance with manufacturer's instructions. Prime all surfaces prior to application of the finish coat. Instructions to flash all pipes, conduits, sleeves and other projections passing through the membrane waterproofing. Instructions as to minimum thickness of the membrane. Instructions to flood test the waterproofed area before backfilling.

The first step, therefore, in instituting a sound quality control program is to fully understand the quality levels for each operation that will be performed. In many cases, these quality levels are included in the specifications and need only to be read, understood and carried out.

Walk-throughs conducted to inspect and review acceptable levels of quality ought to occur on a regular basis. Any substandard work should be rejected, and if subcontractors disagree with the ruling, the project manager and/or architect should be requested to review and comment on the acceptability of the work in question.

Quality should be addressed at job meetings and high quality levels should be commended while poor quality levels should be criticized and corrected. Sometimes a simple thing like providing adequate lighting in an area under construction can vastly improve quality levels. This attention to quality will not be lost on the owner, architect or subcontractors, and the results will be a much better working relationship between all parties—and a much shorter punch list!

6

Safety on the Job Site

In the ten minutes or so it takes to read this chapter two fellow workers will die as a result of an industrial accident and 170 more will be clenching their teeth in pain while awaiting treatment for what will eventually be a disabling job incurred injury. Three thousand fellow construction workers will probably die this year because of construction accidents and 500,000 more will suffer injuries of some sort and as the company's front line representative, the project superintendent must give job site safety the highest priority for any one of the following reasons:

It's humanitarian—No one wants to be responsible for the injury or death of another person.
It's the law—Federal and state agencies have been created to administer laws relating to safety rules and regulations on the job site.
It's cost effective—Workman compensation and other insurance rates can rise dramatically when accidents are reported and there are many more subtle cost implications.
It could keep you out of jail—In some states a project superintendent can be sued or imprisoned if it is proven that they could have prevented an accident from happening.

So please read this chapter carefully. YOUR FUTURE COULD DEPEND ON IT!

IT'S THE LAW—THE OCCUPATIONAL SAFETY AND HEALTH ACT

In 1970, Congress passed the Occupational Safety and Health Act (OSHA) containing standards and regulations for the health and safety of workers. Several states have also enacted safety legislation since that time, and in 1990, OSHA announced the establishment of a separate Construction and Engineering division. In November 1990, President Bush signed the Omnibus Budget Reconciliation Act that included, among other provisions, increased civil penalties for OSHA violations. These increased fines were the latest in a series of steps to reduce construction injuries and fatalities. The schedule of penalties looks like this:

Civil penalty violation	Penalties Assessed Prior to March 21, 1991	Penalties Assessed After March 21, 1991
Serious or other-than-serious	$1,000 Maximum	$7,000 Maximum
Posting requirement	$1,000 Maximum	$7,000 Maximum
Failure to abate violation	$1,000/day Maximum	$7,000/day Maximum
Willful	(No such category)	$70,000 Maximum

The U.S. Department of Labor, Occupational Safety and Health Administration can provide any number of booklets and pamphlets that explain the various rules and regulations of the agency, and they can provide a small pocket-sized reference manual that all superintendents should have. This orange colored booklet, entitled *OSHA 2202* (reprinted August 1987) is available at no cost from the nearest regional U.S. Department of Labor office.

Although most superintendents are familiar with OSHA requirements, a list of the more frequently reported violations will refresh memories:

1. Lack of perimeter protection on upper floors. Lack of proper guarding of floor openings, slab penetrations. Lack of guardrails and kickplates around stair openings. Lack of fill in steel pan stairs that can create a tripping hazard.
2. Improperly installed safety netting or no netting at all during steel erection of upper floor levels.
3. Improper storage of flammable liquids, LP gas, propane gas cylinders—whether full or empty.
4. Improperly constructed and poorly maintained ladders and scaffolding (more on that later in the chapter).
5. Lack of personal protection—hard hats, goggles, respirators, safety belts, hearing protection.
6. Improperly shored or braced trenchs (and more on that later also).
7. Electrical violations:
   Lack of Ground Fault Interruption and grounding devices on all electrical equipment in service.
   Frayed electrical cables on power tools.
   Exposed wires on temporary lighting lines and lamps in these lines not protected against breakage.
   Extension cords strung on the floor in such a manner as to constitute a tripping hazard.
   Covers on active panels missing.
   Covers on active junction boxes missing and boxes themselves not firmly secured to the structure.
8. Poor housekeeping and accumulations of flammable materials such as cardboard and wood dunnage throughout the building.
9. OSHA job site record keeping not in place, including lack of posting of required documents and up-to-date record of accidents.

HazCom—OSHA's Hazard Communication Standard

On March 17, 1989, a new set of regulations came into effect, which although originally written for employees in the manufacturing sector, has now been extended to the construction industry. The purpose of HazCom is to alert supervisors and workers to the potential dangers associated with the wide range of hazardous materials encountered on the job site.

Many workers have experienced the pungent odor of muriatic acid when used to clean masonry, and they might have even experienced the mild burning sensation when this acid accidentally contacts the skin. The effects of other industrial chemicals are not so apparent, and not many workers may be aware of the deadly effect that is caused by breathing methylene chloride vapors over an extended period of time—and methylene chloride, at one time, was a prime ingredient in paint removers. The purpose of HazCom is to identify these potentially hazardous materials and provide information as to the proper storage and handling of them.

The HazCom program has five essential parts:

- The preparation and dissemination of a companywide program.
- Establishment and maintenance of a Material Safety Data Sheet (MSDS) file.
- Establishment and maintenance of a chemical inventory list.
- Container labeling requirements.
- Establishment of an employee training program.

The Written Program. Each contractor is required to prepare a written program setting forth the procedures they will follow in order to comply with HazCom act. A person within each organization is to be named the administrator of the program. The administrator is to advise the project superintendent whenever a hazardous product is being shipped to the job site for the first time, and the proper MSDS for that product is to be on hand. A copy of the company's HazCom program is to be kept on the job site at all times.

The Material Safety Data Sheet File—the MSDS. When hazardous materials or products containing hazardous ingredients are purchased, the vendor will send an MSDS sheet for that product to the home office, from which it will be distributed to the field. Before being filed away in the program binder, this sheet should be thoroughly read and understood. Handling and usage instructions are included in the MSDS as well as any special storage requirements. First aid and emergency procedures are explained in the data sheet and personal protection equipment recommendations are listed.

The Chemical Inventory List. A hazardous chemical inventory list of all known chemicals in use on each job site must be maintained on the job site. When a hazardous chemical is brought on the site for the first time, the program administrator will add it to the project's list of chemicals. If there is question as to whether a product is classified as "hazardous," the program administrator should be contacted.

Container Labeling. The HazCom act requires labels to be affixed by the vendor on all containers containing hazardous materials. Each label is to contain the identity of the hazardous chemical, the part of the anatomy effected by the chemical, and how the body is effected by the chemical (for example, "Irritates the lungs when Inhaled," or "Avoid Contact With Skin—May Cause Severe Rash.")

The name and address of the manufacturer also appears on the label, and if a material is transferred from the shipping container to another container on the site, a label must be affixed to the second container. Containers without labels should be brought to the attention of the Program Administrator promptly so that they can be indentified and labeled correctly.

Employee Training. A training program for employees is to be established in order to acquaint them with methods used to detect a hazardous chemical release. Employees are to be acquainted with the physical and health hazards associated with chemicals in use on the construction site, and they are to be informed of protective measures to be taken when using these chemicals. Job site safety talks are part of the suggested training plan and certain chemicals are discussed at these meetings, and actual labels from containers are passed around to familiarize workers with the information they contain.

New Developements in Construction Safety Regulations

OSHA enacted Regulation CFR 1926 (Subpart P) in 1990, and this regulation deals with trenching and excavation classifications so that proper shoring procedures can be established. This regulation creates a new term, "competent person" or CP for short. The definition of a CP is somewhat complicated, but the reasoning behind the need for a CP is not. A signifigant number of on-site injuries and fatalities occur because of open trench cave-ins. CFR 1926 is aimed at reducing these injuries and fatalities and requires that a "competent person" identify and predict dangerous conditions and have the authority to take corrective action and keep workers from entering into areas deemed unsafe.

Supervisors are now given the responsibility of determining whether an excavation is safe enough to work in, and the liability for a wrong decision does not have to be spelled out. That is possibly the rationale behind the regulation, that guesswork will be eliminated and a superintendent or a CP will make certain that a trench is safe to enter. The CP must be able to classify soil according to the classifications contained in Subpart P of the regulation and depending upon the soil classification, determine if shoring is required and how it is to be installed.

CFR 126 soil classifications:

Stable rock—Requires no specific slope angle and trenchs with 90 degree walls are acceptable.

Type A soil—(most desirable material)—Can be sloped 3/4 to 1 or 53 degrees as long as no ground water is present and no vibration is present nearby.

Type B soil—(average material)—Can be sloped on a 1:1 or 45 degree angle.

Type C soil—(least desirable material)—Must be open cut to a slope of 1.5:1 or 34 degrees.

The soil type can be easily defined by the CP if a sample has been analyzed by a testing laboratory to determine compressive strength or shear strength. A simpler test, included in the regulation, is the "thumb print" test. A handful of soil is picked up and the thumb is pressed into it. If under slight pressure the thumb penetrates the sample, it is probably Type C material. If thumb pressure slightly indents the soil it is probably Type A, and if thumb pressure begins to penetrate the indentation, it can be classed as Type B. Most CPs will probably feel a little more confident if the soil classification was performed by a laboratory rather than a thumb, particularly when the issue of liability is considered.

The DOT CDL

In April 1992, the U.S. Department of Transportation (DOT) will mandate that all truck drivers operating vehicles weighing more than 26,001 pounds are to have a commercial drivers license (CDL). Many states already have such a requirement in effect, but in 1992, CDL will become a federal law creating three classes of licenses:

Class A—Required to operate any combination of vehicles with a gross combination weight of 26,001 pounds or more, provided the weight of the vehicle being towed exceeds 10,000 pounds.
Class B—Required if a single vehicle weight is 26,001 pound or more, or any vehicle that tows another weighing less than 10,000 pounds (this applies to most buses and dump trucks).
Class C—Required to operate any vehicle with less than 26,001 pounds gross vehicle weight or any vehicle that tows another weighing less than 10,000 pounds GVW (this would apply to vans, pick-up trucks, passengers cars–station wagons).

Further "endorsements" are required to operate double/triple trailers, passengers carrying vehicles, tank trucks, vehicles carrying hazardous materials or wastes, and for drivers of school buses.

THE JOB SITE SAFETY PROGRAM

There are few secrets to establishing a successful safety program in the field. What's needed is a clear, concise safety program, periodic job site safety meetings to explain and expand on the program and a firm commitment from top management on down. When fellow tradesmen are aware that safety is important to the superintendent, they, in turn, will become more safety conscious. Safety awareness is contagious.

Creating a Set of Safety Rules and Regulations

A printed set of safety rules and regulations posted on the job site will serve several purposes: it will tend to refresh the memory of long-term employees and it will serve as the basis of an orientation for newer workers. The written program will assist in enforcing disciplinary action for violators. In this day and age, disgruntled employees have been known to institute lawsuits against their employers for wrongful discharge. If an employee is dismissed for repeatedly safety violations without being completely aware that certain actions constitute grounds for dismissal the company may end up with a lawsuit. When a new set of safety rules has been established and posted at the site, they should be distributed to all workers both company or subcontractor, but a safety meeeting should be held in which not only the rules are explained, but the company's commitment to the program stressed.

A typical set of safety rules and regulations should encompass, as a minimum, the following topics:

1. A poster containing a list of Emergency telephone numbers:
   Ambulance, paramedics, and other emergency medical service numbers.
   Nearest hospital with emergency room facilities (include address and basic directions).
   Fire department.
   Police.
   After hours telephone number of key personnel.
2. Personal protective equipment policies and requirements:
   Hard Hats—Worn at all times except when the superintendent determines they are no longer needed, or a stated policy indicating conditions when hard hats are not required (such as when working in completed, occupied buildings involving nonhazardous work, for example, touch-up painting on office walls).
   Goggles, safety glasses or face shields—Mandatory when drilling, burning, grinding, sawing, jack-hammering.
   Ear Plugs and respirators when prescribed by the superintendent.
   Gloves when handling rough lumber or materials that can splinter, metal with burrs or sharp edges or when other conditions warrant their use.
   Shirts worn at ALL times. The wearing of 100 percent synthetic materials by anyone engaged in burning, welding, or using open flames will be stricitly prohibited. (If this kind of clothing catchs fire, it will continue to smolder until removed from the victim. Wool or cotton clothing will self extinguish when ignited.)
   Shoes—Safety toe work shoes are preferable. Sneakers or running shoes will not be permitted.
   Shoe laces to be tied at all times.
   Radios, if permitted at all, are to be kept on low volume. No Walkman type radio or tape player with ear plugs will be permitted on the site.
   Rain gear and protective foot gear will be worn when inclement weather warrants.
3. Safety check of tools and equipment:
   Tools that do not operate properly will not be used.
   Electric tools with frayed cords must either be repaired or not operated at all.
   Cutting tools such as chisels, hatchets or hammers with mushroom heads cannot be used since they are the cause of injuries from flying metal chips when these mushroom heads shatter.
   Cables, chains, hoists, lifting equipment will be checked daily for visual defects.

4. Electric safety check:
   Ground fault protection to be in operation at all times.
   Safety guards on electrical equipment cannot be removed or blocked open.
   When checking or repairing any piece of electrical equipment it must always be UNPLUGGED.
   Extension cords are to be strung at least seven feet above floor level. If conditions make this impossible, plank each side of the cord to prevent a tripping hazard.
5. Power actuated tools:
   These kinds of tools must not be loaded or operated by anyone not thoroughly checked out and trained in their use.
   Tools are to be inspected prior to being used and inspected after the day's use.
   Loaded tools must not be left unattended.
   Workers in adjacent areas are to be notified when these kinds of tools are to be operated.
6. Hazardous materials checklist:
   Gasoline and other flammable materials are to be stored only in factory sealed containers or approved safety containers.
   Oxygen cylinders are to be stored at least 25 feet away from other types of cylinder gas.
   When not in use, all gas cylinders are to have safety caps installed.
   All gas cylinders are to be kept away from open flames and welding operations.
   When oxygen and acetylene cylinders are being used, they must be transported in special carriers provided for that purpose and secured in those carriers.
   Closures on masonry cleaners and other corrosive liquids are to be adequately secured.
7. Ladders and scaffolding:
   All ladders are to be inspected prior to use.
   Field-made ladders must be constructed of sound lumber. Any broken cleats or rungs must be replaced immediately or the ladder is to be taken out of service. DO NOT PAINT WOODEN LADDERS (they become very slippery).
   Ladders must have firm footings. Secure them to the structure so they extend three feet above a landing.
   Pipe scaffolding to be properly cross-braced and tied back to the structure. The bearing surface must be leveled and firm. Scaffolding planks to be sound and of proper thickness, width and length.
   No subcontractor will be permitted to use the scaffolding owned by another company without signing a "hold harmless" clause.
8. Perimeter openings:
   All open stairwells are to have temporary railings until permanent ones have been installed.
   Perimeter railings/cables and toe boards are to be installed on all elevated floors before workers are allowed on those floors.
   All floor openings are to be covered completely or barricaded to prevent anyone from falling through them. If a worker removes any temporary protection in order to install or perform work, it will be replaced immediately when that work has been completed.

9. Fire protection:
   Every effort is to be made to extend a water main into the site as quickly as possible in case it is needed for emergency purposes.
   Every worker operating welding equipment, cutting torchs or soldering with open flame must post a fire extinguisher in the immediate area before these operations can begin. No open fires will be permitted on the job site at any time. Temporary heating equipment must be installed only with the approval of the superintendent. No heaters with open flames can be in operation without an attendant on the site or in the building.
10. Disciplinary action for safety violators—causes for suspension:
    Anyone violating OSHA regulations or company safety rules and regulations.
    Any worker reporting for work intoxicated.
    Any worker found using alcoholic beverages or controlled substances on the site.
    Horseplay.
    Fighting or provoking a fight.
    Failure to report an accident in which the worker was involved.

Note: The word "suspension" is used rather that dismissal. If an employee is wrongfully discharged for a safety violation, the potential for a lawsuit is created. It is better to suspend an employee either caught in the act, or accused of a serious violation until an investigation can produce sufficient evidence to support or refute the accusation. There have been cases where someone appeared to be drunk when actually they were having a reaction to a prescription drug.

When a set of company safety rules has been prepared and distributed to workers at the first job site meeting, each attendee should sign a form acknowledging the fact that they have been read the rules and they understand the company's program.

At the bottom of the last page of the written program, the following wording should be added:

Date: ____________________ Project: __________________________

I, ________________________________ state that I have received and read these

Safety Rules and Regulations and that I understand them and agree to follow them.

________________________________ ________________________________

(Employee's signature) (Superintendent's signature)

Implementing the Safety Program

First line responsibility for implementing a safety program falls on the superintendent, since he is on the site daily. Taking shortcuts, performing work improperly, misusing equipment and tools and careless work habits are the reasons most accidents occur, and a superintendent's should be alert to any of these conditions.

The U.S. Occupational Safety and Health Administration conducted a study of 3,496 fatalities recorded from 1985 to 1989 in the construction industry and their findings are listed below:

How Construction Workers Die
33% from falls from elevated areas
22% struck by an object or piece of equipment
18% by being caught between two objects
17% by electric shock
10% by other conditions

During a tour of the site, if safety violations are observed that may result in accidents a superintendent must not walk past them because he has something else of importance to do at that moment. Don't say "I'll stop back later and have that situation corrected." When workers on the project feel that safety is not being treated with the urgency and priority that was initially stressed, the wrong safety message will have been broadcast loud and clear.

The key elements to an effective safety program are rather simple and uncomplicated:

1. Repetition of the proper safety procedures is a key element. Conduct weekly safety meetings. They don't have to be lengthy, but a few rules can be reviewed each week, a few observations of good or poor safety procedures can be reported.
2. If and when an accident occurs, an immediate investigation must be conducted and a brief meeting held to discuss the cause of the accident and how it could have been avoided.
3. Rigid enforcement of the use of personal safety equipment. Often easier to do with the company's employees than those of the subcontractors. (Refusing a worker access to the work area because of his lack of proper safety equipment will bring some results, or establishing a monetary penalty when proper personal safety equipment is not used is also effective. When subcontractors are advised that any of their employees violating personal safety equipment rules will be cause for a $50.00 back charge, these rules wiill probably be complied with rather quickly!)
4. When workers are observed working in an unsafe manner, instruct them on the spot and show them the proper way to perform that operation.
5. Perform daily safety inspections and issue instructions to correct any unsafe or potentially hazardous condition as quickly as possible.
6. Investigate accidents promptly to determine what went wrong and how the accident could have been prevented. Don't try to place blame—just try to ensure that the necessary steps are taken to prevent another occurance.
7. Stress good housekeeping procedures at all times. Remember—a clean place is a safe place to work! When subcontractors repeatedly ignore instructions to

clean-up, contact the home office and threaten substantial clean-up back charges if that situation continues.

8. Lastly, but probably most important. Set a good example. If a superintendent is trying to enforce the hard hat rule, but fails to wear one, what will other think? When office personnel visit the site, they must also abide by the rules.

What to do when an OSHA inspector arrives at the job site:

1. Ask the inspector for proper identification if it has not already been presented.
2. Ask whether this is a routine inspection or if the visit is to investigate a complaint received by OSHA or if it is to investigate a previously reported accident.
3. Call the home office and notify them that an OSHA inspector is at the site and advise them of the nature of the visit—routine, reported complaint, accident investigation. If the home office prefers to have management present, ask the inspector if he could wait a reasonable time before beginning the inspection. If the inspector won't wait, let him proceed, in your presence.
4. The inspector may begin the inspection by requesting certain documents:
   OSHA Form 200—Log and Summary of Occupational Injuries and Illnesses
   OSHA Form 101—Supplementary Record of Occupational Injuries and Illnesses Survey
   OSHA Form 2005—Summary Occupational Injuries and Illnesses Survey
   All of these forms are required by law to be posted in a prominent place in the field office. The inspector may also ask to review the company's safety program.
5. The inspector may request a meeting with a foreman from each subcontracting trade currently working on the job in order to conduct a preinspection meeting prior to a job site walk-through. If this is the case, assemble these foremen as quickly as possible.
6. As the inspector walks through the building or the site, accompany him and note any deficiencies or items requiring corrective action. The inspector may take photographs of certain existing conditions, and if so, note what was photographed and why.
7. If a violation is observed and the inspector suggests prompt corrective action, direct someone to take care of the matter immediately. Any violation that poses a present danger to life and property must be corrected as quickly as possible.
8. If there are questions concerning the nature or validity of the violation, ask the inspector for clarification so that the nature of the violation is clearly understood. The questioning should not be argumentative, but merely to fully understand the situation and the OSHA regulation that has been violated. Make detailed notes for discussion with the home office after the inspection has ended.
9. An inspector has no legal right to shut down a job without a court order, so if that threat is made, ask to see the court order.
10. When the inspection has been completed, fill out a work sheet similar to the one shown in Figure 6-1 and send it to the office at the close of the work day.

With a concerted effort and dedication to the problem, we can all help to make construction one of our nation's safest industries.

Contractor's Jobsite OSHA Inspection Work Sheet

Page 1 of 2

Name of Employer____

Address____

Job Location____

Type of Construction

Building ______ Heavy ______ Highway ______ Other ______

Name of Compliance Officer(s)

__________________State C.O.______Federal C.O.__________

__________________State C.O.______Federal C.O.__________

Opening Conference was held Yes ______ No ______

Persons attending (give name and affiliation)

____

____

____

(For notes on walk around inspection see reverse side)

Closing conference was held Yes ______ No ______

Persons attending (give name and affiliation)

____

____

____

Closing conference summary:

____

____

____

Submitted by__________________

Title__________________

Date__________________

Figure 6-1 Job Site OSHA Inspection Report.

Page 2 of 2

CONTRACTOR'S JOBSITE OSHA INSPECTION WORK SHEET

Employer____________________________

Job Site____________________________

Address____________________________

City____________________________

Date____________________________

Compliance Officer(s)__________________ __________________

On the basis of the walkaround inspection the C.O. noted the following violations:

Location	Apparent violation(s) noted	Comments

Signed____________________________

Title____________________________

Figure 6-1 ***(continued)***

7

Managing Effectively

If only one word could be used in a construction project superintendent's job description, the odds on favorite would be manager:

Manager of a complicated engineering process—construction.
Manager of tens or hundreds of semi-skilled and skilled workers.
Manager of a continual flow of equipment and materials.
Manager of a scheduling process that is fraught with potential delay.

THE ART OF MANAGING PEOPLE

The construction industry is probably one of the most competitive businesses in the country, and one of the keys to success is the ability to extract the best and most productive efforts from everyone involved in the construction process—in other words, managing people effectively.

Managing is an art, and like so many artistic endeavors, requires constant practice to perfect its fine points. Managing requires a delicate touch at times and a firm hand at other times. It is important to recognize when vigorous supervision is required and when it is time to back off.

There are warning flags that when raised become indicators of too much supervision or not enough supervision.

Signs of too much supervision:

- Crew members never volunteer ideas or suggestions, but wait for direction from their supervisor.
- Crew members are not self starters but wait to be told exactly what to do before commencing work.
- A supervisor who spends more time "doing tasks" than supervising.
- A need to constantly apply pressure to keep everything and everyone in motion.

Signs of too little supervision:

- Crews that do not listen to reasonable suggestions from their supervisor.
- Crews that spend a great deal of time talking instead of working.

- Crews that extend coffee breaks and lunch hours well beyond the alloted time.
- Crew members coming to work late and leaving early on a consistent basis.

A superintendent must strike the right balance between relying on the good judgment of a crew leader while standing in the wings observing, ready to offer advice when needed.

RATE YOURSELF ON YOUR MANAGEMENT STYLE

A simple test may reveal whether your management style is conducive to creating good worker attitudes. Be honest in the answers to the following fifteen questions. Check off your answers in one of three columns on the left—Always, Usually or Seldom. At the end of the test add up the points, and if they total thirty-five or higher you are on the right track. If the total is substantially less than thirty-five points, a reevaluation of management techniques is in order.

Always [3 pts.]	Usually [2 pts.]	Seldom [1 pt.]	Management Style
_______	_______	_______	1. Do you set a good example by putting in a full day's work and stand ready to pitch in whenever there are deadlines?
_______	_______	_______	2. Do your lower level supervisors and other workers feel welcome to discuss opinions and gripes with you?
_______	_______	_______	3. Are you receptive to new ideas or do you shut people off when they try to discuss them with you?
_______	_______	_______	4. Do you keep your people advised of any changes or new developments from the office that may affect their job assignments or duties?
_______	_______	_______	5. Do you periodically let your people know if they are doing a good job, and do you offer constructive criticism from time to time?
_______	_______	_______	6. Do you explain why certain assignments are critical and must be done in a certain way and within a certain time limit?
_______	_______	_______	7. Do your workers feel that you would go to "bat" for them when the occasion arises?
_______	_______	_______	8. Do you show respect and concern for your workers?
_______	_______	_______	9. Is the relationship between you and your workers generally good?
_______	_______	_______	10. Do you give your workers opportunities to develop, and do you present them with challenges and encourage learning?
_______	_______	_______	11. Are you quick to place blame without thoroughly investigating the situation?
_______	_______	_______	12. Whenever possible do you bring some of your lower level supervisors and workers into the decision-making process?
_______	_______	_______	13. When you give employees deadlines, are they necessary and are they reasonable?
_______	_______	_______	14. Are your instructions to your workers clear, or are you frequently asked to repeat them?
_______	_______	_______	15. Do you think your employees respect you and would they go to "bat" for you?

Anyone with a score of 40 or higher can go on to the next chapter!

MANAGING FOR BETTER PRODUCTIVITY

Productivity in the construction industry has been almost flat in the past twenty years, and with the cost of labor and materials constantly on the rise and competition being what it is, most construction companies have been faced with lower profits. Many reasons can be stated for the lack of increased productivity ranging from restrictive labor practices incorporated into collective bargaining agreements to multitiered layers of management in complex projects that delay the decision-making process.

Although superintendents cannot be held accountable for all causes of low productivity at the job site, any efforts that result in increased productivity via more effective management techniques can have a decided affect on the profitability of a particular project. When a general contractor performs much of the work with his own forces and an increase in productivity of just 5 percent can be attained, the effect on the bottom line is substantial. For example, in a small construction project of $1 million the following scenario might serve to illustrate the effect of increased productivity and, conversely how low productivity changes the bottom line.

Warehouse "X"—contract sum $1,000,000

Cost breakdown:		
Direct labor	40%	$400,000
Direct materals	40%	400,000
Construction equipment	5%	50,000
General conditions	5%	50,000
Company overhead	6%	60,000
Profit	4%	40,000

If productivity could be increased by just 5 percent resulting in a $20,000 reduction in direct labor costs, all other things being equal, profit will increase by 50 percent to $60,000! And if productivity goes below the estimated labor cost by the same amount, the cost of labor will increase to $420,000 and profits will plummet by 50 percent to $20,000. Work it out yourself to check these figures.

There are no quick cures to increase productivity, nor are there any magic wands to be waved to create better rates of productivity, but the prime area in which to look for some answers is in construction labor motivation. A motivated worker will be a productive worker and a demotivated worker will not only produce less work but also will tend to influence others as well.

The Business Roundtable, in their study of the construction industry in general, and of productivity within that industry in particular, developed lists of the most common labor motivators and demotivators. The lists are based on questionnaires and interviews obtained from more than 1,000 workers at twelve large industrial construction sites. Table 7-1 lists the motivators; Table 7-2 the demotivators. One of the items in the demotivation list pertains to material availability, and at six of the sites surveyed workers listed material availability as being of major importance. Figure 7-1 is a form that the Business Roundtable survey team devised for foremen to use in order to develop costs associated with material non-availability along with other factors that affect productivity during the normal work day. How does your project stack up?

Table 7-1 Factors that Motivate Workers

Survey Results of Motivators on Twelve Construction Projects

	Projects											
Motivators	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Good craft relations			1*			2	2		1	1		
Good orientation program	3	3	1		1	1	1	2				2
Good safety program		1*	1	1*	2*	3		2*	2			
Work itself	2		2	2	2		3		2			2
Overtime					3		3					
Pay			2	1	1	2	2	2	2		2	2
Recognition				1*	1*							
Goals defined			1	1	1		1					
Open house & project tour	2	1		2								
Well-planned project						2*	2*	1*				
Suggestions solicited			1*		1*	1		2*	1			

* = demotivator and motivator
KEY: 1 = somewhat important
2 = major importance
3 = extremely important

Absenteeism, Worker Turnover and the Affects on Productivity

Just when that new worker seemed to be getting the hang of forming those concrete beams he decided to quit, and that other guy in the crew would be a terrific worker if he wasn't absent so much. Are these familiar words? Some causes for worker turnover and absenteeism are unavoidable and beyond control, but more likely than not they mask a problem with supervision.

"Poor supervision, unproductive relationships with the boss, poor planning, and generally poor management" were cited as prime reasons for turnover during that same motivation survey conducted by the Business Roundtable. The reasons for excessive absenteeism can be linked to one or more of the following factors:

Poor relationship with the boss,
Unsafe working conditions,
Excessive amounts of rework,
Poor craft supervision,
Poor overall management,
Poor planning,
Excessive surveillance by the boss, and/or
Inadequate tools and equipment.

There are other reasons for absenteeism, some controllable, some not. Problems such as transportation from the workers home to the job site, moonlighting or overtime availability on that second job, and personal and family illnesses can not be controlled.

Table 7-2 Factors that demotivate workers Courtesy: The Business Roundtable

Survey Results of Demotivators in Twelve Construction Projects

	Projects											
Demotivators	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Disrespectful treatment		3	3	2		1			3	3		2
Little accomplishment			1		2					2		
Material availability	2	2	2		3	1	1	2	1	2	1	2
Tool availability	2	2	2		3	1	1	2	1	2	1	2
Redoing work	1	1	1	1	1				1	1	2	2
Crew discontinuity	1		2		1		2					2
Project confusion	1	1	1	1	1	1	1	1	1	1	1	1
Lack of recognition	2	2		1*	1*		1	1			1	
Productivity urged but no one cares	1	1	1								2	2
Ineffective utilization of skills	1		1				2	1			2	
Incompetent personnel	1	1	1	1	1		1	1	2	2	2	2
Lack of cooperation among crafts	1		1*					1			3	3
Overcrowding		1			1							
Poor inspection programs		1		1					1	1		
Communications breakdown	1	1	1	1	1	1		2	2	2	2	2
Unsafe conditions	1	1*		1*	2*		2	1*		2		2
Lack of participation in decision making	1	1	2*	1	1*			1				

* = demotivator and motivator
KEY: 1 = somewhat important
2 = major importance
3 = extremely important

Managing Productivity Through Overtime

When work falls behind schedule or sometimes when that "big push" is needed, workers may be requested to work hours beyond their normal 40 hour work week. There may be times when due to conditions beyond the contractor's control, the project begins to fall behind schedule. This is often the case when unforeseen subsurface conditions are encountered and delays in earth excavation affect subsequent operations. Delays can occur when sophisticated dewatering systems have to be designed and installed to combat underground water conditions that were not or could not have been anticipated.

When the owner insists that the original construction schedule be maintained and authorizes overtime in order to get the project back on track, how will actual productivity be affected? Limited amounts of overtime appear to have little or no effect on productivity, although working an occasional Saturday, may not be as productive as a normal work day. However, extended overtime has a profound effect on productivity and studies show that a work schedule of sixty hours or more per week for two months will result in such decreased productivity that the project completion date will actually

Foreman Delay Survey

CRAFT: ____________________

NAME OF FOREMAN: ____________________ GENERAL FOREMAN: ____________________

(DATE) DAILY EVALUATION: ____________________ NUMBER IN CREW: ____________________

PROBLEMS CAUSING DELAY

	MANHOURS LOST				
	Number of Hours	X	Number of Men	=	Manhours
1.a Waiting for materials (warehouse)	______		______		______
1.b Waiting for materials (not received or not ordered)	______		______		______
2. Waiting for tools or tools not available	______		______		______
3. Waiting for equipment	______		______		______
4. Equipment breakdowns	______		______		______
5.a Changes/redoing work (design errors)	______		______		______
5.b Changes/redoing work (prefabrication errors)	______		______		______
5.c Changes/redoing work (field errors)	______		______		______
6. Move to other work area	______		______		______
7. Waiting for information	______		______		______
8. Interference with other crews	______		______		______
9. Overcrowded working areas	______		______		______
10. Plant coordination/authorizations	______		______		______
11. Other ____________________	______		______		______
____________________	______		______		______

COMMENTS: ____

Figure 7-1 Form to Survey Material Availability on the Job Site. Courtesy: The Business Roundtable.

have been *extended* beyond the point where it would have been if only a forty hour work week had been in effect.

Table 7-3 reveals the relationship between hours, worker productivity and costs during frequent fifty hour work weeks, and Table 7-4 contains the same kind of

Table 7-3 Productivity/Cost Relationship 40 hour vs 50 hour work week

1	2	3	4	5	6	7	8
	Productivity Rate		Actual Hour Output for 50 hr. Week	Hour gain Over 40 hr. Week	Hour Loss Due to Productivity Drop	Premium Hours	Hour Cost of Overtime Operation (at 2×)
50 Hour Overtime Work Weeks	40 Hr. Week	50 Hr. Week					
0-1-2	1.00	.926	46.3	6.3	3.7	10.0	13.7
2-3-4		.90	45.0	5.0	5.0	10.0	15.0
4-5-6		.87	43.5	3.5	6.5	10.0	16.5
6-7-8		.80	40.0	0.0	10.0	10.0	20.0
8-9-10		.752	37.6	–2.4	12.4	10.0	22.4
10-11-12 & up		.750	37.5	–2.5	12.5	10.0	22.5

Courtesy: The Business Roundtable

information for extended periods of sixty hour work weeks. Just like the old saying goes. "Too much of anything is not good."

Managing Procrastinators

We've all experienced working with the type of person that keeps putting things off. In most cases these procrastinators are pretty good workers once they get started, but getting them started can be frustrating at times. Firing a procrastinator may not be the solution because the replacement may not be much better. So face the procrastinator and explain the facts of life. Explain how a given task completion, if delayed, will throw the entire schedule out of kilter. Explain in detail how the completion of blocking-in the wall, for instance, will delay the completion of a sheetrock in that room, which in turn will delay the ceramic wall tile installation, which will delay the installation of the wall-hung toilet fixtures, which will delay the final plumbing inspection that will ultimately extend the issuance date of the Certificate of Occupancy. This worker may

Table 7-4 Productivity/Cost Relationship 40 hour vs. 60 hour work week

1	2	3	4	5	6	7	8
	Productivity Rate		Actual Hour Output for 60 hr. Week	Hour gain Over 40 hr. Week	Hour Loss Due to Productivity Drop	Premium Hours	Hour Cost of Overtime Operation (at 2×)
50 Hour Overtime Work Weeks	40 Hr. Week	60 Hr. Week					
0-1-2	1.00	.90	54.0	14.0	6.0	20.0	26.0
2-3-4		.86	51.6	11.6	8.4	20.0	28.4
4-5-6		.80	48.0	8.0	12.0	20.0	32.0
6-7-8		.71	42.6	2.6	17.4	20.0	37.4
8-9-10		.66	39.6	–0.4	20.4	20.0	40.4

Courtesy: The Business Roundtable

be new to construction work and does not realize the sequences in which work must be completed or possibly the procrastinator does not realize the importance of obtaining an occupancy permit on schedule.

Explain the dire consequences of not completing each phase of work on time and then get the procrastinator's commitment to complete his task quickly. Somehow it is more difficult for a procrastinator to miss a deadline if he has had an opportunity to comment on the task and agree to meet certain deadlines. Don't remind the procrastinator of his deadline once it has been set. Give him the impression that you have faith in him and he won't let you down. Remember, you can always fire him!

Is There a Right Way and a Wrong Way to Assign Work?

If some of the workers on the job site don't seem to be following directions and always seem to ask lots of questions before beginning their assignment, it might be necessary to review the manner in which they are being directed:

1. Are instructions precise? Although some older, more experienced workers may not need details, younger, less experienced workers may.
2. Are too many orders and instruction being given at one time? Enough direction needs to be given to permit the crew to work during most of the day. Don't burden them with more instructions than that.
3. Avoid playing favorites and giving easy tasks to the same workers day after day. Spread the less strenuous tasks around when they occur, otherwise, alienation will become acute.
4. Don't flaunt authority. If you've got it, everyone knows it! The days of whip cracking are over.
5. Encourage and answer questions when work assignments are handed out.
6. Try not to interrupt one assignment before it is completed in order to start another one. Not only is this non-productive and confusing to the workers, but it also imparts a feeling that you don't know what you are doing.
7. Instructions should be given in a clear, concise, professional manner, not in an off-handed way.
8. Weigh the manner in which instructions and assignments are given. Watch the tone of voice. Harsh words or shouted commands are not necessary.
9. Explain the quality levels that both you and the company expect.
10. Don't be afraid to comment on a job well done, but don't overdo it, use compliments sparingly and they will be more effective.

Managing Each Crew Member Effectively

In every work crew there are one of two workers that can always be counted on to do a good job and get the work done properly and quickly, and there are other members of that same crew that will not pull their weight. It is not fair, nor is it productive in the long run, to place a greater burden on some conscientious workers while allowing others to contribute less. Overworked workers will tend to "burn out" after a while, and this may have a serious effect on the entire crew. Correct unbalanced work crews. There are a number of signs that will highlight the urgency to do so:

- Employee complaints voiced when some workers are unfairly burdened while others are observed "goofing off." Ignoring these complaints will have a detrimental effect on productivity.
- Work that has to be redone at a higher frequency than before because dedicated workers are trying to meet deadlines, but getting little help from other, less productive crew members.
- Productivity bottlenecks because slowdowns in one sequence of work affects a subsequent task.
- Idle employees who are having their hundredth cigarette of the afternoon while other crew members are busily working.

Unbalanced work crews should be made balanced as soon as they are discovered. If good lines of communication have been established between worker and superintendent, it is likely that problems relating to work loads will be discussed openly and in a friendly atmosphere, and with the information provided, work will be distributed more fairly.

MANAGING SUBCONTRACTORS

More and more general contractors are relying on specialty contractors (subcontractors) to perform all of the work on today's construction project. Project superintendents feel that they have less control over the work force when subcontractors are engaged. On projects where the work is entirely subcontracted, superintendents give directions and instructions to the subcontractor's foreman or supervisor—not directly to their workers.

The responsibilities of each subcontracted trade will be set forth in their subcontract agreement, which will also include that portion of the specifications to be followed along with the construction drawings. The construction process is not, however, limited to what is or is not included on lines on a drawing or words in a book, but relies heavily upon people relationships. A superintendent needs to establish the proper relationship with each subcontractor foreman and supervisor. A system of give and take will generally result in getting the work done promptly, with the least amount of paperwork. One favor begets a favor, and as long as the scoreboard remains even, all parties should ultimately gain.

Always remember that the subcontractor's foreman wants to show his boss that he has performed well and has turned a profit for his company. If through the general contractor's superintendent that goal can be achieved while enhancing the general contractor's goals, all parties can become winners.

MANAGING THE FLOW OF MATERIALS AND EQUIPMENT—THE FOLLOW-UP

Follow-up. The most important word in the construction vocabulary. Delivery of key materials and equipment is essential for a smooth and uninterrupted work flow. How many times has the expression, "It's on the truck" been heard? Probably as many times as "The check is in the mail." All during the construction process, purchase orders will be issued and future delivery dates scheduled by the vendors. Some suppliers are more prone to miss production dates than others, and these suppliers need more attention. On very large construction sites, expediters are often hired merely to track deliveries of materials and ensure that they are on the site when needed. On smaller construction sites this task falls to the project manager or superintendent. The old adage, "The squeaking wheel gets the grease" is certainly true when it comes to following up previously promised delivery dates for critical items. Not only will it be necessary to confirm delivery dates for materials and equipment ordered by the company, but often it becomes necessary to verify delivery dates for equipment and supplies ordered by the subcontractors.

When it becomes necessary to call an equipment manufacturer rather than rely on information provided by the local distributor or sales representative, the following information must be in hand prior to making the call.

Purchase order number issued by the company or by the subcontractor with specific product data information on it.

The name of the vendor placing the order along with their purchase order will also be required if the order had been placed by a sales representative or through a local distributor.

The location of the manufacturing plant, the name of a person to contact within that company and their phone number.

With this information and a phone call to the equipment supplier, it may be possible to ascertain a production and shipping date. Since follow-up calls will be made periodically until the actual shipping date arrives, it is necessary to obtain the name and telephone extension number of the vendor contact.

The final vendor follow-up will occur when it has been determined that shipment is imminent and either trucking or railcar information is available. When shipping by truck a "pro" number is assigned to the shipment by the trucker, and this number plus the manufacturer's name and shipping point will be all that is needed to begin tracking the shipment once it leaves the manufacturer's dock. With the computerized operations most trucking companies have, it becomes easier to determine whether a specific shipment has been off-loaded at an interim warehouse to be placed on another vehicle for local delivery or is on the way to the project.

Helpful follow-up tips include:

Use that large wall calendar in the trailer.

Mark the date of the first phone call and the date that a delivery was promised.

If the initial delivery date subsequently changes, mark that down as well.

If and when follow-up calls are required, a history of past broken promises will be on record.

An alternate to marking directly on the calender would be to get some of those little yellow "stick-ums" and apply them to the calender with notes.

GOOD HOUSEKEEPING IS GOOD MANAGEMENT

People work better in a clean, well-lit environment and an often overlooked tool in managing people productively is managing the atmosphere in which people work. A dirty, cluttered work area leads to all kinds of worker attitudes. "Why should I pay attention to the quality of my work when this whole place looks like a pig sty?"

Good housekeeping is contagious, workers are less prone to clutter a clean floor than one with lots of construction debris on it. Empty barrels should be placed in strategic locations throughout the building and on the site to be used as trash receptacles. Everyone's cooperation is needed to overcome one of the major sources for disagreement between general contractor and subcontractor, the timely cleaning of construction debris from the work area. So remember a part of people management involves an orderly and uncluttered work site. Productivity and quality may increase, some accidents may be prevented and charge backs for clean up may be avoided.

Consider these good housekeeping suggestions:

1. Are there sufficient empty containers in the building and on the site to receive trash such as coffee cups, lunch wrappers, cigarette packs and miscellaneous papers?
2. Are there sufficient dumpsters on the site to receive daily debris?
3. Are all these containers being emptied when full so that trash spill-overs don't create more clutter?
4. Do you supervise by example. If you throw that empty candy wrapper on the ground how do you expect others to follow the rules?
5. Is the field office a good example of a clean, uncluttered work space?
6. Are newcomers—both company workers and subcontractors—instructed on how to keep the workplace clean?
7. Does company policy or contract provisions permit the use of charge backs for clean up that is not performed by subcontractors within a reasonable time frame? And, if so, are these back charges issued promptly to inform the subcontractor that the company intends to adhere to its policies?
8. Is the site policed periodically to ensure that construction debris is not being blown off the site onto adjacent properties or blocking emergency walkways and roadways?

Set aside time for housekeeping inspections the same as required for safety inspections. In a way both of these activities can have a very visible impact on the construction process.

8

Basic Construction Law

Chances are that at one time or another a project superintendent will become involved in a legal proceeding caused by a dispute between the contractor, client, design consultants, subcontractor, or supplier or even an employee of the company. Our society is quick to sue when wronged, and with more than 700,000 attorneys practicing in the United States (one for every 5 square miles) there are plenty of litigators ready, willing and able to assist those who wish to pursue legal action. The purpose of this chapter is not to create more "guard house" lawyers but to familiarize the project superintendent with the more common types of disputes and claims, why they occur and what should be done if one looms on the horizon.

Legal matters fall into two broad categories—criminal and tort law. Criminal law needs no introduction to TV viewers. Tort law can best be defined as a civil wrong, one in which the court hands down a decision involving monetary rewards rather than jail sentences as is the case where criminal law is concerned. Tort law involves disagreements over personal, property or economic conditions and these disagreements may have come about for one of the following reasons:

1. Intentional,
2. Through negligence, or
3. Neither intentional nor through negligence, which in legal terminology is referred to as nonculpable.

Although the law is the law, each case is tried on its own merits, and a court decision in one case based on what seems to be similar circumstances in another may not result in the same decision. For instance, one court decision ruled that a contract requiring a contractor to treat all earthwork as "unclassified" voided the contractor's claim for an extra cost for rock removal, when rock was discovered during building excavation. In another case, however, under the same conditions, the court ruled in the contractor's favor, stating that the contractor was misled by the erroneous test borings included in the bid documents.

How would you rule in the case of the paving contractor who signed a contract to resurface an asphalt parking lot and the specifications accompanying the bid request did not require the contractor to replace any existing sub-base? However when the new paving was being installed, it began to crack because the sub-base was inadequate. Should the paving contractor be held responsible for the cracking of the new surface even though the contract excluded any work on the sub-base? The Court of Appeals in Louisiana held the contractor responsible because he should have used his expert knowledge to advise the owner of a potential problem.

Each dispute or claim must be viewed and assessed on an individual basis and judged on its own merits with no conclusions drawn until a legal expert has reviewed the facts. When it appears that a claim or dispute is in the offing, the superintendent should begin collecting all of the facts surrounding the disagreement in case it escalates into a formal complaint.

WHAT TRIGGERS MOST CONSTRUCTION DISPUTES?

1. Plans and specifications that contain errors, omissions, ambiguities, or construction details that don't pertain to the particular project under construction.
2. Incomplete responses, inaccurate responses or even nonresponses to questions requested by one of the parties to the contract.
3. Inadequate administration of the project by either the general contractor, owner, design consultants or subcontractor.
4. Unwillingness or inability to fulfill the requirements of the contract.
5. Site conditions that differ materially from those contained in the contract documents.
6. Existing conditions, other than site conditions, that differ materially from those in the contract documents (particularly when working on retrofit or rehab projects).
7. Extra work—change orders.
8. Delays, disruptions to the project schedule.
9. Inability to meet the financial demands of the project.

Plans and Specifications that Contain Errors and Omissions

Most specifications contain a phrase that states "the contractor is to examine the contract documents, both plans and specifications and shall notify the architect and owner at once, if any errors, inconsistancies or omissions are discovered" and in some cases, the specifications state that failure to do so makes the contractor responsible for the consequences. Even though the specifications state that these errors must be presented immediately and in writing, that does not necessarily absolve the designers of their duty to provide clear, concise documents to the builder. Many potential claims have not been pursued by contractors because they felt they had not notified the owner about these errors and omissions, in writing in a timely fashion, when in fact a valid claim did exist and could have been initiated. Remember that each case stands on its own merits. If in doubt, consult the company's attorney.

When an inconsistency exists between the plans and specifications there is an "order of precedence" that may have been established in either the contract or in the specifications. This order of precedence will direct the contractor to the document that takes priority, and this ranking order is generally:

1. The written contract.
2. The specifications.
3. The plans.
   a. Large scale details will take precedence over smaller scale details.
   b. Schedules such as finish schedules and door schedules will take precedence over designations on the plans themselves.
   c. "Note" sections on drawings, such as structural drawings, take precedence over notes on the details on the individual drawings. (A "Note" on the structural drawings may indicate that all slabs are to be 4,000 psi concrete, while a note on the floor plan might indicate 3,000 psi. The 4,000 psi will prevail, in most cases.)

Although these orders of precedence should be viewed as guidelines, common sense and prior knowledge enter into the equation. Where a contractor's prior knowledge of a situation would have enabled him to resolve a discrepancy (if he had prior knowledge because of having worked in the building previously) the chances of recovery of any damages becomes very remote.

Incomplete or Inaccurate Responses to Questions

"Put it in writing" becomes the order of the day in today's complex construction market. The use of RFIs and RFCs will document the fact that questions were indeed raised and answers requested. A nonresponse or an inaccurate response to a critical question can have a serious impact on a tight construction schedule, and if a dispute or delay claim should arise at a later date the documents generated when the request was first made may provide substantiation or denial of the claim. With the widespread use of fax machines, written confirmation of a request for information or clarification and the reply is as easy as tapping out a phone number.

Inadequate Administration of the Project

Any or all of the parties to the contract can be held accountable if they do not diligently carry out their administrative duties. The owner must pay approved requisitions promptly and must not delay making key decisions that could affect the progress of the job or the contract sum. The architect and engineer must review and process shop drawings promptly and respond to contractor questions regarding interpretation of the plans and specifications.

The contractor must provide competent, full-time supervision on the job site, and the subcontractors hired by the general contractor are to do likewise. Failure on the part of either party to properly supervise the progress of the job or quality of their work is cause for a claim by the owner if schedules are not met or poor quality workmanship is rampant.

Unwillingness to Comply with the Contract Documents

Disagreement will often arise between subcontractor and contractor or contractor and owner because of a difference in interpretation of each other's obligations under the terms of their respective contracts. Unless these issues are resolved quickly they tend to escalate, and one party's refusal to perform what the other party feels is a direct contractual obligation often leads to charge backs, which in turn, creates more disagreements. Compromise—"splitting it down the middle" is often less expensive than arguing in front of a judge, and when disagreements are solved, everyone's energies can again be directed toward completing the project.

Site Conditions that Differ Materially

Although many contractors feel that they are Superman, they do not have x-ray vision and must rely on the accuracy of material presented by the architect to evaluate subsurface conditions. Contractors submitting a bid proposal are always directed by the bid documents to visit the job site and become familiar with existing conditions. Most bid documents state that a contractor will be held responsible for any condition that could have been discovered during a "reasonable" inspection of the site. What is reasonable is the key issue. Contractors are not required to conduct their own subsurface investigation but are to rely on the information presented by the owner; however, if rock outcroppings are clearly visible on the site the contractor must expect to encounter rock even if the test borings do not indicate its presence.

During the course of construction, should any underground conditions be encountered that differ materially from those indicated on the plans and in the specifications, or differ materially from conditions found on other portions of the site, extra costs may be involved. At that time written notice should be sent to the owner outlining the contractor's concern along with reasons why these extra costs should be honored. Site-related problems can seriously impact a construction schedule and unexpected or unforseen subsurface conditions need to be dealt with promptly and if not resolved amicably, a formal claim may be considered to protect the contractor's interests.

Existing Conditions that Differ Materially

When retrofit or rehab work is being undertaken, the designers will generally rely on as-built drawings from the previous construction work in order to detail much of the new work. Sloppy, inaccurate as-builts will certainly affect the details for the installation of new work, and when a contractor commences with the retrofit expecting to uncover a nonbearing wall, for example, but finds a bearing wall, this condition "differs materially" from that shown on the drawings. In most cases the architect will grant a contract sum increase to cover the costs involved in performing this additional work, but there are other times when the contractor's request will be met with "You should have known." There again, when conditions exist that differ materially from those indicated in the plans and specifications, written notification must be sent to the owner or architect notifying them of these conditions, why they could not have been anticipated and the potential for extra costs.

Extra Work—Change Orders

Change orders can originate from the owner or architect wishing to add to or delete items of work from the contract, or they can emanate from a subcontractor or general contractor when work is encountered that is presumed to be above and beyond the terms of their contract. Whenever and from whatever source change-order work or extra work authorization arises, some form of written documentation should be prepared prior to starting this work. The nature of the work to be performed, how it is to be documented—by either a lump-sum quote or on the basis of "time and material"—and how these costs will be repaid should be included in this written memo. Lack of written agreement as to what is to be done and lack of a commitment to pay are often the main reasons for disputes arising out of change-order work.

Delays

Delays can occur because of somewhat controllable factors such as material and equipment deliveries or failure to man the job properly, and delays can come about because of conditions over which the contractor has no control, such as labor disputes, strikes, indecisions on the part of the owner or his consultants or because of unusual or severe weather conditions. Delays can be classified into one of four legal categories:

1. Compensable—A delay for which the contractor will be entitled to a contract price increase and an extension of time because of some action caused by the owner.
2. Noncompensable—A delay whereby the contractor is not entitled to anything and assumes all of the consequences for the delay.
3. Excusable—A delay for which no party can be adjudged responsible.
4. Nonexcusable—A delay caused by the contractor.

Weather related delays. Weather is one of those uncontrollable factors that can create a delay, but it will not result in a compensable delay; however, under certain conditions it may be considered excusable. And although the contractor will not be allowed an increase in contract sum, he may be allowed an extension of time. When the construction contract contains a liquidated damages clause, an extension of time can reduce or eliminate any potential assessment of liquidated damage penalties by the owner.

The A.I.A. General Conditions document defines adverse weather as a weather condition documented by substantiating data that conditions were abnormal. Several court decisions have stated that contractors must not expect to work continuously throughout the life of a project without anticipating some weather delays; however, severe or abnormal conditions may be cause for a delay claim when presented with data supporting the nature and severity of the weather pattern. Therefore, severe or prolonged periods of inclement weather should be documented in the daily diary or daily log book with notations as to how the daily operations have been affected. Was a complete day's work lost or just a portion of it? Which portion of work was affected? Did it impact on other trades, and if so, how?

When it appears that an abnormal weather pattern has settled in, a call to the local state or U.S. Weather Bureau will confirm the number of inches of rain or snow that fell each day, or the continuation of extremely cold or hot weather, and how this prolonged weather pattern compares with previous years. Armed with this kind of information a weather related delay can be presented in a manner where its chances of being accepted will be greatly increased.

Acceleration—What it is and How Does it Relate to Delays. The term "accelerate" is often heard on a construction project and occasionally used when discussing the possibility of picking up the pace of work when the schedule has slipped. From a legal standpoint, however, the definition of acceleration is quite different.

When a contractor has been delayed in the normal performance of his work because of some action or inaction taken by the owner, the construction schedule may need to be extended. When the owner recognizes these delays and accepts them but directs the contractor to complete the project per the original completion date, legally, "acceleration" has been created. The owner should then expect to reimburse the contractor for all costs associated with this effort.

Unless a lump-sum arrangement has been established to reimburse the contractor for acceleration costs a weekly review of all such costs must be established so that the owner is kept abreast of costs on a current basis, since these acceleration costs can escalate rather rapidly.

Inability to Meet the Financial Demands of the Project

In construction projects rather large sums of money are needed in order to meet weekly payrolls and pay for the materials and equipment required to keep up with the job progress. If the owner, general contractor or subcontractor do not have the wherewithal to meet these financial demands, surely construction-related claims and disputes are just over the horizon.

On occasion an owner may decide to proceed with the construction project before all of the financing arrangements have been finalized, and progress payments to the general contractor may be delayed or reduced.

The general contractor in turn will more than likely remit payment to his subcontractors in the same proportion as payment received from the owner. The "pay when paid" clause permitting the general contractor to do this is a standard clause in most contracts with their subcontractors. The ripple effect of continually late or reduced payments will eventually cause delays in the progress of the project and trigger a series of claims, from suppliers to subcontractors to general contractors.

When a general contractor receives full and timely payments from the owner but decides to use that money to pay subcontractors and supplier working on other projects, there is the danger that disruptions to his total cash flow may have serious effects on all jobs. The same scenario can be painted for subcontractors who may receive a general contractor's payment for one project, but being short of cash use that money to pay overdue bills on several unrelated jobs.

WHAT TO DO IF CALLED UPON TO GIVE A STATEMENT TO A LAWYER

When a lawsuit has been initiated, lawyers on both sides will begin to accumulate evidence to support their claim, and anyone having personal knowledge of the dispute will undoubtedly be interviewed. Performed under oath in a lawyer's office and a stenographer is present to take down testimony verbatim, this interview is referred to as a deposition, a document that could be entered into evidence if and when a trial were to take place. When a deposition is taken by your company's lawyer it tends to take on a more friendly tone, but when a deposition is taken by the other side, a lawyer may attempt to confuse and intimidate the witness. In case the project superintendent is called on to give a deposition, some guidelines published by a respected Boston law firm may prove helpful.

1. Tell the truth—always.
2. Think before speaking, organize your answer.
3. Answer the question and stop. Do not volunteer information since it is the opposing attorney's job is to uncover the facts.
4. Answer as though you were dictating a letter; make the answer thoughtful.
5. Do not answer a question you don't fully understand. Ask the examiner to repeat or rephrase the question. Do not say, "Do you mean X" or "Do you mean Y?"
6. Talk in complete sentences unless a simple "yes" or "no" will do.
7. Speak only of what you have seen or heard. When a question is phrased "Do you know?", it may call for an answer that you cannot respond to based on personal experience. If that is the case, so state.
8. Do not guess a date, name or occurrence. If you can't recall precisely, state that you cannot recall.
9. Be as specific or vague as your memory dictates. If you can't recall a specific date but believe the event took place within a two week period, state so. "I believe it happened between January 1st and the 15th."
10. Do not think out loud. Don't explain your thought process in reaching an answer, just answer the question and don't relate it to another occurrence that has no bearing on the case.
11. When testifying about conversations, make it clear that you are either quoting directly or paraphrasing the conversation.
12. When requested to answer a question calling for a complicated series of events or extensive conversations, summarize whenever possible and let the examiner ask for details.
13. Never characterize your own testimony by saying, "I'm doing the best I can" or "In all truthfulness."
14. Avoid superlatives such as "best" or "worse" and don't use words such as "never" or "always," the opposing attorney may use these words against you in the future to confuse you.

15. Do not testify as to what other people know unless you are asked specifically for such a statement.
16. Do not state your opinion unless specifically requested.
17. If you are questioned about information in a document that has been introduced as an exhibit, you may request to look at that document to refresh your memory.
18. If information is in a document that has not been entered as an exhibit, answer the question if you can. Recall the answer only if you can do so without referring to that document. Don't tip off the examiner that a document exists that he doesn't know about. Its up to him to make the discovery without your assistance obviously this refers to a question asked by the opposing attorney.
19. Do not let the examiner put words in your mouth. Phrase your remarks in your manner, not his.
20. Beware of phrases such as "Is it fair to say, sir, that...", what follows from the examiner is rarely "fair."
21. Do not answer a question with more than one part unless you are certain that you fully recall all other parts. If you don't recall all parts of the question, ask the examiner to repeat them.
22. Pay particular attention to introductory phrases by the examiner because your answer may be accepted as having agreed with these introductory remarks.
23. Whenever a recess is called, consult with your attorney.
24. If you are interrupted when answering a question, feel free to ask the examiner to restate the question and begin all over again.
25. If you are caught in an inconsistency, don't get rattled. State the reason why you may have been inconsistent only if you are asked, otherwise state what your present recollection is.
26. Do not bring any documents with you unless you have previously discussed it with your attorney.
27. Never express anger to the examiner or argue with him. Your attorney will calm things down.
28. Don't make jokes, don't use obscene language and don't state anything "off the record." The deposition is all "on the record."
29. Everyone is prone to make mistakes in recalling facts when giving a deposition. If you discover an error in your testimony during the deposition, correct it then. If the mistake is discovered afterwards, it can be corrected at the time you are presented with a written copy of the deposition to review and sign.

THE ALTERNATIVES TO LEGAL ACTION AND THE COURTS

Arbitration

The A.I.A Document A210—General Conditions to the Construction Contract contains a provision permitting the use of arbitration proceedings as a method of settling disputes and refers to the rules established by the American Arbitration Association, commonly referred to as the Triple A. The Triple A is a public service, not-for-profit organization that provides the services of arbitrators to listen to both parties in a dispute and hand down a ruling. The Triple A has a pool of 55,000 experts, in all areas of expertise, that are available to arbitrate a dispute. The Triple A will provide arbitrators who have contracting, engineering or architectural experience when a construction related disagreement occurs. Therefore a dispute is aired in front of a panel composed of persons familiar with construction terminology. And when terms such as "shooting a grade with a gun" are used, the meaning is clear. A judge in a formal court proceeding might ask if anyone was injured.

Although an arbitration proceeding is similar to a court appearance and each party to the dispute usually has an attorney present, the atmosphere is much more informal. Facts are presented by both sides and each side can cross-examine the other. Evidence is admitted in much the same manner as in court proceedings, but the arbitrators can waive some of the standard rules of evidence.

Arbitration proceedings generally last no more than three days, except in rare cases, and a panel's decision is usually rendered within two to four weeks. The cost of arbitration is usually much less than costs associated with long, protracted court appearances, and when the arbitrators decision is handed down, it is binding on both parties.

Mediation

A more informal approach to dispute resolution is mediation, a process in which both parties to the dispute are brought together by a mediator who hears both sides of the disagreement. Although a mediator does not usually impose a binding settlement, he does search out the strong and weak points in the arguments on both sides and attempts to guide both parties to a compromise, mutually acceptable settlement. During the mediation process, lawyers representing both parties to the dispute are often present and submit evidence and witnesses to support their client's case.

The Triple A offers mediation services, and there are a number of organizations in the private sector that are beginning to offer these kinds of alternative dispute-resolution services to the construction industry

Many disagreements should never reach the stage of potential legal or arbitration action. Disputes occur frequently during the construction process, and if ignored, they tend to grow bigger, not disappear. When it appears that a dispute is forming, the project superintendent should begin to gather all of the documentation to support the company's position. A quick resolution should be sought, and this often means compromising from ones' steadfast position. A little "bending" by one or both parties will result in a prompt resolution and everyone can get back to the business at hand—completing the project.

9

Rehab and Remodeling Projects—What Makes Them Unique

Rehabilitating older buildings and retrofitting industrial and commercial buildings can be a profitable undertaking for those contractors having experience in these forms of construction projects. But if not approached properly, these kinds of building projects can turn into real problem jobs.

Often the drawings prepared for the rehab or retrofit work are based on information obtained by the architect after visiting and inspecting the site, or they may originate from as-built drawings prepared by the previous contractor. Unless a diligent effort has been made to verify existing conditions during this design stage, the contractor who ultimately works on the project will have his hands full.

There are two basic types of rehab work; complete or "gut" rehab, where all interior finishes and mechanical and electrical systems are demolished back to the building's shell, and partial rehab, where sound finishes are left intact and major portions of the building's mechanical and electrical systems will be left as-is or upgraded to meet local building codes.

When a general contractor is preparing an estimate for a rehab project, a checklist ought to be established in order to ensure that some of the contingency items will be included in the estimate. The project superintendent's experience can be invaluable in preparing a cost estimate when the initial site/building inspection is made. After a brief review of the drawings in the office, a site inspection is the next order of business and particular attention should be directed toward the following items:

1. When wall, ceiling and floor finishes are to be removed, will their removal damage the substrate, or will they be able to be demolished easily?
2. Are the existing conditions referred to in the bid documents actually "existing?"
3. If there are existing utilities such as water, electricity and even workable heating systems, can any of these utilities or systems be used during some or all phases of construction?
4. Will it be possible to apply a new finish over an existing surface, as the drawings require, or is the existing surface so unsound that it might be necessary to laminate sheetrock over it in order to apply the new finish?

5. Do any of the items to be removed have any scrap value?
6. How long will the demolition process take until such time as new construction can commence?
7. Does the building appear to contain asbestos bearing materials, even though the contract drawings indicate that none is present?
8. Are there old transformers in the building that could possibly contain PCBs? If so the owner must be directed to remove them prior to the start of construction.
9. Are there any environmental issues that could present a problem? Does there appear to be abandoned underground fuel tanks where none were indicated on the site drawings?

During the walk-through, any evidence of substantial water leaks should be noted and the damage caused by these leaks also noted. Check any notes on the drawings or in the specifications to determine which party is responsible for any added construction costs that may occur because the building was left in a state of disrepair.

Cutting and Patching

It seems as though a contractor never includes enough cutting and patching money in an estimate. In a rehab or retrofit project much more attention has to be directed toward not only the costs to cut and patch but also the methods by which the work can be accomplished. The project superintendent's experience can be invaluable when this phase of the job is being estimated. Large chases for new ductwork may require some shoring prior to cutting and many require some structural supports when complete. When cutting is performed on or around plaster wall finishes, quite often unsound plaster will have to be removed far in excess of that required just for the opening. Older beam-and-post buildings or wood-frame construction may require additional reinforcing if certain parts of their structural system have to be cut away to permit installation of new components.

BEFORE DEMOLITION BEGINS

What is to be removed and what is to remain must be very clearly marked, and once marked the demolition crew must fully understand these markings. If walls and systems to be removed are spray painted with DayGlo™ orange, the crews should know that anything not sprayed thusly are to remain. Some superintendents actually spray paint "Remove" or "Keep" right on the object to be removed or to stay. A tour around the building, both inside and out, should be conducted before any demolition takes place, and a preconstruction survey taken to document any structural cracks or otherwise existing deteriorated surfaces that were or weren't noted on the drawings but may present a problem once demolition begins. This walk-through should take place in the presence of the owner's representative and any unusual or potentially dangerous or costly conditions noted and even photographed.

An inspection of all existing floors, walls and ceilings to remain should also be included in this tour. Lightly tapping plaster walls may reveal unsound surfaces that may have to be removed, and any such condition should be reported to the architect, in writing, before work begins.

If major portions of the building are to be demolished and there are nearby neighbors, provisions should be made to have water and hoses available to wet down the area and reduce airborne dust to a minimum. Fire extinguishers of the proper type and capacity should be placed in areas where open flames from cutting tools will be used. When cutting out embedded metal items with a torch, remember to keep a fire watch. The hot metal remaining in the wall may cause some combustible materials to smolder for quite a while after burning operations have ceased.

SAFETY CONCERNS WILL BE CRITICAL

Falling debris, unanticipated weak spots in floors and walls, debris piled up inside and outside the building, open flames around combustible materials, jack hammer operations going full blast—the rehab project is an accident just waiting to happen and the project superintendent must be more sensitive to these concerns than ever before.

Compressor air hoses supplying power to air actuated tools may snake along the floors, and if left unguarded will become prime tripping hazards. Extension cords for electric tools ought to be strung overhead so as not to provide another tripping source. As openings in floors are created during the demolition or cutting process, they must be either covered or barricaded promptly. Has the electric service been disconnected at the main panel or just at some distribution panels? Don't accept anyone's word about what is or what is not an active electrical conduit. The project superintendent should accompany the electrician on an inspection of any active panel to ensure that the danger of electric shock is eliminated before existing feeders are cut and removed. Debris inside the building must be removed on a daily basis. Boards ripped from walls and floors with nails sticking up will cause foot and hand lacerations unless all exposed nails are either removed or bent over immediately. Once the demolition process is underway, the superintendent's prime concerns will be safety and verifying existing conditions and existing dimensions.

ARE EXISTING CONDITIONS REALLY EXISTING?

When substantial areas of new work are to be installed after existing finishes have been removed, a detailed dimensional check needs to be taken once the old finishes have been removed. Since the new work will have been dimensioned assuming certain existing wall thickness, it is necessary to survey and verfiy these "rough" dimensions once the old finishes have been removed.

If the dimensions for the new partitions coincide with the verified dimensions after the old finishes have been removed, no adjustments will be required. But if the new architectural dimensions are greater than, or substantially less than, those required to make the new work fit, the mechanical and electrical drawings will probably have to be changed. Certain dimensions must be held, such as those required for public corridors to meet handicap codes and means of egress. If dimensions verified *after* demolition vary considerably from those assumed *prior* to demolition, it is possible that a major design will have to be considered, and the sooner these discrepancies are noted and reported, the sooner the project will be able to proceed. If, and when, conditions are uncovered that differ materially from those on the plans or in the specifications, the owner and architect should be advised of the variations and the impact they will have on both project cost and schedule.

Requests for clarification and requests for information may probably be used quite often during the early stages of construction and all parties need to work together very closely while all of the problem areas are uncovered and recommendations and solutions are offered, reviewed and finalized.

NEEDLING, EXPANDERS AND PANNING

For those superintendents beginning their first rehab project, some new techniques and terminology will be added to their previous experiences. It is fairly common to create new openings in existing structural or load-bearing walls when projects are being rehabbed, and when these kinds of openings are required, the process of "needling" will present one option. A load-bearing wall must be prepared in such a way that portions of it can be removed in order to fit the new work, while retaining the structural integrity of the wall. Needling provides support above the proposed new opening until such time as a more permanent structural support can be provided.

When a foot-thick masonry wall is going to be needled, for instance, a series of holes will be created about two feet higher than the elevation of the proposed permanent lintel or support. These holes will be cut through the existing wall on approximately two-foot centers, thereby allowing a steel or wood beam to be inserted through this opening and extended far enough on both sides of the wall to be supported by shores. Once the individual needling beams have been inserted through the wall, and the shores are in place, pockets on each side of the future opening will be cut to receive a new lintel or support beam. The bearing plates set in these pockets will then be grouted to provide a level surface and then the supporting lintel beam will be installed and secured in place. The needling beams and shores can now be removed, and the holes created for the needling beams filled with mortar. The new opening can now be completed. Generally a needling plan will be reviewed with the structural engineer who may also wish to inspect the various phases of the work prior to final break through.

Expanders and Panning

When existing windows are to be removed and new ones installed in their place, care must be taken during the removal process. It is not unusual for existing window frames to have been anchored into their masonry openings, and attempts to completely remove their frames at this point could create considerable damage to the surrounding rough opening. If the existing window frames are sound, they may be left in place and quite often the architect will have indicated that they are to remain in place. When replacement windows are to be sized to fit into the opening created by the removal of sash only and not the surrounding frame, the space between the masonry opening and the replacement window jamb must now be filled with some sort of cover plate. These cover plates are called expanders or panning. The expanders lock into the replacement window frame and span the gap between the existing frame and the masonry opening. Any variations caused by the old frame being slightly out of plumb or out of square can be adjusted when these expanders are custom fit into each opening. Expanders or panning are installed on both jambs and the head of the window, and the new window sill will usually provide the proper closure at that point.

THE IMPORTANCE OF JOB PHOTOS

The old saying, "A picture is worth a thousand words," is certainly true when applied to rehab work. Progress photos are important in all kinds of construction work, but doubly important during a remodeling or retrofit project. As back-up for additional work authorization or as documentation for a condition that "differs materially" from the contract documents, professional-quality photographs are good insurance. Black and white photographs also preserve problems and solutions that may have to be referred to on future jobs, and it is much easier to turn to a photo to illustrate a procedure than trying to explain it to someone who has never experienced that condition.

ENVIRONMENTAL ISSUES

Asbestos was used extensively years ago, not only for pipe insulation, but also as an ingredient in roofing felts and shingles, floor coverings and wall and ceiling panels. Asbestos in building products exists in two forms—friable and nonfriable. Friable asbestos products are those that can be crumbled in the hand and turned into a powdery substance that releases dangerous asbestos fibers into the atmosphere quite easily. Nonfriable asbestos-bearing materials are those in which the asbestos fibers are mixed with a bonding agent and can only be released when the product is sawed, drilled or cut. Vinyl composition tile, asbestos siding and shingles and roof felts are categorized as nonfriable products. Friable asbestos in buildings generally takes the form of pipe and breeching insulation, while nonfriable materials are generally found in roofing products and ceiling and floor finish materials.

Although a visual inspection may uncover materials that look like asbestos, the only sure way of determining whether a product contains asbestos is to submit a sample to a laboratory for analysis. Asbestos abatement can be achieved one of three ways: removing the material from the building, enclosing the asbestos in an airtight enclosure, or encapsulating the asbestos by covering it with a protective material and sealing all the edges.

If asbestos is discovered in a building being renovated, the project superintendent should notify the owner and architect and request instructions on how it is to be handled. Under no circumstances should a superintendent disturb any materials suspected of containing asbestos, but he should report his findings to his office and to the client immediately so that a specialized company dealing in asbestos abatement can be contacted for removal of this hazardous product.

L.U.S.T. (Leaking Underground Storage Tanks)

There are about 1.5 million known underground storage tanks that must be replaced in accordance with a federal law enacted in 1984, and there are probably several million more that, while not subjected to the federal regulation, are slowly but surely coming under state regulation. There are probably thousands or possibly millions more that have escaped the scrutiny of both federal and local officials, and it has been estimated that 50 percent of all underground fuel storage tanks are leaking.

Because of the rather severe penalties involved, most property owners have taken steps to comply with the existing laws that pertain to L.U.S.T., but there may be other underground tanks that were abandoned and forgotten about—until they are accidentally uncovered during construction. Most construction contracts today include provisions that relieve the contractor from the responsibility of removing leaking underground storage tanks inadvertently uncovered during construction. But caution is the word when one of these tanks is discovered in a place where it was not anticipated.

If a tank is discovered, the owner and architect should be notified immediately. Care must be taken not to puncture the tank and release its contents into the surrounding soil. If a leak does occur, it must be reported to the appropriate Environmental Protection Agency within twenty-four hours and the leak repaired. Unless directed otherwise by the agency to which the leak was reported, the owner of the property must not only stop the leak but follow other procedures:

- Remove as much product from the tank as possible to prevent further release.
- Prevent further migration of the leaked product into surrounding soils and, more importantly, into the groundwater.
- Monitor any potential fire and safety hazard.
- Within twenty days after reporting the leak, the owner must submit a detailed report summarizing the abatement procedures that have been taken. Another report is required forty-five days later.

In some cases, where underground tanks have leaked their contents into surrounding soils, a series of soil monitoring wells may be required in order to observe the migration of any contaminants over a period of time, possibly as long as five years.

The Environmental Audit

With all of the concern for the environment nowadays and the complex set of laws enacted to protect the environment many contractors are having environmental "audits" conducted for the site on which they are going to work. In and around certain metropolitan areas, open fields may have been used as dumping grounds for hazardous chemicals by industrial neighbors before the consequences of these irresponsible acts were fully understood. When site work commences on these kinds of sites, dangerous materials could be unearthed threatening worker and contractor alike.

Within the last decade two pieces of federal legislation were enacted to undo the wrongs of earlier years: The Superfund Amendment and Reauthorization Act, known as SARA, and the Comprehensive Environmental Response Compensation and Liability Act, shortened to CERCLA, in governmentalese. SARA places the responsibility for hazardous waste clean-up on the owner of the property, but CERCLA can assign responsibility to the contractor who had worked the land years before, claiming that he had some part in the "chain of custody" of the land.

Site assessments are often requested by a contractor before commencing work on a site. Consultants specializing in such matters can be hired to determine if past owners could have used toxic materials and dumped toxic wastes on the premises, and a "walkover" the site can be conducted to discover any visual evidence of toxic wastes being buried or dumped on the property. If there is a possibility that the site is contaminated, the consultants will conduct on-site soil sampling both of surface and underground soils to determine the nature and extent of contamination. When these tests have been completed and evaluated, a report will be issued to the contractor, who can then decide whether to proceed.

10

The Punch List and Other Close-out Requirements

Most construction contracts include a provision to withhold 10 percent from each requisition submitted by the contractor, and this retainage, which often represents the contractor's entire overhead and profit for the job, is not to be released until all of the close-out requirements included in the contract have been met. Human nature being what it is, at the end of a project everyone is thinking about that new job starting in a few weeks, and the pressure applied all through the current project seems to level off as construction activity winds down. But an extra effort must be exerted to clean up all loose ends and obtain final payment before moving on to another project, leaving a satisfied owner on the just-completed building.

Typical project close-out requirements are usually defined in the contract specifications and include the following:

1. Cleaning the building and grounds and remove all construction debris from the site.
2. Clean elevator pits and shafts, electrical closets, pipe and duct shafts; remove mortar drippings from masonry walls not previously cleaned.
3. Maintain all finished surfaces in good order, and if any are damaged have them repaired.
4. Wash and wax vinyl floors, vacuum carpeted areas, wash windows inside and out, clean all toilet partitions and fixtures, and remove protective paper from stainless steel accessories and panels.
5. Furnish complete sets of operating and maintenance manuals.
6. Submit as-built drawings.
7. Submit all quarantees, service and maintenance contracts.
8. Submit release of liens from each subcontractor along with a general release of lien from the general contractor.
9. Furnish the Certificate of Occupancy, indicating that all inspecting agencies have signed off on the project.
10. Complete the punch list.

THE PUNCH LIST

Although the punch list was number 10 on the previous list, it is one of the items to be addressed very early in the construction sequence. By stressing concerns over quality of work at the initial stages of construction and pursuing the quest for quality work throughout the entire project, the resulting punch list at the end of the job should not be too extensive. Preparing for the architect's punch list at the final stages of construction is everyone's responsibility, and punch lists will have been kept to a bare minimum if each subcontractor "punchs" out their work as it is being completed.

This is the ideal time for a superintendent to uncover many of those annoying minor defects that can be repaired in a few minutes while the appropriate subcontractor is still on the job, but might otherwise take weeks to correct after that particular sub has gone to another job. So punch list work begins early in the game, in fact just before that first subcontractor leaves the site. In the final stages of concrete foundation work or structural steel erection, the architect should be requested to inspect the work and issue a punch list promptly so the subcontractor can perform any corrective work prior to leaving the site. Another inspection by the architect or engineer will "sign off" these trades and the punch list will have gotten off to a good start. As other trades complete their work and pack up their tools, and materials, the superintendent should review their respective specifications sections, and after a walk-through inspection create a prepunch list to be handed to each subcontractor with instructions to complete the work by a specified date.

The review of the specifications may disclose some other items that might have escaped the superintendent's attention if he hadn't reread these sections, and he might also be reminded of other punch list requirements such as:

- Are any spare parts required?
- Is "attic stock" required, and, if so, how much and what kind?
- Are scraps of carpet exceeding a certain size to be retained?
- Is the painter required to leave a can or two of every kind of paint used and also submit a list of paint colors, types and manufacturer?
- Is the flooring contractor responsible for washing and waxing tile floors and vacuuming carpeted areas?
- Are extra sets of keys required for certain locksets, or for all of them, and how are they to be turned over to the owner—in individual boxes or tagged and in a key cabinet?

A quick tour of the building when it is being readied for turnover to the owner should be made to check certain items at random:

- Flip a light switch on and off when passing through the building. Do they function properly, are the fixtures lamped correctly?
- Go into the bathrooms, turn the lights on and off, open a faucet or two, flush a toilet. Does everything function properly? Is the water turned on (might be turned off because there is a leak someplace)? Swing the doors on the toilet partitions. Do they close properly? Do they lock okay?

- Swing a few doors at random in the building. Do they close or return to an open position, signaling improper installation? When the door closes, does it close and lock properly?
- If operative windows have been installed, try to open and close a few. Is this easy or difficult to do? Are the windows clean, labels removed? If screens are required, are they in the windows or stored on the site?
- Look for stains on ceiling tiles, which may mean leaks in pipes above the ceiling.
- In the mechanical room, have all of the pipe markings been installed? Are valves tagged? Are there any piping charts or diagrams to be framed and mounted?
- Check a few electrical panels to see if the electrician has installed typed directories.
- Are engraved plastic plaques installed on certain pieces of equipment?

A comprehensive and thorough prepunch out inspection will keep the real punch list to a minimum, and when the official punch list arrives, it should be relatively short and simple, ensuring prompt completion of this critical close-out requirement

DEMOBILIZATION

As the completion of the project advances, there are other close-out procedures involved in demobilizing and preparing to move on to another site and another project. When the Certificate of Occupancy (CO) has been obtained and the owner takes possession of the building, all utilities previously registered in the contractor's name must be transferred to the owner's account. Water, gas and electric meters have to be read as quickly as possible to prevent these costs from being charged to the contractor.

Turning the Project Over to the Owner

As construction nears completion, the building will be readied for occupancy by the owner. Generally all HVAC systems will have been made operational and construction filters will have been replaced by the permanent ones. Depending on the season of the year and where the project is located, either the heating plant or the cooling equipment will be functioning, and energy costs at this phase of construction are still being borne by the general contractor. Since turnover of the building includes transferring energy costs to the building's owner, the faster this transition takes place, the less energy costs will have to be absorbed by the contractor.

Partial or Phased Occupancy

Many building owners, anxious to occupy their new facility, wish to begin installing equipment, setting up furniture and outfitting their building prior to the final completion of the project. They may even go so far as to prepare a list of the areas with anticipated beneficial occupancy expectations so that the completion schedule can proceed in that manner.

Construction contracts will often include a clause allowing the owner to occupy any completed or partially completed portions of the building for the sole purpose of fit-up and will include the terms and conditions for this early occupancy. For instance, the owner may be obliged to accept the equipment that services those areas and pay the utility costs for same. The owner generally assumes responsibility for security to those areas being outfitted.

When both owner and contractor agree that certain areas are ready for partial or beneficial occupancy, a walk-through should be conducted to list the presence or absence of any marks, scrapes, dings or damage on wall, ceiling and floor surfaces—particularly on door and door-frame surfaces. With such a list and some close inspection it will be possible to avoid arguments about who damaged which areas during the owner's move-in.

Temporary protection of the pathway of the movers is always a good idea, and owner and contractor should resolve, far in advance of the move-in, what kind of protection will be provided, where it will be installed and who will pay for the installation and the removal.

If the building has elevators and they have not yet been inspected and signed-off, any use of these elevators may require operation by the subcontractor's mechanics, and generally there is a cost associated with running the elevators for move-in. The question as to who will pay for the elevator operation must also be resolved in advance. Remember that unless a Temporary Certificate of Occupancy (TCO) has been obtained, phased or partial occupancy is limited to the fit-up of the building. Without a TCO or CO, the owner may not occupy the space for any purpose other than fit-up, and he should be so advised.

SUBSTANTIAL COMPLETION

When the architect determines that all or a portion of the building has been substantially completed, he must prepare a Certificate of Substantial Completion for those areas. This certificate sets forth the date when the owner assumes responsibility for security of the premises, maintenance of the equipment within or servicing the area or areas and also assumes all utility costs for this equipment. Warranties will commence on the date of Substantial Completion, so for this and other obvious reasons, it is important to obtain this certificate—not just a verbal acceptance of the space or spaces.

If during this period of Substantial Completion, the architect or engineer determine that any work has not been installed in conformance with the requirements of the contract documents, the warranties on those nonconforming items do not start until they have been reworked and accepted. Prompt attention to any nonconforming work at this time becomes important so that extended warranties do not develop.

If this transfer is not made promptly, it will be difficult or almost impossible to backtrack meter readings after the owner has occupied the building, but electrical charges have not been transferred from builder to occupant. Utility companies should be notified in advance so that this situation does not occur.

At the end of a job, the office trailer is usually crammed with documents—plans, specification books, shop drawings, correspondance and the like. This is the time to clean house. Duplicate drawings and specification books should be discarded after first checking with the office to determine whether they wish to keep extra copies of any particular set of plans and specs. The working set of drawings, the one that contains pencil notations made in the field, should be rolled up and labeled. Any drawings used in the preparation of as-builts should also be saved, at least until the formal set has been reviewed, approved and accepted by the owner. Shop drawings with original architect/engineer approval stamps should be placed in folders, marked appropriately and then stored in a box. Review of correspondance, contracts, purchase orders and transmittals should be reviewed with the project manager, and any papers to be discarded should be taken care of at that time.

It is best not to be too hasty in discarding any documents that could conceivably be needed in the immediate future, so it might be a good idea to take another box and label it "Hold for 90 Days" and place all of those questionable pieces of paper in there. Either have all of these boxed documents transported back to the office or whereever the company has established a records storage area. A good sweeping, dusting and floor polishing and the office trailer is all set for that next interesting construction project.

III

Basic Construction Technology

The chapters in this section will present the project superintendent with basic information about the most commonly encountered components of construction. Technical specifications, grading standards and systems and component standards are quite often changed or slightly modified by industry trade associations or trade groups from time to time.

Technology within the construction industry is advancing rapidly in some areas, making some of today's performance products as old as yesterday's newspaper. The project superintendent needs to bear this in mind when reviewing product data in chapters 11 through 26. General technical data and specifications should be cross-checked with current project specifications. At the end of chapter 26, there is a list of various trade groups and industry assocations, complete with addresses and telephone numbers in case the project superintendent wishes to obtain more information about a particular product, or to verify that he or she is working with the latest product data.

11

Excavation and Site Work

Almost all construction projects involve some degree of excavation and site work, whether it be as simple as removing some existing asphalt pavement and base before the installation of a new driveway or parking lot, or includes mass cuts and fills on a large suburban building site. Nowhere will the requirement for proper scheduling, staging and contingency planning be more acute than in this critical stage of the construction cycle where unknown subsurface conditions and unpredictable weather will put a superintendant's knowledge and skills to the test.

Working with readily compactible, properly draining soils is one thing, but dealing with deep structures on less than adequate bearing surfaces surrounded by poorly draining soils can be quite another. This chapter will deal with soil characteristics and classifications, and the next chapter will discuss coping with difficult soil conditions.

THE SITE INVESTIGATION PRIOR TO THE START OF CONSTRUCTION

Site investigation begins in the bidding stage of the project, when the contractor is assembling an estimate. Most bid documents stipulate that the contractor is to visit the site and become familiar with any existing conditions that such a visit could disclose. This site visit, along with any test borings accompanying the bid documents, will make the contractor more aware of existing soil conditions prior to preparing the site-work portion of the estimate.

So if time and opportunity permit, a thorough investigation of the site should be made prior to preparing the final estimate to check out the following:

1. Composition and consistancy of soils that are apparent from a visual inspection.
2. The presence of rock or rock outcroppings.
3. The presence of surface water or underground water.
4. The composition of any existing buildings or structures to be demolished, or foundations or concrete slabs remaining from previously demolished buildings.

5. The presence or absence of any utilities—water, storm and sanitary sewer, gas, electricity.
6. Any other site structures that may have to be abandoned, such as headwalls, bridge abutments, underground vaults.

If there are questions about subsurface conditions, and if time permits and the owner grants permission, it might make good sense to dig a test pit or two to clarify matters. The costs associated with this exploratory work may prove to be a bargain if rock, underground water or buried obstructions are encountered when the bid documents fail to note them. Of course any such test pits should be covered up immediately so as not to provide the competition with the fruits of your company's labor.

If there had been other structures built on the site and it is possible to talk to the excavator who performed that work, valuable information about soil conditions may be obtained.

TEST BORINGS—WHAT DO THEY REVEAL AND WHAT DON'T THEY TELL YOU

Test borings included in bid documents provide the structural engineer with information about soil composition and bearing capacities prior to the final foundation design, and they also provide some information about subsurface conditions. These test borings can be performed in a number of ways:

Auger boring—By either hand or with power equipment. This method is frequently used for shallow explorations above a known water table where partially saturated sands, silts and soft to stiff cohesive soils are expected.

Hollow stem flight auger—Power operated. The hollow stem of the auger serves as a casing and will hold a coring sample.

Wash type boring—A jetting action created by drilling fluid acting directly on a light bit drilling head that removes cuttings from holes. This is a common method used to obtain samples in sand and gravel where boulders are not likely to be encountered. Due to the nature of the procedure, undisturbed samples cannot be obtained.

Rotary drilling—A power-driven bit removes cuttings from a hole aided by circulating fluid. This type of boring is generally limited to soil samples and rock cores that will be only six inches deep.

Percussion drilling—This method is actually power chopping with a limited amount of water at the bottom of the hole creating a slurry. Sometimes used in combination with auger boring when penetration of coarse gravel, boulders or rock formations are encountered.

Rock core drilling—When coring into weathered rock or bedrock, a power drill is used in combination with circulating water.

The most common form of test boring is one in which a steel casing is driven into the ground and a clean sample of the soil is removed from within the casing using a sampling device called a "spoon." As the steel casing is being driven, the number of blows-per-foot required to drive it downward are recorded and will provide a log of the soil's resistance. After the borehole has been cleaned of loose soil, the sampling device, the spoon, is driven to the bottom of the hole with a free falling weight and the number of blows-per-foot of penetration by the spoon will be used to provide a more accurate measure of soil resistance since the resistance offered by the steel casing will be ignored. This "blow" count provided by the spoon as well as the quality and composition of the soils dredged up will reveal the type of soil and related bearing capacity encountered at the elevations from which the data was taken. But it is important to note that soil formations can change drastically in both a linear and vertical direction and what might represent one soil condition at the exact location of a boring may not be true five, ten or fifty feet away.

Analyzing a Typical Test Boring Log

A typical test boring log created by auger-boring and spoon-sampling device is shown in Figure 11-1. Reading across the top line of data reveals the depth at which water was discovered (20.5 feet) and the ground elevation (+25.14), which relates to all other elevation data on the sheet. This boring was taken with an auger and not a driven casing; therefore no casing blow count has been included.

The blow count on the sampler reveals that it took 4 blows with a 140-pound weight to drive the sampler the first 6 inches, and reading across that first line, it took 8 blows to drive the spoon to a 1-foot depth, 7 more blows to drive it down to 18 inches and 8 blows to drive it to a 2-foot depth. Not until the sampler has reached a depth of 8 feet below ground elevation does the soil begin to reveal any substantial resistance, requiring 28 blows to drive the spoon from 8 feet to 8 feet 6 inches.

The resistance to hammer blows may have been caused by debris in that layer of soil since the blow count dimishes substantially as the sampler passes through the metal and wood fragments. Soil resistance of any consequence does not show up again until the sampler has been driven somewhat below the ground water level (designated as GWL) at a depth of 20–22 feet. It would appear that data from this test boring indicates that the area being investigated must have served as a dump in the past.

There are different forms for reporting test boring data and Figure 11-2 displays another format in which three borings are pictured on one page with graphics to show different soil strata. The engineer preparing this data also provided a cross-section of the subsurface conditions from boring locations B-19 to B-22 to B-23 (see Figure 11-3). However since no borings were taken between these three locations, the rock layer shown is supposition only.

Equating Blow Counts with Soil-Bearing Capacity

Foundation design is largely based on soil-bearing capacities, and generally buildings two to four stories in height will require soil-bearing strengths in the neighborhood of two to four tons per square foot. The correlation of the blow count of a 140-pound

PROJECT	- Figure 11 - 1 -	SHEET 1 OF 2
CONTRACTOR	BORING LOG	LOCATION
		BORING NO. B-8
		LINE & STA.
		OFFSET

DEPTH OF WATER 20.5 FT. ___ FT. CASING OUT DATE: 1-12	DATE, START: 1-12-83	GROUND ELEVATION +25.14
DEPTH OF WATER ___ FT. ALL CASING OUT DATE:	DATE, FINISH: 1-12-83	GROUND WATER ELEV.

CASING O.D. 6" I.D. 2¼"	WEIGHT OF HAMMER CASING NA LBS. SAMPLER 140 LBS.	HAMMER FALL ON
SAMPLER O.D. 2" I.D. 1 3/8"		CASING NA SAMPLER 30"
COUPLING O.D. Auger I.D.	INSIDE LENGTH OF SAMPLER 24 IN.	

DEPTH BELOW SURFACE	CASING BLOWS PER FOOT	SAMPLE NO. DEPTH ELEV FT.	BLOWS PER 6" ON SAMPLER FROM TO 0-6	6-12	12-18	18-24	DENSITY OR CONSIST. MOISTURE	PROFILE CHANGE DEPTH ELEV.	IDENTIFICATION OF SOILS REMARKS
0	Rec.	S-1						0.02'	Asphalt pavement 2" thick
		0-2'	4	8	7	8		1.7' (+23.9')	S-1 Fill=Gr. c-f SAND, little silt, trace m-f gravel w/ paper
		S-2 2-4'	6	7	8	11			S-2 Same as S-1
		S-3 4-6'	4	6	7	8		Garbage	S-3 Same as S-1 with paper and wood
		S-4 6-6.9'	4	100/5"				Fill	S-4 Fill=Gr. c-f SAND, little silt with paper
10		S-5 8-10'	28	18	22	48			S-5 Fill=Brown c-m+-f SAND, tr. silt, with metal frags.
		S-6 10-10.7'	15	111/2"					S-6 Fill=Grey c-f SAND, some silt with wood fragments
	USED HOLLOW STEM AUGERS	S-7 15-17'	5	7	13	25		18.0' (+7.1')	S-7 Fill=c-f SAND, little silt trace metal and wood frags.
20		S-8 20-22'	46	30	20	10	▽ GWL +4.6	SM	S-8 Brown c-f SAND, some m-f gravel
		S-9 25-27'	8	6	9	9			S-9 Gr. c-f SAND, little silt, some m-f gravel
30		S-10 30-32'	9	6	6	8		33.0' (-7.9') OS-Pt.	S-10 c-f SAND, little silt, trace m-f gravel
		S-11 35-37'	24	21	24	27		36.7' (-11.6') SM	S-11 Top: Gr. Organic Silt, some c-f SAND, some m-f gravel Bot: Brown peat
40									

Soils Engineer: ______ Driller: ______

Drilling Inspector: ______ Helper: ______

VISUAL IDENTIFICATION TERMS USED

	Clayey Soils	At Boil Moisture	Relative Density (D_R) of granular soils			Consistency of Clayey soils		
Clayey SILT	slight PI.	Thread 1/4"	loose	(L)	0 - 40%	soft	(S)	0.1 - 0.5 tsf
SILT & CLAY	low PI.	Thread 1/8"	medium compact	(MC)	40 - 70%	firm	(F)	0.5 - 1.0 tsf
CLAY & SILT	medium PI.	Thread 1/16"	compact	(C)	70 - 90%	med. hard	(MH)	1.0 - 2.0 tsf
Silty CLAY	high PI.	Thread 1/32"	very compact			hard	(H)	2.0 - 4.0 tsf
CLAY	very high PI.	Thread 1/64"				very hard	(VH)	over 4.0 tsf

Proportions used: trace = 1 - 10%, little = 10 - 20%, some = 20 - 35%, and = 35 - 50%

Figure 11-1 Boring Log.

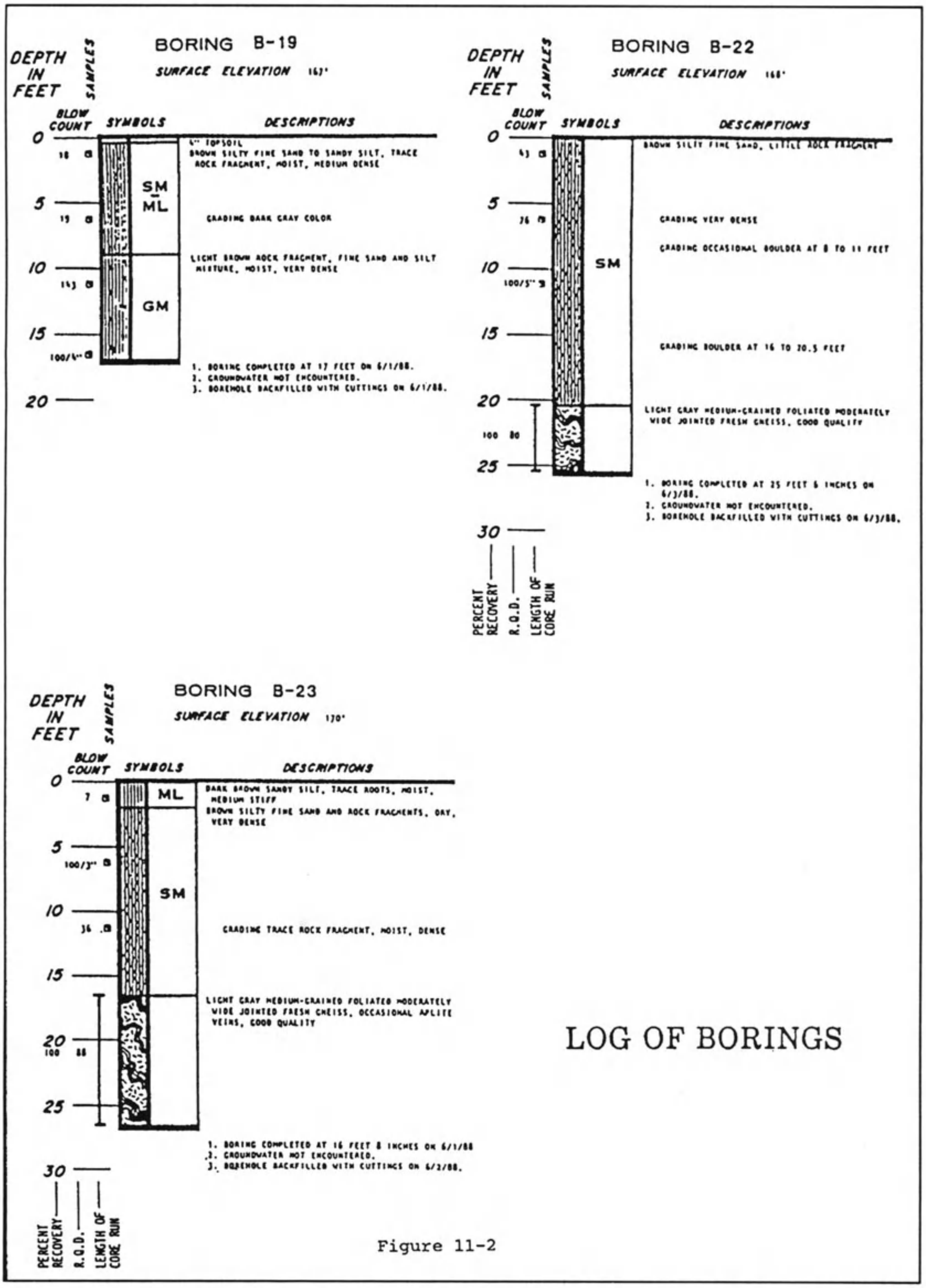


Figure 11-2 Log of Borings.

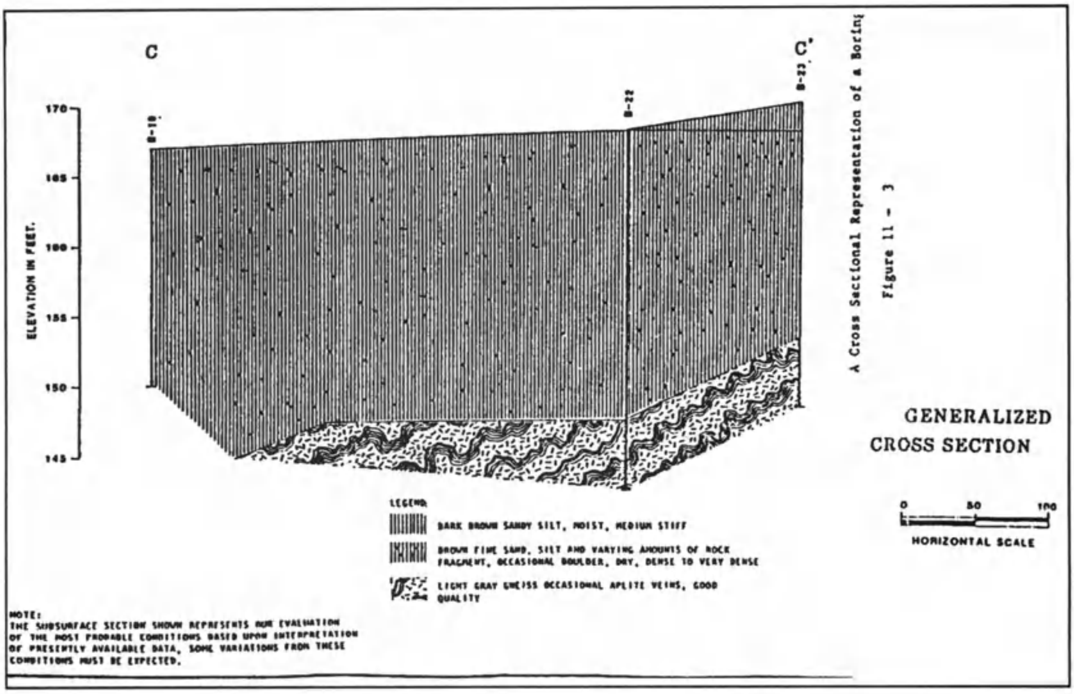


Figure 11-3 A Cross Sectional Representation of a Boring.

hammer dropping 30 inches on a 2-inch spoon where soil composition is either sand or clay is as follows:

Type of Soil and Consistancy	Blow Count Per Foot	Compressive Strength (Tons/SF)
Sand		
Loose	15	1 to 4 tons
Medium compact	16–30	1 to 4 tons
Compact	30–50	4 tons–over 35 blows
Very compact	50 or more	More than 4 tons
Clay		
Very soft	less than 3	less than ⅓ ton
Soft	4–12	⅓ to 1 ton
Stiff	12–35	1 to 4 tons
Hard	35 or more	More than 4 tons

A simple test to simulate a blow count standard penetration test (SPT) can be achieved, by using what might be called the "squeeze test," a very unscientific approach, but one that can give a fast indication of a soil sample's resistance. Certain fine grain soils react in certain ways when squeezed in the hand, and by picking up a sample of soil and squeezing it, it is possible to relate resistance to squeezing to resistance to penetration and hence to blow count.

SPT Blows Per Foot	Squeeze Test of Soil Consistancy
Less than 2 blows	Very soft, like toothpaste.
Between 2 and 4 blows	Consistency will be soft and can easily be molded by light finger pressure.
Between 4 and 8 blows	Requires strong finger pressure to mold.
Between 8 and 15 blows	Sample can be easily indented by thumb pressure but penetrated with only some effort.
Between 15 and 30 blows	Soil sample will be very stiff, but readily indented with thumb nail.
More than 30 blows	Sample will be hard and can be indented with thumb nail only with difficulty.

SOIL COMPOSITION

Since excavation work requires working with many different kinds of soils, a little better understanding of a few soil basics will make it somewhat easier to understand test boring data and deal with the many problems that may be encountered when working with soils. Soil consists of rock, rock particles and organic matter such as tree limbs, leaf mold, roots and various other forms of plant and animmal life. Minerals in the soil from the presence of rock and soil contain mixtures of all of these ingredients in proportions that can vary considerably from one location on the site to another. But soil is not just soil and rock is not just rock.

Rock Classifications

Igneous rock—The type of rock that was formed from molten materials that solidified millions of years ago. Granite, basalt, rhyolite, andesite and diorite are all forms of igneous rock.

Sedimentary rock—Composed of sand, clay and other substances. Created when existing rock formations broke into small particles and, carried away by water, combined with the remains of plant and animal life, and in the presence of mechanical pressure or chemical action formed sedimentary rock such as bluestone, limestone, travertine, shale and sandstone.

Metamorphic rock—Rock that originally was formed from either igneous or sedimentary rock after heat, pressure and moisture acted on the initial formation. Some forms of metamorphic rock are gneiss, marble, slate, soapstone and quartzite.

Rock Subclassifications

There are also subclassifications of rock whose terms are in general use in the industry today.

Bedrock—Rock that lies where it was initially formed and contains no other soil component, nor does it rest on any other soil at depths likely to be encountered during excavation. Bedrock is sound, hard rock that is capable of supporting loads of 60 tons to 100 tons per square foot.

Weathered rock—Bedrock in a state of deterioration and generally discovered where bedrock and overburden meet. Weathered rock is not suitable for very heavy loadings, and weathered rock can exist in a fairly sound or highly deteriorated state:

Fresh—No visible sign of decomposition and rings when struck by a hammer.

Slightly weathered—Slight discoloration inward from any open fractures, but otherwise similar to fresh.

Moderately weathered—Discoloration throughout with some weaker minerals such as feldspar decomposed within the sample. Still very hard and cannot be broken by hand or portions can't be scraped away with a knife.

Highly weathered—Rock that can be broken by hand or scraped away with a knife. Most of the minerals in the sample will be decomposed.

Completely weathered—Sample can be easily crumbled but rock structure has been preserved.

Residual soil—The most advanced state of weathering in which the rock structure has been completely destroyed.

Boulders—Although many specifications define "boulders" as being rock less than one cubic yard in size, the proper classification of a boulder is a rock that exceeds 10 to 12 inches.

Cobbles—Rock particles that measure between 2 and 10 inches.

Pebbles—A rock particle that ranges in size from .16 inches to 2 inches.

Gravel—Unconsolidated rock measuring 2 millimeters to 6 inches in size. Gravel as a soil mixture contains rock fragments, and unless the mix has a large proportion of shale in it, it is considered excellent foundation base material that can support 10 tons per square foot.

Sand—Just about the smallest size rock found on a site, containing particles measuring 0.2 mm to 0.6 mm. Sand makes for a good compactable base when confined in an excavated area. Compacted sand can support loads of 6 tons per square foot, but loosely consolidated sand is not nearly so desirable.

Silt—Tiny particles of rock in the .005 mm to .05 mm range. Generally regarded as an unreliable foundation base material since its frictional resistance makes it susceptible to flow. Silt is usually slow draining and difficult to excavate because of its small size. In some cases, however, when silt is dry it can support loads up to 2 tons per square foot.

Definition of Soil by Grain Size

Sieve Size	Corresponding Soil Classification
12″ plus	Boulders
3″ to 12″	Cobbles
¾″ to 3″	Coarse gravel
No. 4 to 3/4″	Fine gravel
No. 4 to No. 10	Coarse sand
No. 10 to No. 40	Medium sand
No. 40 to No. 200	Fine sand
Passing thru No. 200	Silt and clay fines

Still More Common Soil Classification and Characteristics

Clay—This material is further classified as soft, medium or stiff containing inorganic particles less than the size of those in silt. Clay looses its plasticity when dry, and it shrinks and cracks in that state. Clay will expand when wet and generally has very little strength in that condition. Although clay is generally considered not suitable for foundation material, under certain conditions it is capable of supporting loads up to 5 tons per square foot.

Hardpan—A mixture of cohering particles of sand, gravel and clay, or cemented sand and gravel in its natural state. The stability of hardpan can vary greatly because of its make-up and underlying strata. Occasionally when hardpan overlays stable rock, it can support 12 tons per square foot, but its use as a structural bearing surface must be analyzed very carefully.

Till—Till is a glacial deposit of mixed soils containing vestiges of clay, sand, silt, gravel and boulders. Till finds use in earth dam construction because it can usually be used to create an impervious substance. Loose till is another matter, and it varies so much in composition that if used, uneven settlement will probably occur. Some types of till can support foundations loads in the 10 ton per square foot range.

Loess—Wind blown deposits of fine grain soil, light brown in color. This soil is very difficult to compact and is not considered a viable candidate for structural fill.

Topsoil—A soil mixture containing sand, silt or clay along with humus. Topsoil cannot be used for structural fill.

Allowable Bearing Values For Various Soils—Expressed in Terms of Tons Per Square Foot

Bedrock, granite, gneiss, traprock in sound condition	100 tons
Foliated rock, schist, slate in sound condition	40 tons
Sedimentary rock, hard shale, siltstone, sandstone in good condition	15 tons
Well compacted gravel and sand	10 tons
Compacted gravel and sand–gravel mixes	6 tons
Loose gravel, compacted coarse sand	4 tons
Loose coarse sand, sand-gravel mixes, compacted fine sand or wet confined coarse sand	3 tons
Loose fine sand or wet confined sand	2 tons
Medium stiff clay	2 tons
Soft clay	1 ton

PLAYING IT SAFE WHILE EXCAVATING

Depending upon the type and cohesiveness of the soil encountered during excavation anyone working in a trench deeper than six feet could be working in a death trap. In 1988, according to OSHA statistics, excavation cave-ins and trench collapses were responsible for 318 injuries for every 1,000 full-time construction workers. This rate increased to 508 injuries per 1,000 workers engaged in laying sewer and underground pipes. And OSHA states that fatalities because of trenching failures were 112 per cent higher than the already scandously high death rate for the construction industry in general. Recognizing the seriousness of this workplace hazard, OSHA updated their excavation standards, effective March 5, 1990.

OSHA Standard 2226

This new regulation contains the following requirements:

- Before excavation begins, the contractor must establish the location of all underground utilities by either contacting the local utility companies or the owner of the property or "Call-Before-You-Dig."
- A safety program must be in effect prior to the start of work. Any employee who may be exposed to vehicular traffic must be provided with a proper warning vest.
- No employee will be permitted to operate any piece of equipment unless they have been properly instructed in its use.
- The contractor must appoint a competent person whose job it will be to inspect excavations on a daily basis and make note of any hazardous conditions. No employee will be allowed within an area designated as hazardous until that condition has been corrected.
- OSHA has established three soil classifications and corresponding methods of proper sloping and shoring for each type of soil encountered (This is discussed more fully further on.)
- Slopes maintained at 1½ to 1 require no further precautions; however, when steeper slopes are considered, the method and materials for shoring are to be approved by a registered engineer and a copy of the engineer's report must be kept at the job site at all times.
- Contractors may elect to use a trench box or approved shield in lieu of shoring.
- Shoring, bracing or underpinning support systems must be installed in order to ensure stability of adjacent structures such as buildings, sidewalks, walls and paved areas.

OSHA Soil Classifications

OSHA has established three soil classifications and each one has a corresponding shoring requirement in order to prevent cave-ins.

Type A soil—Defined as a cohesive soil with an unconfined compressive strength of 1.5 tons per square foot (tsf). Clay, silty clay, sandy clay, clay–loam and some silty clay loam soils as well as hardpan and cliche are considered to be Type A.

Type B soil—An OSHA classification of cohesive soils with a compressive strength greater than 0.5 tsf, but less than 1.5 tsf and includes granular soils such as angular gravel, silt, silt loam, sandy loam, and in some cases sandy clay loam and silty clay loam. Included in this category are previously disturbed soils except those classed as either Type C and Type A soil that is fissured or subject to vibration.

Type C soil—Soils having a cohesive strength of 0.5 tsf or less and includes such soils as gravel, sand, sandy loam, submerged soil from which water is freely seeping, submerged rock that is unstable or material in a sloped, layered system where the layers dip into the excavation, or a slope of four horizontal to one vertical, or steeper.

OSHA's Thumb Test

OSHA includes a thumb test in their regulations for those field personnel who want to make a quick check in order to "type" the soil being excavated.

Type A soil—To qualify for this classification, the soil will have an unconfined compressive strength of 1.5 tsf and can be readily indented by the thumb, but can only be penetrated by the thumb with considerable effort.

Type C soil—One with unconfined compressive strength of 0.5 tsf and a sample of which can be easily penetrated several inches deep by thumb pressure and can be molded by light finger pressure.

OSHA has no thumb test for Type B soil, but since the compressive strength of that soil type is greater than 0.5 tsf, but less than 1.5 tsf, would it not be reasonable to assume that the thumb test would be halfway between that of a Type A and a Type C soil? That is probably just as scientific an approach as the whole thumb test approach anyway. But the OSHA soil classification does have an impact on the maximum allowable slopes for excavations less than twenty feet deep.

Type A soil	Slope to be 3/4 to 1 (53 degrees maximum)
Type B soil	Slope to be 1 to 1 (45 degrees maximum)
Type C soil	Slope to be 1 1/2 to 1 (34 degrees maximum)
Stable rock	Slope can be vertical (90 degrees)

According to OSHA a slope of 1 1/2 to 1 is acceptable for any type of soil condition.

COMPACTION AND COMPACTION TESTS

When excavated areas are backfilled, some degree of compaction is generally required.

Under wall footings	95%
Under column footings	95%
Under slab on grade	95%
Under paved areas	95%
Outside foundation walls	90–92%

In order to determine compactability of soil, two commons methods of testing are used: the proctor test and the nuclear density test.

The Proctor Test

By determining the relationship between moisture content and soil density, as well as soil-aggregate composition, it is possible to measure the degree of compaction that has been achieved or is achievable in various kinds of soils. The proctor test is performed by taking samples of soil at the site and testing them in a laboratory. The equipment for this test is relatively simple and consists of several molds, either four or six inches in diameter, a rammer, a sample extruder, a laboratory balance (scale), a ten-inch straightedge, various size sieves and some mixing tools—a pan, trowel or spatula.

After the soil sample is taken in the field, it is passed through a number of sieves to determine particle size. The sample is then divided into four specimens, and water is added to each of these four samples in varying amounts. After water and soil are thoroughly mixed, each sample is placed in a mold where it is compacted with the rammer—twenty-five blows when a four-inch diameter mold is used; fifty-six times when the mold is six inches in diameter. The top of each mold is struck flush with the straightedge, and the soil sample is then removed from the mold. The moisture content of each sample is calculated, and the data is plotted on a curve along with the dry density values of the sample. The curve represents the relationship between dry density and moisture content, and the corresponding percentage of compaction can then be determined.

The Nuclear Density Test (NDT) for Compaction

One type of NDT requires driving a spike into the ground to create a hole for a gamma ray emitting rod to be placed. This gamma ray rod emits 100 percent until it bounces off the soil in much the same manner that radar bounces off of metal. When the gamma ray output return registers 95 percent that means that the soil into which the rod has been placed has reached that degree of compaction.

There are newer NDT machines that do not require actual soil penetration. They emit their gamma rays directly onto the surface of the compacted ground where the percentage return is measured. A proctor test has to be taken prior to the commencement of an NDT in order to establish the parameters of the soil being tested and also to calibrate the nuclear machine before performing the actual test.

A HANDY EXCAVATION CHECKLIST

Rough grading operations:

1. Are all erosion controls in place?
2. When accessing a public road from the site, is there a sufficient area set aside for antitracking materials?
3. Are all trees to remain properly protected?
4. If testing procedures are required for fill areas, has a lab been selected and approved?

5. What procedures are to be followed if underground water or unsuitable soil is uncovered?
6. Are all control points properly protected?

Underground utility installation:

1. Are all lines installed at proper elevations to permit adequate flow as dictated by building codes?
2. Do these lines deviate in either line or grade from locations shown on contract drawings? If so, note all variations for as-built drawings.
3. Has the proper bedding material been placed under pipes as required. Is approved backfill material on hand?
4. Have all pressure tests, infiltration and exfiltration tests been taken prior to backfill. Have all authorities inspected the underground utilities and signed off?
5. Have all thrust blocks been installed and installed correctly?
6. Do any lines require a bitumastic or other type of coating prior to backfill?

Rock blasting operations:

1. Has a preblast survey been conducted?
2. Is the blasting subcontractor licensed in accordance with local and state requirements?
3. Are all OSHA regulations being followed? Are the explosives stored properly?
4. Have prearranged blasting signals been established, and are the surrounding site occupants aware of these signals? Are signs posted to turn off two-way radios?
5. Are blasting mats of the proper size and condition on the site if required?
6. If seismographs are required, are they in place and functioning properly?

Paving checklist:

1. Check subgrade elevations prior to placing paving base to ensure that the proper depth of base material can be placed and compacted.
2. If concrete curbs have already been installed, have they been backed up with sufficient fill to prevent movement as the paving base is being placed and rolled?
3. Are all catch basins and manholes set to the proper elevation?
4. Are any saw cuts required where new paving meets old?
5. As the roller proceeds to compact the subbase walk alongside to see if any soft spots are visible.

Landscaping checklist:

1. Inspect rough grade to ensure that it pitches away from building.
2. Check subgrade and finish grades to verify that proper topsoil depth can be attained.
3. Check for previously settled compacted areas. It is usually less expensive to fill depressions with general fill rather than topsoil.

4. Has subgrade been tilled prior to spreading topsoil. Do the specifications require that it be done?
5. Avoid compacting the topsoil once it has been spread.
6. When laying down sod, make sure it is placed in a staggered pattern.
7. When trees are planted, are they supported properly?

12

Dealing with Difficult Site and Foundation Problems

With the availability of prime building sites being slowly diminished and becoming more expensive, clients begin to select sites that may have marginal soil characteristics requiring more complicated excavation procedures and more sophisticated foundation designs. When buildings are designed to be built over soils with poor load-bearing qualities at normal foundation depths, quite often pile foundations are designed to provide the most practical solution to the problem.

PILE FOUNDATIONS

A pile is, quite simply, a vertical member driven into the ground to assist in supporting of a load imposed by the structure above. Piles can be divided into two categories: friction piles and end- or bottom-bearing piles. The friction pile provides load-bearing capabilities because of the cohesive nature of soil surrounding it as it clings to the pile. The end-bearing or bottom-bearing pile develops its load-bearing capacity by resting on bedrock or penetrating into dense soil layers.

The use of piles dates back to 1600 B.C. Archeological evidence reveals that the Romans used wood pilings to support a bridge over the Tiber River. Pile foundations are generally more expensive than conventional concrete foundation systems; therefore, the pile type should be selected for economy as well as for its structural applicability.

Wood and Timber Piles

Timber piles are very economical for certain types of light- and moderate-loading conditions. Douglas fir, southern pine, and Norway pine are the more common wood species used and are available untreated or preservative impregnated. When wood piles are driven into an environment that is constantly wet, creosoting may not be necessary if cost considerations are critical, but when soil conditions are alternately wet and dry, untreated wood piles will deteriorate rather rapidly. So one of the factors determining the use of wood piles will be the presence or absence of a wet–dry soil condition.

Wood piles will usually have a minimum tip diameter of eight inches and a butt diameter of twelve inches. Splicers or joiners are available if it becomes necessary to extend the length of a standard pile. After a timber pile has been driven to design depth and the butt has been cut off, at least two coats of hot creosote oil and sometimes an additional coat of coal tar pitch will be applied before the pile cap is cast.

The Steel H Pile

An H pile can be used as either an end-bearing pile or a friction pile because of its considerable perimeter area. These piles are well suited for driving through underground debris such as old concrete foundations or buried timbers. When fitted with a Pruyn point (a pointed, hardened steel cap that is often welded to the tip of a pile) these piles can be driven through softer material directly into hard rock. Some of these points are manufactured with integrally cast cutting teeth, allowing them to be driven through boulders and become embedded into ledge rock below.

H piles are classified as nondisplacement piles since they cause little or no disturbance to the surrounding soil and create less "heave" when driven in relatively soft soils. The size of an H pile can range from a 10″ × 10″ section to a 14″ × 14″ section and typically an HP 10 × 42 will be used, but other rolled sections and weights such as HP 12 × 53 or a hefty HP 14 × 73 are sometimes more suitable. H piles can rust when in contact with water over a very extended time frame, so the presence of underground water may be a limiting factor in their being selected.

Pipe Piles

Pipe piles can be of the open-end or closed-end type. When driven open ended, the pile casing is subsequently cleaned out and filled with concrete thereby attaining very high bearing capacities. In some instances, the material that accumulates inside the pile casing will be left in place, but when the design requires that the inside be cleaned out and filled with concrete, the process becomes quite expensive and therefore limits its use. With closed-end pipe piles, the bottom end is fitted with a conical point or flat plate to withstand the driving force, and once the pile has been driven it is inspected to ensure that it is free of debris and water before being filled with concrete.

Tapered Pile Tip Piles—TPTs

A TPT is comprised of a pile stem made of wood, steel or pipe fitted to a precast concrete tapered tip. Driving resistance is created by the displacement and densification created by the tapered tip. These piles are used to advantage when high bearing capacities are required in soils of marginal condition and where minimal lengths are desired to meet design bearing capacity. TPTs can be driven rapidly and when fitted to wood piles can achieve load capacities of 20 to 30 tons. When TPTs are fitted to steel pipe mandrels, capacities of up to 180 tons can be attained. These types of piles are very well suited to sandy soils at depths of 70 feet or more.

Tapered Piles

Several years ago, the Raymond International Corporation developed a pile system called Step Taper Piles in which a series of steel jacketed casings, each of differing diameters, are joined together to form a step-down cylinder. The diameter of the STP decreases from a top dimension of 18 inches to a 14-inch bottom dimension, and when filled with 8,000 psi concrete, these bottom-bearing piles can achieve a load-bearing capacity of 250 tons.

Composite Piles

Piles of different materials can be joined together to form a composite driving member. One form of composite pile might consist of a timber lower section joined to a pipe pile and used to advantage where the less expensive portion is submerged in water while the more costly section remains above the water level. An H pile lower section can also be joined to a precast concrete upper portion to form another kind of pile that could be driven through underground obstructions.

Cast-in-Place Concrete Piles

These types of pilings are basically concrete filled tubes and are different from concrete filled pipe piles in that the shell or casing thickness is required to be only thick enough to resist driving installation and still remain an open shell. These thin-wall casings are usually installed with a mandrel in order to maintain stability while being driven, and when the mandrel is withdrawn, concrete is poured into the casing.

Precast Concrete Piles

Precast concrete piles can be made in either square or octagonal configurations and contain prestressed steel strands within a 5,000 psi or 6,000 psi concrete encasement. If these piles are not autoclaved (steam-cured) they must generally air-cure for a period of 28 days to obtain maximum design strength before being driven. The pile heads of precast concrete piles must be protected from direct hammer impact when driven, and a heavy ram with low impact velocity is the hammer of choice. Precast concrete piles are often used where underground conditions are alternately wet and dry, and they are frequently used when a pile will be partially or totally submerged under water.

Pressure Inject Footings—PIFs

Developed by the Franki Foundation Company, these unique pile structures are more commonly known as Franki piles. The Franki pile is created by driving a steel tube, ranging from 12 inches to 24 inches in diameter, to a suitable bottom-bearing depth. (Driving is performed by either fitting a boot onto the bottom of the tube and driving it in much the same manner as any other pile, or "bottom" driving by placing a plug in the bottom of the tube and allowing the drop hammer to impact directly on the plug, creating an action that actually pulls the casing or tube down to design depth.) Once there, the plug is partially expelled from the tube by additional blows from the hammer (see Figure 12-1).

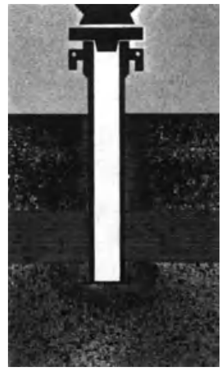
The Franki Pressure Injected Footing Technique

While we offer expertise in many foundation techniques, Franki's special forte is the Pressure Injected Footing (PIF)—invented, developed and perfected by Franki. The technique has been continually improved and refined over the last 70 years and is today a sophisticated process incorporating current geotechnical principles and utilizing up-to-date equipment.

Phase 1
DRIVING

In "top-driving", the drive-tube, fitted with a steel boot, is driven to the bearing stratum by diesel hammer. A charge of dry concrete is compacted into a sealing plug with drop-hammer blows and partially expelled, displacing the boot, while the tube is held.

For "bottom-driving", the plug is added at ground surface. Tube-plug friction is such that repeated drop-hammer blows on the plug "pull" the tube into the soil. At the desired depth the tube is held and the plug partially expelled.



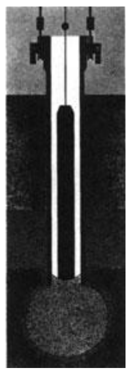
Top-driving

Bottom-driving

Phase 2
BASE

Manufacture of the PIF now commences, with the feeding in of very small charges of zero-slump concrete, each being driven out into the soil with blows of high energy—60,000 to 200,000 foot-pounds per blow, depending on design load.

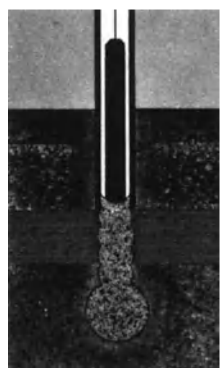
As the tube is maintained at the same elevation, repeated injections of concrete result in an expanded base or bulb, providing an enlarged bearing area and also progressively strengthening the bearing stratum by compaction. The process continues until the specified energy per unit volume of concrete is reached. The finished base becomes a totally efficient load-transfer device, custom tailored to the individual soil condition, its size varying inversely with the initial soil density. It has actually been *pre-tested* with high-energy blows, enabling Franki to guarantee its ability to support the design load safely.



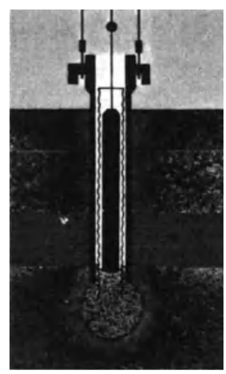
The Finished Base

Phase 3
SHAFT CONSTRUCTION

In the *uncased-compacted-concrete* procedure, successive charges of zero-slump concrete are rammed out against the soil as the tube is withdrawn in short lifts. A seal is always maintained to exclude water or soil. *Cased shafts* are made by inserting a steel shell, placing and compacting a zero-slump concrete plug and withdrawing the tube. The shell is later filled with 4"–6" slump concrete. Both shaft types can be reinforced if needed for uplift or shear. Other shaft types are available for special situations.



Uncased Shaft



Cased Shaft

NOTE: For specifications and design details see "Technical Data Supplement", 2.2a/Fra.

Figure 12-1 Franki Pressure Injected Footing Technique.

After the casing is in place, small charges of zero-slump concrete are fed into the tube and driven into the soil with high energy blows of up to 200,000 foot-pounds per blow. A concrete bulb is thus formed at the base of the tube, and when an uncased pile is being created, additional loads of zero-slump concrete are fed into the casing as it is being withdrawn. When a cased shaft is called for, a steel shell is inserted into the hole and filled with 4 inch or 6 inch slump concrete. Depending on design, reinforcing bars may or may not be installed in either cased or uncased pile.

Underpinning Piles

When existing structures require underpinning, piles can be driven in the conventional manner or installed by jacking against the existing structure. After the pile is in place, some sort of support bracket will be placed under the structure requiring support, and this bracket or brackets will be welded to the pile.

Pile Driving Rigs and Pile Driving Hammers

Pile driving rigs can be operated by either steam or diesel power and can be fitted with a variety of driving hammers depending on the type of pile and the conditions under which it is to be driven. Hammers can be of the direct impact type or vibratory attached to the rig with leads.

Single-Acting Impact Hammers. Many older rigs are of the single-acting type, which relied on steam pressure to raise the piston attached to the ram. When the high-pressure steam is released, the hammer or ram will fall by gravity and drive the pile downward. The force that drives the piston acts only in a single direction hence the designation "single-acting."

Double-Acting Impact Hammers. Double-acting hammers can be operated by either deisel or steam power, and when operated by steam pressure, the striking ram is raised by steam pressure and the steam pressure is also used to start the piston on its down stroke so that a reciprocating motion is created. Double-acting hammers are able to apply more blows per minute than single-acting hammers and therefore create more rapid pile penetration.

Diesel-Powered Hammers. Diesel-powered hammers use the downward stroke of the ram to compress air in a combustion chamber. When fuel is injected into this chamber, the resulting explosion not only drives the ram downward, but also helps to raise the ram after the blow has been delivered, preparing the hammer for another trip downward.

Vibratory Hammer. These hammers contain a motorized vibrator that vibrates the pile into the ground rather than driving it. The vibratory hammer is attached or clamped to the top of the pile and creates oscillations that are transferred to the pile and into the soil, where soil adhesion is broken allowing the pile under the weight of the hammer to lower itself into the ground. In ordinary soils, vibratory hammers can drive piles rather quickly; however, the vibration created in the process may travel through the ground and damage surrounding buildings or structures.

Jetting Piles

Installing piles by jetting involves introducing large volumes of water, under pressure, around the tip and sides of the pile as it is being introduced into the ground. The pressure of the water jet, usually in the 75 psi to 175 psi range displaces the soil directly in contact with the pile allowing it to ease into the earth. Jetting piles is a tricky operation because excessive soil may be displaced and tip-bearing capacities of the soil reduced. And higher pressures during the jetting operation may force the pile out of alignment.

Test Piles and the Load Test

Most pile installations begin with the driving of a test pile. One or more piles will be driven to design depth and a measured load will be placed upon them (see Figure 12-2). A means of measuring the movement of the test pile or piles is then established and after twenty-four or forty-eight hours, the movement of the pile is recorded. The imposed load should result in a settlement of about 0.01 inches per ton of test load when recorded after a twenty-four hour period. If the test pile fails, the engineer will require another test to be conducted after another pile is driven. From time to time there have been various methods of dynamic pile testing in use. With low-voltage

A STATIC PILE LOAD TEST SCHEMATIC

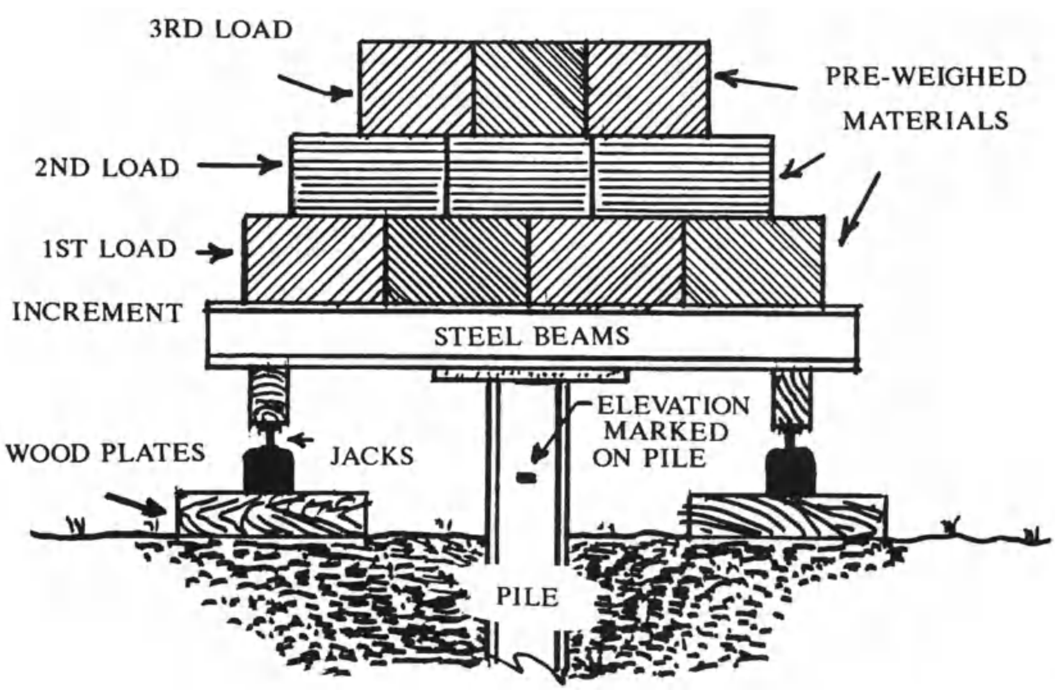


Figure 12-2 Schematic of a Typical Pile Load Test.

electric leads attached to the hammer and to the pile, and both leads connected to a battery-powered computer that has been appropriately preprogrammed, the driving resistance force is monitored as the pile is being driven. When design depth has been reached, a printout of the achieved bearing capacity can be obtained from the computer.

The Pile Driving Formula

Quite often a formula is used when a test pile is being driven in order to provide an evaluation of actual soil-bearing capacities. The most widely accepted formula is the Engineering News Record Formula developed in 1920 by the engineer A. M. Wellington. The ENR formula has three variations, one for a drop hammer, one for a single-acting hammer and one for a double-acting hammer and for those who are curious, this formula is as follows:

For drop hammers $L = \dfrac{2WH}{s + 1.0}$

For single acting hammers $L = \dfrac{2WH}{s + 0.10}$

For double acting hammers $L = \dfrac{2E}{s + 0.10}$

L = Safe load bearing.
W = Weight of ram or striking parts, in pounds.
H = Height of stroke in feet.
s = Set penetration per blow, in inches.
E = Rated energy of the hammer as listed by the manufacturer, in foot-pounds.

The formula used when driving a test pile is then compared with the results obtained after a successful load test has been conducted. If the ENR formulas prove correct, the pile driving operator will continue to use it as a gauge for driving the balance of the piles.

Common Pile Driving Terms

Brooming—The effect produced on the top of a timber pile when it has been subjected to pounding by the hammer. The wood fibers tend to separate and fan out like a broom. This is a condition to be avoided since blows on a broomed head will not be fully absorbed and transmitted to the shaft.

Refusal to penetration—When a pile has been subjected to repeated hammer blows near or at design depth, and it resists moving downward, this is known as refusal.

Quake or ground quake—As a hammer continues to deliver blows to a pile, the soil surrounding the pile tends to loosen and the ground quakes. As the quake increases there is less friction around the pile. When driving friction piles, the presence of ground quake takes on added significance.

Tapping in—When piles are driven in a cluster, soil pressure may build up between the piles causing one or more of them to rise slightly. When this occurs, it becomes necessary to have the pile driving rig "tap" these piles down again.

Kips—Abbreviation for kilopound or 1,000 pounds. When the term "4 kips" per square foot is used, it denotes 4,000 pounds per square foot.

A Pile Driving Checklist

1. Pile contracts are often based on a lump-sum price to drive a total length of pilings, and a unit price is generally included in case additional lengths are required. A daily log of actual lengths driven should be maintained in order to compare with the quantity included in the lump-sum agreement.
2. Rarely are all piles driven to the exact location indicated on the structural drawings. Some piles will "walk" while being driven, and their final location must be plotted at the end of the day and transmitted to the engineer for approval. If the driven location is not acceptable, another pile may have to be driven as quickly as possible and the cost of this added pile will be charged against the lump-sum footage.
3. If a pile is driven in the wrong location by the pile driving subcontractor because of an error in plotting, and is unacceptable to the engineer, the cost for a replacement pile will be charged to the subcontractor. So it is equally important to verify the initial driving location of all piles.
4. Piles that split, bend, become crushed or cannot penetrate underground obstructions and must be abandoned are usually applied against the lump-sum quantity, which if exceeded, will result in extra costs to the general contractor. This is another reason for keeping a detailed, daily log of pile driving operations.
5. When clusters of piles are driven in locations requiring some redesign of pile caps, the general contractor may be responsible for the added costs of the pile caps as well as the engineer's cost to redesign.
6. At the conclusion of the pile driving operations, an as-built drawing is required, and it is important to determine at the outset of this operation whether the subcontractor or general contractor assumes responsibility for the preparing this drawing.
7. The pile driving rig should be left on the site until such time as the design engineer officially accepts the location of every pile.

CAISSONS

Although caissons, like piles, are load-bearing members sunk vertically in the ground, they differ in that they are designed to act as columns in compression. Caissons are meant to transfer superstructure loads through unsuitable soil layers down to bedrock or otherwise hard stratum. Caissons can be straight shafted or belled bottom. Drilled-in caissons are constructed by driving or drilling a pipe casing with a reinforced cutting edge into the ground. Power augers are also used to create a shaft for the caisson, especially when dry, cohesive soils are encountered. At times drilling mud or a bentonite slurry are used to stabilize the excavation prior to filling the hole with concrete. This process is known as "mudding."

GEOTEXTILES

Geotextiles are various kinds of synthetic fiber cloth manufactured specifically to provide a separation between layers of earth to:

Replace expensive graded aggregate filters around subsurface drainage pipes.

Prevent soil erosion.
Prevent contamination between one soil layer and the next, thereby increasing the load-bearing capacity of marginal soils.
Control the growth of weeds.
Prevent fine soil infiltration into leaching fields and other draining areas.

Replacing Expensive Graded Aggregate Filters Around Subsurface Drainage Pipes

Instead of placing perforated drainage pipes in stone-filled trenchs where fines from surrounding soils may ultimately clog the draining capacity of the aggregates, the ditch can first be lined with a filter-type geotextile. A layer of stone will then be placed at the bottom of the filter fabric-lined ditch, and then the perforated pipe will be placed in the ditch. When additional stone is placed around the sides and top of the perforated pipe and the filter fabric is lapped over the top of the trench, the addition of this geotextile will ensure superior drainage and will prevent clogging of the aggregate by infiltration of fines. Geotextiles used for subsurface drainage are permeable enough to allow liquids to pass through while retaining the outlying soil. These fabrics will have a large number of openings so that when some become blocked, there will be sufficient openings to prevent impairing the filter's performance.

Preventing Soil Erosion

When placed on river or stream banks under a layer of riprap, the geotextile prevents the soil from eroding under the protective layer of rock as the water rises and falls, ebbs and flows. The hydraulic effect of flowing water will tend to erode the soil under any protective layers of stone without a geotextile installation.

Preventing Contamination Between Layers of Soil

Outdoor recreational facilities such as soccer, baseball or football fields or tennis courts require adequate subsurface drainage in order for the playing surface to drain properly after a rainfall. The drainage systems under these kinds of playing fields have multiple layers of various types of permeable soils and aggregates, and when a layer of the proper geotextile is placed between layers, the subsurface drainage areas are less likely to become clogged.

Weed Control

Landscaping contractors find many uses for geotextiles. When placed under mulch around shrubs and trees, filter fabrics will allow water to pass through to the plant's root system while preventing weeds and other forms of vegation from penetrating the fabric from below. Geotextiles are used effectively behind timber retaining walls. Geotextiles installed vertically behind the timbers act as soil stabilizers while permitting water to flow through the wall. When placed over an area excavated for a brick or stone walkway prior to installing a compacted layer of sand and followed by another fabric layer prior to placing a second layer of compacted sand, a firm base will be established that is unlikely to erode when subjected to the weather.

Preventing Fines from Entering into Leaching Fields

More than 33 percent of all U.S. households have on-site waste treatment plants—septic systems, and the leaching fields are an important part of the disposal process. Filter fabrics installed in the leaching field trenchs prior to placing pervious soils around the perforated drainage pipe can extend the life of the leaching area by keeping infiltration of soil fines to a bare minimum. In areas where good draining soils are not present and large quantities of gravel or stone must be imported, geotextiles may be a more economical approach to the problem by reducing the amounts of gravel or stone required.

DRAINAGE MATS

A product consisting of a filter fabric and an impermeable fabric sandwiched between a drainable core, drainage mats find wide acceptance when placed against underground foundation walls to prevent water seepage into below-grade work areas or parking structures. When more than a coat of damp proofing material is required to provide dry space below ground, these foundation mats provide an extra measure of security against water infiltration.

Drainage mats are typically constructed of an outer layer of a nonwoven geotextile fabric heat bonded to a core of pencil-eraser shaped plastic cones, which are bonded to an outer layer of impermeable fabric that will be placed against a foundation wall previously coated with a waterproofing liquid. At the base of the foundation wall, a footing drain should have been installed either before or after placing the drainage mat. Once the outer surface of the foundation wall has been backfilled with compactable free draining material, the drainage mat will begin to go to work.

The theory behind the drainage mat is fairly simple. When the impermeable side is placed against the foundation wall, held in place by an adhesive, and the wall is then backfilled, any water entering through the foundation backfill will pass through the outer or filter fabric side of the mat and fall vertically down the space created by the plastic eraser-shaped spacers. The water will be carried away from the building when it reaches the footing drain.

GABIONS

Although geotextiles can be effectively used to retain soils, they are often used in conjunction with other structures, and gabions are quite often the structure of choice when forming an inexpensive retaining wall. Gabions are simply wire boxes into which stones, rock or other forms of large aggregates are placed in order to form a retaining wall. The heavy, intertwined galvanized wires of the gabions become receptacles for the stone and provide a structure that can yield to earth movement but still maintain its full retaining qualities (see Figure 12-3). Gabions will allow water to pass through unimpeded, and as time goes on, the mass of rock or stone actually becomes more stable as vegetation grows and silt collects between the stones.

Gabions are generally furnished knocked down and must be set up in box form. Each unit is then wired to its neighbor. When placed vertically as well as horizontally, they are stepped back as they rise. As each gabion is filled with rock or stone, its lid is folded down, wired closed and the next layer placed on top and wired back to the one underneath. Gabions can be formed into curved sections to fit around bridge piers or culverts and are installed with simple hand tools

Reno mattresses fulfill the same function as a gabion except that their wire shape is more like a mattress, hence their name.

DEWATERING

Controlling surface water and ground water during the construction process is required on most construction projects from time to time. Dewatering can be as simple as creating a swale to collect and divert surface water, or it can require one or more sophisticated procedures. Knowing exactly which type of dewatering system to use often requires the services of an engineer or experienced dewatering contractor to prevent some of the problems that improper dewatering techniques can create. Damage to adjacent buildings, cofferdam instability, bottom heaving of excavated subgrades, and uplift of partially completed underground concrete structures can result from improper dewatering procedures. There are a number of dewatering options available to the contractor, ranging from a simple trash pump installed in a pit to the rather elaborate deep-well system.

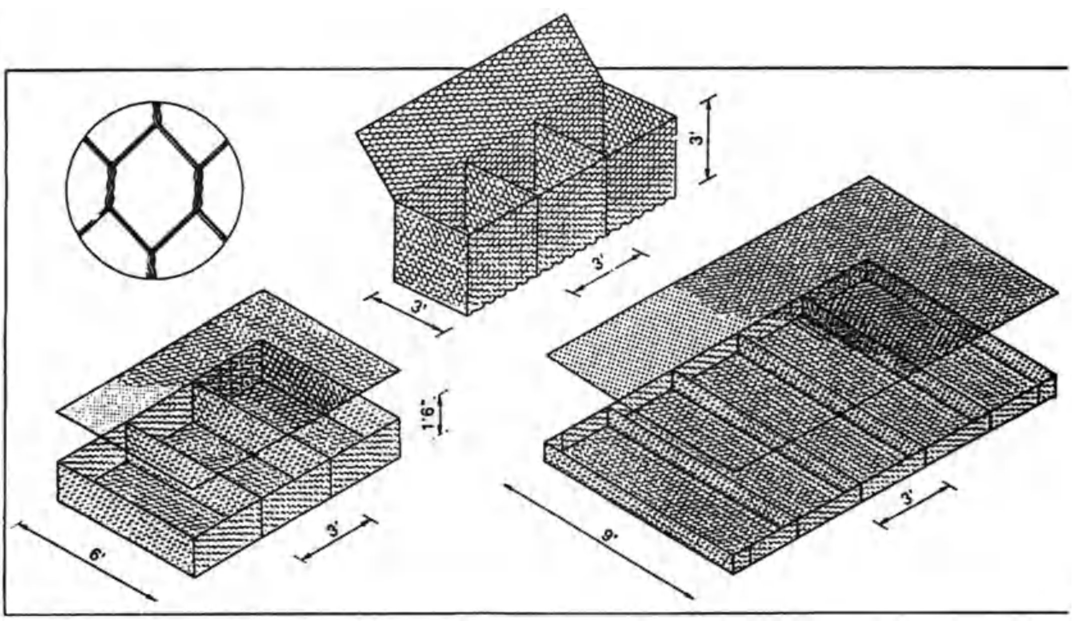


Figure 12-3 Gabions and Reno Mattress. By permission of Maccaferri Gibbons Inc.

Understanding the Nature of Soils and the Dewatering Process

The lateral movement of water through soils is largely determined by the most pervious (porous) layer. Vertical movement is generally dictated by the least pervious or permeable soil layer. A careful and thorough review of available test boring data, or better yet, a test pit, might provide a forewarning of just where and how subsurface water will be traveling or areas where the water may become trapped. These clues will provide more insight into the selection of the best method of dewatering.

When ground water is discovered, a dewatering scheme must be devised to not only lower the water table sufficiently for work to proceed, but also consider the possible affect that the dewatering may have on adjacent buildings or structures. Improper dewatering can result in severe structural damage to existing structures if uncontrolled pumping causes lateral loss of ground when improperly filtered pumping systems remove soil fines along with the water. When this occurs, a phenomena known as consolidation takes place, and soil particles become more closely packed by the application of loading as they rush to fill the voids left by the water. Although many soils can absorb these loads without consolidating, clays of low permeability may take considerable time before this consolidation occurs, and any settlement effect will not be immediately noticeable.

Infiltration Problems

Along coastal areas, an improper dewatering system may result in salt water intrusion, which in years to come may have a corrosive effect on any underground structures built in the dewatered area. Where dewatering takes place in areas adjacent to, or in the midst of older industrial complexes, the depletion of ground water in the new excavated areas may cause earthbound industrial contaminants from past years to filter into this new excavation. Where an aquifer is the potable or domestic water source for surrounding residential or commercial buildings, excessive dewatering may temporarily upset the yield from wells in the area.

Hydraulic Gradients—"Draw Downs." When ground water levels are lowered by pumping, the flow of water from the aquifer creates a funnel effect within the water table (see Figure 12-4). In section, this funnel effect is more noticeable (see Figure 12-4a), and with multiple wells or well points these funnels will be almost continuous (see Figure 12-4b). The funnel-shaped water line is known as the "hydraulic gradient" or just plain "gradient." The maximum gradient achieved by the well is called the "draw down," and pumps and well sizes and locations are designed to maintain this draw down in the face of the surrounding water flow.

Engineers do have an elaborate formula for designing dewatering systems. One formula is used for confined aquifer dewatering and another for water table aquifer calculations. Both formulas take into account soil characteristics, existing and proposed water levels, draw down configurations, well depth and well diameter.

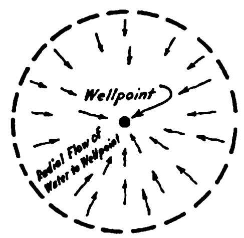


Figure 12-4 Flow of Water From Aquifer to Well Point.

COMMONLY USED DEWATERING SYSTEMS

Deep Wells and Shallow Wells

Probably the most common form of dewatering, this method involves sinking a casing into the ground and installing a submersible or line-shaft turbine pump to eject the water. Shallow wells are those above twenty five feet in depth, and deep wells may be several hundred feet into the ground. The well casings housing these pumps are sometimes filled with stone, or the wells themselves may be elaborate wire and mesh affairs or simply a steel casing with a series of slots or holes cut or burned through the casing circumference.

Suction Wells

A suction well scheme uses a series of wells, usually four inches to eight inches in diameter and connected to a header pipe often ranging in size from two to three feet in diameter. This header pipe is connected to a vertical turbine pump operating under net suction conditions. Suction pipe water evacuation is often used when large quantities of water must be pumped with a minimum number of wells. This system sometimes requires multiple stages when deep dewatering is required.

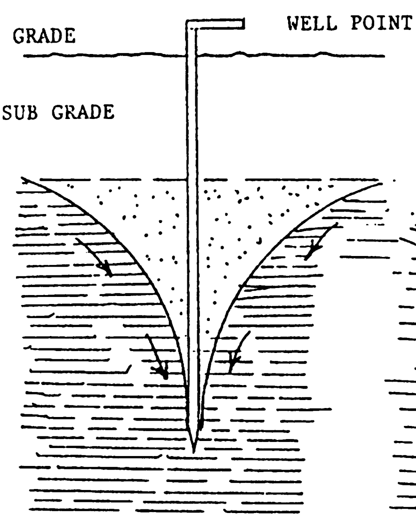


Figure 12-4a Funnel Effect.

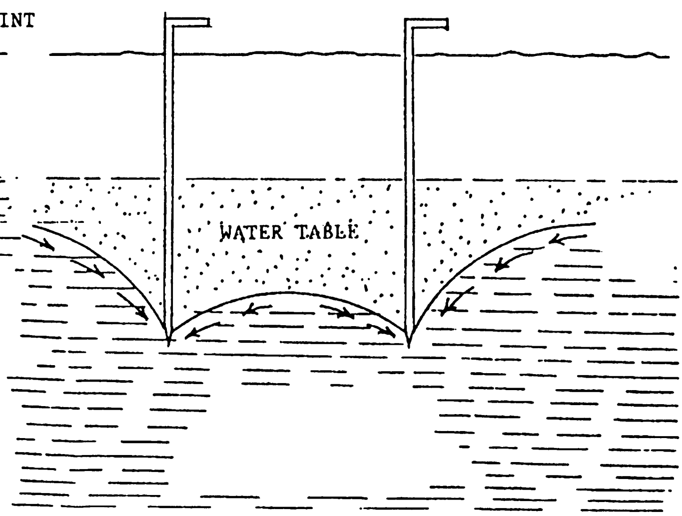


Figure 12-4b Funnel Effect when Multiple Well Points are Installed.

Ejector Pumps

Sometimes called eductor pumping, this system uses a contraption that contains a nozzle and a venturi with a supply and return aperture. When the device is placed near the bottom of a well, and high-pressure water is forced through the supply side of the ejector, a flow that forms a vacuum in the venturi chamber is created. Water is then drawn up the well casing where some of it returns to the supply-side pressure pump to be forced back down into the well. Water that is not diverted to the pressure pump will then flow out of the excavation. Although this is a rather inefficient method of dewatering, the ejector pump system is often used when a large number of low-capacity wells are required particularly in fine-grained soils where high vacuum in the well point is required.

Electroosmosis

This dewatering process involves low-voltage electrical current that is applied to the surrounding soil. Anodes and cathodes are included in the water-collection process. When water molecules are subjected to an electrical charge, capillary action occurs, and the water will migrate through the soil to the cathodic collection system. Infrequently used, electroosmosis does find application in situations where soil stabilization is critical.

Well Points

A frequently used method of dewatering, particularly when large open-cut excavations are required. Individual collection tubes or pipes are placed down through the soil to an elevation below the water table. These individual wells, sometimes as close as three feet on center, are connected to a manifold, which in turn is connected to a vacuum pump system. As the vacuum pump evacuates the air from the individual wells, water begins to travel up to atmospheric pressure and enters the manifold where it will flow to a well sump containing a submersible pump for discharge out of the system. Figures 12-5a through j illustrate the various stages and components of the construction of a well point system within a large cofferdam.

Quite often the individual wells in the well point system will be lowered into place by a process known as "jetting" (see Figures 12-5c and d). Jetting requires a high-volume water source. Water must be pumped through a pressure pump to produce a stream of water in the range of 750 psi. A special jetting nozzle (Figure 12-5b) is inserted into an empty steel casing suspended from a crane, and as the high-pressure water is injected through the jetting nozzles, the soil is rapidly displaced around the steel casing, allowing it to descend into the ground.

Upon reaching the lower elevation required for the wells, jetting ceases, and the jetting nozzle is withdrawn, leaving the empty steel casing in its place. Each well point will be lowered into the casing and will consist of two pipes (see Figure 12-5a), an outer well-screen pipe and an inner solid pipe that will convey the water to the surface.

The outer well-screen pipe is first lowered into the empty casing, and then coarse sand is hand shoveled completely between the pipe and the outer steel casing. Once complete, the casing will be withdrawn. This well-screen pipe has closely spaced filter

Figure 12-5a Filtering Pipes Used in Dewatering Process.

Figure 12-5b Jetting Casings.

Figure 12-5c Driving the Jetting Nozzles.

Figure 12-5d Withdrawing the Jetting Nozzles.

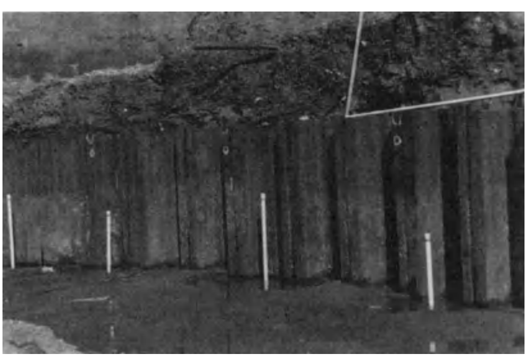


Figure 12-5e Individual Well Pipes.

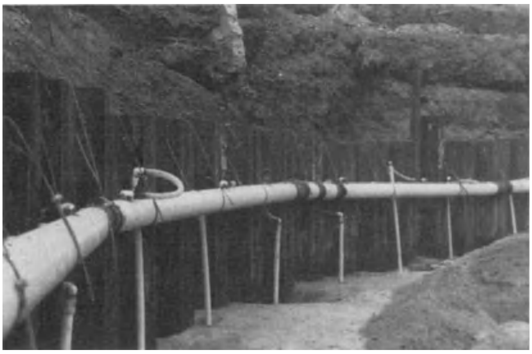


Figure 12-5f Manifold System.

Figure 12-5g Manifold System Connected to Vacuum Chamber.

Figure 12-5h Gasoline-Driven High-Pressure Water Pump.

Figure 12-5i Electrical Submersible Pump.

Figure 12-5j Lowering the Submersible Pump.

slots, each no more than 12/1000th of an inch wide. The pipe collects the water that gravitates to it, and the inner solid pipe, $\frac{3}{4}$ of an inch or 1 inch smaller in diameter with a 45 degree angled cut on its bottom, will then pick up this water when the entire system has been completed and the vacuum pump has been activated.

Once the well points have been set in place, a manifold is installed and each well is connected to it via a flexible hose (see Figure 12-5e, f.). A valve is placed between the well point and the manifold in case "tuning" or throttling of an individual well becomes necessary. Vacuum pumps are then installed, the submersible pump is dropped into the sump and the system is ready to function (see Figures 12-5 g, i, j). A stand-by vacuum pump and a stand-by submersible pump are installed in case the primary pump or pumps fail. When this kind of system is installed, it generally must continue to operate around the clock, and a specially designed vacuum switch can be installed and connected to the job site security system to warn of low vacuum or pump failure.

13

Concrete

Concrete is an ancient building material tracings its origins back to the Roman Empire where the word "concretus" meant "growing together." The early Romans mixed lime with cement and added a material called pozzolana, a volcanic ash from a source near Mt. Vesuvius. The resulting mixture was capable of hardening under water and the Romans were thus able to build complex aquaducts, bridges and foundations. Reinforced concrete made its appearance between 1850 and 1880, and the new era of construction began. What was once just an ordinary, unglamorous construction material is now being developed into a space age product capable of achieving compressive strengths that exceed 50,000 psi.

Concrete is composed of cement, sand, water and aggregate in what should be a rather simple amalgam of materials, but in reality, concrete is a complex, sophisticated building product. Concrete's primary attributes are its relatively easy and rapid availability and workability coupled with its competitive cost due, in part, to its distribution through a wide network of local, independent businessmen. Concrete can attain great compressive strength when properly cured and earns high marks in durability. All of these attributes do not come easily but depend upon attention to a number of quality control functions:

- Precise measurement of water content.
- Type, size and amount of cement and aggregate.
- Type, size and placement of reinforcement within the structure to be created.
- Proper placement and curing of the product during all weather conditions.

Much of concrete's residual strength depends on the amount of water added to the matrix—too much and the end product will be substantially weakened—too little and its lack of workability may have the same end result. Although trap rock, gravel and river stone aggregates are commonly used to make concrete with compressive strengths in the 2,500 psi to 4,500 psi range, high-strength igneous rock and hard limestone aggregates can easily increase these strengths to 12,000 psi. Concrete is strong in compression but weak in tensile strength, and reinforcing material and its placement is another key element. And lastly, improperly placing and finishing concrete can produce a high maintenance end product. Conversely, proper placement methods will produce a durable, trouble-free product.

ADMIXTURES

In the 1960s the use of admixtures in the preparation of ready-mix concrete became more widespread. The purpose of these chemicals was to make it easier for the contractor to place concrete faster and in a more economical manner. These admixtures could create more durable concrete, concrete that could reach or exceed design strength in very hot or very cold weather with a minimum amount of protection from the elements. Probably the most common form of admixture in use today is one that creates air entrainment. Closely behind in popularity are other admixtures that either speed up or slow down the "setting up" process of the concrete.

Air-Entraining Admixtures

Air-entrained concrete produces a much more durable concrete when used for exterior purposes, particularly in those areas of the country where weather patterns create freeze–thaw cycles. This admixture produces millions of microscopic bubbles in the concrete as it cures. These tiny voids will trap water that penetrates the surface of the concrete and will provide the space needed when water freezes and expands in the process. Air entrainment is introduced into exterior precast concrete products as well; however, the degree of air entrainment is somewhat lower since there is generally more cement in the higher compressive strength product and air entrainment tends to reduce compressive strength in concrete.

For every 1 percent of added air entrainment, compressive strength may be reduced by as much as 5 percent. Usually air entrainment in cast-in-place concrete is between 4 percent and 8 percent. Side benefits of air entrainment are as follows:

- It reduces bleeding.
- It provides better cohesiveness.
- It improves pumpability.

Retarders

Concrete begins to "set" when hydration, the chemical action between the water and cements commences. The process of hydration triggers the tricalcium silicate reaction cycle that causes concrete to ultimately harden and reach design strength. Retarders extend the dormant stage of hydration and when hydration does begin, it is slowed down by the use of this admixture.

Retarders are most commonly used when placing concrete in hot weather and they are added for the specific purpose of slowing the set time to keep the concrete workable longer. Retarders are sometimes used by precast concrete manufacturers to delay hydration so that the vibration transmitted to embedded items or reinforcing steel will not break the bond that might occur during normal vibratory operations. When placing concrete on bridge decks, retarders are used occasionally to keep the concrete in a plastic state longer while the progressive loading and steel deflection of the deck's structural members takes place. Retarders are not recommended for cold-weather concrete since they slow cement hydration and delay set time.

Accelerators

Accelerators are used to hasten set time and increase the early compressive strength of the concrete. In cold weather, set time increases as temperatures decrease (see Figure 13-1) and accelerators used in proportions of as much as 2 percent by weight of cement content will cause more heat to be generated during the early stages of set. When mass concrete is being placed and thermal cracking may occur, accelerators should not be used. Accelerated set time can also be accomplished without an admixture if Type III cement (high early) is used instead of the more common Type I cement.

Water Reducers

As the name implies, this admixture eliminates the need for normal water content in the concrete. Water reducers are effective when used to achieve one of the following conditions:

- To increase slump with no change in water–cement ration or cement content.
- To lower water–cement ratio with no change in slump.
- To lower the cement content with no change in slump or water–cement ratio. With a water-reducer additive and by lowering the water–cement content while increasing aggregate content, the water–cement ratio will remain the same and the yield will be constant with no change in slump.

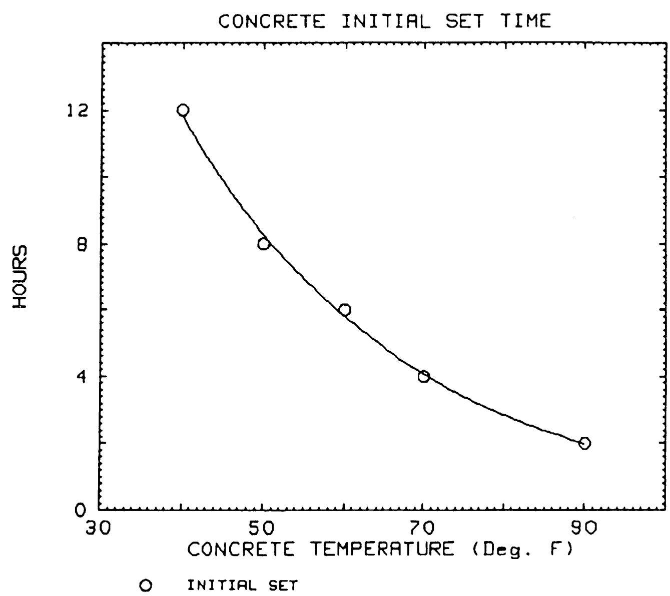


Figure 13-1 The Relationship of Set Time to Temperature.

Lower water content adds considerably to increased compressive strength, abrasion resistance and impermeability. Water-reducing admixtures may delay initial set, however, by as much as 1½ hours.

Superplasticizers

Sometimes referred to as high-range water reducers, superplasticizers provide improved slump retention, better flowability and increased compressive strengths. The advantages realized when this admixture is used are as follows:

1. Because of the need to add less water to the concrete mix, concrete containing superplasticizers will attain higher compressive strengths with no increase in cement content.
2. These higher compressive strengths are obtained quicker so that concrete forms can be stripped sooner, which provides for a faster production cycle with no additional forms.
3. Increased flowability may be required when placing concrete in intricate architectural forms, and the use of superplasticizers will create that flowability without compromising the quality of the concrete.
4. Increased flowability is also desirable to permit complete encapsulation of multiple, closely spaced or complex reinforcing bar patterns.
5. The dense concrete produced when superplasticizers are used will result in a product that is more resistant to moisture–water penetration.

The value of using superplasticizers and thereby reducing water content can be illustrated by comparing two different mix designs, both using Type I cement at a rate of 470 pounds per cubic yard. One mixture has a superplasticizer added to it, the other does not.

	Slump	1-Day Strength	7-Day Strength	28-Day Strength
No admixture	3″	1,100–1,200	3,500–3,600	3,700–3,800
With superplasticizer	6–8″	2,000–2,100	3,800–3,900	4,900–5,000

First generation superplasticizers were effective for only forty-five minutes and had to be added to the transit mix at the job site, but second and third generation products maintain their life over an extended period of time and are added at the batch plant.

When using superplasticizers, it is important to beef up the wall form supports to resist a full liquid head because faster placement rates will increase pressure on the forms. All joints need to be tight to eliminate leaks from the more-liquid-flowing material. Vibration is still required when this product is used or else excessive honeycombing may appear.

Fly Ash

During the 1970s and 1980s, coal-fired power plants generating electrical power gained increased popularity because of the fluctuation in oil prices. These coal-fired plants produced fly ash as a by-product, and one of the immediate commercial uses for this material was as an additive to ready-mix concrete. Fly ash, when added to concrete, allows the water content to be slightly reduced while still retaining workability. Fly ash was shown to reduce shrinkage in concrete and helped to increase the pumpability of the material. It has been estimated that more than 50 percent of all ready-mix concrete sold in the United States in the 1980s contained at least some proportion of fly ash.

Silica Fume

This admixture is made of microscopic particles of silica roughly the same size as a particle of Type I cement. Silica fume actually "glues" the concrete mix components together, producing a product with compressive strengths in the 10,000 psi range. Silica fume concrete is more dense and less permeable than conventional mixes. It produces a product that is more resistant to abrasion and has superior resistance to penetration by chlorides such as those present in road salt or sea air. The addition of 14½ pounds of silica fume per 100 pounds of cement will increase the compressive strength of the concrete by about 6,000 psi.

CONCRETE REINFORCING

Concrete's low resistance to shear and tensile stress places great importance on the type of reinforcing material and its placement in the form. The most common type of concrete reinforcement today is steel—deformed and smooth reinforcing bars and welded wire mesh. Reinforcing steel in column and wall forms must be located correctly, and steel placed in concrete slabs must be kept at the proper elevation via the use of the proper bar support. A wide variety of rebar and mesh supports are available for most installations. Figure 13-2 illustrates some of the more common rebar accessories.

Reinforcing bars are designated by numbers corresponding to size and weight. Welded wire mesh is identified by either wire spacing or wire gauge designations

Deformed Reinforcing Bar Designations, Sizes and Weights per Lineal Foot

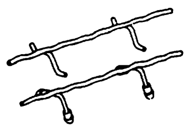
Bar Number	Diameter (In Inches)	Diameter (In Decimals)	Weight per Foot Length (In Pounds)
2	½	.250	.167
3	⅜	.375	.376
4	½	.500	.668
5	⅝	.625	1.043
6	¾	.750	1.502
7	⅞	.875	2.044
8	1	1.000	2.670
9	1*	1.128	3.400
10	1 ⅛*	1.270	4.303
11	1 ¼*	1.410	5.313
14	1 ½*	1.693	7.650
18	2*	2.257	13.600

*These sizes are rolled in rounds equivalent to square cross section area.

BAR SUPPORTS

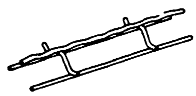
Slab Bolster

Slab Bolster is used to support lower slab steel from the slab form. Legs are spaced on 5" centers. Available in 3/4" to 2" heights, 5 and 10 feet lengths and bright basic, galvanized, plastic tipped or stainless steel.



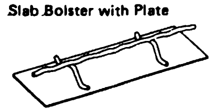
Slab Bolster

Slab Bolster with Plate is same as above with the addition of a bearing plate for use on fill or other soft material.



Slab Bolster with Plate

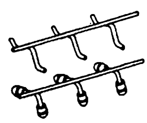
Slab Bolster Upper is used for supporting one layer of steel above another.



Slab Bolster Upper

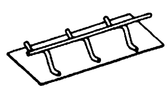
Beam Bolster

Beam Bolster is used to support lower beam steel from the soffit form. Legs spaced on 2-1/2" centers. Available in 3/4" to 5" heights in 5 or 10 feet lengths. Manufactured in bright basic, plastic tipped, galvanized and stainless steel.



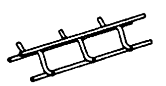
Beam Bolster

Beam Bolster with Plate is same as above with the addition of a bearing plate for use on fill or other soft material.



Beam Bolster with Plate

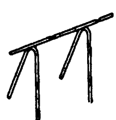
Beam Bolster Upper is used to support successive layers of steel, one above the other.

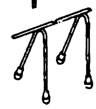


Beam Bolster Upper

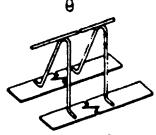
Continuous High Chairs

Continuous High Chairs provide support for upper slab steel eliminating the need for carrier bars. Fabricated in 2" to 15" heights and 5 and 10 feet lengths with legs spaced on 8" centers. Available in bright basic, plastic tipped, galvanized and stainless steel.

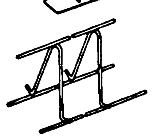




Continuous High Chair with Plate is used to support upper slab steel on fill or other soft material.

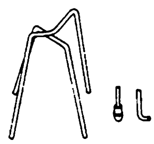


Continuous High Chair Upper is used to separate two layers of steel.

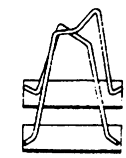


Individual High Chairs

Individual High Chairs are used for supporting upper steel directly or by means of a carrier bar. Available in 2" to 15" heights in bright basic, plastic tipped, galvanized and stainless steel.



Individual High Chair



Individual High Chair with Plate

Individual High Chair with Plate is used for supporting upper slab steel on fill or other soft material.

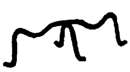
High Chairs for Metal Decks are fabricated with different length legs to fit the design of the metal deck. Other information same as Individual High Chairs, above.

MISCELLANEOUS CHAIRS

Bar Chairs are used to support wide spaced light steel in slab construction. Available in 3/4", 1", 1-1/2" and 1-3/4" heights in bright basic, galvanized and stainless steel.

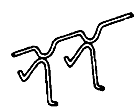
Bar Chair

Joist Chairs are used to support two bottom bars in the ribs of joist or grid type slabs. Available in 4", 5" and 6" overall widths; 3/4", 1" and 1-1/2" heights; bright basic, plastic tipped, galvanized and stainless steel.



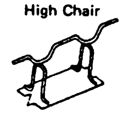
Joist Chair

Special Continuous High Chairs are designed to support ice skating rink tubing or radiant heating tubing.



Special Continuous High Chair

Special Bar Support and Spacer is manufactured to a required specification. Available in a variety of heights and lengths and in bright basic, plastic tipped, galvanized and stainless steel.



Special Bar Support and Spacer

Figure 13-2 Common Rebar Accessories. By permission of Richmond.

Welded Wire Mesh Sizes—By Mesh Spacing and Wire Gauge

Wire Spacing	Top Gauge	Bottom Gauge	"W" Designation	Weight Per 100 Square Feet
6 × 6	10	10	W1.4/W1.4	21
6 × 6	8	8	W2.1/W2.1	30
6 × 6	6	6	W2.9/W2.9	42
6 × 6	4	4	W4.0/W4.0	58
6 × 6	3	3	W4.7/W4.7	68
6 × 6	2	2	W5.4/W5.4	78
6 × 6	1	1	W6.3/W6.3	91
6 × 6	0	0	W7.4/W7.4	107
4 × 4	14	14	W0.5/W0.5	11
4 × 4	12	12	W0.9/W0.9	19
4 × 4	10	10	W1.4/W1.4	31
4 × 4	8	8	W2.1/W2.1	44
4 × 4	6	6	W2.9/W2.9	62
4 × 4	4	4	W4.0/W4.0	85
4 × 4	3	3	W4.7/W4.7	100
3 × 3	10	10	W1.4/W1.4	41
2 × 2	16	16	W0.3/W0.3	13
2 × 2	14	14	W0.5/W0.5	21
2 × 2	12	12	W0.9/W0.9	37
2 × 2	10	10	W1.4/W1.4	60

Fiberglass Concrete Reinforcement

Fiberglass reinforcement has been used for years as a substitute for welded wire mesh in slabs on grade and in sidewalks. This material, made of polypropylene, is lightweight and uneffected by the presence of chlorides in concrete or by chloride infiltration. Fiberglass, usually in chopped form, can be added directly into the concrete at the mixing plant thereby eliminating the need to install reinforcing material at the site. As an added benefit, the multidirectional strength of this material is helpful in reducing and controlling cracks.

What Does the Future Hold for Concrete Reinforcing?

The tensile strength of welded wire mesh is between 70,000 and 80,000 foot-pounds per square inch and billet steel (rebars) is about the same. Imagine a material that is 250 percent stronger, a product of space age technology that is in commercial use in other parts of the world? That product is carbon fiber reinforcement. The Japanese are producing lightweight precast concrete panels using this strong fiber and they have been able to reduce the weight of a typical panel from sixty-five pounds per square foot to approximately twenty-one pounds per square foot. This lighter but considerably stronger material will permit contractors to prefabricate much larger panels and hoist them in place with smaller cranes. With the use of this material known as CFRC (carbon fiber reinforced concrete) a new dimension of lightweight cladding materials and lighter weight supporting structures will open up for designers. This appears to be the concrete reinforcing material of the future.

CONCRETE PLACEMENT

When other than moderate temperatures and weather conditions prevail, the placing and curing concrete must be done in such a manner as to compensate for those factors that will adversely affect the end product. During very hot or very cold weather, precautions must be taken as the concrete is being placed, as well as after it has been placed and the curing cycle commences.

Hot-Weather Concrete Placement

When concrete is placed in hot weather, it has a tendency to cure faster, and although admixtures such as retarders can be ordered with the ready-mix at a premium cost, there are a number of common-sense measures that can be used, at no additional cost. Truck deliveries have to be scheduled more precisely in hot weather so waiting time before unloading is kept to a minimum. When the owner has inspectors on-site, they will usually reject any truck that has not discharged its load of concrete within two hours after leaving the plant, and for good reason. Hydration will have progressed to the point where proper curing will not be possible after the concrete has been unloaded. Crew sizes must be planned to assure rapid unloading and placement of concrete on hot summer days, and if delays do occur for some unforeseen reason, the ready-mix plant should be advised so they can reschedule subsequent deliveries. Once the concrete has been unloaded, it should be vibrated and screeded as quickly as possible, however, care must be taken to avoid overvibrating and overfinishing. In hot weather a cement shake should never be used as a surface drier.

A Few Helpful Tips for Hot-Weather Concrete

- Always have an extra vibrator handy because vibrators seem to malfunction, especially when they are needed.
- When placing a slab on grade and there is no vapor barrier on the subgrade, dampen the earth before placing the concrete.

Curing concrete during hot weather should begin immediately after finishing. Improper curing can reduce strength by as much as 50 percent, and when summer concrete is cured properly it not only retains its design strength but shrinks less and produces less cracks.

Cold-Weather Concrete Placement

When the outside temperature is 40 degrees F and falling, and a concrete pour is scheduled, all of the paraphenalia for protection and temporary heat should be at the job site in case it is needed. Heaters, fuel for these heaters, insulated blankets, rolls of reinforced polyethylene and woods studs should be close at hand in case temporary protection and temporary heat is required to allow the concrete to cure properly. Although these temporary heat and protection methods can be costly, the decision to provide protection to newly placed concrete in the winter must be weighed against the cost to remove and replace concrete that may have been allowed to freeze if these measures were not employed.

Most ready-mix suppliers automatically add hot water to their concrete after a certain date when cold weather can be expected, and when temperatures are near or at the freezing point these suppliers should also be heating the sand and aggregates before they are introduced into the concrete mix. Prior to placing winter concrete in forms, the forms should be free of ice. When concrete is to be placed on metal deck, those forms should not only be free from ice but should also be warmed from below by using space heaters. And after the concrete has been placed, it must be protected against sudden changes in temperature during the early stages of curing since thermal shock will cause considerable cracking as the concrete continues to cure. The use of high-early cement or an accelerator type admixture may be good insurance in reducing the potential for freezing as well as reducing finishing time.

A Few Helpful Tips For Cold-Weather Concrete

- Don't depend on admixtures or special cements alone when temperatures drop below 50 degrees F. Erect barriers to keep the wind away from the concrete or provide a heated enclosure.
- Slabs lose moisture rapidly with the application of temporary heat so prompt and proper curing must not not be delayed.
- Avoid overworking cooled slabs and don't get on these slabs too soon.

CURING CONCRETE

The transition from ready-mix to durable concrete takes place during the curing cycle. Improperly cured concrete may result in strengths that are cut in half. To obtain a hard, durable surface with a minimum number or cracks and little or no preceptible shrinkage, proper curing techniques must be used.

There are several methods that can be employed to achieve proper curing:

1. Apply a membrane curing compound by either spraying or rolling on the surface of concrete slabs immediately after the troweling process has been completed. On vertical walls or irregular surfaces, the membrane compound can be applied as soon as the forms are removed. Application rates vary from product to product, but they should all be applied at rates or coverages recommended by the manufacturer. Don't cut corners on coverage since most materials are not that expensive and less than complete absorption might result.
2. Curing by water is effective as long as it is continuous. The surface of the concrete must be kept damp during the process, but if the surface is allowed to dry between sprays, craze cracks will surely develop.
3. Waterproof paper applied directly over the concrete surface after it has received a thorough spray of water is quite often used as an effective curing procedure.

The edges of the paper should be lapped generously and sealed with tape to create a continuous cover.

4. Damp burlap has been used for years as a curing medium, but the burlap used for this purpose must be free and clean of any foreign substances that might leach out and stain the concrete. After placing burlap over the concrete slab or walls, it should be sprayed periodically with water so that it remains moist during the curing cycle.
5. Polyethylene sheets can be used as a blanket with the same effect as the waterproof paper as long as its edges are lapped and sealed.
6. Damp sand or straw can also be used as curing agents as long as they remain in place and are kept moist. These materials can be somewhat messy to remove, however.

When concrete is placed during very hot or very cold weather there are certain added precautions that ought to be considered:

Hot-weather curing should commence immediately after finishing. If the concrete is exposed to the sun, best results can be obtained by using a white-pigmented membrane curing compound that increases reflectivity and reduces temperature build-up from the sun.

During hot weather when walls are being cured, spray water on the outer surface of the forms from time to time and keep the top surfaces damp and covered with polyethylene.

Even during cold winter months, freshly placed concrete can lose its moisture rapidly in the presence of temporary heat, so don't skimp on the curing compound.

The length of curing depends on the type of cement in the concrete and the temperature at which the concrete is being cured. Type I Portland cement is the one in general use when the special properties of Type II and Type II cements are not required. Type II Portland cement should be used when moderate sulfate resistance or moderate heat of hydration is required, and Type III cement (known as high early) is to be used when early strength is required. The table below contains recommended curing times and the relationship to design strength, temperature and type of cement used.

Curing at 50 degrees F(Days)

Percentage Design Strength Req'd	**Type Cement**		
	I	II	III
50	6	9	3
65	11	14	5
85	21	28	16
95	29	35	26

Curing at 70 degrees F(Days)

Percentage Design Strength Req'd	**Type Cement**		
	I	II	III
50	4	6	3
65	8	10	4
85	16	18	12
95	23	24	20

PRECAST CONCRETE

Precast concrete can be structural or architectural or a combination of the two. Manufactured in a plant, the variety and color of precast concrete is limited only by the designer's imagination and the engineer's calculations. The difficulty with precast panels lies in the complete and careful review of all shop drawings to ensure that the method of attachment to the new structure is complete and that the subcontractor responsible for providing and installing all clips, embedments or welds has fully coordinated his work with the precast manufacturer. Openings in the panels must be reviewed and coordinated with the appropriate subcontractors, and when precast shop drawings have been completed and approved by the architect and engineer, they should be circulated to any other trades that may have work related to the precast.

Designing and installing proper connections is of prime importance. These connections will be subjected to live and dead loads, wind loads and seismic forces and must be designed to compensate for any movement in the structure resulting from expansion and contraction, shrinkage and deflection. These connections need to be adjustable to compensate for field conditions, and typical precast connections can be placed in one of the following categories:

Direct bearing (Figure 13-3a)—Required when panels bear directly on a foundation or on a rigid support where potential for movement is negligible.

Eccentric bearing (Figure 13-3b)—Necessary for those panels above the level of the first support member where movement from the support system is anticipated and where panels will be attached or supported by a structure located in a different plane.

Tie-backs (Figure 13-3c)—Are connections that are designed to keep the panels plumb and provide resistance to loads imposed by the wind and seismic movement.

Alignment connections (Figure 13-3d)—Are required to adjust for variations in the panel itself caused by warpage or bowing when manufactured. These types of connections are not used to transfer design lateral loads.

Column and beam cover connections (Figure 13-3c)—Are designed to attach precast panels to structural beams and columns in such a manner as to carry only the load of the precast member and allow for any structural movement. These connections must be easily accessible for securing and adjustment.

Masonry tie-back connections (Figure 13-3f)—Are used when precast panels will be attached as cladding to masonry walls and require an adjustable anchor and embedments in the masonry wall.

Prestressed Concrete

Concrete is very weak in tensile strength but strong in compression, and the concept of prestressing reduces tensile stress to near zero. Prestressing is a method whereby a force can be applied to a structural concrete member or floor slab by placing high-strength steel cables, referred to as tendons, in the beam or slab mold, stretching the tendons to a predesignated stress level and then casting the concrete around these

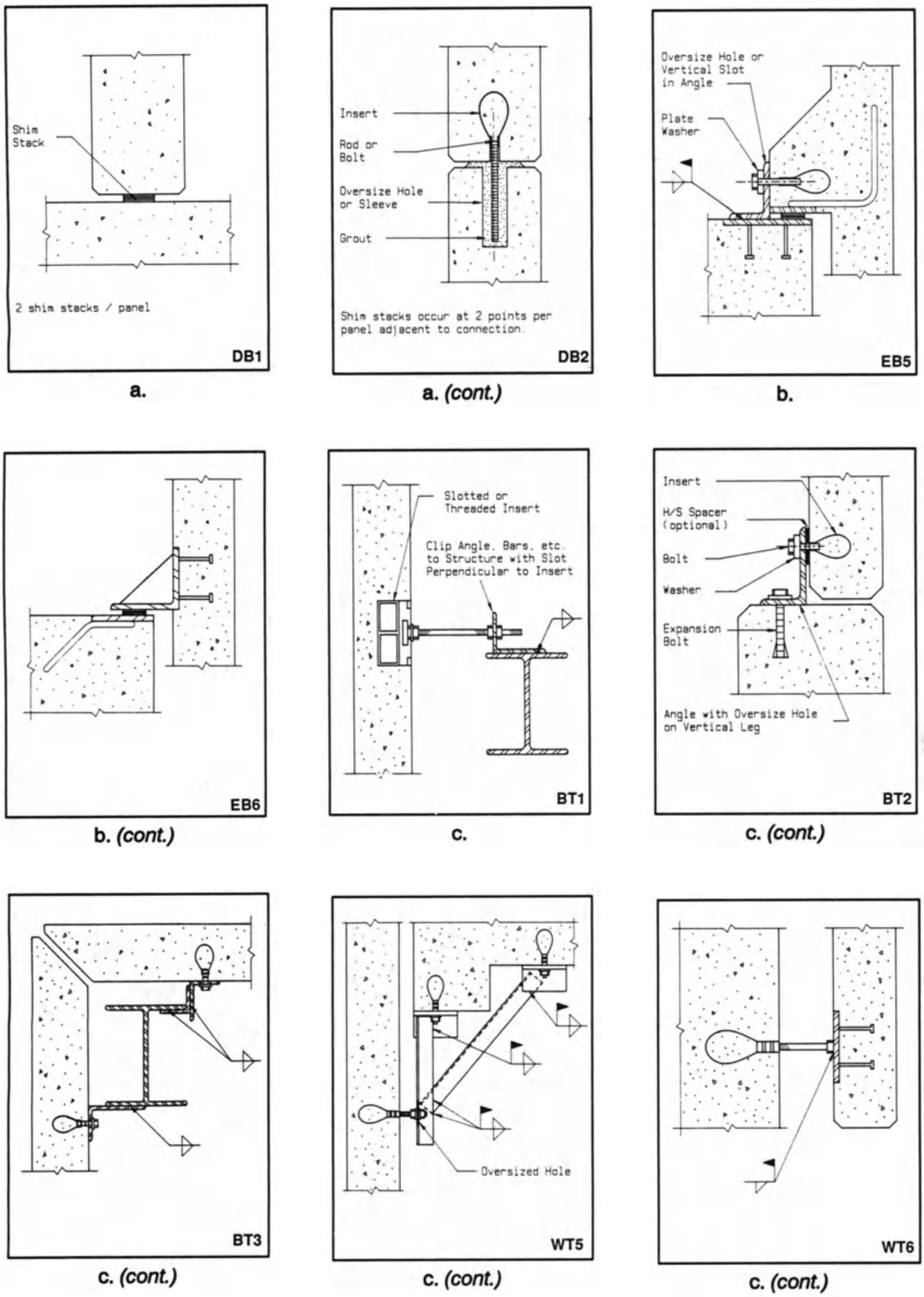
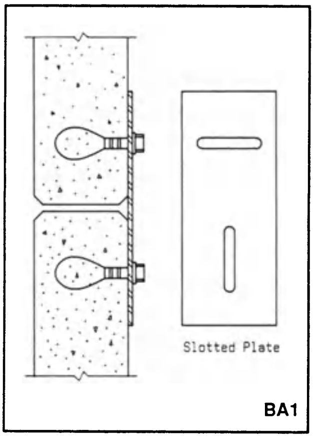


Figure 13-3a to 13-3f Precast Concrete Connections.



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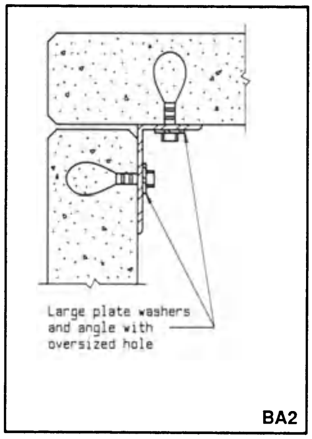

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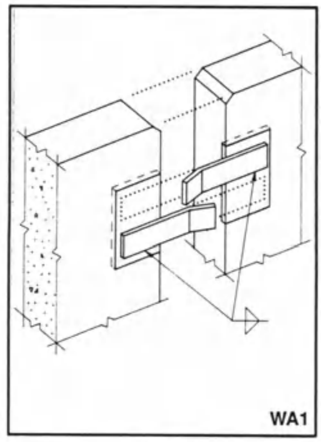

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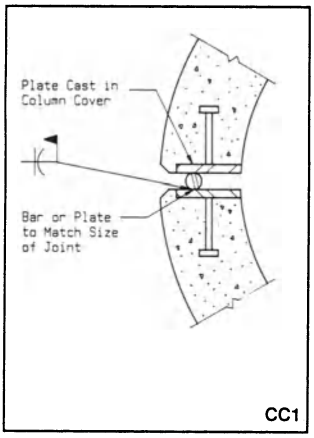

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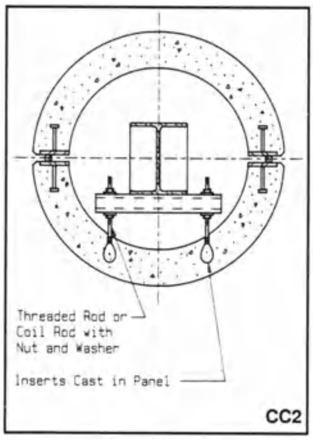

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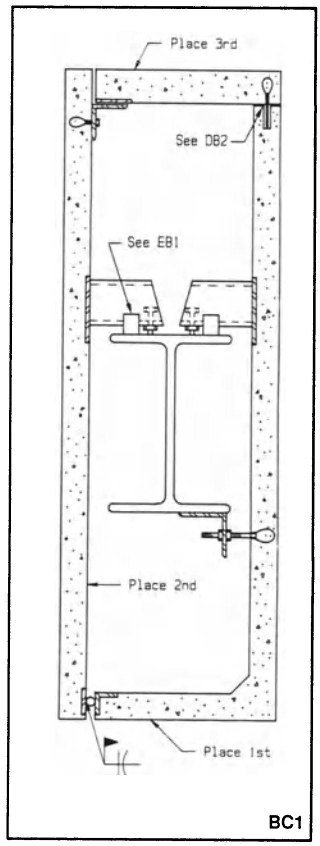

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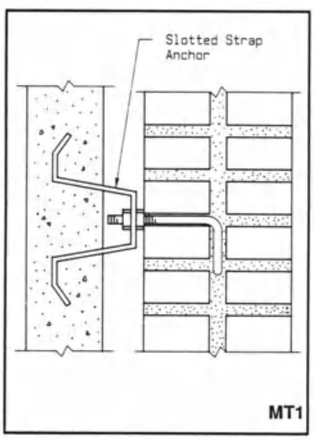


f.

stressed tendons. Once the concrete is cured, the stretching device is removed and the stress in the tendons is released, causing the concrete itself to become stressed as the internally bonded steel wires attempt to return to their original length.

Post-tensioning is somewhat different in that the tendons are placed in conduits in the soon-to-be-poured concrete structural member or slab. The conduits are encased in the concrete, and after the concrete has cured, the tendons within the conduits are stretched to a predetermined level and are then anchored at each end of the concrete member. The conduits are filled with grout to create a permanent bond and reduce the possibility of tendon corrosion. The beam or slab is then considered post-tensioned.

Tilt-Up Concrete Panels

In its simplest form, tilt-up construction involves casting concrete wall panels and other vertical concrete members on the job site in a horizontal position and after curing, tilting them up vertically to become wall panels. Box-outs are provided for windows, door openings and openings for other trades. Forms are generally simple wall panels with possibly a form liner installed or articulation to provide some architectural treatment to the outer face of the panel. This type of construction is subject to the vagaries of the weather since the panels are often poured out in the open without any type of protective enclosure and schedules have to take this into account.

Roller-Compacted Concrete (RCC)

Roller-compacted concrete is zero-slump concrete that contains three to five bags of cement per cubic yard instead of the five to six bags in regular concrete, and it is sometimes used in dam construction, as paving for airport parking aprons or for haul roads. Roller-compacted concrete has very little water content and looks much like damp gravel. It is batch plant mixed on the site and hauled to the placement area in dump trucks where it is spread by bulldozer and then compacted to very high densities by a vibratory roller.

In certain situations RCC is less expensive than asphalt paving. In 1987 the Portland Oregon International Airport was accepting bids for a 7.5-acre parking lot and the design consisted of nineteen-inch subbase placed over the compacted subgrade with four-inch aggregate course, eight inches of asphalt paving and a final five-inch top course of asphalt. Roller-compacted concrete was specified as an alternate method using a four-inch to six-inch aggregate base under thirteen inches of RCC to be placed in two lifts. When the bids were opened, the RCC quote was 32 percent lower than the lowest asphalt paving price.

NEW DEVELOPEMENTS IN CONCRETE

Research in the field of concrete has focused on the development of high and ultrahigh compressive strength materials. At one time, concrete attaining a compressive strength of 10,000 psi was looked upon as quite an achievement, but now buildings are being designed and built with considerably higher yield concrete using exotic additives and aggregates.

The development of high-strength concrete began in Chicago in 1962 when 6,000 psi concrete made its debut. In 1989 an office building was constructed on Wacker Drive in that city using 14,000 and 17,000 psi concrete in its columns. Most of these high-strength mixes use silica fume and fly ash additives and while compressive strengths in the 21,000 to 28,000 psi range have been developed using natural rock aggregates, even higher yields, some in the 50,000 to 70,000 psi range have been produced by using specially developed ceramic aggregates. Many of these superhigh concrete mixtures are in the design-development stage now, but the future may very well produce some exciting construction techniques using this strong, durable material.

ALLOWABLE TOLERANCES IN CONCRETE CONSTRUCTION

Whenever the contract specifications refer to acceptable tolerances for various types of concrete construction, the American Concrete Institute (ACI) is the authority most often quoted. Sprinkled throughout a concrete specification section will be the phrase "Comply with ACI 301" along with various subsections of ACI manuals that contain the industry standards. The following lists tolerances for some of the more common types of concrete construction.

General building cast-in-place:

Plumb—In lines and surfaces of columns, piers and walls:

¼ inch in any 10 feet.
1 inch for the total height of the structure when less than 100 feet tall.
—For exposed corner columns, control joint lines and other verticle joints exposed to view:
¼ inch in any 20 feet.
½ inch maximum for the total structure when less than 100 feet tall.

Levelness from grades or elevations specified on the plans or in the specifications:

For slab soffits, ceilings and beam soffits:

Plus or minus ¼ inch in any 10 feet.
Plus or minus ⅜ inch in any bay or in any 20 feet.
Plus or minus ¾ inch in total length of structure.
—Exposed lintels, sills, parapets, horizontal lines or grooves exposed to the public eye:
Plus or minus ¼ inch in any bay or 20 feet.
Plus or minus ½ inch in maximum length of the structure.

Linear building lines when related to dimensions shown on drawings and the relationship to columns, walls, beams and partitions:

Plus or minus ½ inch in any bay.
Plus or minus ½ inch in any 20 feet.

Plus or minus 1 inch for the entire structure.
Floor openings, wall openings, sleeve locations:
Plus or minus 1/4 inch as to size of the opening.
Plus or minus 1/2 inch as to location of the center line of the opening.

Cross section dimensions of columns, walls, slab thickness:
Where sections are less than 12 inches, plus tolerance is 3/8 inch, minus tolerance is 1/4 inch.
Where sections are more than 12 inches, plus tolerance is 1/2 inch, minus tolerance is 3/8 inch.

Footings:

Horizontal dimensions: formed—plus 2 inches, minus 1/2 inch.
—Unformed—plus 3 inches.
—Cross sectional thickness plus dimension—no limit, minus dimension—5 percent.
When the footings are built to receive masonry construction, they should meet these tolerances:
Alignment in 10 feet—plus or minus 1/4 inch.
Maximum for total length of 50 feet—plus or minus 1/2 inch.
Level in 10 foot length—plus or minus 1/4 inch.
Maximum for total length of 50 feet—plus or minus 1/2 inch.
Footings for other types of construction shall be level to a degree of plus 1/2 inch or minus 2 inches.
Stairs—For any individual step: Riser—plus or minus 1/8 inch; tread—plus or minus 1/4 inch.
For flight of stairs: Riser—plus or minus 1/8 inch; run—plus or minus 1/4 inch.

Concrete slab finish tolerances designated by ACI are as follows:

Class AA (an expensive and very difficult tolerance to attain and generally specified for critical areas only and not large expanses)—Depressions between high spots shall not be greater than 1/8 inch below a 10-foot straightedge when 4 of 5 consecutive readings are taken.
Class AX—Depressions between high spots shall not be any greater than 3/16 inch below a 10-foot straightedge.
Class BX—The class of slab generally placed on metal decking. These tolerances shall be not greater than 5/16 inch between high spots when a 10 foot straightedge is used.
Class CX—Depressions under a 10-foot straightedge when placed on the high spots shall not be greater than 1/2 inch in 10 feet.
Tolerances for mass concrete structures:

Linear alignment—Plus or minus ½ inch in any 20 feet, plus or minus ¾ inch in any 40 feet and plus or minus 1 ¼ inch in any length of 80 feet or more.
Plumb—Plus or minus ½ inch in any 10 feet of height, plus or minus ¾ inch in any 20 feet of height and 1 ¼ inch plus or minus in any height of 40 feet or more.
Levelness from dimensions shown on the drawings—plus or minus ¼ inch in any 10-foot length, plus or minus ½ inch in 30 feet of length or more.
Precast concrete panels:

Height and width of panel (tolerances apply to variation from design dimension):
 Under 10 feet—plus or minus ⅛ inch.
 Between 10 and 20 feet—plus ⅛ inch, minus 3⁄16 inch.
 Between 20 and 30 feet—plus ⅛ inch, minus ¼ inch.
 For each added 10 foot length over 30 feet—plus or minus 1⁄16 inch.
Panel thickness—plus ¼ inch, minus ⅛ inch.
Location of embedded items:
 Inserts, pipe sleeves, bolts and similar embedments—plus or minus ⅜ inch
 Reglets at edge of panel—plus or minus ¼ inch.
 Electrical outlets, hose bib locations—plus or minus ½ inch.
Erection tolerances—distance between panels:
 Panels under 10 feet and between 10 feet and 20 feet—plus or minus 3⁄16 inch.
 Alignment in both horizontal and vertical joints—¼ inch.

A CONCRETE CHECKLIST

1. Carefully read the concrete specifications and all of the notes on the structural drawings well in advance of the start of concrete work. Highlight important items.
2. Check the type of finish required on various components that might dictate the type of form required.
3. Review mechanical and electrical drawings to verify location and size of openings, penetrations, sleeves, box-outs, Review door, louver, window and areaway details if they are to be installed in concrete work.
4. Determine responsibility for locating embedded items. Who furnishes, who supplies layout information and who installs the embedments?
5. Has the order for reinforcing steel been placed, when will the shop drawings be submitted, how long will it take to have the engineer approve them and how long will it take to receive the materials on the site? And what about accessories—have the proper type and quantities been ordered?
6. Has the concrete mix design been submitted and approved?
7. Do the dimensions on the structural drawings coincide with those on the architectural drawings with respect to overall dimensions, locations of elevator and duct shafts, stairwells and other openings—horizontal and vertical?
8. Consider ordering some stock lengths of rebars just in case some last minute corrections are required.

9. Are procedures established in case last minute changes, questions or clarifications are required of the architect or engineer?
10. Thoroughly review all requirements for inspections and testing.
11. Check to determine what shop-drawing requirements are yet to be met. Are any samples of materials required by the engineer?
12. Are construction and control joint locations clearly defined?
13. Will shoring be required, and if so, will a shoring plan have to be submitted for approval? Is it clear as to how long the shores must remain in place?
14. Are there restrictions on the number of square feet of slab or walls that can be poured at one time?
15. Has the method for curing been determined and are all materials on the job site?

14

Masonry and Stone Construction

The first brick masonry units were manufactured by the Egyptians about 10,000 B.C., and the early Romans used brick in their construction some 2,000 years ago. Brick manufacture in the United States, patterned after that in England, started in the mid-1600s. The first recorded use of mortar was in the year 2690 B.C. when the Great Pyramid of Giza was being built in Egypt. The first use of Portland cement occurred in the early 1800s. So we can see that masonry construction has been around for quite some time, but there are still a great number of questions concerning proper masonry construction.

Masonry construction today is primarily devoted to the use of brick, block, structural clay products, natural and cast sone. Walls constructed of masonry can be basically classified as load bearing and nonload bearing, cavity walls, veneer walls and solid walls and subclassified as composite walls or single wythe walls. These subclassifications can be further divided into other categories based upon products used and methods by which they are set in place.

BRICK

Bricks used in construction come in various sizes, shapes and colors, generally containing clay or shale as their basic ingredients. Brick classification is based upon its use, and the American Society for Testing and Materials (ASTM) publishes standards for each brick use.

Building brick	ASTM C62	Made of clay or shale in three grades based on exposure to weather. Grade SW is for severe weather usage; grade MW for use in moderate climate; grade NW when not exposed to weather.
Face brick	ASTM C216	Clay-based brick for interior–exterior use. Three types available based on color variations. Type FBS, wide color range; type FBX, narrow color range; type FBA, non-uniform in size, color.
Ceramic glazed	ASTM C216	Face brick made from clay or shale and having a structural clay face.

Sand–Lime brick	ASTM C73	Made from 5–20 percent hydrated lime and sand. Graded same as face or common brick. Good frost resistance and better fire resistance than face or common brick. Available in three grades.
Concrete brick	ASTM C55	Made of concrete in same size as common brick. Grade N for use as architectural veneer; grade S for general use. Type 1, moisture controlled; type II, non-moisture controlled.
Industrial floor brick	ASTM C410	Used for industrial flooring. Made from clay or shale. Type T, resistant to thermal/mechanical shock; type H same as T but resistant to chemicals; type M, where low absorption is required; type L, has high degree of chemical resistance.
Pedestrian pavers	ASTM C902	For use in patios, walkways, floors, plazas.
Fire brick	ASTM C155	For use in fireplaces, flues, high temperature uses.

Bricks can be classed as solid or hollow. A "solid" brick is one with 25 percent maximum coring, and a "hollow" brick is one with a minimum cored area of 25 percent and a maximum of 60 percent. These cores can be either round, square or rectangular and are found in those bricks manufactured by an extrusion or dry-press process. The cores allow the bricks to cure better in the furnace, are lighter and therefore less expensive to transport and the cores provide a better mechanical bond in the wall.

There are some totally solid bricks that have slight depression on one bed surface. This depression, known as a "frog," is found in bricks manufactured by the molded process and its purpose is much the same as a core: reduced weight and better bond. Bricks are available in a variety of standard sizes as shown in Figure 14-1, and special shapes can be purchased at premium prices.

CONCRETE BLOCK

Concrete blocks can be used as either back-up for another cladding material or as an architectural material when colors or textures have been manufactured into the product. Concrete block has several classifications:

Hollow-load bearing	ASTMC 90	Made with either lightweight or normal weight aggregates. Grade N, for exterior walls above and below grade and for interior walls; grade S, limited to above grade.
Nonload bearing	ASTM C129	Available either as hollow or solid and made with normal or lightweight aggregates.
Solid-load bearing	ASTM C145	Made with normal or lightweight aggregates. Net area is 75 percent or more.

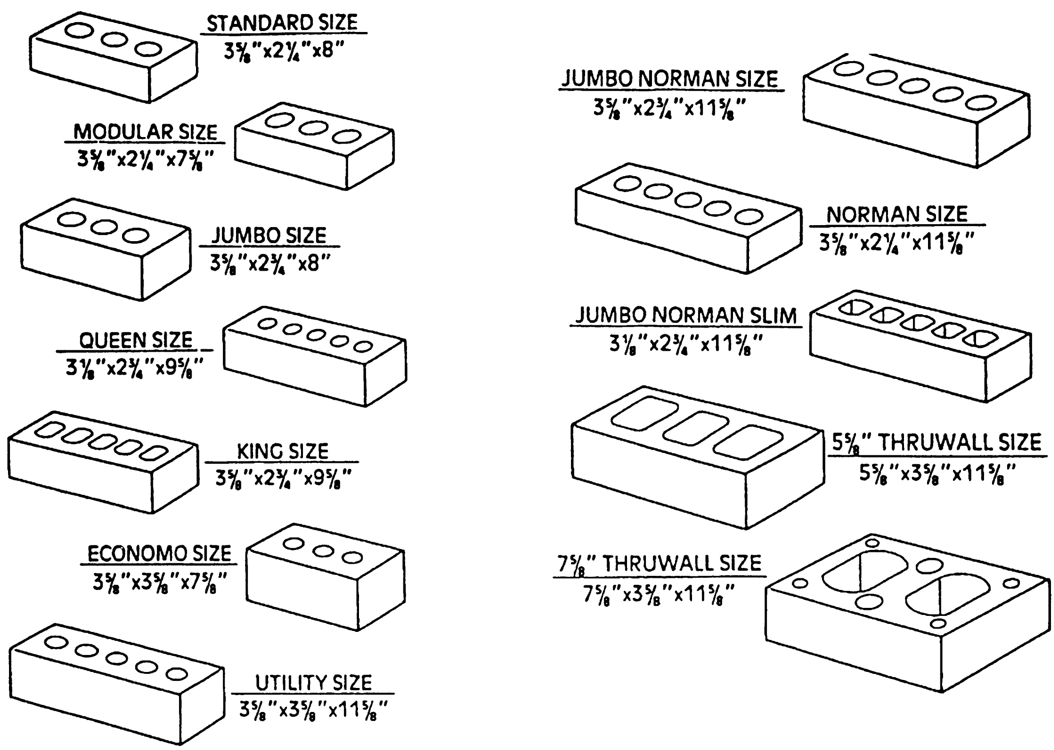


Figure 14-1 Common Shapes of Brick.

Concrete blocks are manufactured in a variety of colors when they are going to be used to create an architectural wall, and various face configurations are also available from local suppliers. There are split face blocks, scored or ribbed-face blocks, blocks with dummy joints both horizontal and vertical and fluted or striated blocks. Among the specialty blocks there are screen blocks, sound-absorbing blocks, jamb blocks, lintel blocks, insulated blocks and curved blocks.

STRUCTURAL CLAY TILE

There are two basic classifications of structural clay tile available: 8W series with a nominal face dimension of 8 inch × 16 inch, and the 6T Series with a nominal face dimension 5 ⅓ inch × 12 inch.

Structural clay tile can be further classified as "standard" for general interior and exterior use, or "special duty" where resistance to impact and moisture transmission is a requirement. And there are load bearing and nonload bearing tiles available as well. But no matter what type masonry unit is going to be used, quality of materials and quality of installation will spell the difference between trouble-free, life-time durability or a product requiring frequent repairs and maintenance. Selecting the correct mortar for a specific application, mixing it and applying it properly is the first step in quality masonry construction.

MORTAR

Mortar is the bonding agent that holds all of the bricks and blocks together. It differs from concrete in that bond strength as opposed to compressive strength is the key physical property. Although concrete and mortar contain Portland cement, lime in mortar is one of the major differences between the two. The lime in mortar creates plasticity, and while quality concrete has minimum water content, quality mortar has maximum water content for workability.

Bond strength is the most important physical property of cured mortar, and mortars are classified as to their bond strength as well as compressive strength. Where a masonry wall will be subject to high wind loadings, a mortar with high tensile bond strength will be required, and where a masonry wall will be load bearing, a mortar with high compressive strength may be the thing to use. Recommended general uses for mortars are listed below:

Type N—Medium strength mortar in the 750 psi range, for general use in walls above grade and used whenever these walls are going to be exposed to the weather, that is, parapet walls and chimneys.

Type S—This mortar approaches the highest obtainable tensile bond strength, and also has reasonably good compressive strength qualities (1,800 psi). Recommended wherever maximum flexural strength is required in both reinforced and nonreinforced walls.

Type M—Has high compressive strength (2,500 psi) and is recommended for use in unreinforced concrete walls below grade such as foundations, retaining walls, manholes.

Type O—Low-strength mortar (350 psi) for use in general interior, nonload-bearing walls. This mortar should not be used where exposures are severe and where freezing temperatures may occur.

Mortar Admixtures

Accelerators—Speeds setting time by 30 to 40 percent and increases 24 hour strength by 150 percent or more. Some accelerators contain calcium chloride and may not be accepted by the architect–engineer.

Retarders—Extends board life of fresh mortar by as much as 4 to 5 hours and finds use in slowing down the set of mortar when temperatures exceed 70 degrees farenheit.

Integral water repellants—Reduces water absorption and is useful when concrete masonry units in a single wythe wall will be exposed to the weather.

Bond modifiers—Improves adhesion to block especially useful when glass-block walls are being built.

Color pigments—Although mortar can be purchased premixed in a variety of colors, pigments can be added directly to regular gray mortar for aesthetic reasons.

Corrosion inhibitors—Used in marine environments where salt air may penetrate the mortar and begin to corrode any wall reinforcement or anchors.

MASONRY WALL TILES

In order to connect a masonry veneer to a back-up system or to secure one masonry wythe to another, wall ties must be installed. Although at times when a brick-and-block wall is being built, horizontal joint reinforcement may be used to hold the two walls together as well as provide reinforcement, a mason can choose from a wide variety of ties and anchors or various sizes and configurations. Each type of back-up wall system requires a slightly different tie or anchor not only to hold the two wall systems together but also to allow for differential movement, to transfer loads and in some cases to restrain movement.

Brick to Wood Studs
(Figure 14-2a)

The corrugated flexible tie made of 16 to 26 gauge metal is the most preferred tie. It is first nailed to the wood stud and bent to form an anchor, which is then placed in the brick coursing to be secured in the mortar bed.

Brick to New Concrete Construction
(Figure 14-2b)

A dovetail slot anchorage is placed in the concrete form and the slot is stuffed with a removable material so that concrete flowing into the form will not fill this slot. After the concrete form is stripped and before masonry is installed, the anchor portion with a tee shaped end is slipped into the triangular dovetail slot embedded in the concrete to form secure tie. A conventional corrugated tie can be used as well.

Brick to Existing Concrete Construction
(Figure 14-2c)

A channel slot wall-tie system, composed of a slotted channel frame and a dovetail anchor with a tee-shaped tail is often used to tie back into an existing concrete wall. The slotted channel is bolted to the existing concrete wall with an expansion bolt. The dovetail tie with the tee shaped tail is slipped into the slot in the channel.

Brick to Concrete Masonry Units (CMU)
(Figure 14-2d)

There are several types of wall ties that can be used to connect a block back-up wall to a brick veneer. A rectangular box tie or a box cavity wall tie can be used if the two coursings are aligned; however, when the front and back masonry coursing do not align, a two piece adjustable tie must be used. One such tie is a U-shaped double eye anchor that will be attached to the back-up CMU, and a pintle tie with downward positioned legs to fit into the eyes of this back-up anchor will become embedded into the coursing of the brick veneer.

Brick or CMU to Structural Steel (Figure 14-2e)

These ties are meant to be welded to the steel structure and then placed on the web of a CMU. There are hook-on anchors with slots to fit over the web of a steel column and bridge the CMU turning downward into the core of the block. There are also weld-on slots, generally done in the steel fabricator's shop. These slots are usually six inches long and are used in conjunction with a Vee tie that connects through the welded slot resting on the top of the masonry coursing where it will be secured by the mortar bed.

Brick To Steel Studs (Figure 14-2f)

Although there are several forms of brick–steel stud ties, they are all composed of two parts. One part is screwed to the steel stud, and the other part rests on the masonry coursing. A screw-on anchor with triangular tie can be used. A screw-on channel slot with tee-clip triangular tie or a screw-on anchor plate with adjustable pintle tie will work equally well.

The Cavity Wall Controversy. Although a cavity wall has been proven to provide maximum protection against water infiltration, there is a growing controversy over the methods by which these cavity walls are constructed. Until the mid-1960s, most cavity wall construction was of brick and block. The outer wythe of brick was separated from the inner block wall by a space measuring two to four inches, creating a cavity. The air space in the cavity was thought to provide some degree of insulation, and in later years foam board insulation was introduced into the cavity to provide very definite insulation value. Wall ties held the two courses together, and when galvanized ties were used, long life was to be expected. Flashing installed at the base of the cavity and wherever the cavity is interrupted by a window sill, a lintel or shelf angle will collect any moisture penetrating the outer wall, and with weep holes placed strategically above the flashing, water introduced into the cavity will have an escape route. Keeping the cavity clean was and is a major problem, particularly when the cavity is two inches wide. A layer of pea gravel or sytrofoam beads placed directly behind the weep holes and nestled in the base of the flashing helps to provide good drainability.

The cavity wall, beside providing good drainage characteristics, can develop into a highly thermal-resistive wall when insulation is introduced into the cavity, and this composite wall exhibits very low sound-transmission qualities. The fire resistance of such a wall goes without saying, and costs are very competitive with other kinds of exterior wall assemblies.

Is the Steel Stud Back-Up System a Ticking Time Bomb?

Although light gauge steel framing has been used in construction since the 1920s, when it was introduced in residential construction in England, metallurgy and other physical sciences have since grown by leaps and bounds. But there is still a great deal of controversy about brick and steel-stud back-up construction.

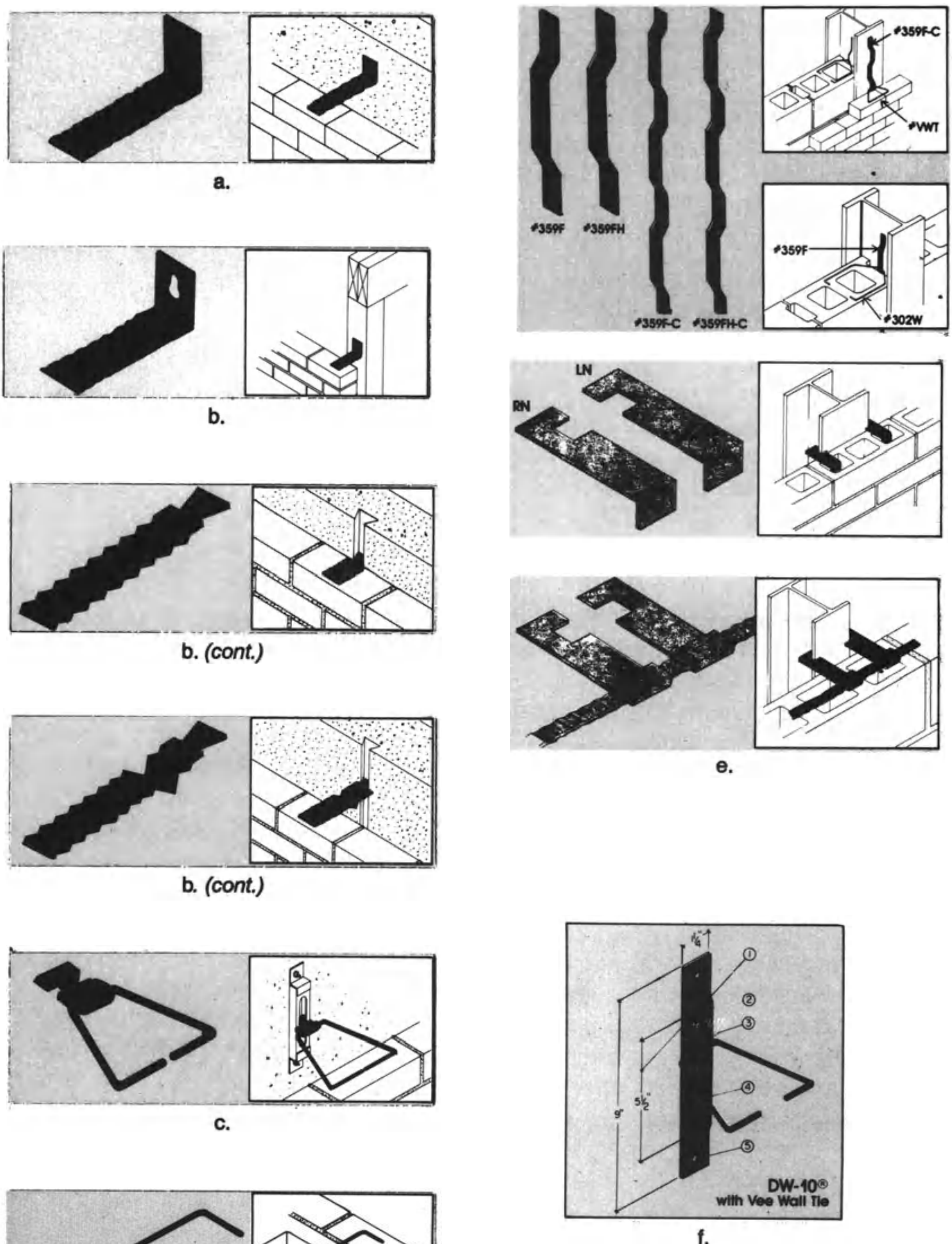


Figure 14-2a to 14-2f Masonry Wall Tie Selections. By permission of Hohmann & Barnard, Inc.

A typical brick-veneer, steel-stud back-up cavity wall assembly consists of the brick, wall ties, a steel-stud framing system faced on the cavity wall side by exterior grade gypsum sheathing. Flashings and weep holes are installed in just the same manner as a brick-block wall assembly, and insulation can either be placed within the cavity or in between the studs before the interior layer of gypsum board is attached. At first critics of this wall assembly stated that the steel-stud back-up was too flexible and would cause cracks to form in the masonry skin causing rapid deterioration of the mortar joints. When the metal-lath and steel-stud industry completed several testing programs, it appeared that this objection had been overcome, and then attention began to focus on the steel studs and the metal ties that held the brick veneer to them. Critics of the system point out that if water penetrates the cavity and moisture remains there for any length of time, the masonry ties could become corroded by the action of water and salts present in the brick and mortar thereby creating a weakness in the assembly. If the exterior gypsum sheathing is punctured during the assembly of the wall, or if all penetrations through it are not properly sealed, the same corrosive action could attack the steel studs resulting in a failure of the entire wall.

The critics of this system seem to have overlooked one important question, if no water is allowed to remain in the cavity and if wall ties and steel studs are adequately protected, is the time bomb defused? The controversy is not yet settled. Supporters of the steel-stud system state that when quality of construction is maintained in each and every component of the steel-stud assembly, the wall will drain properly and all steel components, heavily galvanized, will remain structurally sound for an unforseeable period of time. They point out to their detractors that a poorly constructed brick-block wall can leak quite a bit and be unsound structurally if the block back-up was installed with total disregard for good masonry practices. The argument is by no means settled, but it does make one very important point: it may not be the system that is at fault, but the way in which it was constructed.

EFFLORESCENCE—WHAT IT IS AND HOW TO CONTROL IT

That fine, white powdery substance that seems to grow on the face of some masonry walls is known as efflorescence, and it is formed by the deposit of water-soluble salts left on the surface of the wall as the water in the masonry and mortar begins to evaporate. In order for efflorescence to occur, three conditions must be present:

1. Water-soluble salts must have been deposited in the wall from either the masonry units themselves or the mortar or grout used in the assembly, or possibly a combination of any of these sources.
2. There must be enough water in the assembly to dissolve these salts.
3. A path must have been created to allow these dissolved salts to migrate to the surface of the wall.

If either moisture or water-soluble salts is missing from the masonry wall, no efflorescence will appear. The main source of alkalies for the salts comes from Portland cement, and sometimes by using a low-alkali cement, the appearance of efflorescence will be eliminated or at least greatly reduced. Soluble salts can also be present in the sand used in the mortar mixture. One way to avert this problem is to purchase clean, washed sand. These salts can also be found in some local water supplies. Although lime has sometimes been blamed for the appearance of efflorescence, its chemical analysis has proven that it is not contributory to the dissolved salt problem.

Controlling Efflorescence

Since this phenomena occurs when water-soluble salts are dissolved within the masonry wall, it would seem reasonable to assume that care should be taken to eliminate or reduce the chances of introducing these salts into the system. The amount of water used in constructing the wall should be kept to a minimum and further infiltration of water into the wall should be avoided.

Checking the water supply for salts, using clean, washed sand and low-alkali mortar is a start. The next critical step is keeping water out of the system. This can be accomplished by maintaining good construction techniques. Full-bed mortar joints, compacted and properly tooled is good insurance against water infiltration, and of course the brick or block being layed up must be dense enough to keep water penetration during a rainfall to a minimum. And during the masonry wash-down operation, the wall should not be flooded continuously.

Removing Efflorescence

Efflorescence that appears in small blotches on the surface of the masonry wall can be removed by scrubbing with a stiff bristled brush dipped in a mild detergent. There are specialty cleaners manufactured just for efflorescence removal, and when used in accordance with the manufacturers instructions probably present the best way to handle large areas. Muriatic acid, diluted in water in proportions of one part acid to twelve parts water, is a time-honored method of removing efflorescence.

Although some contractors will apply a clear masonry sealer to the wall once the efflorescence has been removed, this may not cure the problem of recurrence, just prolong it. Using silicon will cause moisture to become trapped in the wall, and as water evaporates and crystallizes, the salts remaining in the assembly, the expansion caused by the crystal formation may cause spalling. The newer, breathable acrylic sealers may prevent this crystal build-up but really won't eliminate any further efflorescence from appearing if both water and salts remain in the wall.

Good Brick-Cleaning Procedures

By taking certain precautionary steps while the brick wall is being installed, the cleaning problems may be reduced substantially. A few tricks of the trade should prove helpful.

- When brick is delivered to the job site, keep it up off the ground.
- As the work progresses, protect the wall from weather conditions each day to keep out excessive water.

- Scaffolding should be kept far enough away from the wall so that the mortar drippings fall to the ground and don't adhere to the wall.
- At the end of the day, tilt the top scaffold board to remove any excess mortar that could splash on the wall in case of an overnight rainfall.
- Remove all excess mortar from the surface of the wall, during and after joint tooling.

The Bucket and Brush Method

Cleaning operations ought to begin twenty-four to thirty-six hours after the wall has been completed and a properly selected cleaning agent, mixed in the proportions recommended by the manufacturer should be at the ready.

- Remove large globs of mortar with a hand tool since masonry cleaners will not effectively remove large particles of hardener mortar.
- Mask any areas, such as those containing architectural metal work, that may become damaged by the cleaner. Read the manufacturers instructions carefully in this regard.
- The entire wall should be hosed down with water. Unless this is done, the cleaning solutions used on the upper walls containing dissolved mortar particles may stain the lower portion of the wall as they flow over dry areas and are absorbed.
- The cleaning solution should be applied to the wet wall with a long handle fiber brush (never use a metal wire brush). Cover a small area and scrub the brick not the mortar joints. Allow the solution to remain on the wall for five to ten minutes while the wall is being scrubbed vigorously.
- Rinse thoroughly as each small area is being cleaned.

Sandblasting as an Alternative Cleaning Method

Sandblasting is dangerous to people, surroundings and to brick masonry. Sandblasting is frequently used to remove multiple layers of paint from brick walls and while it is effective, it also erodes the surface of the brick and the mortar. Sandblasting requires a great deal of skill, and must be carefully controlled. When care is not taken, it is almost impossible to avoid exposing the inner portions of old brick and increasing the size and number of cracks in the mortar thereby permitting water infiltration and the ravages caused by freeze–thaw cycles.

Brick walls can be blasted with somewhat softer materials such as corn cob or ground walnut shells and these softer materials will be less damaging to the surface of the wall.

MASONRY TROUBLESHOOTING TIPS

Flashing Systems

1. Since flashing is difficult to install perfectly level, it has a tendancy to trap water at low spots, so it should be installed continuously whenever possible. Avoid laps.
2. When flashing must be lapped, the lap joints should be at least six inches and bonded together with an approved mastic.

3. Flashing should not stop short of corners, but should continue around the corners and around all jogs in the wall.
4. Although some architects instruct contractors to cut the flashing off flush with the wall and seal the end with caulking, this detail is not correct. The flashing should extend beyond the face of the wall to form a drip if the flashing is metal or fabric bonded to metal. If the flashing is plastic, a proper drip cannot be formed.
5. The top edge of flashing in a cavity wall with concrete back-up will be sealed in a reglet; when the back-up is masonry, the top edge will be secured in the back-up's mortar joint; when the back-up is steel stud, the top edge of the flashing should be covered with a layer of building paper.
6. Puncturing the flashing must be avoided. When flashings are installed over lintels that are bolted to the structure, a compressible material should be placed over the bolt head to prevent a puncture.
7. Flashing installed in the bottom course of masonry can function properly only when the cavity has been kept reasonably clean from mortar droppings and the weeps can function as they are meant to do.

Keeping Cavity Walls Clean

1. Catch drippings by lowering a board into the cavity suspended by a wire so it can be raised periodically to remove the droppings. On the way up, knock loose any protruding mortar fins. This system will not work, however, when they are multiple masonry ties joining the two wythes together or if the cavity is less than one and a half inches wide.
2. Mortar should be placed in a bed that angles away from the cavity toward the front of the wall so that as the brick is placed on it in a rolling motion, excess mortar will be squeezed toward the outside of the wall rather than to the cavity side.
3. Cleanouts can be installed in the wall by laying every third brick dry. As the wall progresses upward, these bricks can be removed so that the cavity is cleaned out. When the wall is completed, these brick will be reinstalled with mortar.

STONE MASONRY

Building stone can be divided into two rough categories:

Cut stone—Large thin slabs that will be applied to the exterior or interior surface of a building and the accessory pieces that go with them such as stone sills, copings, lintels, door and window trim column covers and stair treads.

Ashlar stone—Small pieces of stone ranging in size from six inches to twenty-four inches in length and two inches to sixteen inches high that will be layed up in various patterns similar to masonry units.

Cast stone is a man-made product that approximates precast concrete rather than building or ashlar stone. This material is a product manufactured of concrete or mortar with other ingredients or matrices so that the end product has the appearance of natural stone. Colors are added to the mix, and the final product can be mechanically or chemically etched to achieve the desired texture. Cast stone weighs about the same as limestone and is attached to the structure via embedments cast into the product and fastened in place with clips, hangers, bolts or weldments in much the same manner as precast concrete.

Stone Design and Construction Details

Indiana limestone is one of the more popular building stones. A quality product with a warm pleasing tone, it had been selected as cladding for such notable structures as the Empire State Building in New York and the Tribune Tower in Chicago. Many of the design and installation details for limestone apply to other types of stone as well.

Receiving, Storing and Handling Building Stone. Stone should be handled carefully so as not to chip or crack its edges or scratch its surface and should be stored on sturdy skids or pallets to keep the stone off the ground. Smooth finish stones can be stacked leaning against one another, but textured stones need to be separated with spacers. When prolonged storage is anticipated, the stone should be covered with a poly tarp that permits air circulation around the stones.

Lifting Stone in Place. Installing building stone is generally performed by an experienced installer using slings attached by clamps or lifting lugs. Slings that are too short may rub against the edges of the panel, causing damage, and if clamps are used to raise the panels or pieces, pressure pads must be installed to prevent damage to the face of the stone.

Support Systems and Methods of Attachment. Hot-dipped galvanized or stainless steel supports in the form of strap anchors, rod anchors, dovetail anchors, expansion anchors and especially designed anchors are used to attached stone panels and accessories to a building structure similar to those in Figure 14-3. Once in place, most stone panels and accessory pieces are joined together with mortar joints, although some contemporary stonework has been designed to be set "dry" with no mortar but with the joints sealed by caulking. However when mortar joints are specified, conventional Portland cement/lime mortars will be used. Care should be taken as in any other masonry job to avoid using mortar with high alkali content so as to keep efflorescence to a minimum.

Although some forms of building stone are so dense and nonporous that efflorescence will not occur, limestone is one exception. Care must be taken to prevent large amounts of water from passing through the stone from rear to front or else these white salts will be deposited on the face of the stone. Weep holes at the base course and above all shelf angles can help in evacuating any water that becomes temporarily trapped behind the stone. The Indiana Limestone Institute of America, Inc., publishes a list of do's and dont's that apply to limestone installation and can apply to other forms of building stone as well.

1. Coping stones should be pitched toward the roof instead of toward the facade of the building so as to avoid discolorations on the face of the stone as it weathers.
2. Provide washes and drips on all projecting stones.

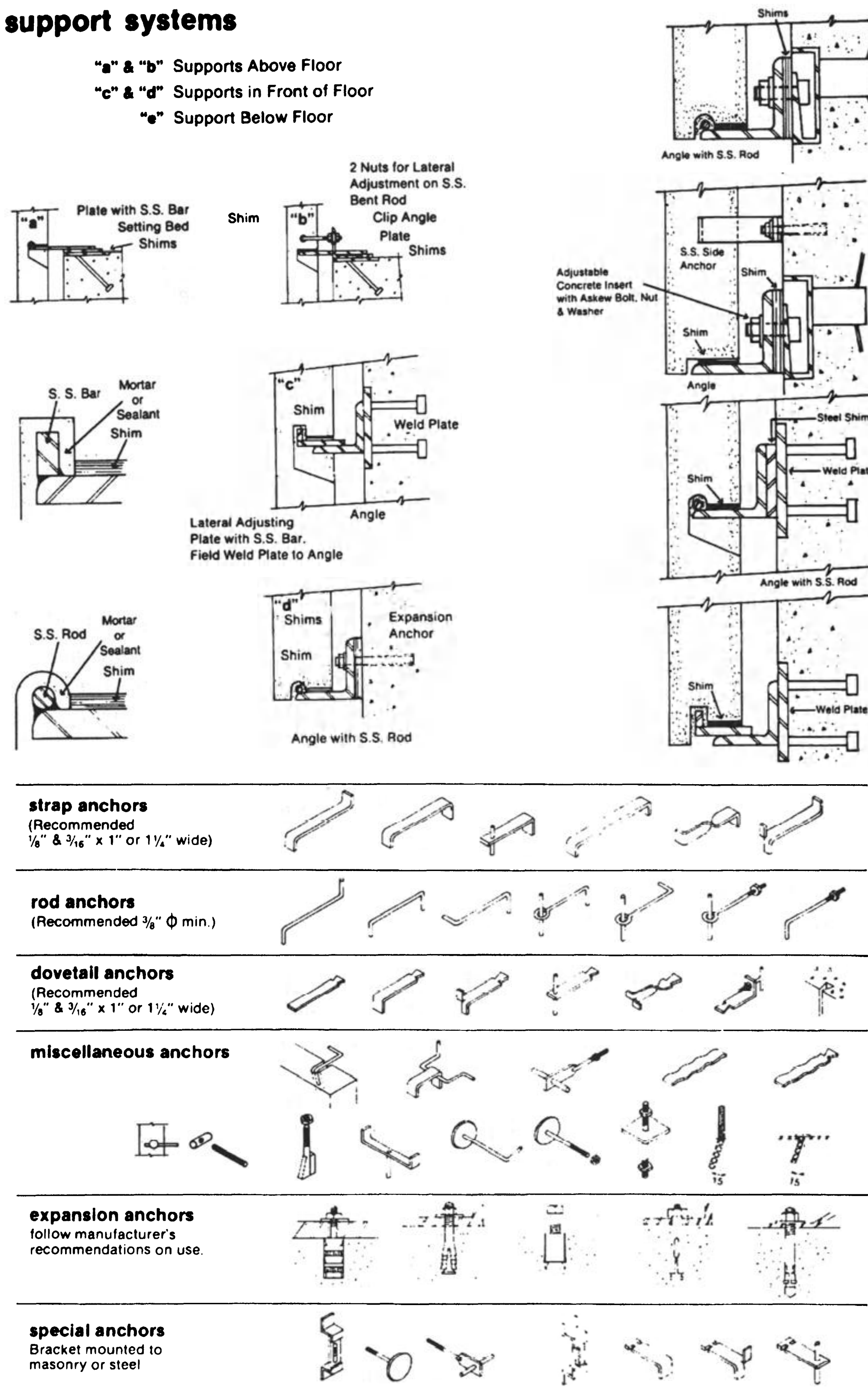


Figure 14-3 Typical Support Systems and Anchors for Attachment of Stone Work. Courtesy: Indiana Limestone Institute of America, Inc., Bedford, Indiana.

3. Do not use the stone as a form for concrete. Alkalis in the concrete may infiltrate and stain the stone.
4. Prevent physical contact between the back of the stone and any walls, columns, slabs or beams. Expansion of any of these components may push the stone out of alignment. Maintain a one inch minimum clearance between stone and other structural members.
5. If exposed stone patios are built over a heated space, insulate the ceiling of the room below. Warm stones can absorb water and a sharp drop in outside air temperature may freeze and crack the stone.
6. All mortar joints should be tooled to maintain moisture resistance.
7. When masonry butts against a stone pilaster the vertical joint should not be filled with mortar or else it will crack. Use a flexible sealant instead.
8. Dowel pins installed through a relieving angle at an expansion joint must not be embedded solidly in the stone. A compressible filler should be installed at the base of the dowel pin to allow for thermal expansion.
9. Avoid setting stone in mortar in freezing temperatures. The stone may expand in hot weather and crack the mortar. When mortar is used Type N with a compressive strength of 750 psi is recommended.
10. If joints are to be pointed after setting, a lean mix should be used. If a strong mix is used any movement in the building might place excessive stress on the joints and create a spalling condition at the edge of the stone.

A MASONRY CHECKLIST

1. Carefully review the specifications to determine if all required submittals have been approved and that all required materials are either on the job site or readily available from dealer stock.
2. Review details of support angles, flashings, embedded items, openings for doors, windows and their related shop drawings.
3. How will relief angles be adjusted? Before masonry begins or as it progresses?
4. Review details of window openings, jamb, sill and head details as they relate to flashing installation and determine who furnishes the flashing and who installs it.
5. Minimize cuts in masonry by laying out in advance of the masonry crew.
6. Protect walls at the end of each day, and if cavity walls are being built, inspect the cavity daily to verify that it has been kept clean of mortar droppings.
7. Two scaffold planks nearest the wall should be cleaned of mortar droppings and turned over to prevent staining the wall.
8. Check weep holes. Are they installed with proper pitch, in proper location and free of clogging debris?

A GLOSSARY OF MASONRY TERMS

Ashlar masonry—Masonry consisting of rectangular stone units.

Buttress—A bonded masonry column protruding from the wall decreasing in thickness from base to top.

Coping—A cap or finish on the top of a wall, pier or column.

Corbel—Masonry courses that project from a wall in an increasing dimension as they ascend.
Header or bonder—Brick layed flat with end surface exposed, usually to bond two courses together.
Pier—Isolated column of masonry.
Pilaster—A column bonded or keyed into a masonry wall.
Terrazzo—A topping compound consisting of two parts marble chips and one part Portland cement.
Rubble—Masonry composed of irregularly shaped stones layed without regular coursing.
Wythe—A continuous vertical section of wall one masonry unit thick.

15

Steel and Steel Structures

Primitive man learned to make iron by placing iron ore and charcoal in a clay pot and building a fire in the pot. A crude bellows provided the forced draft that started a smelting or reduction action that deposited iron at the bottom of the pot, which when removed and hammered, could be forged into a variety of shapes. This was a far cry from the process discovered in the mid-1800s that formed the basis of the giant steel industries being developed in Europe and America. The blast furnace was invented by Henry Bessemer, an English metallurgist whose process was thereafter referred to as the Bessemer process. This process involved the introduction of forced air into the pig iron refining procedure, which raised the temperature of the crucible so that any impurities in the molten pig iron were burned away, and in the process, a more malleable metal was created—steel.

The major steel producers in the United States today use either open-hearth or basic-oxygen furnaces. The newer basic-oxygen furnace closely resembles its Bessemer process ancestor. Ninety-nine and one half percent pure oxygen is combined with carbon and other impurities to create very high temperatures in the furnace, thereby burning off unwanted elements in the pig iron as it is converted to steel. Various minerals and metals added to the molten steel in its crucible enhance certain characteristics:

Nickel—Improves the hardenability of steel and enhances impact strength at low temperatures.
Sulfur—Increases machinability.
Manganese—Increases strength and hardness.
Carbon—The principal hardening element in steel.
Molybdenum—Prevents brittleness because of tempering.
Vanadium—Gives steel a fine grain structure, improves fatigue values.
Silicon—A deoxidizer, improves strength.
Phosphorous—Improves machinability of high-sulfur steels and imparts some resistance to corrosion.

TYPES OF STRUCTURAL STEEL

The basic types of structural steel for construction use have been given designations by the American Society for Testing and Materials (ASTM) ASTM and steel manufacturers and steel fabricators refer to these ASTM grades when orders are being placed.

ASTM A36—This is the primary steel for building construction purposes and is available in rolled structural shapes, plates, sheet piling, H-piles and bars.
ASTM A572—This low-alloy, high-strength steel is available in four yield strength levels: 42, 50, 60 and 65 ksi (kilopounds per square inch). Grades 42 and 50 are for use in structures and grades 60 and 65 are used for bridge construction.
ASTM A588—More commonly referred to as "weathering" steel, this grade is high-strength, low-alloy and is available in yield strengths of 42 ksi and 46 ksi as well as 50 ksi for plates, bars and shapes. These steels are exposed to permit a weathering process to take place, which creates a deep brown patina on the surface of the steel.
ASTM A514—A quenched and tempered alloy grade, this grade of steel is used primarily for welded plate work in bridges and other structures requiring yield point levels of 90 to 100 ksi.

Other ASTM Designations

A242—High-strength, low-alloy steel for thicknesses up to 4 inches. A corrosion resistant steel.
A282—Low and intermediate strength carbon steel plate. For storage tank construction.
A328—The standard grade of steel for sheet piling.
A441—High-strength, low-alloy, manganese-vanadium structural steel. High strength to weight steel—a substitute for phased out A440 steel.
A500—Cold-formed, welded and seamless carbon steel for use in pipe and tube sections to 64 inches in peripheral measurement and 1/2 inch in thickness. Available also as square and rectangular tubing.
A501—Hot-formed welded and seamless carbon steel tubing available also in squares and rectangular sections ranging from 1 to 10 inches in cross section and up to 1 inch thickness.
A633—Normalized high-strength, low-alloy structural steel suited for use where temperatures reach minus 50 degrees F.
A690—High-strength, low-alloy steel for H-piles and marine sheet piling. Has corrosion-resisting qualities.
A709—Bridge structural steel.
A852—Quenched and tempered, low-alloy steel with 70 ksi yield strength used where corrosion resistance and good notch toughness qualities are required, primarily in welded structures.

A steel member is often referred to as a "rolled section," a designation based on the method by which it has been formed from an ingot. In this process the red-hot ingot is actually rolled back and forth between rollers, where it is transformed into an "H" shape. By transferring the emerging steel member to an adjacent "gate," another set of roller dies can further refine and define the shaping process, thus the final rolled section configuration is produced.

BASIC STRUCTURAL STEEL DESIGN

Steel structure design consists of columns, girders and spandrel beams. Gravity acts on the skeletal framework of a building in a vertical direction through the columns. Girders and beams connected to these columns assist in the transferring of loads imposed by the roof, floor and exterior wall construction back to the foundation. Additional loads will be placed on the structure by the placement of equipment and fixtures in the building, and all of these loads are referred to as "dead loads." The "live load" of a structure is imposed by the weight of the people occupying the building and the weight of the desks, furniture and equipment they bring with them. Another "load" that must be considered in structural steel design is wind load, imposed on the building by the forces of nature—wind.

A steel structure is subjected to many other forces because of the physical properties of the steel itself and there are a number of terms used by structural engineers that may require definition.

Uniform loads—Loads distributed over an entire span or over a portion of the span of a beam.

Point loading—Load concentrated in one spot on a beam or bearing surface.

Deflection or deformation—The sag in a beam or girder under load.

Elastic limit—The maximum load that can be imposed in a structural member without creating permanent deformation once the load has been removed.

Yield strength—Loading a structural member to the point where it begins to show evidence of permanent elongation or deformation.

Bending moment—The moment that produces bending at a beam or other structural member.

Shear—A force acting downward and a reactive force acting upward, like a pair of sissors cutting paper.

Moment—A force about a point.

Tipping moment—An overturning motion generally caused by wind loads acting against a lightweight, slender structure.

Spandrel—An exterior beam extending from column to column that supports an exterior wall load.

Thermal expansion—Movement of the steel members affected by temperature change. When expansion takes place, contraction will also occur as temperatures cool down and the steel shrinks back to initial dimensions.

Plate girders—A structural member having the same shape as a rolled "W" member but beefed up with either top and bottom flange plates or web plates or intermediate transverse stiffeners in order to carry the very heavy loads that will be imposed upon it.

PREPARING FOR THE ERECTION OF A STEEL STRUCTURE

Structural steel is one of the more common trades subcontracted by a general contractor, but the project superintendent will bear a great deal of responsibility in order to provide a rapid, cost-effective erection cycle. The foundations must be checked to determine if they have been prepared properly to receive the steel structure. The site must be readily accessible to the men, materials and equipment that will soon be arriving.

Foundation Preparation

Anchor bolts will hold the structural steel columns in place on the foundation while the balance of the framework is being erected, and the accuracy with which these anchor bolts have been placed will determine the speed with which the erection process can begin. If the anchor bolts are placed inaccurately: the general contractor will incur extra costs as well as delays in erection time. Careful placement of anchor bolts begins during the concrete foundation phase of the project, when templates can be used to establish accurate bolt patterns and lasers or transits are set up to check exact bolt locations. Prior to erecting the structural steel it is essential that all anchor bolt locations be verified through some sort of as-built drawing, which should be prepared by the concrete installer, the steel subcontractor or the general contractor. When any anchor bolts are found to exceed an acceptable tolerance with respect to location or pattern, the contractor is left with two choices: move the bolts or change the configuration on the bolt hole locations in the structural steel column base plates. Unless this survey is conducted early on, the steel fabricator may have already welded base plates to columns that have been loaded on their trucks awaiting delivery and the cost to unload and modify these base plates will be quite high. Redrilling new anchor bolt locations in the concrete foundations and installing some form of expansion bolt might be the only alternative. If an as-built drawing had been prepared while the structural steel was being fabricated, modifying the base plates would probably result in little or no additional cost:

Site Preparation

Whether steel erection will be performed by a tower crane or a mobile crane on tracks or rubber tires there will be a fair number of tractor trailers entering the site to deliver materials, and they must be able to travel to the erection area without encountering too many obstacles. All existing and temporary overhead utility lines must be raised to a safe height and protected against accidental damage. Recently backfilled trenches should have been compacted to the point where they can support the loads imposed by truck and crane travel. When either trucks carrying steel or cranes are to operate within the building's foundation, properly constructed ramps must be in place to not only protect the concrete walls from damage but also to provide a proper gradient for vehicular traffic. And if any underground pipes have been installed under the future slab-on-grade, these areas must be protected against the concentrated loads that will be imposed by cranes and trucks. Areas around the exterior of the building need to be cleared for storing structural steel materials, and depending on how far the fabricator's shop is from the job site, three or four truckloads of materials may have to be stored on site in order to maintain a steady, continuous erecting process.

Base Plates, Leveling Plates, Leveling Nuts

Sometimes there is confusion over terminology: Is it a base plate or is it a bearing plate? A base plate differs from a bearing plate in that the latter designation applies to a steel plate placed under the end of a beam to provide proper level bearing on the surface that is supporting the beam. A base plate is used to support a column and is usually welded to the base of a column at the fabricator's plant. The anchor bolts prevent lateral and vertical (uplift) movement when the base plate is attached to the building's foundation. Structural steel columns must bear on a level surface and this can be accomplished in several ways. Relatively small or medium-size columns can be picked up by the crane, lowered onto a set of anchor bolts and shimmed to levelness temporarily until the base plate can be permanently leveled with grout. Or the fabricator may ship leveling plates to the site prior to the start of steel erection so the general contractor can place them onto the anchor bolts, level them and permanently grout them to provide the level base for the column base plates.

Leveling plates are used when small or medium-size base plates, in the eighteen to twenty-two range are attached to steel columns. These plates generally about quarter inch thick are sheared to the same size as the column base plate, and the holes in these plates are usually $3/16$ inch larger than the anchor bolts. Leveling plates are sent to the field in advance of the actual steel erection and thereby give the concrete subcontractor or the general contractor time to make some corrections if any anchor bolts are out of alignment. When these plates are grouted they offer a solid contact surface for the steel columns in their initial stages of erection.

When leveling nuts are used to level large base plates, one nut is threaded onto the anchor bolt along with a heavy washer and is brought up to the proper elevation. The other nuts on the three remaining anchor bolts are then adjusted to the elevation of the first nut. Many superintendents spray paint all four nuts and a portion of each anchor bolt so that if any nut has been tampered with, the unpainted metal gap either above or below it will be visible. some column base plates or leveling plates have air relief holes in them to facilitate the grouting process, which will provide permanently level base support.

Proper Procedures for Grouting Base Plates and Leveling Plates. Grout can be either cementitious base or epoxy base, and proper procedures must be followed when using either. Cement-based grout contains hydraulic cement, sand and other ingredients proprietary to the manufacturer to ensure that the grout remains plastic while being used and cures properly with no perceptible shrinkage. Cement grout can be used effectively when ambient temperatures range between 40 degrees F and 90 degrees F. When outdoor temperatures are higher or lower, special cold- and hot-weather precautions need to be taken.

Cement grout is mixed with water to a workable nonsag consistancy and packed under the leveling or base plate with a trowel and a ram or with specialized tools such as a plunger and pump. Pencil vibrators are also used to ensure that all air pockets have been expelled. Forms are not always required when plates are being grouted, but if they are used, the outer edge of the grout should be cut back to the edge of the base plate as shown in Figure 15-1. Before grouting operations begin, all concrete surfaces should be sound, properly cured and clean of oil, grease, laitance and curing compounds.

Cold-Weather Cement-Base Grouting Procedures. Low temperatures delay set time and freezing temperatures during the hydration stage can affect the ultimate strength of the grout. When used at low ambient temperatures, the grout should be stored for at least 24 hours in a storage area maintained near 70 degrees F and water used in the mix should be of the same temperature. Base plates and foundations should be heated to above freezing temperatures, and all signs of frost must be out of the concrete that is to receive grout. Once grout reaches a compressive strength of between 500 and 1,000 psi, it will resist freezing and no further weather protection will be required.

Hot-Weather Cement-Base Grouting Procedures. Prior to the start of grouting, operations in hot weather, the grout should be stored in a cool, dry area at 70 degrees F for at least 24 hours. The concrete to be grouted should be soaked with water 24 hours in advance, and if it appears that either concrete or steel temperatures will exceed 90 degrees F, just prior to the start of the grouting operation, cold water should be sprayed on both concrete and steel surfaces, if possible, shade these areas from direct sunlight at least 24 hours in advance of grouting operations.

After placement, the grout must be protected from extreme drying conditions by covering all exposed areas with continually wetted burlap or a coat or two of white pigmented curing compound applied to the surface of the grout after the moist curing period is over.

Working With Epoxy Grouts. Both epoxy components, hardener and resin, must be stored at temperatures between 70 and 80 degrees F. The epoxy hardener should be

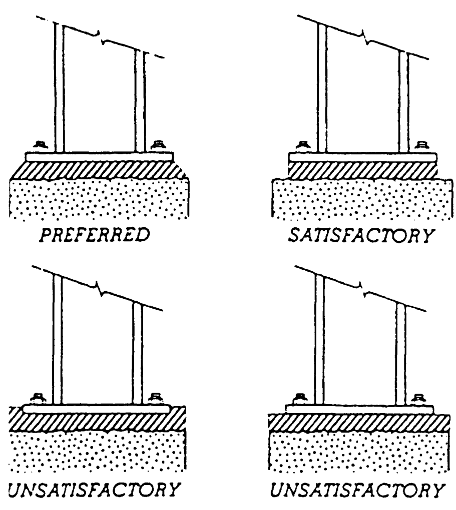


Figure 15-1 Recommended Base Plate Grouting Configurations.

added to the pail containing the resin and thoroughly mixed for at least two to three minutes taking care not to introduce air into the mixture. The entire bag of aggregate that is furnished with the grout should then be added and mixed just long enough for it to become wet and disperse all lumps. Epoxy grout should be used at ambient temperatures ranging from 40 degrees F to 90 degrees F. Temperatures above and below these limits require special procedures. The higher the temperature the quicker the set will be, and placement procedures must be regulated accordingly in all cases. Placement should be continuous and rapid to avoid cold joints and voids under the base plate. Since epoxy grout cannot be easily trimmed, after it has hardened, chamfering must take place prior to hardening, and when forms are used chamfer strips can be built into the forms. The forms used must remain in place overnight until the epoxy is properly cured.

Hot-Weather Epoxy Grouting Methods. Surfaces to be epoxyed in hot weather should be shaded, and base plates should be cooled to below 90 degrees F. But water should not be used to cool the steel or wet the concrete because the epoxy will not bond to these surfaces unless they are perfectly dry. Resin and hardener cannot remain without aggregate for more than five minutes, and it is preferable to delay the placement of the grout in hot weather until temperatures begin to drop later in the day.

Cold-Weather Epoxy Grouting Methods. All epoxy grout components, resin, hardener, aggregate should be stored at a temperature of at least 70 degrees F for a minimum of 24 hours prior to use. All surfaces in contact with the grout must be maintained at 50 degrees F or higher for at least 24 hours before and 48 hours after grouting operations take place. Most epoxies will not cure below 40 degrees F.

STRUCTURAL STEEL CONNECTIONS AND CONNECTORS

The last link in the chain of structural integrity in a steel-framing system is the connection, not only its design but also the implementation of the connection. Columns are structural members designed to resist compressive stresses parallel to their length. Some column loadings are direct (that is, imposed directly upon their center line), but there are also eccentric loadings, those that are not plumb to the center line of the column. These eccentric loads are usually transferred to the column by either a bolted or welded beam connection. This is also known as a moment connection.

Moment connections are designed to resist bending moments and are usually made of angles, structural tees or plates. Shear connections are used to attached beam-to-beam or beam-to-column usually from web-to-web in such a manner that a shearing action would take place if the connection was not properly designed. What are known as "simple connections" are used when wind loads, or gravity loads or both must be considered. Seated connections use a top angle to provide lateral support while not contributing to the rigidity or stiffness of the connection.

Connectors

There are three basic types of connectors: welds, rivets and bolts. Most connection welding takes place in the steel fabricator's shop where components of field-bolted connections are welded to columns and beams. These welded connections are detailed on various shop drawings by the fabricator for approval by the design engineer. Quite often the weld symbols that appear on the shop drawings can be confusing unless the superintendent is familiar with the instructions these symbols convey (see Figure 15-2).

High-strength bolts have replaced rivets as a primary connection device in the field. The high-strength bolts (HSB) are identified by two ASTM numbers: A325 and A490. The A325 bolt is available in type 1 (medium-carbon steel), type 2 (low-carbon martensite steel) and type 3 made with self-weathering steel similar to ASTM A588 steel. The A490 bolt is made from alloy steel and is the stronger of the two. A Type

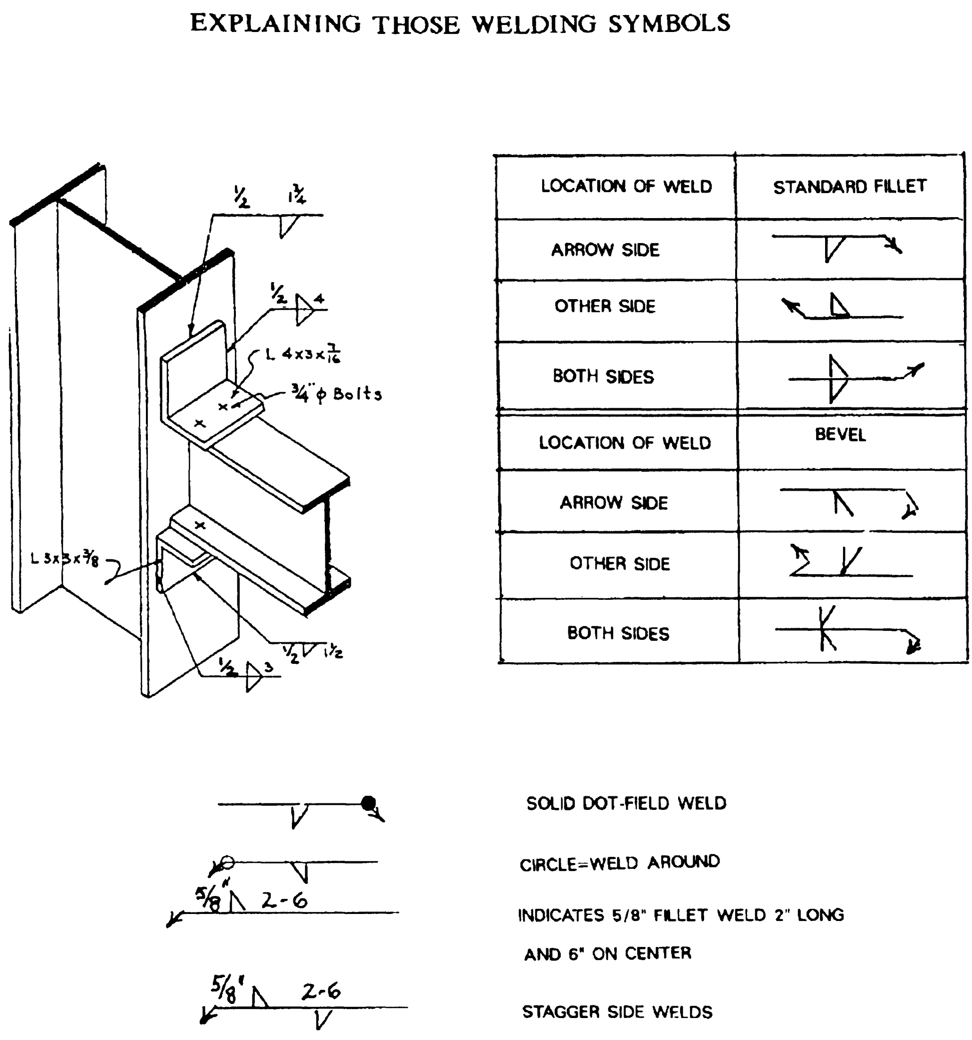


Figure 15-2 Welding Symbols.

1 A325 bolt is identified by the mark "A325" and by three radial lines 120 degrees apart stamped on its head. The Type 2 has three radial lines 60 degrees apart, and the Type 3 has A325 underlined on its head. A490 bolts are marked "A490" on their head.

In years past, turn-of-nut or calibrated wrenches were used to attain proper bolt tension, and these connectors were checked with torque wrenches when the steel inspection process took place. Today the TC (tension control) bolt is widely used. These bolts are high strength and contain a bolt tip integrally attached to the bolt stem with a precision delayed-fracture material. The wrench used to tighten TC bolts has an inner and outer socket. The outer socket fits over the nut and washer, and the inner socket fits over the bolt tip. When the precise torque value has been achieved, the bolt tip will separate from the bolt stem and the socket will spin free indicating proper tension has been achieved. Inspections can now be made visually since all that's required is to look at each bolt to determine if its tip has been sheared off, an indication that design torque has been achieved.

THE "L OVER 360" CONCERN

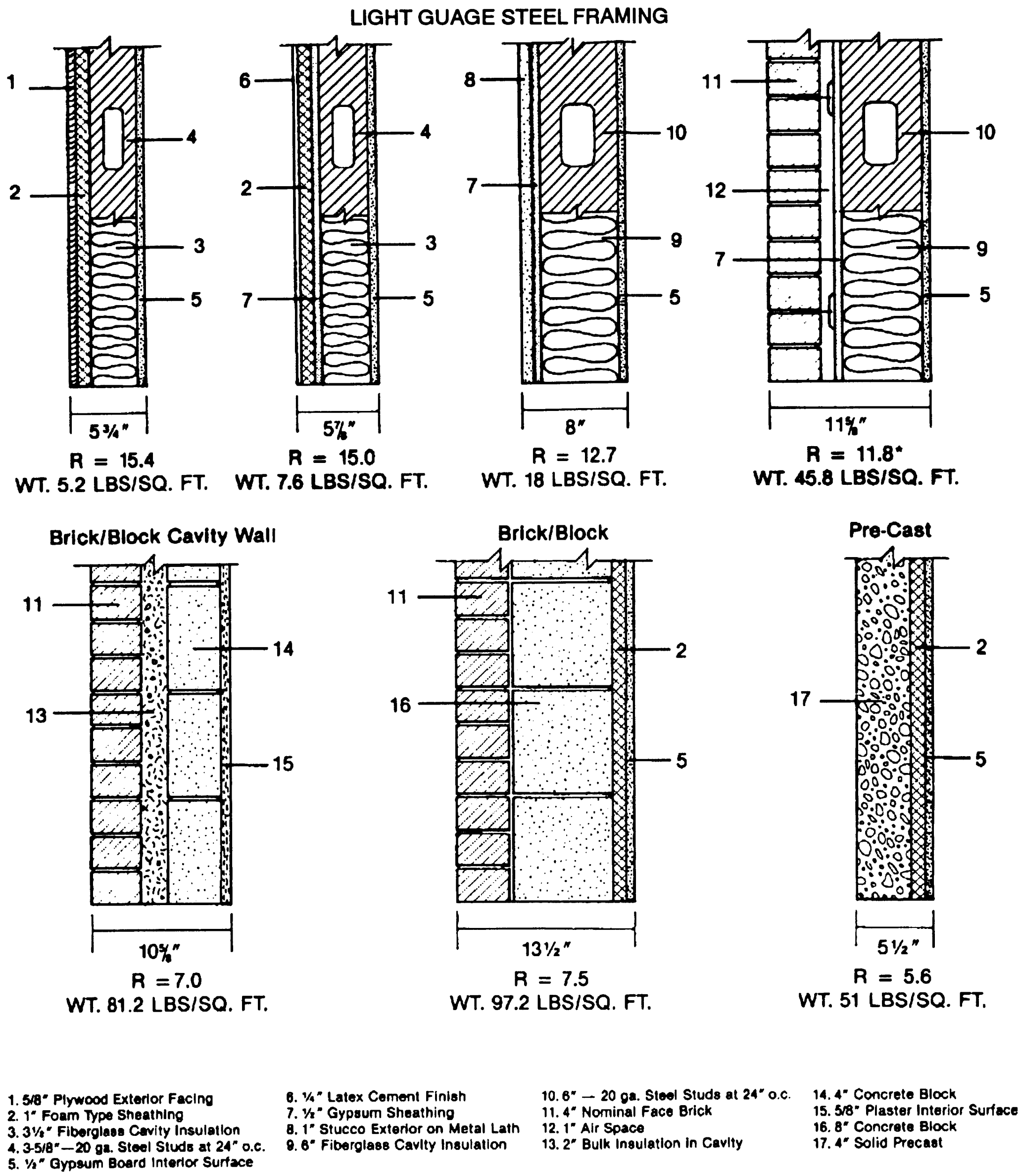
Quite often a superintendent will hear conversations between the architect, engineer and subcontractor in which the term L/360 is mentioned. This term can be applied to steel framing or curtain wall framing, and is concerned with deflection.

Structures are designed to include certain deflection parameters. The structure will move because of wind loadings and upon imposition of other live loads, but if the actual building flexes more that the amount built into the design, cracks may appear in components such as rigid cladding materials and curtain walls. An established rule of thumb is that a member should not deflect more than 1/360th of the length of its span, when the span is expressed in inches. The length of the span is expressed by the letter "L." Or to be more exact, a 30-foot beam (360 inches long) shall not deflect more than 1 inch. If deflection criteria is indicated to be L/240 that means that a 20 foot beam (240 inches) shall not deflect more than one inch. Another term frequently heard in connection with deflection is "Delta," the Greek symbol used to denote difference.

LIGHT-GAUGE METAL FRAMING

The use of cold-formed steel as opposed to hot-formed rolled sections as a structural system for low-rise buildings three stories or less has grown considerably in the past ten to fifteen years. This framing systems offers both owner and contractor several advantages:

1. Less weight per square foot of wall area when compared to other systems (see Figure 15-3).
2. Ability to provide energy savings without sacrificing interior space since insulating batts or rigid insulation can be nested in between the studs.
3. Faster erection time than other systems since its installation is not weather sensitive like masonry or concrete.



"R" values calculated considering all materials in the wall construction plus exterior and interior air film factors. Individual values obtained from the Heating, Ventilating, Air Conditioning Guide published by the American Society of Heating, Refrigerating and Air Conditioning Engineers.

*Per BIA Technical Notes #4, revised January, 1982.

Figure 15-3 Comparative Weights of Wall Assemblies and Corresponding "R" Values. Courtesy: Metal Lath/Steel Framing Association Division of NAAMM.

4. Quality is easier to control since the assemblies can be easily inspected and deficiencies corrected after installation.
5. Noncombustible construction, rodent and insect infestation proof, combined with high strength when compared to conventional wood stud and joist construction.

6. Ease of installation of electrical conduit and plumbing piping because studs and joist come with factory prepunched holes through which conduit and small diameter pipes can be installed.
7. Easily adaptable to several kinds of facing materials: cement plaster, synthetic plaster, brick veneer, prefinished plywood panels, metal panels, stone or ceramic tile.

Light-Gauge Framing Components

Basic components for this structural system consist of C-studs ($3\frac{5}{8}$ inches, 4 inches, $7\frac{1}{4}$ inches and 8 inches deep) formed from 12 gauge to 20 gauge metal and C-joists (from 4 inches to 14 inches deep) available in 12 gauge to 18 gauge metal. Top and bottom track availability is the same as that for studs. All light-gauge framing members are colored coded for easy identification in accordance with the Metal Lath/Steel Framing Association guidelines.

12 gauge	Red
14 gauge	Orange
16 gauge	Green
18 gauge	Yellow
20 gauge	White

There are a number of standard accessories available for light-gauge framing assemblies. Deep-leg tracks are used where nonload-bearing slip track construction is required to compensate for deflection or movement. Foundation clips are available to anchor header joists or runners to concrete foundations, and end clips, channel clips and framing clips can be obtained for screw attachment to other framing components. Cold-rolled channels and flat strapping are used to provide lateral bracing, and web stiffeners are available to prevent web crippling at points of concentrated loads.

Light gauge framing members can be connected by shield-metal arc welding or gas-metal arc welding procedures or by using self-drilling, self-tapping screws. Power-actuated fasteners can be used to secure members to concrete or to hot-rolled steel sections, and spiral-shank nails are available for fastening plywood to the top flange of floor joists.

Light-gauge framing construction lends itself to prefabrication techniques since panels can be made off-site or on one portion of the construction site while foundation work progresses in another area. Quite often steel framing members are ordered cut-to-size. If, however, cuts must be made in the field, a radial arm saw with a friction type blade (280 to 300), an abrasive cut-off wheel on a chop saw will do the trick nicely. A 5 HP saw with a 14 inch blade should be able to handle all cutting requirements.

STEEL JOISTS

Open-web joists are frequently used in structural steel framing systems for reasons of economy, ability to span great distances unsupported and their relative ease of availability. Joists sizes are prefixed by letter designations; H or K series are manufactured in depths ranging from 8 inches to 30 inches and are capable of spanning up to 60 feet.

The LH series are made in depths of 18 inches to 48 inches and can span up to 96 feet; and DLH series, 52 inches to 72 inches deep have the ability to span up to 144 feet. Joists are manufactured in several configurations (see Figure 15-4). The top chord of a joist is designed for axial compressive strength only or as a continuous member subject to both axial and bending stress. The bottom chord of the joist is designed to be an axially loaded member in tension.

RIGID-FRAME STRUCTURES

Single-span rigid frames have been an integral part of the preengineered buildings that gained popularity during World War II when arc welding techniques had progressed to the point where long-span frames could be constructed inexpensively and quickly to meet the growing demands of the war production industries. Rigid-frame structures have been used with great success in constructing indoor tennis courts, gymnasiums, and mill-type industrial buildings. The rigid-frame configurations (see Figure 15-5) can create single-slope profiles, ridge-type sections and rectangular-section buildings with clear spans up to 120 feet.

METAL FLOOR AND ROOF DECKS

Flat sheets of preformed corrugated configuration metal in various gauges, either painted or galvanized, have become the most economical method of constructing roof and floor systems. These metal decks serve many purposes.

- As roof decks.
- As noncomposite floor decks.
- As composite floor decks.
- As forms for self-supporting concrete slabs.
- To provide accoustical properties to floor and roof decks.
- As raceways for electrical systems in concrete slabs.

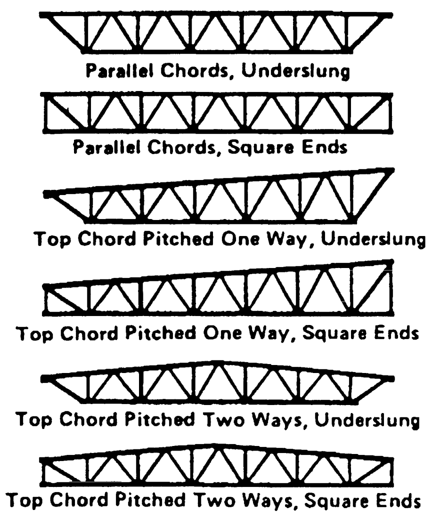


Figure 15-4 Standard Joist Configurations for Longspan and Deepspan Members.

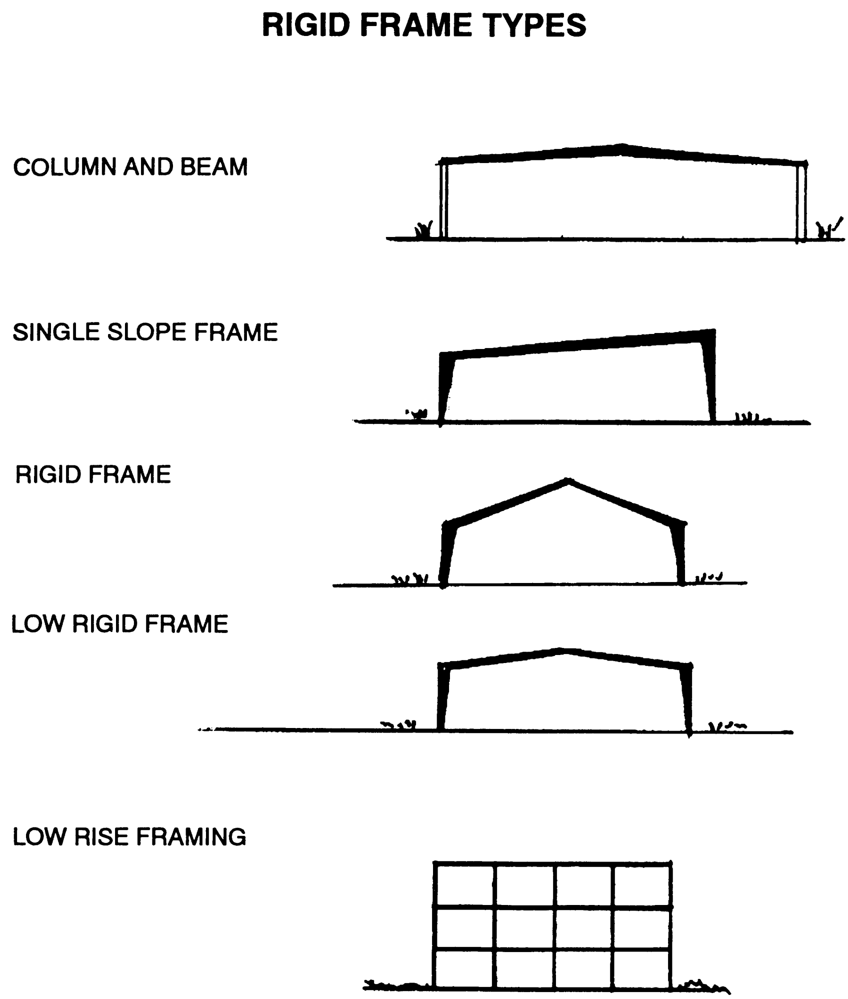


Figure 15-5 Typical Rigid Frame Configurations.

Steel-Deck Materials

Rolled-rib metal panels for noncomposite floor-deck construction are available with a galvanized, painted or uncoated finishes referred to as "black iron." Typically a 4-inch thick slab will be poured on the deck whose flutes are 1 3/8 inches deep, the depth of concrete being measured from the bottom of the flute. The project superintendent should consult with the engineer to determine if shoring the metal deck is required prior to its being loaded with the weight of the concrete.

Composite metal-deck construction involves an interconnection between beams and girders and the slab so they all act together to resist bending. This is accomplished by welding shear stud connectors onto the steel deck where it has been placed over these beams or girders. These shear studs are welded with a special electric welding gun that burns off surface contamination before attaching the stud to the deck and beam (see Figure 15-6). This operation can only take place when the metal deck is perfectly dry.

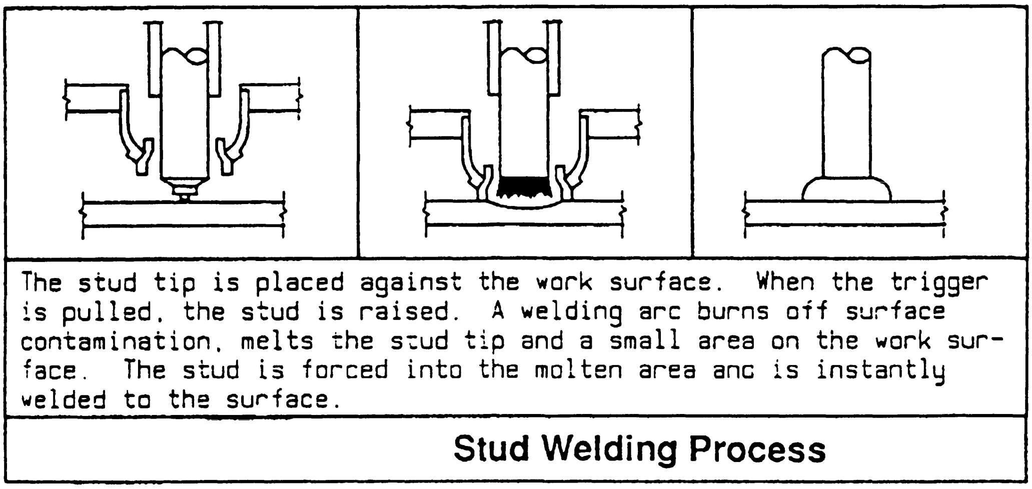


Figure 15-6 Shear Stud Welding Process. Courtesy: Precast Concrete Institute, Chicago, Illinois.

Acoustical metal decks are sound absorbing and can also be used as support for concrete deck or roof loads. The acoustical quality of this type of metal deck is created by punching many holes in the surface of the deck and field-installing fiberglass insulation in the flutes of the deck. Special cellular metal-floor decks are available from several manufacturers that allow raceways to be created for both low-voltage and line-voltage electrical cabling. Trench headers and duct headers provide transverse raceways and special floor outlets or "tombstones" permit access to the wiring that will eventually fill these raceways. Metal roof-deck material is available in narrow, intermediate, wide and deep-rib configurations. The ability to clear span increases from narrow to deep-rib configuration, and special long-span roof decks are manufactured to support specific live loads while clear spanning to thirty feet.

A STRUCTURAL STEEL CHECKLIST

1. Is there a complete set of engineer-approved shop drawings on the site? Are all deck penetrations included on these drawings?
2. Have all overhead and lateral clearances been checked so that cranes and trucks transporting the fabricated steel to the site can enter the area where steel will be erected?
3. Have the steel subcontractor's electrical requirements for welding machines during erection been established and confirmed. Who furnishes and who pays for usage? Will portable generators be required?
4. Has a "shake-out" area been established and is access around the building properly prepared for the crane and the trucks?
5. Has an anchor bolt survey been taken, and if corrective action is required has a plan been established?
   a. Extend the bolts if they are too short.
   b. Bend them if within allowable tolerance accepted by engineer.
   c. Drill in new expansion bolts or swaged bolts.

   d. Have steel fabricator slot base plate or fabricate new one.
   e. Change the length of the column if the problem is one of height, or cut foundation or pier to lower its elevation.
6. Have all pockets for wall-bearing beams been checked and have bearing plates been installed?
7. Is steel fabricator responsible for OSHA perimeter protection on upper floors, and if so, does he have all materials on site?
8. Have all floor and roof openings been located and dimensioned accurately?
9. Is the steel fabricator to furnish and install the concrete pour stop or edge stop?
10. Is steel erector to perform work for other trades while on the job, such as adjusting hung lintels for mason, cutting openings in beams for mechanical trades, installing and adjusting connections for precast or curtain wall subcontractor? Where does the contract responsibility for these functions lie?
11. Does the steel-deck or composite-deck construction require shoring prior to pouring elevated concrete slabs, and if so, how long must the shores remain in place?
12. Is field paint touch-up required, what about painting welds on roof deck?
13. Is an inspection by an engineer or inspection laboratory required when the structural steel erection has been completed but prior to that subcontractor leaving the job site?

16

Wood—Lumber, Plywood and Millwork

Wood is the only building product that comes from a renewable source. It is strong, durable and biodegradable and requires the lowest amount of energy to convert it from its natural stage to a finished construction product. Wood used in the construction industry fits roughly into one of six categories:

Rough carpentry, framing lumber and timbers,
Finish carpentry materials,
Plywood products,
Reconstituted wood products,
Laminated structural wood members, and
Millwork.

Although there are numerous species of wood, they can be divided into two basic divisions: hardwoods and softwoods.

HARDWOODS AND SOFTWOODS

The two major classifications of wood do not necessarily refer to their hardness or softness, but refer to the type of tree from which they are taken. Hardwood comes from deciduous trees, those that shed their leaves at the end of the growing season. The more common hardwoods are ash, basswood, beech, birch, butternut, chestnut, elm, hickory, maple, oak, poplar and walnut. Softwoods are those trees such as evergreens that do not shed their leaves; only cypress, tamarack and larch vary from that pattern. Typical construction softwoods are cedar, fir, hemlock, larch, pine and spruce.

Hardwoods are often used for flooring, furniture, cabinetry and millwork, while softwoods find wide application as framing lumber, although pine is quite often used as trim or incorporated into various types of millwork. Wood has a great capacity to withstand bending stresses, an important characteristic for beams, rafters and joists. Compression parallel to the grain is also very high in wood framing members, however resistance to shear is rather low. Because wood is a product of nature, its characteristics vary from tree to tree as well as from section to section within the same tree. Therefore some method is required to select and grade those pieces of lumber that have average characteristics for the species and those pieces of lumber that are either above or below the median quality level for each species. That is accomplished by grading lumber for both appearance and structural quality.

The first attempt at grading lumber was made in Scandanavia in 1754 by Swan Alverdson. By 1833 written grading standards were adopted in the United States, at first for lumber harvested in Maine. Moving west, lumber grading rules made their appearance in the Great Lakes region toward the end of the nineteenth century. The Western Wood Products Association was formed around the turn of the century, and by 1924 various grading associations around the country developed product standards with the assistance of the U.S. Department of Commerce. The two premier lumber-grading associations in the country today are the Western Wood Products Association and the Southern Pine Inspection Bureau.

WESTERN WOOD PRODUCTS ASSOCIATION—WWPA

Douglas fir, Western red cedar, mountain hemlock, hem-fir, ponderosa and sugar pine are a few of the more than twenty-three wood species graded by the WWPA. Member mills of the WWPA stamp or brand their product in such a manner that the customer clearly knows what he is buying. A typical grade stamp is shown in Figure 16-1.

The components of a WWPA grade stamp are as follows:

a. "WWP" is the official stamp of the WWPA and indicates that its grading rules apply to this lumber.
b. Each mill belonging to the WWPA is assigned a number. Sometimes the mill name is used in lieu of the number.
c. The grade identification of the lumber.
d. The species is also identified on the stamp—Douglas fir in this case.
e. Moisture content is indicated. The symbol S-Dry reveals a moisture content of 19 percent or less. (A mark of MC-15 would indicate moisture content not more than 15 percent, and a mark S-GRN indicated a moisture content exceeding 19 percent.)

The other major lumber grading association in this country is the Southern Pine Inspection Bureau, and its affiliate Timber Products Inspection located in Conyers, Georgia. Both of these organizations have their own distinct inspection and grading stamps, as shown in Figure 16-2.

Figure 16-1 Western Wood Products Association Grade Stamp.

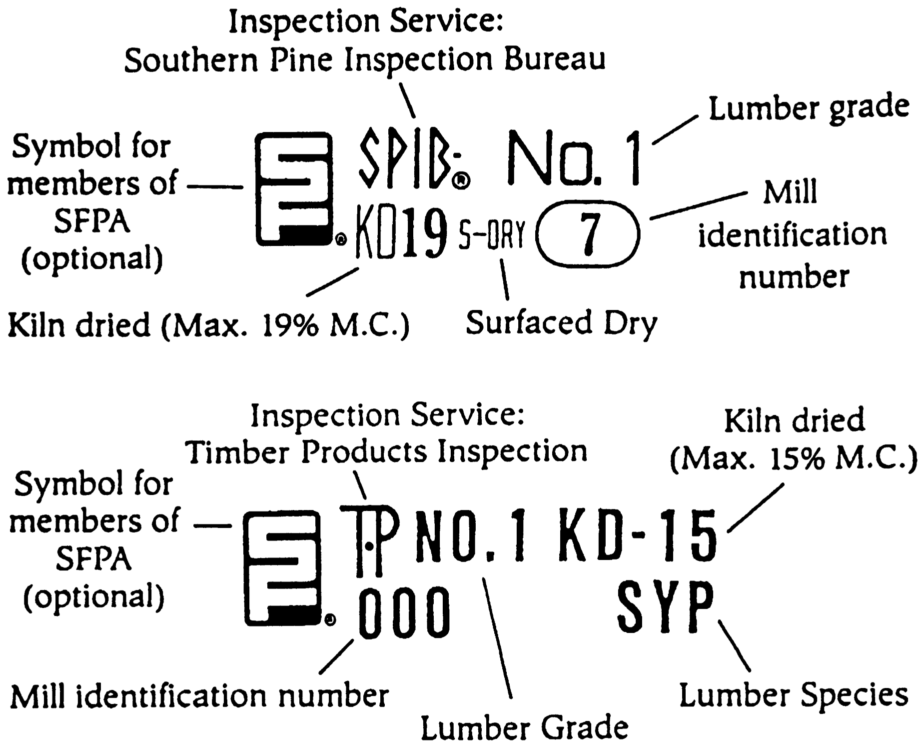


Figure 16-2 Typical Grade Stamp for Southern Pine Inspection Bureau and Timber Products Inspection.

ROUGH CARPENTRY MATERIALS

Most rough carpentry materials, including framing lumber, timbers and decking products pass through the Western Wood Products Association and the Southern Pine Inspection Bureau, and the construction superintendent ought to gain some familiarity with each association's more commonly used grades. WWPA specifications for framing lumber are as follows.

Framing Lumber

Framing grade lumber is comprised of 2 × 4s and other sizes up to, and including, 4 × 4s graded CONSTRUCTION (highest grade), STANDARD and UTILITY. Light framing lumber, a subcategory, is a grade that can be used where higher strength structural values of framing lumber grade are not required. STUD grade framing lumber is limited to members 10 feet or less in length and is an all-purpose grade specifically used for stud framing purposes.

Structural Light Framing

A grade of lumber to be used when higher bending ratios are required, the structural light framing designation applies to wood sized from 2 × 4 to 4 × 4. Structural light framing grades range from SELECT STRUCTURAL (highest grade) down to No. 1, No. 2 and No. 3. No. 1 grade should be used in those instances where long spans or high loads will be anticipated, and No. 3 should be used in light loading applications.

Structural Joists and Planks

This category refers to those pieces of lumber sized 2 × 5 up to 4 × 16. They are graded similar to structural light framing—SELECT, No. 1, No. 2, No. 3.

Design values (in terms of pounds per square inch) for four different wood species are listed below. Note the high structural value of western cedars.

Western Woods	Select structural	1,150–1,300 lbs per square inch
	No. 1	975–1,100
	No. 2	800–925
	No. 3	475–550
Ponderosa pine and Lodgepole pine	Select structural	1,200–1,400
	No. 1	1,050–1,200
	No. 2	850–975
	No. 3	500–575
Western cedars	Select structural	1,300–1,500
	No. 1	1,100–1,300
	No. 2	925–1,050
	No. 3	525–625

MSR Lumber

Machine Stressed Lumber is dimensional lumber that has been especially tested by calibrated electromechanical equipment to meet certain modulus of elasticity standards. In addition to machine testing, each piece of lumber is visually inspected to meet specified quality standards. During the testing process that takes place while the wood is being graded, mechanical rollers exert a bending force on each piece of lumber. The ability of the lumber to retain its original shape under bending pressure is what is contributory to its superior performance. If the stress test readings meet the lumber's specified stiffness requirements it is sorted according to a modulus of elasticity (E) class, marked with a special color coding and stamped MACHINE STRESS RATED.

FOHC Lumber

Free of heart center lumber (FOHC) is a designation that applies mainly to heavy timbers, those that are 5 inches by 5 inches or larger. This lumber is sawed from the heart or center or pith of the tree. FOHC lumber is used where a minimum amount of twist must be maintained and seasoning check is of critical importance. Because FOHC lumber comes from the center of a tree, delivery time is somewhat extended since a log in excess of 24 inches must be located and sawed at the mill to produce one 6 × 12 timber.

Seasoned Lumber Grades

Lumber 2 inches or thinner can be dried to produce a moisture content of 19 percent or less, and that lumber will be stamped "S-Dry." Surfaced framing lumber in excess of 2-inch thickness is typically shipped unseasoned and its grade stamp will be marked "S-Grn;" although some lumber may be stamped KD (the designation for kiln dried), that is a process for drying lumber and may not relate to any specific moisture content.

Southern Pine Lumber

Most of the material passing through the Southern Pine Inspection service is designated to be treated with a wood preservative. Fully 50 percent of all Southern Pine products were "treated" as of three years ago, and in addition another 20 percent is used in manufacture of wood trusses. The remaining 30 percent of southern pine finds its way into rough structural lumber, dimensional lumber, boards and decking usage.

Structural Light Framing grades of southern pine range from SELECT STRUCTURAL (highest grade) to DENSE SELECT STRUCTURAL (where good appearance is required) to No. 1, No. 1 Dense, No. 2, No. 2 Dense and No. 3, which is recommended for general construction purposes. Light framing grades of southern pine 2 x 4 lumber, 2 inches to 4 inches wide are graded CONSTRUCTION (highest grade) STANDARD, UTILITY, and ECONOMY (suitable for bracing and blocking).

Southern pine used for studs are graded STUD and structural joists and planks, 2 inches to 4 inches thick and 5 inches or wider are graded the same as dimensional lumber except that a No. 3 Dense grade is added. Southern pine seasoning requirements restrict moisture content to a maximum of 19 percent in lumber 2 inches or less in thickness. Lumber stamped "KD-15" or "MC-15" will have 15 percent moisture content, the designation "KD" pertains to kiln dried lumber.

TREATED LUMBER

Strong, versatile, easy to work with, lumber does have two shortcomings: combustibility and susceptability to decay. However lumber treated with fire retardent and wood preservative chemicals can overcome these two handicaps.

Fire-Retardant Lumber

Fire-retardant lumber is available in two grades: interior and exterior grade. Both display similar fire retarding characteristics, but exterior grade resists leaching out of the impregnated chemicals. Wood treated with fire retardant chemicals in years past had a tendency to release some chemical residues. A process known as "blooming," it was caused by the lumber absorbing moisture from the atmosphere. Chemical treatment technology in recent years has produced an end product with low hygroscopicity, a term that means low water-absorption qualities. These new fire retarding chemicals have also reduced the corrosiveness that earlier treated lumber exhibited, which caused nails and screws to fail over time. In addition, some of these new chemicals impart resistance to termite infestation and decay in wood when used above ground. Flame spread ratings for treated lumber are as follows:

Class 1 or Class A	0–25 flame spread
Class 2 or Class B	26–75 flame spread
Class 3 or Class C	76–200 flame spread

Chemical Treatment for Wood Preservation

Lumber decays because it is a food source for a number of invaders–insects and fungus, and chemical preservatives make wood fibers unattractive to insect infestation and fungus growth. There are three broad categories of wood preservatives:

Waterborne—Used in residential, commercial, recreational, and agricultural uses. Waterborne preservatives include acid copper chromate, chromated copper arsenate, ammoniacal copper arsenate and chromated zinc chloride.

Creosote—Including creosote–coal tar mixes, used primarily for impregnating railroad ties, utility poles and marine piling.

Pentachlorophenol—Known simply as "Penta" and used in industrial applications and for utility pole preservation.

The most common preservative used in construction lumber would be chromated copper arsenate, referred to as CCA. When lumber is to be pressure treated it is placed in a cylindrical chamber where high pressure forces the chemicals deep into the fibre of the wood and subsequently this treatment lasts for years. Some test Southern Pine stakes treated with CCA have been driven into the ground at various locations throughout the country to evaluate the effective life of the treatment, and in some cases no failure of chemical retention were observed after forty years.

There are various levels of chemical retention, expressed in pounds of preservative per cubic foot of wood, and the American Wood Preservers Association recommends the following retention levels for various usages:

Use/Exposure	Retention (pounds/cubic foot)
Above ground	.25
Ground contact—fresh water	.40
Wood foundation	.60
Salt water	2.50

FINISH CARPENTRY

The term "Finish Carpentry" pertains to items of work on the interior of a structure and would include interior trim, wall paneling, shelving, built-ins, flooring, stairs and the installation of millwork items including the hanging of doors. Many wood species used in finish carpentry work are graded according to appearance and include terms such as "selects," "superior" and "clear." Most lumber yards sell select in either C or D grade, and when a particularly fine appearance is required ponderosa pine in either C select or B & B better would be the proper selection.

Appearance grades of finish carpentry materials can generally be purchased in either vertical grain or flat grain, a reference to the pattern of growth rings. Vertical grain lumber is cut from a log so that the growth rings are perpendicular to the face of the lumber. Flat grain boards are cut from logs in such a manner that the growth rings are parallel to the face of the lumber (Figure 16-3).

Vertical grain boards are more resistant to abrasion and although more costly, should be used whenever flooring applications are considered (for instance, stair treads, nosing strips, wood thresholds). Flat grain boards will expose the softer spring growth of the tree and will absorb stain faster and in a more variegated pattern.

Standard sizes for select lumber are often referred to in terms of "quarters," which is the nominal thickness of the board. Nominal and surface thicknesses and widths are listed below:

Nominal Thickness	**Surfaced Thickness**	**Nominal Width**	**Surfaced width**
4/4	3/4″	2″	1½″
5/4	1–5/32″	3″	2½″
6/4	1–13/32″	4″	3½″
7/4	1–19/32″	5″	4½″
8/4	1–13/16″	6″	5½″
9/4	2–3/32″	7″	6½″
10/4	2–3/8″	8″ and wider 3/4″ off nominal dimension	
11¼	2–9/16″		
12/4	2–3/4″		
16/4	3–3/4″		

Grades for Western Region finish carpentry materials are based on the characteristics to be found in a board that has been dressed S4S (square 4 sides) and measures 1 inch × 8 inches × 12 feet in length. The characteristics of the grade will vary in proportion to this size board (that is, two small knots in any 12-foot length). Select grades are divided into three sub-grades: B & BTR—1 & 2 Clear, C-Select and D-Select. B & BTR—1 & 2 Clear is the highest appearance grade and many pieces graded with

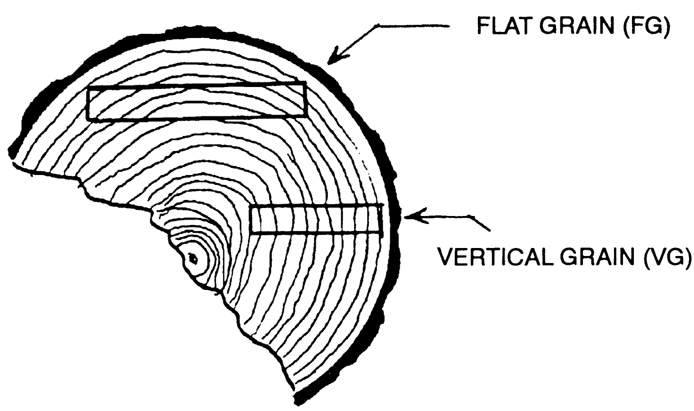


Figure 16-3 Flat and Vertical Grain Boards Cut from Logs.

this designation are perfectly clear while other have a few minor characteristics such as two sound tight pin knots or slight traces of pitch.

C-Select. ranks slightly below B & Btr in appearance and is permitted to have two small sound tight knots, light pitch over not more than half of its face, a small pitch streak and two very small pockets over its entire surface. (A pocket is a well defined opening between the annual growth rings that usually contains pitch or bark. A "very small" pocket is 1⁄16″ wide and 3″ long or 1⁄8″ wide and 2″ long. A "small" pocket is 1⁄16″ wide and 6″ long or 1⁄8″ wide and 4″ long or 1⁄4″ wide and 2″ long. A "medium" pocket is 1⁄16″ wide, 12″ in length and a "large" pocket will measure not more than 4 square inches)

D-Select. is the grade between the higher finish grades and board grade, and it can be obtained with a finish appearance on one side but with more numerous characteristics on its reverse side. D-Select lumber can have four small knots, four small pockets, medium pitch over two thirds of its face and one medium pitch streak in each 12-foot length. Australian clears are actually D-Select pieces cut 4 inches or wider and 6 feet and longer and contain degrees of pitch slightly in excess of those permitted under the D-Select grading classification. Pitch Selects are also similar in appearance to D-Select except these grades allow any amount of medium or heavy pitch.

Finish Grades

This grading category pertains to boards narrower than 5 inches and graded on both edges and the better side or face. The reverse face can be one grade lower. Finish grades are divided into three subgrades: Superior, Prime and E, each one available in VG (vertical grain), FG (flat grain) or MG (mixed grain—a combination of VG and FG).

Superior Finish. Many pieces are perfectly clear and this lumber is recommended for interior trim and cabinet work where stains, natural or painted finishes will be applied.

Prime Finish. Where finishing requirements are not as exacting, prime grade can be specified. This grade is permitted to have four fixed knots one inch or smaller, four medium pockets, medium pitch over not more than two thirds of its face area and limited pin holes.

E Finish. Boards that can't meet the exacting standards of Superior and Prime fall into this category, which allows six fixed 1 1⁄4 inch knots, one 3⁄4 inch hole from any cause for each 4 feet of length and six small pockets.

There are numerous other grades assigned to board lumber both rough or surfaced, for use in interior wall facings, shelving, siding, sheathing, cabinet work and general building purposes. These classifications apply to lumber 1 inch × 8 inch × 12 feet in length and fall roughly into one common grade and five alternate board grades. The Alternate board grades include "Select Merchantable Boards" used for paneling and shelving where a knotty appearance is required. "Construction" grade boards are used for subflooring, roof and wall sheathing and concrete form work. "Standard" grade boards have usage similar to construction grade, and "Utility" boards are often shipped in mixed West Coast species lots. Economy boards are suitable for crating, bracing and low-grade sheathing.

PLYWOOD PRODUCTS

Structural plywood panels are generally sold according to the veneer grade on their front and back surface, with designations such as C–D or B–C or A–C. Plywood panels are also sold according to their intended usage, such as sheathing, underlayment, and subflooring. Plywood is also identified as to its intended weather exposure—interior use, exterior application and any fire-rating requirements.

Plywood Veneer Grades

N—A smooth surface, natural finish veneer, free of open defects and composed of Select, all heartwood or all sapwood. This grade is used in natural finish furniture and cabinet work.

A—A smooth, paintable surface containing not more than eighteen neatly made repairs to its surface and used for those applications less demanding than N grade.

B—Plywood with a solid surface containing circular repair plugs and tight knots not exceeding 1 inch. Some minor splits in the veneer surface are permitted.

C Plugged—An improved grade of C where splits are confined in size to ⅛ inch in width, and knotholes are limited to ¼ inch and ½ inch.

C—Tight knots not exceeding 1½ inches are allowed and knotholes up to 1 inch across the grain are permitted. Limited splits are allowed and stitching is permitted.

D—Knots and knotholes to 2½ inches across the grain, along with limited splits and stitching characterize this grade.

The American Plywood Association stamps plywood panels with one of four exposure durability classifications:

Exterior—Made with a fully waterproof bond and designed for permanent exposure to the weather.

Exposure 1—These panels also have a waterproof bond and are used where long construction delays may expose the panels to high moisture conditions before being closed in. These panels are not meant to be used for permanent exposure to the weather.

Exposure 2—Constructed with intermediate glue. To be used where moderate delays in protecting the work are to be expected.

Interior—A plywood panel manufactured with interior glue since the panel is intended for interior usage only.

There are other categories of plywood that are performance rated by the APA and there are others that are classed as "specialty" panels.

Performance Rated Plywood

Sheathing Ext-APA—Used for subflooring and wall and roof sheathing as well as siding on utility buildings. An exterior grade material.
Structural I and II Ext-APA—For engineered construction applications, furnished unsanded.
Sturdi-I-Floor-Ext-APA—For use as a combination subfloor and underlayment where carpet and pad will be placed. This product is touch-sanded and manufactured as a tongue and groove panel.

Specialty Panels

Decorative—Rough-sawn, brushed, grooved and striated faced panels used in both interior and exterior applications for siding, paneling and built-ins.
High density overlay panels (HDO)—An abrasion-resistant panel that finds use as concrete form material or for signage, as well as for some countertops and cabinet work. These panels have a semiopaque resin–fiber overlay on both sides.
Medium density overlay panels (MDO)—A panel with a smooth, opaque, resin–fiber overlay on one or both sides that finds usage as a paintable surface for either interior or exterior application.
Marine plywood—Manufactured of Douglas fir or western larch only. Contains special solid core construction. Marine plywood can be purchased with high-density or medium-density overlay faces.
Plyform—Plywood especially manufactured for concrete form work where reuse is essential. This plywood panel is available in two subclasses: Class 1 and Class 2. Class 1 panels are the most commonly used since they are stiffer and stronger. Plyform with HDO faces is available when the finished concrete product requires a smooth surface.

Fire-Resistant Plywood (FRT)

Second generation FRT plywood used as roof sheathing has recently been found to have a delamination problem. The homebuilding industry began using FRT plywood years ago for roof sheathing, but within three to five years after installation the fire retardent chemicals turned the sheathing brown, causing the wood to delaminate and lose strength and start to crumble.

First generation FRT that uses ammonium sulfate as the retardent agent does not appear to pose much of a problem, only the ammonium phosphate second generation plywood that made its appearance in the early 1980s seems to present delamination problems. A third generation FRT containing no monoammonium phosphate and no diammonium phosphate is now on the market, and it appears that no delamination will occur when it is used.

A Glossary of Wood Terms

Bow—Longitudinal distortion of a piece of lumber from a true plane when measured from one end to the other.

Check—Separation of the layers of wood occurring generally across the rings of annual growth.
Crook—Distortion of a piece of lumber along its edge.
Cup—Distortion of lumber from a true plane measured from edge to edge.
Dimension lumber—Lumber cut to standard 2 × 4 thru 2 × 12 sizes in lengths ranging from 8 feet to 24 feet.
Heart—The small pith that occurs in the center of the log.
Sound knot—A knot that is as hard as the surrounding wood, shows no sign of decay and is solid across its face.
Split—Lengthwise separation of wood.
Tight knot—A knot firmly fixed in position.
Twist—A combination of cup, bow and crook.

RECONSTITUTED WOOD PRODUCTS

Products composed of wood fibers, wood chips, sawdust scraps from planers and "junk" trees such as aspen and alder, bonded together with sophisticated resins at high temperatures or high pressure, or both, are known as reconstituted wood products. Flake board, particleboard, hardboard and chipboard are prime examples of reconstituted wood products. Laminated beams, sometimes referred to as glue-lams are another form of reconstituted wood products.

These new products have many advantages over natural wood products:

- Production costs for particleboard and flake board are approximately 50 percent lower than plywood resulting in savings for the user.
- Panels of reconstituted wood won't shrink, crack, warp or twist like natural products.
- The panels can be impregnated with antifungal agents, pesticides or fire retardent chemicals at nominal cost.
- These panels are free from knots and other natural imperfections, therefore waste is kept to a minimum.
- These panels can be faced with a variety of hardwood veneers or through a "printing" process on vinyl film made to look like expensive natural wood veneers.

Reconstituted Wood Panels

Hardboard. A product made by bonding wood fibers with lignin, the natural adhesive found in wood, and other resins. Tempered hardboard is produced by impregnating the product with oils or synthetics and then baking it to create a harder, more water-resistant board, but the tempering process does increase the brittleness of the panel. Hardboard is often used as backer for other types of wall panels or it can be faced with a variety of plastic coatings to take on the appearance of a wood veneer or stucco.

Particleboard. A somewhat generic term but it is the proper name of a reconstituted wood panel containing very small wood particles bonded together with phenolic resins. Two subclassifications of particleboard would be wafer board and flake board. Wafer board is a panel product made of bonded flakes of wood in the 1/20th to 1/40th inch thickness range and 1¼ inch square or larger. Flake board contains the same bonded wood chips but these flakes are smaller and thinner. Particleboard and its variations are most frequently used as a substrate for veneered panel construction and as a base for high-pressure laminate panel manufacture.

OSB Board. Oriented strand board is an evolutionary product of the particleboard process. By arranging the placement or orientation of the narrow wafers of wood during the manufacturing process, a reconstituted wood panel with greater strength, rigidity and stability can be produced. OSB panels are made with three basic layers: the core containing strands arranged in either random or cross oriented patterns and top face and bottom face with strands oriented in the direction of the panel's length. When all three layers are compressed under very high heat and pressure, a strong, dimensionally stable panel will have been created.

LAMINATED STRUCTURAL WOOD MEMBERS

Often referred to as "engineered," wood products such as beam, arches, joists, trusses and studs are made from composite wood sections. The use of these engineered products will more than likely, grow rapidly in the years to come because of the better utilization of raw materials, along with advances in technology, combining to produce superior products at competitive prices. Some glu-lam beams are now priced competitively with Douglas fir timbers. A 6 × 12 Doug fir beam has a stress rating of 1,800 psi while a 5⅛ × 10½ glu-lam is rated at 2,200 psi.

New structural composite lumber products (SCL) and laminated veneer lumber (LVL) are being used more and more in residential and light commercial construction today. Joists with top and bottom chords made of plywood with a particleboard web is just one example of an SCL. The LVL concept involves preselecting wood veneers that meet high quality-control standards and then laying them up with a waterproof adhesive as heat and pressure are applied. All veneer grains in an LVL run parallel so as to attain the highest stress levels. Without the imperfections such as knots, splits and pockets in natural wood, these LVLs provide uniform performance when used repetitively.

MILLWORK

Millwork can probably be defined as any interior or exterior woodwork exposed to public view. Most superintendents envision millwork in terms of cabinetry work, paneling, architectural lumber, casework and veneered wood doors and door trim. The Architectural Woodwork Institute (AWI) sets the quality standards for the industry and has established three grades of architectural millwork:

Premium grade—The highest quality of material and workmanship and the most expensive grade.

Custom grade—The middle or normal grade of both materials and craftsmanship.

Economy grade—The lowest grade of materials and workmanship used where price outweighs quality.

Millwork Lumber

Wood selected for various millwork applications are chosen for several reasons: for color, for grain and for "figure," the pattern created across the grain. The color of wood is judged not only by its natural state but the color it will achieve when stained or finished. The natural grain pattern of some of the more common woods used for millwork purposes are known to many, but the figure can be enhanced by the way in which the board is sawn from the log. Boards can be sawed from logs in one of three ways: plain sawn, quarter sawn and rift sawn (see Figure 16-4).

Plain-sawn lumber will produce a board with broad grain and with the least amount of waste. Quarter-sawn wood will result in a straight grain board and in some species flake or figure patterns will appear. Rift-sawn lumber will display great contrast between the early and late tree growth. Lumber grades for millwork purposes will be categorized as Class I, II or III, with Class I being the highest grade and a comparison of all three grades for a typical hardwood board will reveal the basic differences.

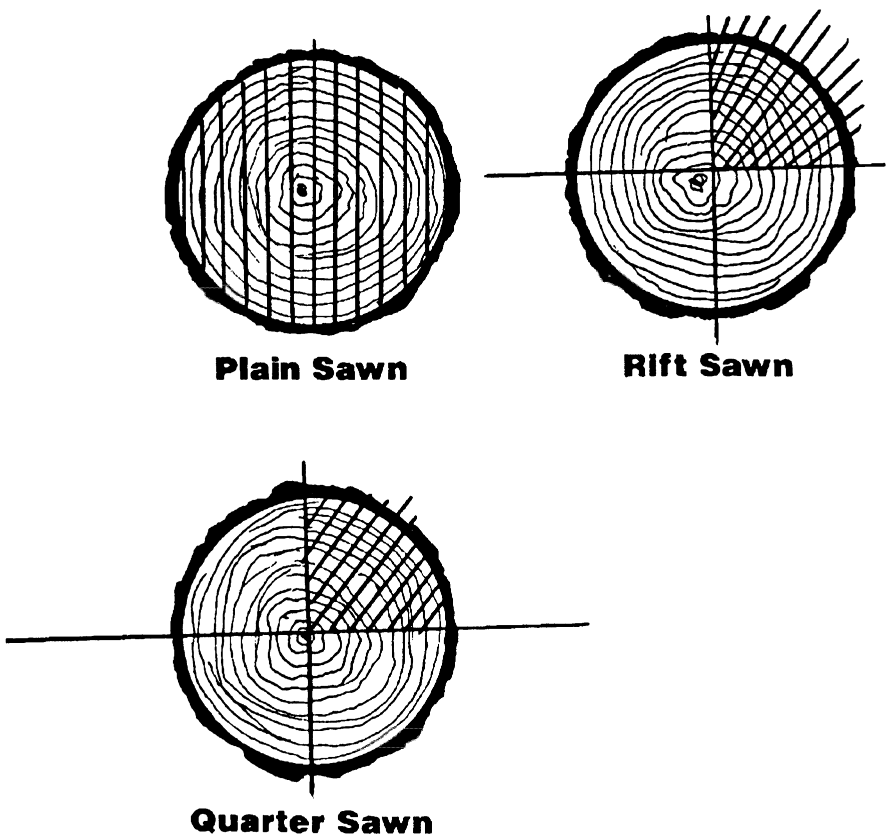


Figure 16-4 Method of Sawing Logs to Influence Appearance of Grain and Figure.

Defect	Grade I	Grade II	Grade III
Tight knot—not exceeding in diameter	⅛″	¼″	⅜″
Worm holes—not exceeding in diameter	None allowed	1⁄16″	⅛″
Patches—not apparent after finishing	18″	24″	36″
Pitch pockets or streaks not exceeding	None allowed	None allowed	None allowed
Checks, splits not exceeding	1⁄32″ × 3″	1⁄16″ × 5″	3⁄32″ × 5″
Stain	None allowed	Permitted in 25% of pieces	Unlimited

Although width dimensions for millwork lumber are the same as those for finish carpentry boards, the nominal and finish thickness of both hardwood and softwood millwork grade lumber does vary somewhat. Lumber used for millwork is first sawn, dried and then surfaced and sanded for end use before it is expected to meet finish thickness dimensions.

Nominal Thickness		Finish Thickness	
Inches	Quarters	Hardwood	Softwood
1″	4/4	¾″	¾″
1¼″	5/4	1 1⁄16″	1 1⁄16″
1½″	6/4	1 5⁄16″	1⅜″
2″	8/4	1½″	1½″
2½″	10/4	2″	2¼″
3″	12/4	—	2½″

Millwork lumber can be manufactured to various profiles by using cutting heads on moulders in the millwork shop to create all kinds of standing and running trim, terms that are frequently used interchangeably. There is a distinction between the two terms, however. Standing trim consists of items of fixed length such as a door or window casing, a window stool or sill or apron—any piece of trim that can be applied with a single length of wood. Running trim is trim of continuing length such as cornice or fascia work, chair rails, base and shoe mouldings.

Paneling

Wood veneers or facing veneers used for architectural millwork paneling can be bonded to either particleboard, plywood or hardboard. Particleboard has excellent flatness and dimensional stability, but only medium-density board displays excellent visual edge quality. Veneer plywood has fair flatness characteristics, good dimensional stability and good visual edge quality. Hardboards display excellent flatness and good to excellent dimensional stability, but are rated only good in visual edge quality.

Veneers for architectural wood paneling can be cut from logs in one of five ways: rotary, plain-sliced, quarter-sliced, half-round sliced and rift-cut (see Figure 16-5). Each cut produces different characteristics in the veneer.

Rotary cut—Follows the annual growth rings of the log and results in a veneer likely to produce a bold grain appearance.

Plain-sliced—Also called flat sliced. Produces a grain pattern similar to that of plain-sawn lumber.

Quarter-sliced—A series of stripelike configurations will be produced by this method. When oak is quarter sliced, sometimes flakes are created in the veneer.

Half-round sliced—Produces an appearance halfway between rotary and plain-sliced veneer.

Rift-cut—Veneers with accentuated vertical grain will be produced and flakelike appearances will be minimal.

The appearance of veneers is greatly affected by the way they have been cut from the log, but when these veneers are laminated onto substrates to create panels, the arrangement of the individual panels will create other interesting visual effects. Panels can be book matched, slip matched, random matched or end matched (see Figure 16-6).

Book matching is achieved by assembling veneers from the same flitch so that successive cuts are alternated face-up, face-down to create a symmetrical side-by-side appearance much like the pages in an open book. Slip matching is created by using successive veneers from the same flitch and laying them side by side with the pattern facing in the same direction. Random matching is just that, selecting veneers from the same flitch randomly and laying them side by side with no specific pattern in mind. End matching is created when the leaves of the veneer are book matched end to end and side to side.

Hardwood veneers are graded A and B, with A being the higher grade. Thirteen criteria are used in grading hardwood veneers, taking into consideration the presence of sapwood, heartwood, color streaks or spots, color variation, mineral streaks, small burl and pin knots, knots, worm holes, open splits or joints, shake or doze (a form of decay that creates a dull appearance in the wood), rough cuts, cross bars and inconspicuous patches.

Plastic Laminates

When plastic laminates are bonded to substrates these overlays fall into two basic categories: high-pressure laminates and low-pressure laminates.

High-pressure laminates are available in five different grades:

General purpose material—.05 inch thick for use on horizontal and high-use surfaces.

General purpose 28—.028 inch thick for vertical surfaces and medium-use exposure.

Cabinet liner grade—.020 inch thick, used to line cabinets.

Postforming grade—.042 inch thick, used to from radius edges, postformed counter tops.

Backer material—.020 thick, used on the reverse side of the laminated panel to provide balance and prevent moisture penetration.

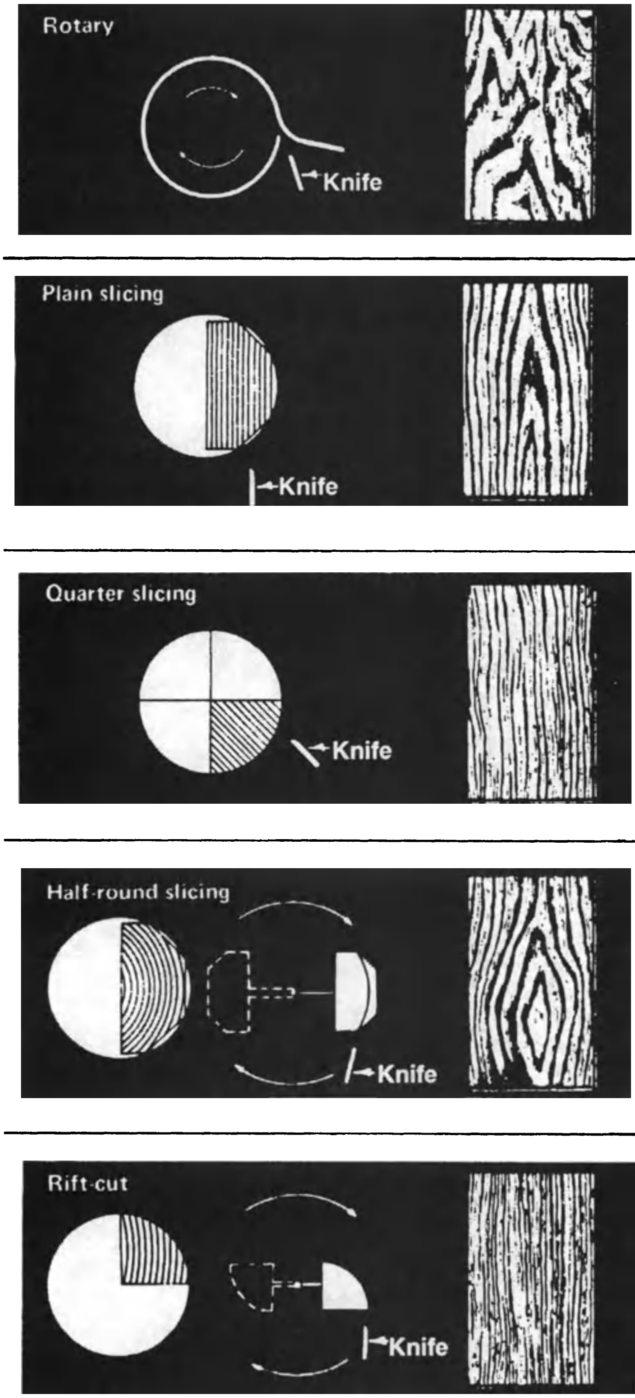


Figure 16-5 Methods by which Veneers can be Cut from Logs. Courtesy: The Architectural Woodwork Institute, Arlington, VA.

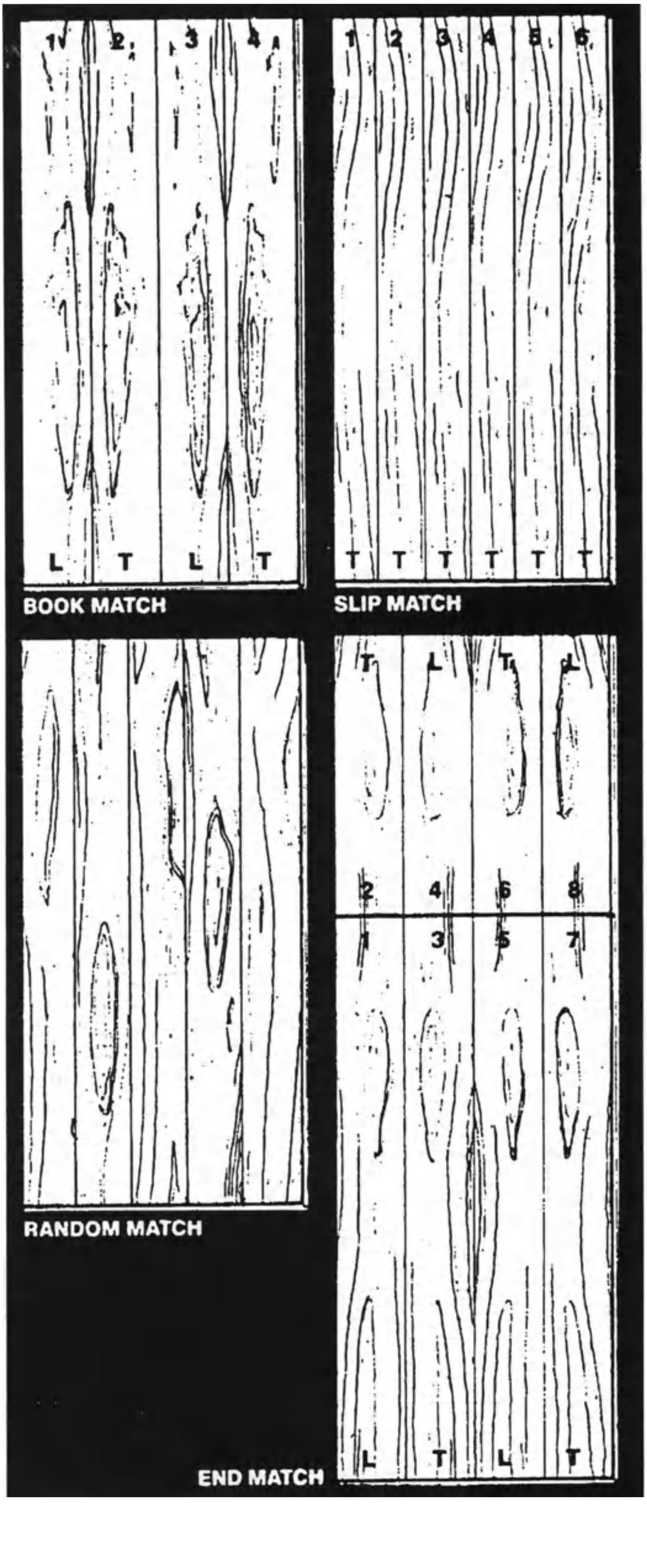


Figure 16-6 Arrangement of Veneered Panels for Visual Effect. Courtesy: Architectural Woodwork Institute, Arlington, VA.

Low-Pressure Laminates

There are a number of vinyl, polyester and melamine materials used to line cabinets or where high-use exposure is not required or economic considerations come into play. Wood doors in general, along with architectural wood doors, will be discussed in detail in chapter 18.

17

Roofing—Thermal and Moisture Protection

No need to stress the importance of a quality roofing installation. What superintendent has not experienced those angry telephone calls from a building owner complaining about persistant roof leaks. An entire building could have been completed to perfection, but that annoying roof leak will remain in the owner's mind above all else. Roof assemblies consist of substrate, the framing or surface under the roof, the insulation installed over this substrate and the roofing membrane material, and each component plays an important role in the overall integrity of the roofing system.

SUBSTRATE CONSIDERATIONS

The type of roof substrate may be a determining factor when deciding which one of the various types of roof assemblies will be used, and premature failure of roofing assemblies can often be traced to the quality or lack of quality of the substrate. Thermal expansion and contraction, deflection and soundness of the substrate are other factors to be considered prior to the selection and installation of the roofing membrane system.

Direct exposure to the elements may create differing rates of thermal expansion between all of the various components within the roof assembly. Parapet walls will probably expand, but at a lesser rate than the copper flashings that tie them together with the main roof deck. The roof deck may have expansion characteristics that differ considerably from all other elements adjacent to its surface. The following substrate conditions need to be taken into account if a long-lasting, weather tight roofing assembly is to be assured:

1. Excessive deflection will cause ponding or possibly failure in the membrane if its elastic limits have been reached.
2. Cracks in the substrate, particular if it is constructed of concrete, may be too large to permit spanning of the roofing membrane. Liquid-applied membranes quite often do not have the capacity to span cracks exceeding ⅛ inch.
3. Spalling or latience on concrete substrates will most likely prevent adherence of any liquid-applied primer or top coat.

4. Expansion of large areas of roof deck without any provision for a working expansion joint may cause rupture of the roofing membrane.

TYPES OF ROOFING ASSEMBLIES

Built-up roofs have three basic components: felts, bitumens and protective caps. This type of roofing assembly has had wide acceptance in the building industry since 1844, and to date, more than 50 billion square feet have been installed. This form of roof assembly began to be seriously challenged in the 1960s when advances in technology produced the single-ply membrane roof and, in later years, long life antichalking coatings advanced the popularity of relatively maintenance-free metal-clad roofs.

The popularity of single-ply membrane roofs not only introduced a new concept in roofing but by the use of new man-made elastomeric materials available in wide rolls, created a product that could be installed rapidly, with less-skilled workers and by companies requiring very little capital equipment. Technology continues to challenge three roofing requirements: ease of installation, long life, and maintenance-free performance. New developements in roofing materials will include increased use of ceramics and even ultrathin sheets of stainless steel membranes, but today's roofing assemblies are generally limited to one of the following five categories.

Built-up membrane roofs
Fluid-applied membrane roofs
Single-ply membrane roofs
Metal sheets and metal panels
Shingles, shakes and tiles

Built-Up Membrane Roofs

There are three basic types of built-up roofing:

Smooth surface—Without any gravel topping, these roofs are light weight and easy to inspect. When damaged the leaks are fairly easy to detect and correct.
Gravel surface—Aggregate is spread over the top membrane of a gravel-surfaced roof after a flood coat of bitumen has been applied in order to protect the membrane from the elements. Gravel-surfaced built-up roofs (BURs) are limited to slopes of 3 inches or less so that gravel slippage is minimized.
Mineral surface—A cap or top sheet can be obtained with weathering grade asphalt embedded with mineral granules to protect the surface of the BUR from the elements.

Built-up roofs have three components: bitumen—a semisolid asphalt or coal-tar pitch material used to coat and impregnate the felts, the felts themselves designed to act in concert with the bitumens to create the moisture resistant surface, and the base flashings that tie all of the roof elements together to create a watertight enclosure.

Bitumens

These materials are refined from coal or crude oil and become more fluid as they are heated. Bitumens not only soak into the felts to provide the waterproof element in the roofing assembly, but they also act as glue to hold these roofing felts together. The felts themselves, made of fiberglass or organic fibers, act in much the same manner that reinforcing acts in concrete—to provide tensile reinforcement necessary to resist the pulling forces at work on the surface of the roof.

Asphalt-based bitumens are available as straight run, cutback or emulsion. Straight-run asphalt is heated asphalt selected on the basis of degree of slope of the substrate, the steeper the pitch of the roof, the higher will be the softening point of the asphalt. Cutback asphalt is a bitumen that has been dissolved in a solvent so it can be applied at ambient temperatures, generally troweled on as a top coat. Asphalt emulsions are bitumens made with either a soap-type emulsifier, a bentonite emulsifier or a modified clay emulsifier, and they can be used either hot or cold on smooth surface BURs.

Coal-based bitumens are self-healing coatings that can be applied either at elevated temperatures as a liquid or when dissolved in a solvent and applied cold. When coal-tar bitumens are used, they require an aggregate surfacing material. The ability of coal tar to "heal" itself is its strong point. This material has a property known as "cold flow" causing it to fill in small hairline cracks and correct any alligatored surface by self-leveling once the roof has been installed.

Asphalt bitumens are graded according to degree of roof slope. Type I is to be used on dead-level roofs, Type II on flat roofs, Type III on steep pitches and Type IV on special steep roofs. Bitumens used on low- or no-slope roofs tend to have lower softening points.

Modified Bitumen Roofing Systems

Modified bitumen roofing systems today fall into two basic categories: SBS and APP. SBS, an abbreviation for styrene butadiene styrene, incorporates fiberglass and polyester reinforcements in the base materials resulting in a more durable, flexible, better weathering membrane. Atactic polypropylene (APP) modified bitumen roofing systems have a hot-melt adhesive built into the roof membrane that allows the seams to be "torched" to seal and bond the membranes together. APP products cannot be hot mopped in place. Modified bitumen roofing systems generally have thicker felts and have greater elasticity, temperature range and elongation qualities than conventional BUR materials.

Vented Base Sheets

Gases tend to build up under roofing membranes, as does condensation, from time to time and an application of vented base sheets will allow these vapors to exit to the atmosphere. Vented base sheets are constructed of a heavy fiberglass mat coated on both sides with asphalt. One side of the sheet has a granular surface to provide the necessary spaces or paths for gases to exit. Another type of vented base sheet has a series of perforations through which bitumen flows to seal it to the substrate below. The spaces between the glued down perforations will provide a passageway for vapors.

The first step in a maintenance program for BURs is to keep roof traffic to a minimum. In those areas where traffic is to be expected, say around rooftop equipment and roof hatch locations, walkway pads should be installed. Debris must be kept off the roof at all times so that sharp objects can't penetrate the assembly. Roof drains should be free from accumulations of leaves and other debris and kept free-flowing. Built-up roofs should be inspected yearly and minor repairs made quickly.

Fluid-Applied Roofs

Fluid-applied membrane roofs can be either cold or hot applied, but they require a dimensionally stable substrate. When applied over concrete, a prime coat is sprayed rolled or brushed on, followed by a top coat. Moisture content of a concrete substrate is critical, and it is advisable to have the manufacturer's representative inspect the deck for acceptable levels of moisture and acceptability of any surface imperfections, including cracks that could ultimately affect the performance of the coating. Some roofing specifications require that a nylon or fiberglass mat is to be mopped directly onto the substrate after the prime coat has been applied but before the top coat is in place. Joints or cracks in other substrate materials are generally taped with nylon or fiberglass-reinforced tape to allow the fluid-applied membrane to span these spaces. Combination liquid neoprene-hypalon or urethane rubber systems can be installed over concrete or plywood substrates. Some of these liquid coatings contain antislip agents such as ground walnut shells.

Urethane foam roofs are another form of fluid-applied roofing. Urethane foam can be sprayed directly on the substrate to provide a watertight membrane and create an excellent insulated assembly. These roof systems do require a protective coating on top of the polyurethane, which will act as protection against UV (ultraviolet ray) degradation and physical damage to the foam. Foamed roofing materials are an excellent choice for reroofing over an existing roof, particularly when that exsiting surface is irregular or of an odd shape.

Urethane roofs can be easily damaged by foot traffic, and their finish appearance is generally wavy and rough. These characteristics should be considered when a foam-roofing assembly is being considered. Liquid-membrane roofs can provide a durable surface that can be easily repaired, and when a leak does appear it is relatively easy to trace its source and location.

Single-Ply Membrane Roofs

Single-ply membrane roofs can be categorized as ballasted and non-ballasted and subcategorized by materials of construction as outlined below:

1. Thermo setting
   EPDM—Ethylene Propylene Diene Monomer
   Neoprene
   PIB—Polyisobutylene
2. Thermo plastic
   CSPE—Chlorosulfenated polyethylene

CPE—Chlorinated polyethylene
PVC—Polyvinyl chloride

3. Composites—Several of the materials in the previous categories bond to various types of backer sheets to form a composite sandwich:
   Glass reinforced EDPM and neoprene sheet
   Nylon reinforced PVC or butylorneoprene
   Polyester reinforced CPE or PVC
   Modified bitumen bonded to polyethlene and aluminum backing or bonded to only polyethylene

When single-ply membranes are applied directly onto a substrate, they must be secured in some manner to prevent uplift when negative air pressure acts on their surface. Depending on the structural ability of the roof-framing system to withstand additional loads, ballast in the form of stone or aggregate spread across the membrane will hold it in place, or if the structure was not designed for any additional weight, adhesives and mechanical fasteners will be used to secure the material in place.

The more common membrane materials in use today are:

EPDM—Ethylene propylene diene monomer membrane is a thermo setting material that can be sealed with a contact adhesive or heat welded when certain formulations are used. Very elastic, flexible, ozone and UV resistant, EPDM membranes are tough, weather and abrasion resistant, roofing materials. During the installation of an EPDM roof the talc that is applied during manufacture must be completely removed from edges that will be lap-seamed. Laps should be at least 3 inches wide and free of talc, dust, or oils, in order to ensure that a proper seal has been made.

Hypalon—A thermoset synthetic rubber made by Dupont, hypalon is a tough, long-lasting roof membrane. By adding sulfonyl chloride groups to the polymer chain during manufacture, hypalon is given the ability to progressively cure when exposed to moisture and UV rays after installation, adding considerably to its strength and durability. When hypalon roofing sheets are sealed, a tool emitting a stream of superheated air is used to soften the rubber while it is being pressed together to create a fused joint as strong as the membrane itself.

Neoprene—A synthetic rubber compound that displays good resistance to oil, solvents and grease. Sometimes neoprene membranes will receive a coat of hypalon to make them more weather resistant.

PIB—Polyisobutylene is a nonvulcanized sheet of roofing membrane that is furnished bonded to a nonwoven reinforced backing material. This composite sheet is weather resistant and stands up quite well in the presence of ultraviolet ray penetration. PIB sheets are not too resilient when first installed but will cure to a rubberlike consistancy over time. Sheet laps are sealed with either a heat gun or by solvent welding. Thermoplastics such as PVC, ECB and EIP are materials that soften when coated with a solvent or are exposed to heat. These materials are not as elastic as EPDM, neoprene or hypalon. They tend to stretch when exposed to heat, but they do not return to their original shape after cooling, an important fact to remember when observing an installation in either hot or cold weather.

PVC—Polyvinyl chloride was one of the early single-ply membranes available in the marketplace. This material can be purchased in either glass or polyester fiber reinforced form, or it is available nonreinforced. The PVC membrane without reinforcement tends to expand and shrink to a greater degree than the reinforced membrane. ECB (ethylene copolymer) and EIP (ethylene interpolymer alloy) are two lesser known thermoplastic roof membranes.

The Upside-Down Roof—IRMA

The inverted-roof membrane assembly places the membrane directly on the substrate (see Figure 17-1) followed by a layer of insulation and topped off with a protective mat and either 10 pounds gravel ballast or a ballast paver. Unlike other roof assemblies where the membrane is exposed to the elements and to potential damage from pedestrian traffic or debris, the IRMA membrane nestles under protection afforded by the insulation and the ballast. Being shielded from the rays of the sun, the IRMA is also protected from the effects of UV rays. Also known as PMR (protected membrane roof), most installers of this system use EPDM membrane loose-laid directly on a concrete substrate or metal deck, but where high humidity can be expected inside the building, a vapor barrier should be placed between the metal deck and the roof membrane.

Metal-Sheet Roof Panels

Metal roofs have been used for hundreds of years and can be divided into two basic groups: preformed metal and formed metal. Preformed metal roofs are manufactured in sheet form and installed with joints nailed or screwed together in place. Preformed-metal roof panels find application where there is a steep pitch on a roof since positive drainage is required to ensure that the joints will not leak. Formed-metal roofing can be installed on sloped roofs with a pitch not less than 1½ inches in 1 foot. The batten type system is frequently used since it results in a maintenance- and leak-free roof. Formed-metal roofing materials range from relatively low-cost aluminum to copper,

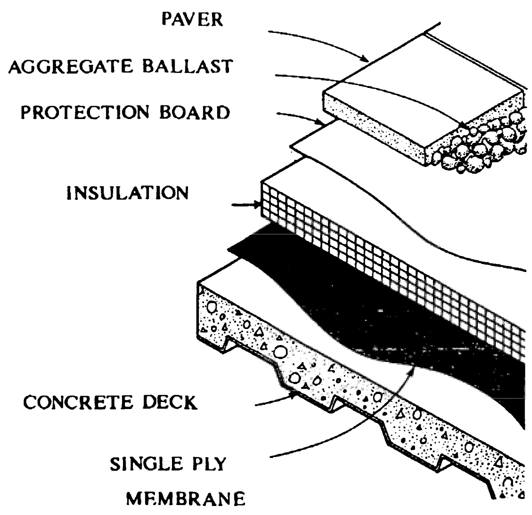


Figure 17-1 The Inverted-Roof Membrane Assembly—IRMA. (Reprinted from Manville Roofing Systems Division brochure with modifications.)

lead-coated copper, terne-coated stainless steel and type 304 stainless steel. Aluminum roofing is generally coated with one of the nonchalking, long-life fluorocarbon finishes such as Kynar™ or Fluoropon™.

Shingle, Shakes and Tiles

These kinds of roofing materials are actually watershedding materials rather than waterproofing materials, since they rely on roof pitch to rapidly drain the water from the surface of the roof. Slopes of 3 inches to 4 inches per foot are recommended in order for these products to work effectively.

Asphalt shingles are widely used for economy and ease of installation. When used on roofs with a slope below 3½ inches per foot, a layer of 15 pound felt should be placed under the shingles, and exposure should be 4 inches to the weather instead of the standard 5 inches to the weather on steeper slopes.

Wood shingles require installation over furring strips so that air can circulate around their underside and allow them to dry between rainfalls. Slate shingles are durable, extremely long lasting, and expensive. Most slate shingle work will be found in restoration projects such as institutions of higher learning, museums, churches or historical structures.

Porcelain enamel shingles and tiles as well as clay and concrete tiles find wide acceptance in various parts of the country. Mission or Spanish style roofs are popular in the Southwest. Mediterranean architecture is popular along coastal areas and used primarily in residential or low-rise commercial and retail buildings. Metal shingles find application on agriculture buildings, commercial and light industrial buildings where long life and asethetic considerations come into play.

Roof Flashings

The other member of the roofing triad are flashings that permit differential movement between all components of the roofing system while maintaining a watertight assembly. Whenever the continuity of the roof membrane is interrupted, some form of flashing will be installed to bridge the gap. Typical flashing applications (see Figure 17-2) will include:

Gravel stop—A metal flashing attached to the edge of the roof to protect and secure the edge of the roof membrane. When ballast is placed on the roof, the gravel stop does what its name implies—it prevent the gravel from rolling or washing over the roof edge. Gravel stops have architectural value and are generally constructed of painted aluminum, stainless steel, copper or terne. The gravel stop must be firmly secured but allow for thermal expansion. It must be of sufficient gauge to prevent "oil canning."

Copings—Similar in nature to gravel stops except they are placed on top of perimeter parapet walls to secure the base flashing continuing upward from the horizontal roof surface.

Base flashings—Usually elastomeric materials that provide watertight integrity at the perimeter of the building and make the transition from the horizontal surface

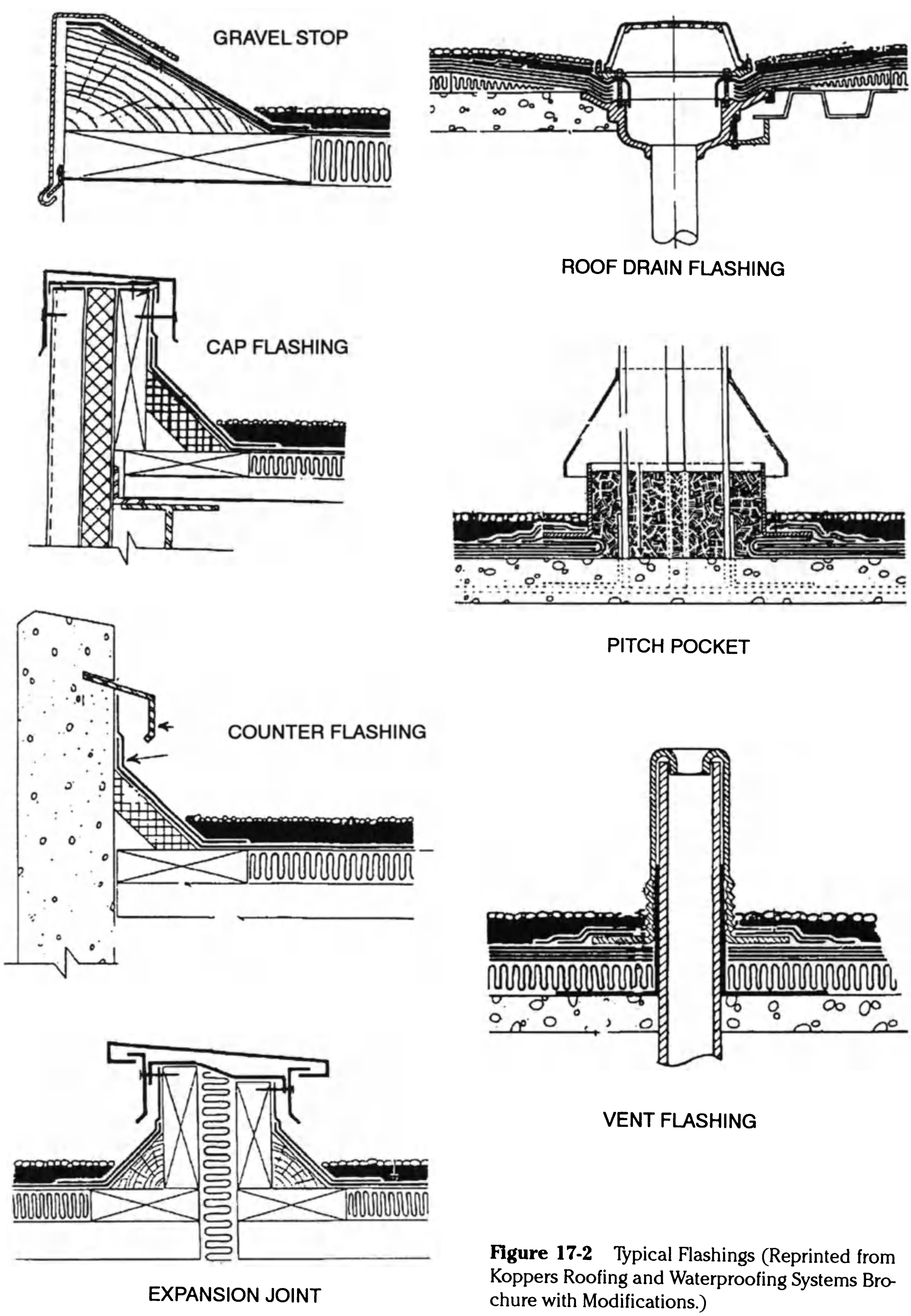


Figure 17-2 Typical Flashings (Reprinted from Koppers Roofing and Waterproofing Systems Brochure with Modifications.)

of the roof to a vertical surface at the parapet or other projections above the roof line. These flashings are quite often used in conjunction with counter flashings.

Counter flashings—These flashings act as a shield to cover the seamed base below and are generally made of aluminum, cooper, lead or stainless steel. Counter flashings can be surface applied with fasteners or can be inserted into a reglet cut into the vertical surface where it is to be installed.

Counter flashings are frequently used when rooftop equipment bases have been flashed into the roof field.

Pipe and conduit flashings—Whenever conduits, pipes or sleeves through which they pass penetrate the surface of the roof they will be flashed into the roof surface with base flashing over which counter flashing will extend. There are factory supplied "boots" that slip over the pipe, conduit or sleeve, which is fastened to the rook deck and then flashed over. The counter flashing, often furnished along with the boot completes the assembly.

Roof-drain flashing—A major source of roof leaks if the proper flashing has not been installed and installed correctly. Water tends to dam around these drains, particularly when they are not cleaned periodically, and all seams and joints must be sealed carefully. Many roof drains that are usually furnished by the plumbing contractor can be purchased with flashings especially designed for them. These flashings, installed according to manufacturers instructions, will certainly lessen the problem.

Roof-vent flashings—Roof vents installed to allow trapped moisture to vent to the atmosphere often are furnished with attached base flashing.

Pitch pockets—Another method of protecting the integrity of the roof when pipes or conduits penetrate the surface. The "pocket" is usually formed of copper and fastened to the roof deck. Pipes penetrating the roof will enter the pitch pocket from below and then the pocket will be filled with pitch, a black, viscous tar distillate that "cold" flows to seal the spaces around the penetrations. Pitch pockets require periodic inspections when first installed to ensure that the pocket is kept full of pitch as it settles in around the penetrations.

Expansion joint covers—When a large expanse is being roofed, an expansion joint will allow for movement in a controlled manner. Expansion joints can be purchased with flexible elastomeric bellows exposed to the atmosphere, while other expansion joints are created of metal with slip joints requiring an elastomeric cap.

Ridge flashings—Along with valley flashing and eave flashings these are forms of flashings associated shingled roofs. Valley flashings provide a path for water flow while protecting the substrate because a shingle cannot be formed to fit that configuration. Ridge flashing prevents water infiltration at the ridge of the roof where the shingles meet, and eave flashings prevents driving rain from blowing under the edge of the shingle.

Gutters and leaders—Although not specifically known as flashings, the purpose of both materials is to direct water away from the roof in such a manner that ice build-ups will not create capillary action that can draw water uphill under the first row of shingles.

Steps to Prevent Roof Leaks

1. The most frequent source of roof leaks is at the perimeter of the building because more movement occurs at that point than any other except at structural expansion joints. At parapets, use nonreinforced elastomeric expansion joint material that can give and take movement. For flush-edge roofs, install a factory fabricated fascia system—not a gravel stop.
2. Roof penetrations, primarily at roof drains, are the next most frequent cause of leaks. Failure of the roof membrane to adequately flash around the body of the roof drain will cause leaks as the pipe expands and contracts over time. Flashing made specifically for roof drains must be installed to avoid leaks in this area.
3. Leaks in the field of the roof can come from abuse, from movement of the substrate or from blisters caused by trapped moisture.
   a. Sharp objects and debris must be kept off the roof to avoid accidental penetrations. In high traffic areas around frequently maintained rooftop equipment a path of walkway pads will prevent damage to the roof surface.
   b. Care should be taken to avoid spilling solvents, cutting and lubricating oils on roofing materials that will become softened or even dissolve in their presence.
   c. By the use of proper roofing accessories such as expansion joints and flashings, splits caused by temperature changes, wind loadings, building settlement and other natural forces will be kept to a minimum. Only with the proper flashings can the shear and tensile stresses that act on roofing membranes be controlled and prevent splits because of movement.
   d. Roof vents will allow trapped moisture to escape greatly lessening the potential for blisters that form when water trapped under the membrane turns to vapor. Most manufacturers recommend one vent for each ten squares of roof surface, and one-way vents allow moisture to escape but resist the entry of moisture from the atmosphere.

THERMAL INSULATION

Insulation serves two purposes: to keep heat in the building during cold weather and to keep heat out of the building during hot weather. The roof area represents the largest source of heat loss or heat gain within a building. The efficiency of thermal insulation is measured in a number of ways by "K" factor, "C" factor, "R" value and "U" value.

K factor is an expression of thermal conductivity that relates to the quantity of heat that will flow through a 1-inch thick material during a 1-hour period when there is a 1-degree F difference in hot- and cold-side temperatures.

C factor is the measure of thermal conductance similar to the K factor, but it pertains to materials thicker than 1 inch having properties that are not uniform through its cross section.

R values expresses the ability of a certain material to resist heat flow or transmission. R value is the reciprocal of a C value.

U value is the measurement of heat that will flow through a specific 1-foot square area during 1 hour taking into consideration the insulating value of any air space within the building such as the one that exists in a cavity wall.

Aged Thermal Values

Before 1983 manufacturers of polyurethane and poly isocyanurate insulation products rated the thermal value of their materials at time of manufacture. But these insulating values were found to decrease over time as air and moisture infiltrated into the foam cells diluting the fluorocarbon gas in these cells. Subsequently aged C and R values are published for these two types of materials and represent the thermal loss that may occur over time.

Insulating Values and Other Useful Information for Materials Frequently Used in Construction

Type of Insulation	"R" Value/Inch	Where Installed	Resistance to Damage Water	Moisture	Fire
Fiberglass batts	3.0–3.17	Walls, floors, ceilings	G	E	G
Rock-wool batts	3.0–3.7	Walls, floors, ceilings	G	E	E
Rigid fiberglass	3.8–4.8	Walls, ceilings, roofs, foundation walls	G	E	G
Phenolic foam	8.3	Walls, ceilings, roofs	F	G	G
Expanded polystyrene	3.6–4.4	Walls, ceilings, roofs	F	G	P
Extruded polystyrene	5.0	Foundations, underslabs, walls, ceilings	E	E	P
Isocyanurate	5.6–7.7	Walls, ceilings, roofs	G	E	P
Polyurethane foam	5.8–6.8	Walls, ceilings, roofs	E	E	P
Isocyanurate foam	4.3	Walls and ceilings	F	G	F
Magnesium silicate foam	3.9	Wall cavities	F	G	E
Perlite	2.5–4.0	Concrete block fill	F	G	G
Rock wool-loose	2.8–3.7	Ceilings	G	E	E

18

Doors, Door Frames and Finish Hardware

Doors can be categorized as a means of closing off building entrances, exits, and interior spaces to people and vehicular traffic, but their individual functions as well as their materials of construction can range far and wide. Frames and hardware hold doors in place, but things get a little more complicated than that.

DOORS

This broad group of products can be subdivided into:
Pedestrian doors—Swinging, sliding, folding, pivoting and pocketing.
Service and vehicular traffic doors—Roll-up, vertical rise, sliding, swinging impact.
Special doors—Gas and fume tight, blast resistant, dark room, lead shielded, freezer doors.

The more frequently encountered door types in a construction project will be pedestrian and service–vehicular traffic doors, and the most frequently encountered pedestrian doors will be made of aluminum and glass, hollow metal or wood, either fire-rated or nonfire rated. The most frequently encountered door frames are hollow metal, followed possibly by aluminum frames with wood frames coming in dead last—at least in commercial and industrial projects.

Hollow-Metal Doors and Frames

Although metal doors and frames have been around for quite some time, the hollow-metal door and frame we know today did not gain popularity until the early 1950s. Today's hollow metal frames are available in five configurations:

Set-up and welded or knocked-down (KD) nonrated door frames.
Fire-rated frame assemblies.
Borrowed lights.
Entrance unit frames with sidelights, transoms or both.
Specials.

Hollow-Metal Door Frames. Standard hollow-metal frames are available as set-up and welded (usually specified when both door and door frame will be subjected to high impact, and rigidity of frame is a prime consideration), and KD, generally confined to interior door frame usage. The KD frame has the added advantage of being able to be assembled and installed after interior-wall framing and drywall is in place. This "slip-on" type frame design is invaluable because it eliminates the need for early frame delivery and allows for rapid installation once it is received on the job. Caution has to be taken to ensure that "spreaders" are kept intact between jambs at the floor level to maintain a plumb installation.

Hollow-metal frames are available in a variety of sizes, metal gauge thicknesses, jamb width and attachment devices. Masonry and stud-strap anchors or compression anchors are available, and depending on the type of wall construction and type of hollow-metal frame being supplied, installation techniques may vary. (See Figures 18-1 for masonry construction, 18-2 for steel-stud walls and 18-3 for wood-stud construction.)

Hollow-Metal Doors. Hollow-metal doors are manufactured in three standard types; full flush, seamless and stile and rail (see Figure 18-4). The full-flush door, available in 1⅜ inch and 1¾ inch thickness, constructed of 16-, 18-, or 20-gauge metal has no visible seams on the face of the door, although there will be exposed seams on the vertical edges where the front and back face pans join and lock together.

The seamless door, available in the same thickness and gauge metals as full flush, have no visible seams on either front and back face nor on its vertical edges. The stile-and-rail hollow-metal door has an internal tubular stile and rail that acts as a structural member. These components are mitered and welded at the corners and are covered by either flush or recessed panels on both faces. A stile-and-rail door is available only in 1¾ inches thickness and is generally built of 16-gauge steel with face sheets of 18-gauge material.

Various manufacturers differ in their individual manufacturing techniques but there are six types of standard core construction used in hollow-metal doors: vertical stiffeners, grid systems and honeycomb cores (for added rigidity and strength), mineral core (for fire ratings) and polystyrene and polyurethane foam (for insulating purposes). Refer to Figure 18-5.

The kalamein door, a kiln dried structural wood core encased with metal faces front and back and locked type metal edge seams is rarely used these days.

Fire-Rated Hollow-Metal Doors and Frames

There are four basic requirements in order to achieve a fire-rated opening: a fire-rated and labeled frame and door, fire-rated and approved door closer, approved latching device with proper latchbolt length and steel-bearing type hinges. There is a wide range of codes affecting the use of fire doors, made more confusing by the requirements of local inspecting authorities, but there are certain basic rules that apply to fire rated hollow metal doors and frames.

RECOMMENDED ERECTION INSTRUCTIONS

IMPORTANT NOTES:

1. **STORAGE OF FRAMES AT THE JOB SITE** — Frames shall be stored under cover on the building site on wood sills or on floors in a manner that will prevent rust and damage. Avoid the use of non-vented plastic or canvas shelters which create a humidity chamber.

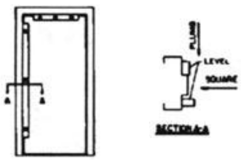
2. **GROUTING AND BACK PAINTING OF FRAMES** — When temperature conditions necessitate the use of anti-freezing agents in plaster or mortar, or the frames are to be fully grouted, the inside of the frames must be coated with a bituminous water resistant paint by the contractor responsible for installation.

3. **ASSEMBLY OF FRAME** — Follow manufacturers recommended procedure.

4. **ASSEMBLY TOLERANCES** — Refer to Installation Guide for Doors & Hardware. (Copies may be obtained from Door and Hardware Institute, 7711 Old Springhouse Rd., McLean, VA 22102.)

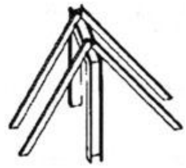
BRACING FRAMES BEFORE WALL CONSTRUCTION

NOTE: Shipping bars should not be used as spreader. Remove shipping bar before setting frame.



PLUMBING THE FRAME

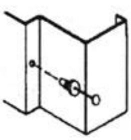
The contractor should provide himself with a carpenter level, square and spreader. Set the frame in desired location and level the header. Shim under jambs if necessary. With frame on line, set spreader and fasten jambs to floor through floor anchors.



BRACING THE FRAME

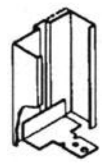
Brace the frame as shown or shore to the ceiling. *Do Not Brace In The Direction Of Intended Wall.* Plumb and square jambs.

RUBBER SILENCERS AND EXTENDED BASE ANCHOR



INSTALL RUBBER SILENCERS

Cut the point from a #6d box or finishing nail. Insert nail in hole to elongate rubber silencers. Moisten the end and insert rubber silencers in predrilled holes on frame stop, remove nail. *NOTE: Install rubber silencers before frame erection to avoid grout filling rubber silencers holes.* In some cases rubber silencers are factory installed.



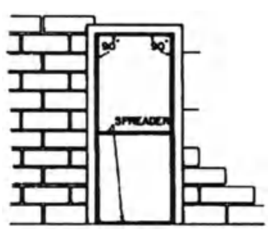
EXTENDED BASE ANCHOR

Extended base anchors are supplied upon request only when required for power tool attachment.

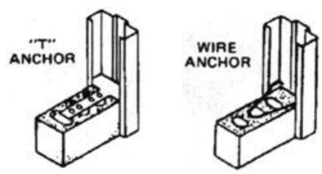
MASONRY CONSTRUCTION

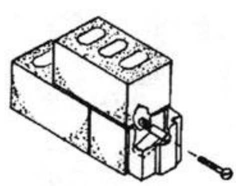
SPREADER

Typical wood spreader must be square and fabricated from lumber no less than 1" thick. Correct length is the door opening width between the jambs at the header. Cut clearance notches for frame stops. Spreader must be nearly as wide as frame depth for proper installation.
i.e., Single door 3'0" = 36"



1. Set and plumb frame. 2. Install three anchors per jamb at hinge and strike levels as wall is laid up. Grout frame in the area of the anchors. Frames may also be supplied with anchors welded in place. 3. A second spreader is recommended at the mid point of the door opening to maintain the door opening dimension. 4. Continually check plumb and square as wall progresses.

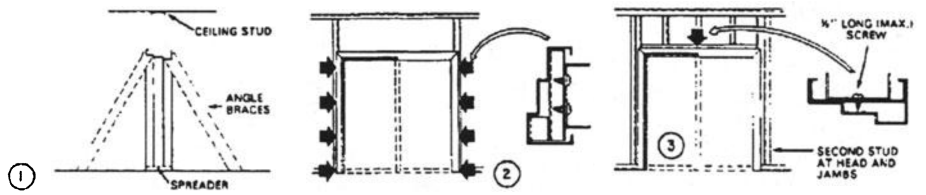




EXISTING WALL ANCHOR

Figure 18-1 Hollow-Metal Frame Installation Instruction for Masonry Walls. Courtesy: Steel Door Institute.

DOUBLE EGRESS FRAMES STEEL STUD WALL CONSTRUCTION



1. ERECT FRAME:

Stand frame up in desired location. Anchor one jamb to floor and set spreader on floor from anchored jamb to loose jamb. Position and anchor second jamb. Plumb, level and square frame, then brace. Also install a vertical brace at center of frame.

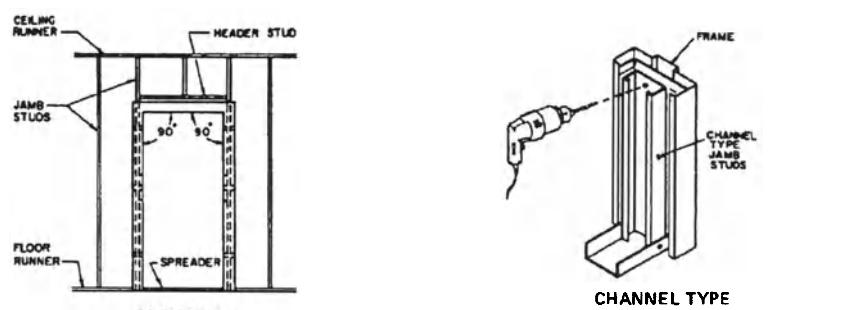
2. ANCHOR JAMBS:

Erect jamb studs and attach frame anchors to studs using screws or welding. If using screws, the installer should drill from the back side of the stud, through both the stud and anchor, then attach screws. Refer to "Steel Stud Wall Construction" Figure 1. Number of anchors and locations will vary with manufacturer.

3. ANCHOR HEADER

Header anchor requirements will vary. The manufacturer's installation requirements should be followed.

STEEL STUD WALL CONSTRUCTION



ELEVATION

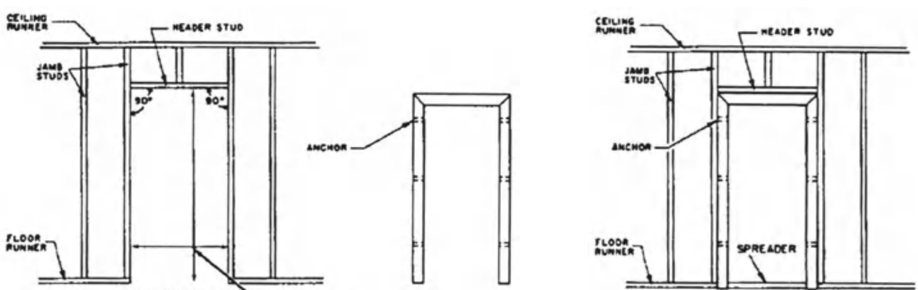
CHANNEL TYPE STEEL STUD

1. Install minimum three anchors per jamb at hinge and strike levels. Position anchors in frame through the throat and tap in with a hammer. Frames may also be supplied with anchors welded in place.
2. Square, brace and plumb frame as shown.
3. Set spreader. Attach jambs to floor through floor anchor or floor extension. Install jamb studs to floor and ceiling runners and tightly against frame anchors.
4. Attach studs to frame anchors as shown.

Position studs in frame throat and attach to anchors with screws or weld. If using screws, the installer should drill from the back side of the stud, through both the stud and anchor, then attach screws. Refer to Item #1, Elevation, for quantity and position of anchors.

NOTE: When attaching header stud to jamb studs, be sure the stud is above frame header. This will assure ample room for attaching plaster lath or drywall and will not interfere with installation of hardware attached to frame header.

STEEL STUD WALL CONSTRUCTION, STUDS ERECTED PRIOR TO FRAME INSTALLATION



ELEVATION

Consult manufacturer's instruction for rough opening dimensions.

1. Insert anchors into jambs. Type, number and location will vary with manufacturer.
2. Place frame in rough opening.
3. Set spreaders, level, square and plumb frame.
4. Secure anchors to steel stud as per manufacturer's instructions.

Figure 18-2 Hollow-Metal Frame Installation Instructions for Steel-Stud Framing. Courtesy: Steel Door Institute.

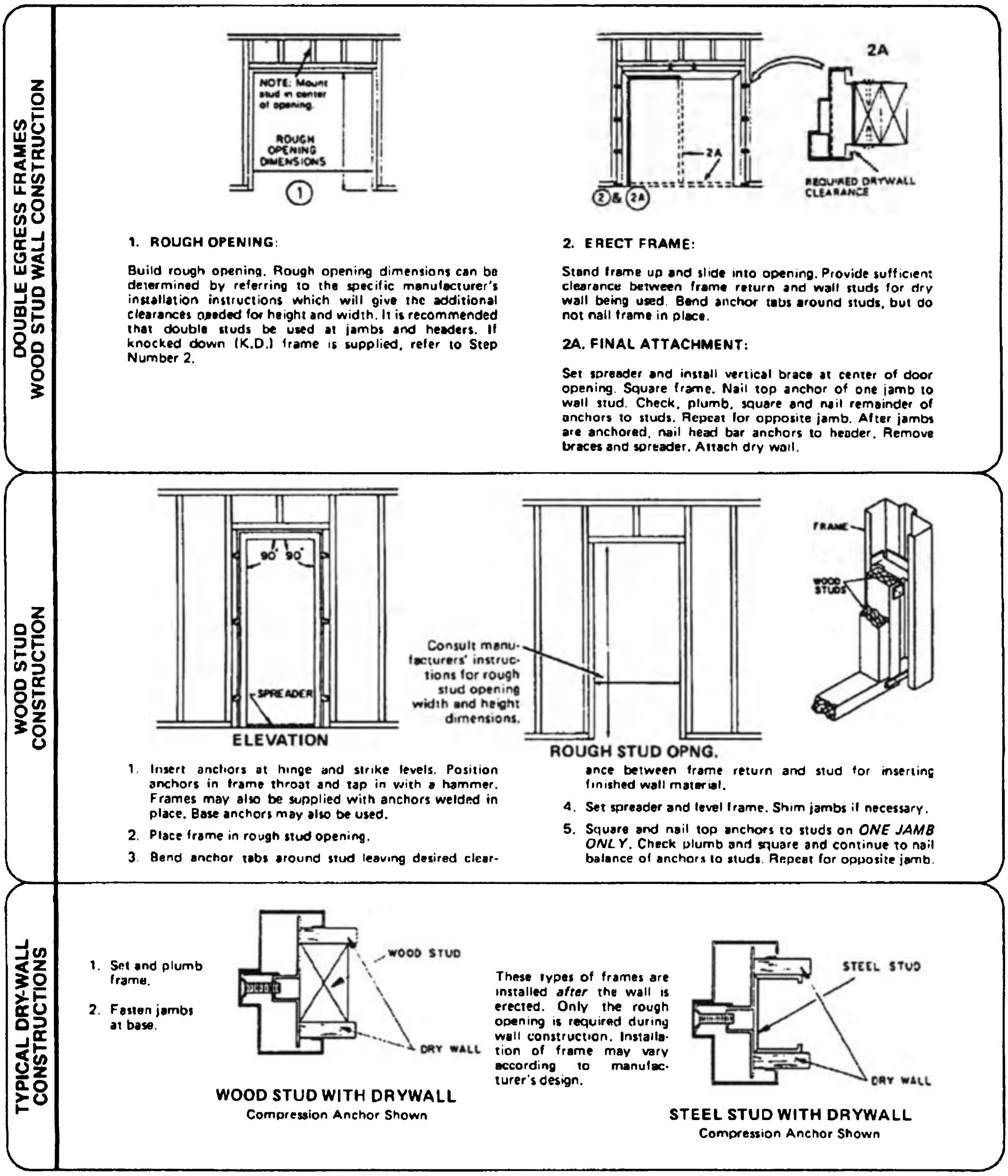


Figure 18-3 Hollow-Metal Frame Installation Instructions for Wood Framing. Courtesy: Steel Door Institute.

Fire-Rated Frames. Metal frames for fire doors are not affected by the same exposure ratings that apply to doors. There are no "hour" fire ratings for frames unless the label specifically states that the frame is rated for something less than 3 hours. If the frame bears a label indicating that it qualifies as a frame for a fire door, it will support a 1/3-hour, ¾-hour, 1½-hour or a 3-hour fire door.

Steel doors, however do carry different fire-rating classifications, and the rating depends on the exposure limitations of the door itself. Fire doors are classified and rated as indicated in the following table:

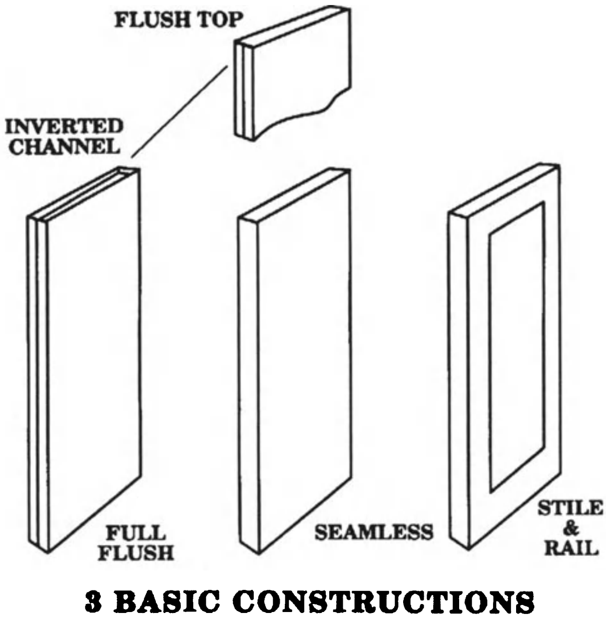


Figure 18-4 Three Types of Hollow-Metal Door Construction. Courtesy: Steel Door Institute.

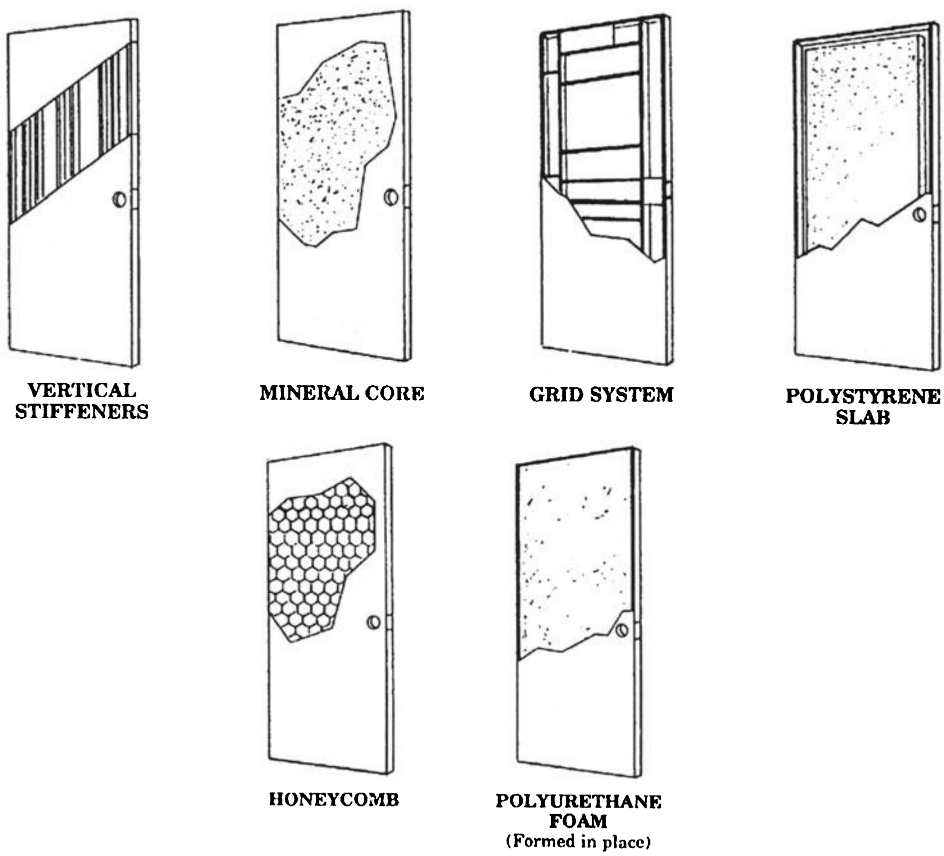


Figure 18-5 Various Types of Core Construction for Hollow-Metal Doors. *Source:* Steel Door Institute Cleveland, Ohio.

Class/Rating	Description and Use	Max. Glass Area Permitted	Wall
Rating			
A 3 hours	Opening in wall separating a building or dividing a single building into two fire divisions	None	3, 4
B 1½ hours	Stairwells, elevator shafts, mechanical equipment rooms	100 square inches	2
B 1 hour	Door openings from corridors and room	100 square inches	1
C ¾ hour	Interior doors	1,296 square inches	1
D 1½ hour	Openings in exterior walls subject to severe fire risk from sources outside the building	None	2+
E ¾ hour	Openings in exterior walls subject to light or moderate fire risk from outside, i.e., fire escapes	1,296 square inches	less than 1 hour
20–30 minutes	Openings designed to provide smoke protection	1,296 square inches	less than 1 hour

"Twenty Minute Without Hose Stream"—Not to be confused with 1/3-hour fire rated doors that have been tested in accordance with standard fire-test procedures. Doors thus marked have been tested for 20 minutes of fire duration but without an exposure to a hose stream. These doors can be installed in 1-hour corridor walls.

Hollow-Metal Transoms and Sidelight Rated Assemblies

Four basic rules govern the use of transom and sidelight configurations in fire-rated assemblies;

1. Transoms can be used in Class B, C, D, and E openings. Some manufacturers have the capability of producing a 3-hour rated transom panel. Transom lights and sidelight combinations can be installed in Class C openings only.
2. The total area of doors, transom panels and sidelights shall not exceed 120 square feet, and no dimension by itself can exceed 12 feet.
3. The total area of door and transom panel cannot exceed 40 square feet for a single door or 80 square feet when a pair of doors is to be installed.
4. Transom lights or panels must maintain the same or greater fire-rating duration than the doors with which they are associated. Glass can be used in transom panels or sidelights with ¾-hour assemblies, but higher fire ratings will require the use of metal panels.

The overall dimension of transom and sidelight frames depend on the maximum size that a manufacturer has been able to successfully test.

Louvers and Glass in Fire-Rated Doors

The installation of louvers in 1½-hour and ¾-hour doors are permitted, but the louver size cannot exceed 24 inches by 24 inches and must have a fusible link. When the use of louvers is permitted, they must be installed in the lower half of the labeled door. Glass installed in rated doors must be labled wire glass not less than ¼ inch in thickness. Regular glazing putty can be used to seal the glass between its metal stops.

Fire-Rated Hardware

Not only must fire-rated hardware serve the normal purpose for which it is intended but it must also stand up to certain rigors imposed when subjected to fire.

Hinges—Must be made of steel because nonferrous metals tend to become elastic at much lower temperature than steel thereby impairing the ability of the door to open and close properly. Bearing-type butts or hinges are required to facilitate smooth operation and minimize wear.

Latching devices—Deadbolts cannot be used in place of latchbolts, but they may be provided in addition to latchbolts except on doors meant to be used as a means of egress. A latchbolt of the correct length for the door being used is important, and any automatic latching devices must be labeled.

Fire exit hardware—Panic devices are required but they must be fire tested and rated as well as meeting panic loading tests.

Closers—The purpose of the closer is to keep the door closed and in a latched position in the event of a fire. Once the door is closed the closer has no other protection responsibility.

Hold-open devices—Doors with electromagnetic hold-open and release devices tied into smoke and fire alarm systems are the only types capable of responding quickly to prevent the spread of gases and smoke throughout the building. Fusible link hold-open devices won't work until the air temperature is hot enough to melt the link, and since smoke and toxic gases are the main causes of death in building fires, these kinds of hold-open mechanisms are not very effective.

Hardware on Pairs of Doors. When pairs of doors are subject to fire ratings, both leaves must have steel-bearing hinges. Closings devices are required on both leaves except where installed in mechanical rooms, which require a closer on the active leaf only. When securing the inactive leaf on a pair of doors in other locations, a self-latching or automatic top and bottom bolt or fire-rated two-point latch should be installed on all pairs of fire-rated doors except those used as exits. Manual flush bolts can be used on equipment room entrances, and where labeled fire exit devices are installed, the self-unlatching feature must work when the active leaf is opened.

HOLLOW-METAL SHOP DRAWINGS—REVIEW AND COORDINATION

Hollow-metal shop drawings can be the source of much confusion, and if not reviewed carefully by the architect, project manager and construction superintendent, delays in delivery will undoubtedly occur and possibly the wrong configuration door and frame will be produced. There are several critical determinations that are required such as proper handing (door swing), door undercut, hardware location (required for reinforcements in the door or frame), frame-throat size and method of attaching the frame to the wall assembly.

Proper Handing

A common method of determining handing is to place one's back to the hinge side of the door frame; if the door swings to the right, it is a right-hand door, if it swings to the left it is a left-hand door. This may work for some doors, but not all. The door and frame handing chart in Figure 18-6 will provide a simpler approach to determining the correct swing of doors.

Door Undercuts

When a finish schedule has been included in the contract documents it is fairly easy to determine how much undercut a door will require in order to avoid rubbing or scraping the finished floor surface. A concrete floor with painted surface or sheet vinyl or vinyl composition tile flooring may still, however, require a call to the architect's office to determine whether any additional air space is required for return air purposes or room pressurization requirements. Carpet and padding dimensions may vary from manufacturer to manufacturer and unless this material has been purchased at the time the hollow-metal shop drawings are being reviewed, a telephone call to a flooring subcontractor may be needed to verify the proper thickness of these materials.

Hardware Locations and any Reinforcements Required

Unless a finish hardware schedule accompanies the approved hollow-metal shop drawings, the manufacturer will generally delay fabrication until specific information about hardware requirements, configurations and locations is received. Quite often a hollow-metal manufacturer will request actual hardware templates before proceeding with fabrication, so it is important that finish hardware purchases are made in conjunction with hollow-metal orders.

Figure 18-7 contains the dimensions of standard hardware locations, and they can be checked against those indicated on the shop drawings. If the architect has reviewed the drawings and inserted dimensions that vary considerably from these industry standards, it would be wise to reconfirm the variances. Installing panic hardware, door closers and other door-frame attachments will require door and possibly door-frame reinforcements and this information must also be included in the finish hardware and hollow-metal shop drawing review process.

DOOR AND FRAME HANDING CHART

How to determine hand of door and frame
Hand all doors by standing outside on key side — facing door

SINGLE DOORS:
When door swings to outside and hinges are on right side of door:
Door is R.H.R.B.—Frame is L.H.

When door swings to inside and hinges are on right side of door:
Door is R.H.—Frame is R.H.

PAIRS OF DOORS:
When door leaves swing to outside and hinges are on right side of active leaf:
Door is R.H.R.B. Active—Frame is L.H. Active

When door leaves swing to inside and hinges are on right side of active leaf:
Door is R.H. Active—Frame is R.H. Active

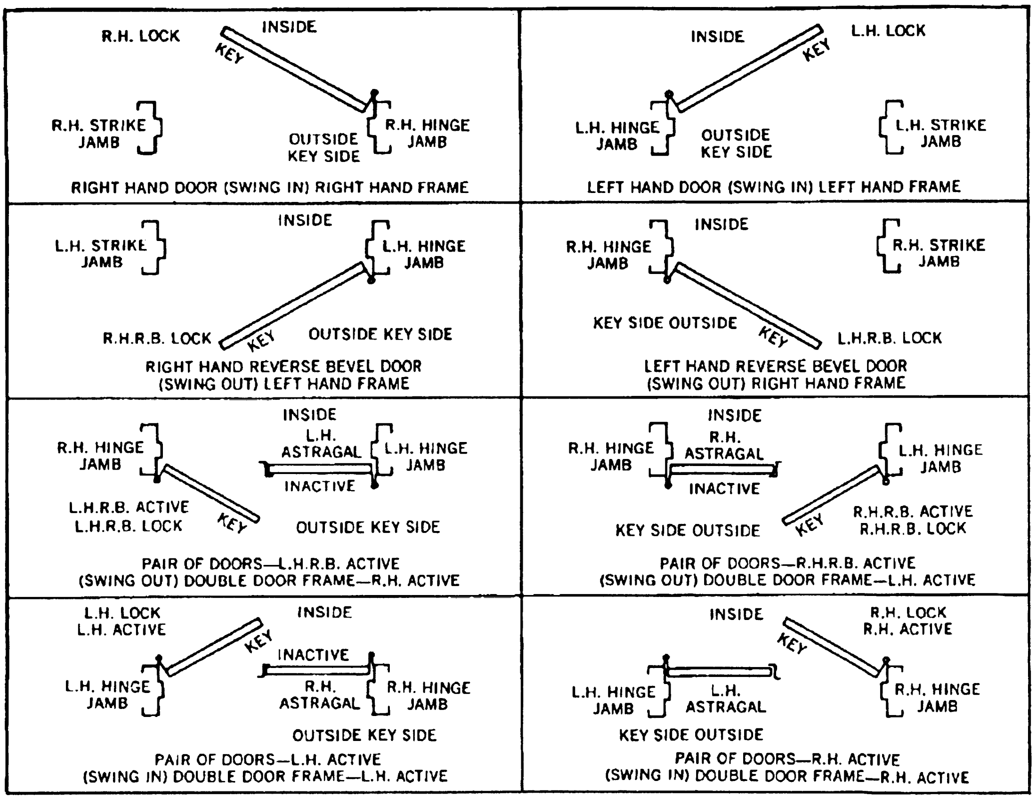


Figure 8-6 Determining the "Swing" or "Handling" of Doors. Courtesy: Steel Door Institute.

Frame-Throat Size and Method of Attaching Frame to Wall

Hollow-metal frame-throat size will depend on wall thickness and whether the frame was meant to wrap around the partition or be mounted flush to the opening. Figure 18-8a reveals some of the more common wall conditions and frame configurations required to meet these conditions.

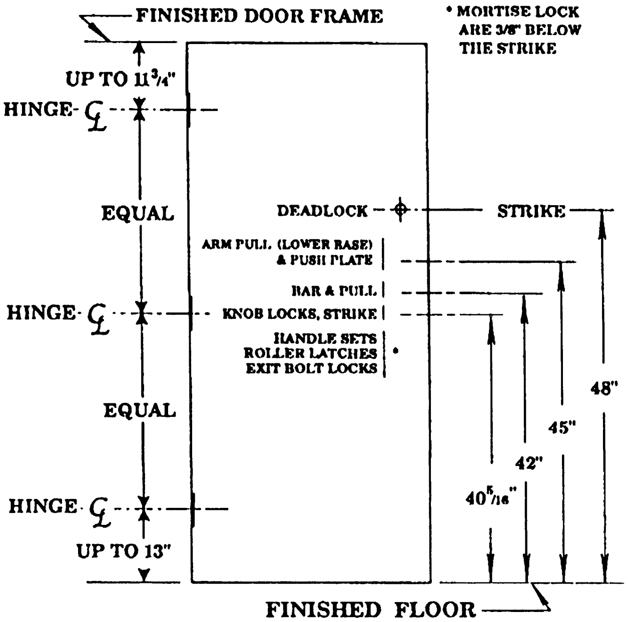


Figure 18-7 Standard Location for Hardware in Hollow-Metal Frames. *Source:* Steel Door Institute, Cleveland, Ohio.

There are quite a few methods of attaching hollow-metal frames to adjacent wall sections. Frames installed in masonry walls can be furnished with tee or strap anchors that are meant to be be bonded into the coursing as the wall is being built. Lead shields or expansion bolts can be used to fasten these frames into already built concrete or masonry openings. Similarly, wood or steel-stud anchors can be used to secure frames to their respective wall assemblies as they are being framed but before sheetrock is applied. In the case of KD frames installed after the wall assembly has been completed, other means of surface-applied fasteners can be provided. Figure 18-8b details some of the anchorage devices available for various types of wall construction.

Painting and Finishing Hollow-Metal Doors and Frames

Generally these types of doors and frames will be furnished with a rust-inhibiting prime coat of paint, but where doors and/or frames are to be exposed to harsh weather conditions or corrosive environments, they are often fabricated of hot-dipped galvanized steel sheets. Galvanized coatings are available in two grades: regular and alloyed. Regular galvanized hot-dipped coatings are indicated on shop drawings with the prefix "G." The alloyed coating is recognizable by the prefix "A." This is a hot-dipped process that has been altered somewhat by either a postgalvanized heat treatment or another treatment step after the initial hot-dip coating. The surface of an alloyed door or frame can be recognized by its dull gray appearance devoid of the spangles associated with a normal galvanizing process. Most galvanized doors and frames receive a factory-applied prime coat before being shipped to the job site, and this information should be passed on to the painter to ensure that the specified finish coat on those doors and frames will be compatible with the primer that has been applied over the galvanized metal.

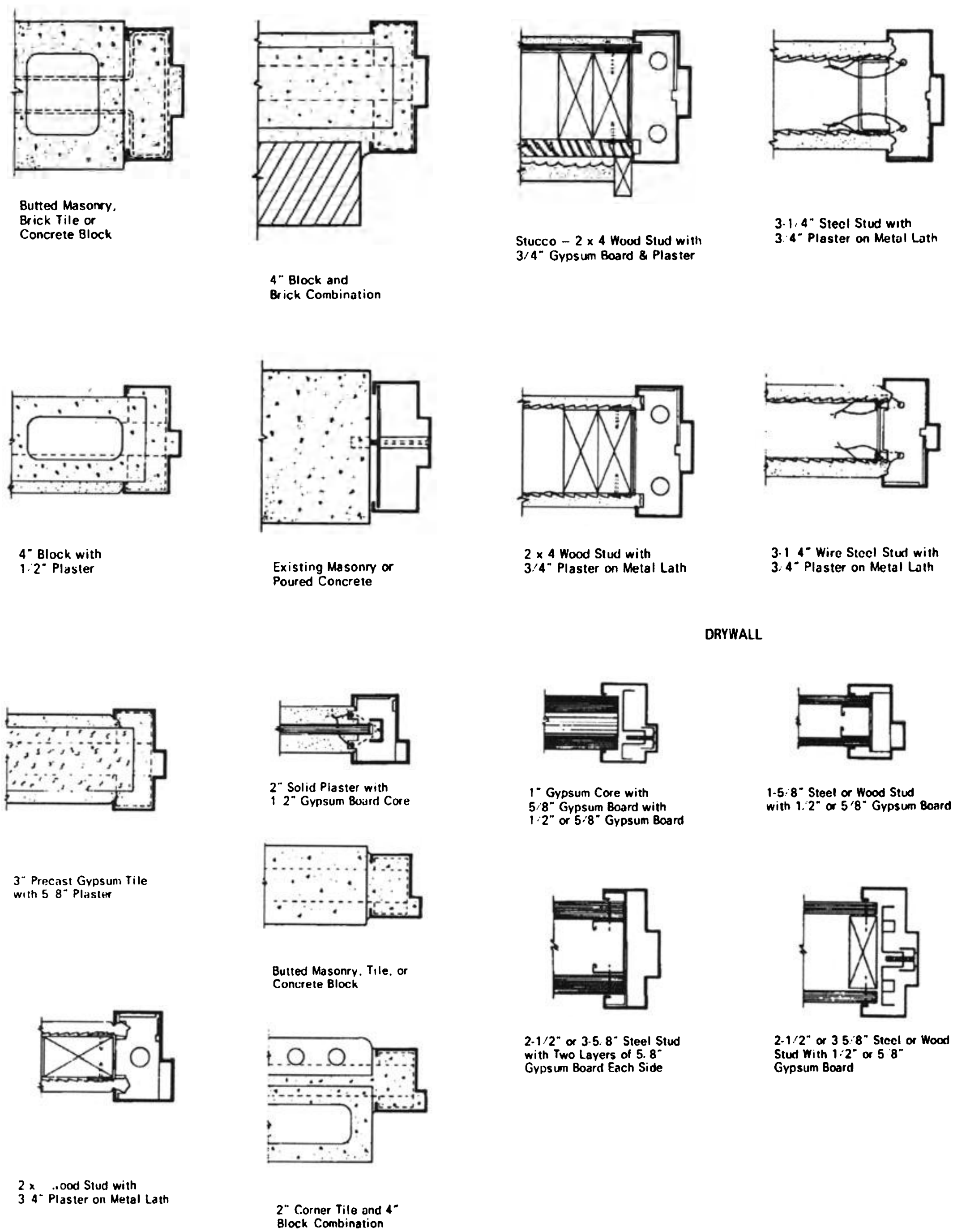


Figure 18-8a Illustration of Common Wall Conditions and Respective Frame Configurations. Courtesy: Steel Door Institute, Cleveland, Ohio.

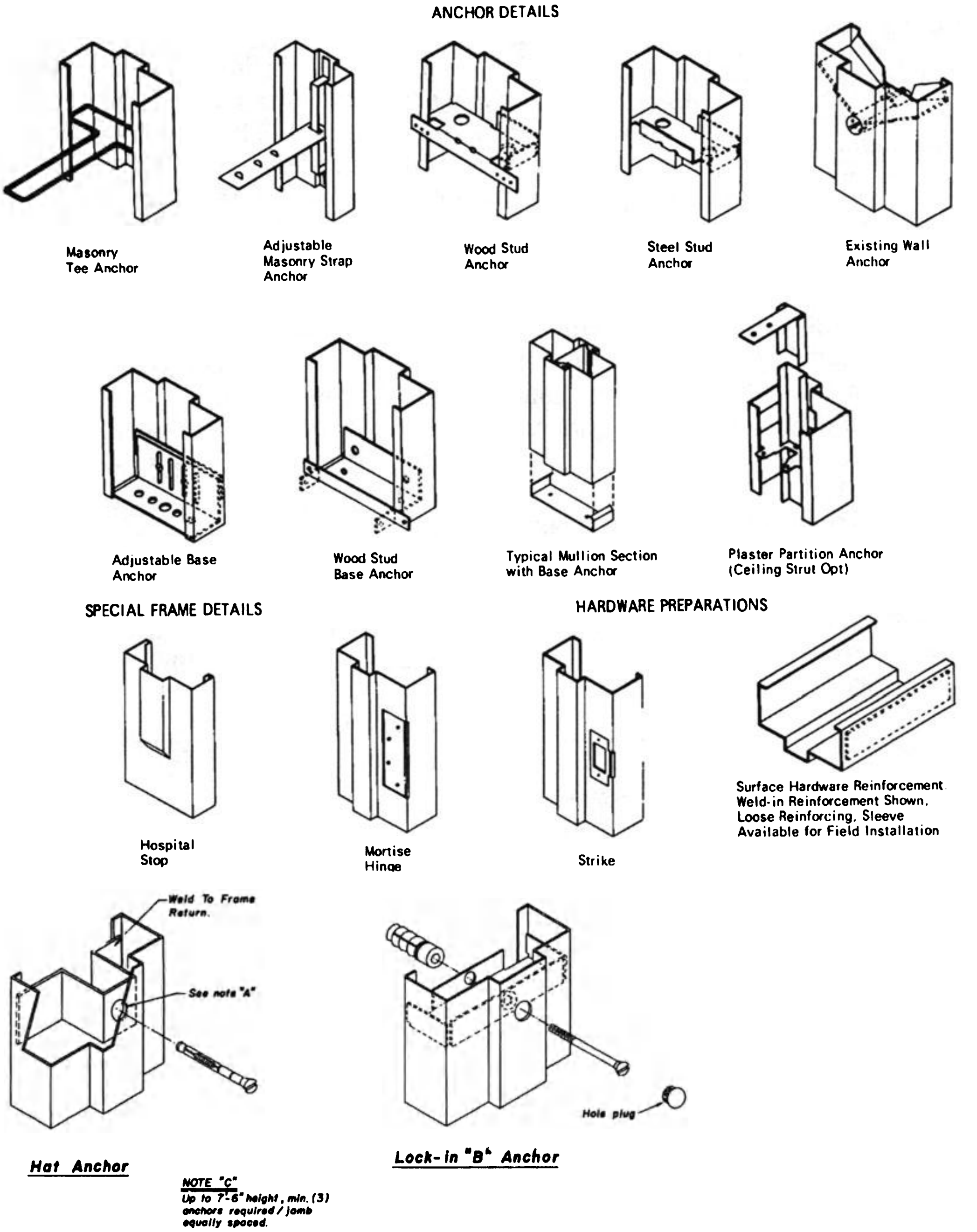


Figure 18-8b Typical Gasket and Anchorage Details for Hollow-Metal Frames. Courtesy: Steel Door Institute, Cleveland, Ohio.

There is another coating on the market called WCGS (wipe-coat galvanized steel) that is marketed primarily by foreign manufacturers. This wipe coat has no required minimum mil thickness and affords little extended protection to the metal. Hollow-metal products furnished with wipe-coat treatment must be quickly protected against the elements with a proper prime and finish coat.

WOOD DOORS

Wood doors used in general construction work are mainly hollow-core or solid-core flush type. Stile-and-rail doors, which include a wide variety of panel configurations, are generally confined to light commercial or residential use; however, they can be found in executive suites of large commercial buildings where their beauty and style are important and where they are not subjected to heavy traffic. The components and nomenclature of both flush and rail-and-stile doors is shown in Figure 18-9.

Flush-wood doors can be divided into several categories: hollow core, solid core, mineral core and special cores. Architectural quality wood doors share, more or less, the same basic method of construction but each manufacturer will add their own individual touches. Basic wood-door construction consists of solid wood stiles, top and bottom solid wood rails, a core and cross banding wood veneer, usually capped by an architectural wood veneer face. The choice of core material and construction depends on use and economic considerations, and the facings on these doors can be constructed of a wide range of wood veneers, reconstituted wood panels such as hardboard or high pressure plastic laminates.

Hollow-Core Doors

These doors can be fabricated with a core of acoustical damping material where sound transmission qualities are important, or they can be made with a honeycomb

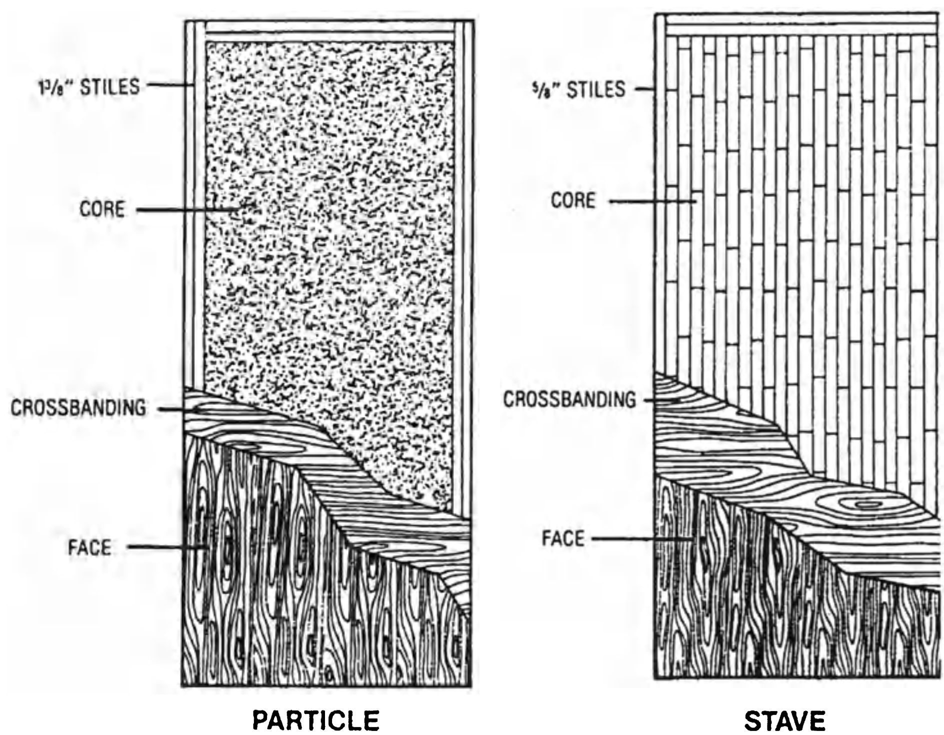


Figure 18-9 Typical Construction of a Particle-Core and Stave-Core Architectural Wood Door.

core of various materials or implanted spiral blanks of reconstituted wood fibers. Hollow-core doors are not recommended where cut-out areas will exceed one half of the door height or when openings exceed 40 percent of the door surface area.

Solid-Core Doors

Solid-core doors can be made with cores of particleboard, with continuous rows of wood block (staves) or with a mineral composition core when fire ratings are required. Particleboard cores are dimensionally very stable, and because they are very dense and heavy, they have excellent soundproof qualities. Wood-staved cores generally are slightly more expensive than particleboard-core doors.

Fire-Rated Wood Doors

Twenty minute doors with mat-formed particleboard core of finger-joined low-density wood-staved core conform to ANSI A208.1. Maximum 1,200 square inch vision-panel openings are allowed when installed with an approved metal vision-panel frame to secure the glass. Forty five minute doors have a core of noncombustible mineral material. A maximum 1,296 square inches of light opening is permitted and a louver not exceeding 24 inches × 24 inches with fusible link is also allowed. Sixty minute doors also contain an incombustible material core. No vision panel exceeding 100 square inches is allowed, and louver size is restricted to a maximum 24 inches × 24 inches size when a fusible link is attached. Ninety minute doors with cores of incombustible mineral material generally have special laminated edges and stiles in order to provide extra strength screw-holding capabilities.

Special Cores for Special Doors

Sound insulating doors with STC (sound transmission coefficient) ratings in the 36 to 42 range are available. To be truly effective these doors ought to be used in conjunction with specials stops, gasketings, seals and thresholds. Grounded doors have embedded layers of wire mesh in the core, which connect to a ground extended and connected to the hinge and subsequently to the door frame.

Lead-lined doors contain a layer of lead $\frac{1}{32}$ inches to $\frac{1}{2}$ inches thick, depending on usage, and are used in X-ray rooms and other areas where low-level radiation must be contained. Lead-lined doors may also be used for acoustical reasons.

Warranties on Wood Doors

Most major door manufacturers offer warranties on their architectural doors, and they all tend to include more or less the same restrictions on door replacement:

1. No warranty on appearance of field-finished doors or on natural variations in the color or texture of the wood.
2. No warranty on normal wear and tear issues.
3. No warranty on plastic laminate-surfaced doors used for exterior applications.

4. Cracking of veneer or plastic laminate caused by improperly hung doors or doors that have a light or louver cut-out area that exceeds 40 percent of the door area or 50 percent of door height is not covered by warranty.
5. Cracking of veneers or plastic-laminate faces caused by lights or louver cut-outs closer than 5 inches to the door edge and minimum of 5 inches from inside face of lockset or latchset cut-out will not be quaranteed.
6. Warpage on doors less than 1¾ inches thick that are wider than 36 inches and higher than 7 feet is not quaranteed, nor is warpage on doors that exceed 7 feet 6 inches if they are hung with three or fewer hinges, including pivot hardware.
7. Doors with different materials on either side are generally not quaranteed against warpage.
8. What is quaranteed:

   Squareness tolerances measured diagonnally that exceed ⅛ inch.

   Warpage for 1¾ inch thick doors that exceed ¼ inch in any 3 feet 0 inches by 7 feet 0 inches when measured with a straightedge over the entire plane of the door.

   Stile rail and core telegraphing if the door varies from a true plane in excess of 1/100 inch in any 3 inch span.

   Tolerance in factory prepared hardware locations if they exceed 1/32 inches for hinges and lock front.

   Prefit doors that are machined and exceed tolerances of 1/16 inch to 1/32 inch.

   For exact warranty exclusions and inclusions, request a copy of the door warranty from your supplier.
9. Door replacement warranties do not include the cost of labor to remove and replace the defective door, nor do they cover the cost to refinish the replacement door.

Aluminum Interior Door Frames

With an eye to aesthetics and relatively maintenance-free life, many architects are specifying aluminum door frames with either clear or colored anodized finishes or electrostatically applied organic coatings. The ability of manufacturers to produce 45 minute and 90 minute fire-rated aluminum frames lined with steel has increased the use of these handsome frames. Shipped KD, they also allow the contractor to install unfinished or finished drywall partitions in advance of their delivery. These prefinished aluminum frames require close coordination between door and finish hardware supplier to ensure that the frames will be properly mortised, drilled and tapped for hinges and strikes. These prefinished aluminum frames are delivered wrapped to protect their finish, but more than normal care must be exhibited during storage and installation to prevent denting or scratching the surface since touch-up can be a difficult process.

Special Doors

Balanced Doors. In cold climates, especially where high stack pressures in buildings manifest themselves as suction on the inner surface of an entry door, the balanced door provides a solution to the difficulty of opening entrance doors. Balanced doors feature a sliding pivot in the head of the door, which allows wind pressures to become balanced in a manner much like a see-saw. An imposed load on one side of the pivot tends to open the door while an opposing load on the other side of the door eases it closed.

Folding Doors. Either accordian or panel fold doors designed to close off small areas like kitchenette or closets or divide a large area into lesser size rooms are generally track mounted and usually require some form of overhead steel support system. These doors can fold against themselves or become fully recessed when stowed in a pocket created in a wall at one jamb. Sound transmission through these openings can be kept to a minimum by pantograph type construction and top and bottom sound seals.

Sliding Doors. Applicable to both pedestrian and vehicular traffic. These doors can be as simple as a two- or three-leaf closet door hung from a track or as complex as multiple motor operated leafs that control access to loading docks or 100-foot wide airplane hangers.

Revolving Doors. Available in diameters ranging from 6.5 feet to 8 feet manually operated, and up to 16 feet in diameter for automatic rotating doors. Primarily used in high pedestrian traffic areas such as large office buildings or hotels, these doors come as packaged units from the manufacturer. The pivot-bearing mechanism is usually installed below the finished-floor level, and the canopy contains the manual speed control mechanism. The interior partitions or "wings," are equipped with emergency release devices that allow them to fold in case the door malfunctions in an emergency situation.

Darkroom Doors. Similar to revolving doors in configuration except they have an inner and outer door instead of the wings in a revolver. Upon stepping inside a darkroom door, the outer door will be rotated to close off the exterior while the inner door will open allowing entry into the room. Some revolving doors can be fitted with lead-lined inner and outer doors when designed to be used for radiology or nuclear uses.

Rolling, Telescoping and Sectional Doors and Grills. Used for either pedestrian or vehicular traffic can be chain or motor-driven, thermally insulated or simply weather sealed. These kinds of doors can be either surface mounted on masonry walls or steel frames, or mounted within exterior steel-channel frames for rigidity. Rolling or telescoping doors with fusible links are being replaced by those with electromechanical release units used in conjunction with the buildings smoke–heat detecting system. Time delays ranging from a few seconds to one minute in conjunction with safety edges provide protection to workers in the area. Rolling grills are quite often used on store fronts located inside malls or in open air markets or food concessions where the facility can be closed but still allow passers-by to inspect the merchandise. It also permits heating and cooling air to circulate within the space.

Radiation Shield Doors. Used in hospital radiation treatment areas and other areas where the generation of neutrons are to be contained. These doors are composed of layers of lead and polyethylene sandwiched between steel faces and edges. The composition and thickness of these layers will vary depending on neutron containment requirements. Quite often sheets of borated polyethylene are inserted to prevent the escape of thermal neutrons.

The components, make-up and end uses of doors does not end here, but the usage of gas- and fume-tight doors, blast doors, and missile-resistant doors may not be experienced by many and their individual requirements cannot be categorized so easily.

FINISH HARDWARE

Beside the fire-rated hardware described in the "Fire-Rated Hollow Metal" section earlier in this chapter, normal hardware requirements generally include locksets, latch or passage sets, butts or hinges in a variety of shapes and sizes, closers, exit devices and protective hardware.

Lock Sets and Latch Sets

These items are designed to hold a door in a closed position. When a deadbolt is installed in a latch it becomes a lock set. Latch sets and lock sets can be purchased in two configurations: cylindrical (Figure 18-10) or mortise (Figure 18-11). Of the two, the mortise lock offers the most secure protection, and not only the lock, but also the door preparation is more costly than standard cylindrical lock sets. When a door does not have to be secured, it is normally fitted with a push and pull plate instead of a passage or latch set.

Hinges

Hinge selection depends on the material of the door and frame, size, thickness and weight of the door, frequency of use and whether the door is exterior or interior. Hinge finishes are dictated by interior and exterior usage as well as architectural considerations.

Butt is another name for a hinge—one that is made of two rectangular metal plates joined together with a pin and mortised into the edge of a door, so it is equally correct to call this hardware item by either name. There are several types of butt–hinge configurations:

Full mortise—Each equal sized leaf of the hinge is recessed, one mortised into the door, the other set into the rabbet of the frame.

Half mortise—Two equal size leaves, one square edged and mortised into the rabbeted frame and the other leaf with the bevel-edge surface mounted on the face of the door.

Full surface—Two bevel-edge leaves, one surface mounted on the frame, and the other surface mounted on the door.

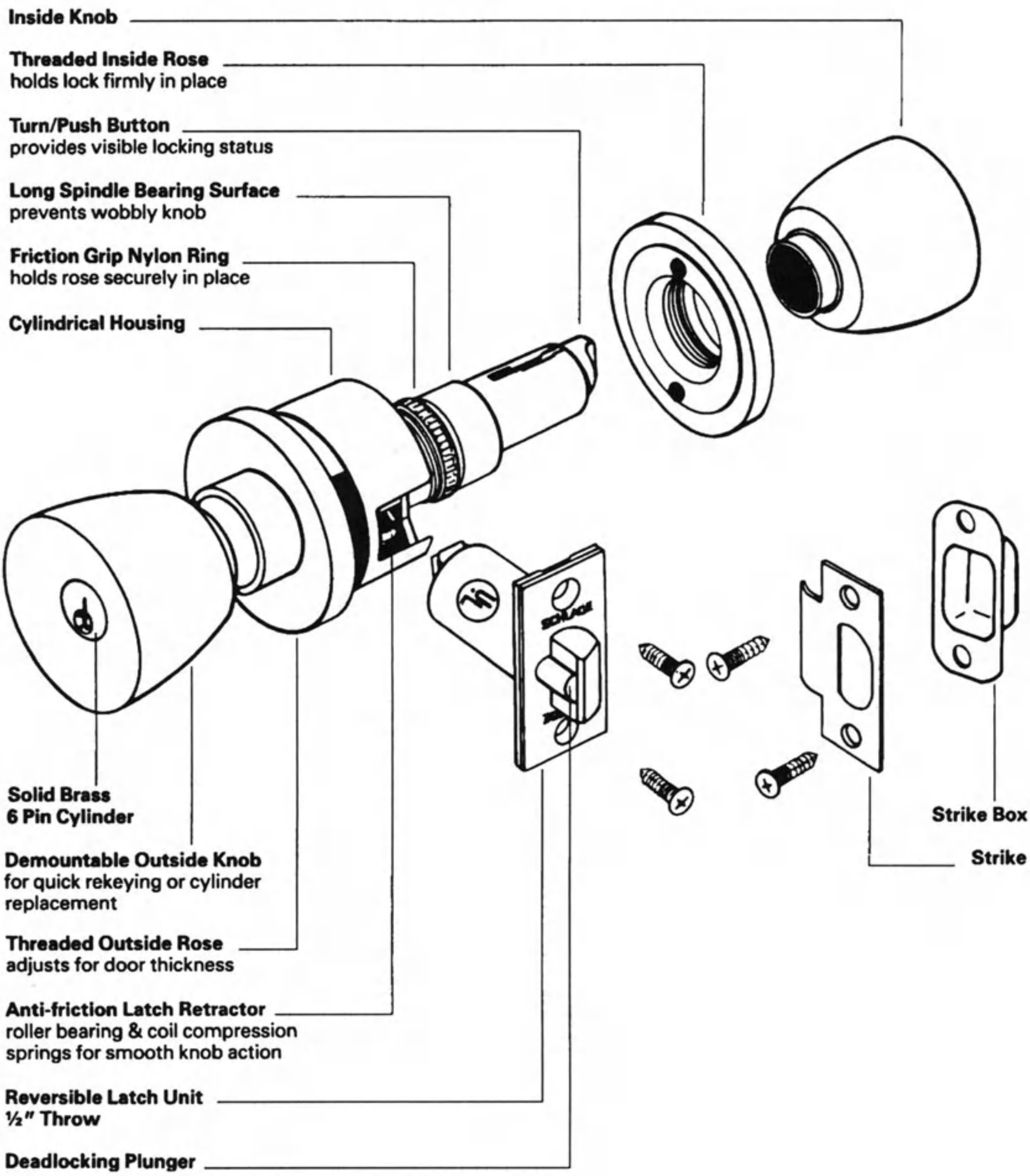
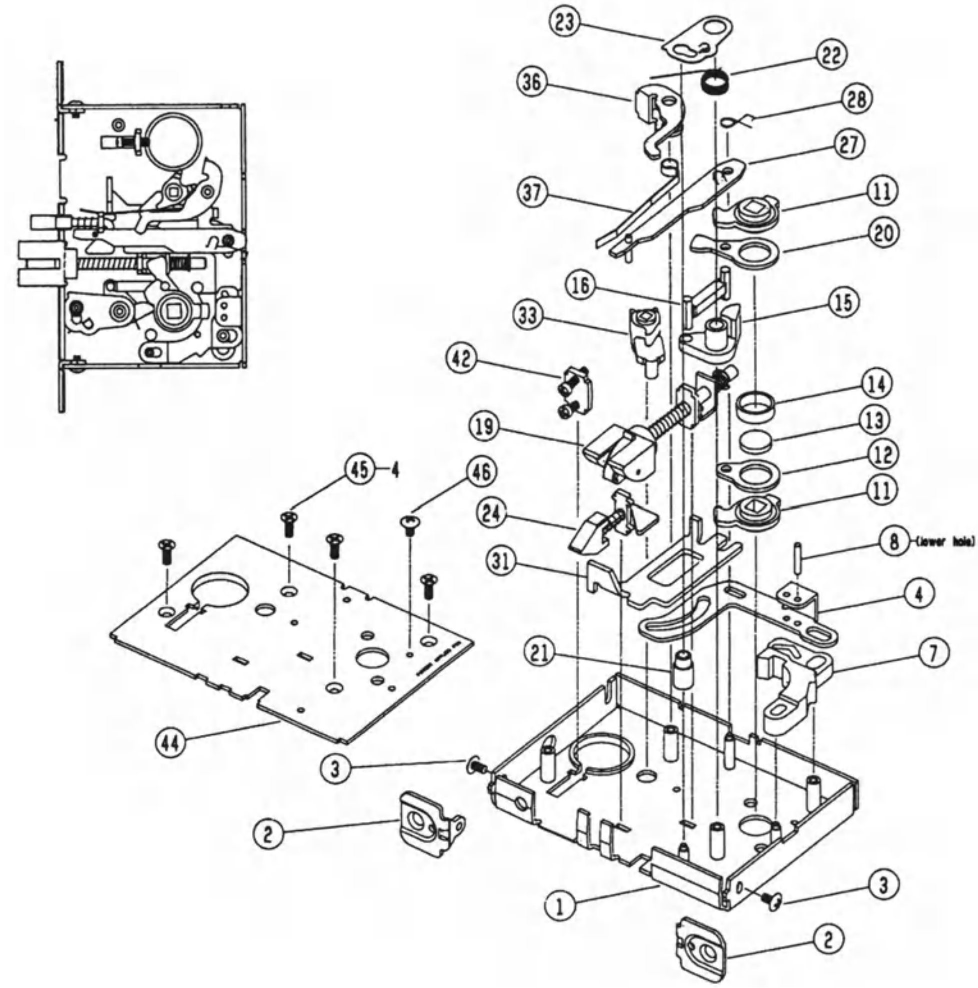


Figure 18-10 Exploded View of a Cylindrical Lock Set. Courtesy: Schlage Lock Company, Fairfield, NJ.

Half surface—Two equal size leaves, one square edged, the other bevel edged. The square edge is mounted into the rabbet on the frame and the bevel edge is surface mounted on the face of the door.

Pivot Hinges. This type of hinge is used on very large and very heavy doors because they transfer the weight of the door to the floor rather than to the jamb of the door frame. Pivot hardware consists of a top pivot, sometimes called a "walking-beam pivot" mounted in the head of the door frame, and a bottom pivot mounted in or on the floor. Occasionally an intermediate pivot is installed to provide better alignment and absorb



1. Lock case
2. Faceplate Tab
3. Faceplate Tab Screws
4. Locking Link
5. Entrance Link
6. Electrified Link (when lock is electrified)
7. Locking catch
8. Link pin
9. Catch pin
10. Catch spring
11. Retractor hub
12. Retractor rocker
13. Blocking plate
14. Retractor hub spacer
15. Retractor crank
16. Retractor link
17. Spindle anchor
18. Dmy spindle anchor
19. Latchbolt Assy.
20. Retractor lever
21. Fire Door fuse (if applicable)
22. Hub spring
23. Fire Door catch (if applicable)
24. Aux. Latchbolt Assy
25 Latchbolt guide
26. Aux. bar guide
27. Aux. stop
28. Stop spring
29. Deadbolt
30. Entrance deadbolt
31. Transfer lifter
32. Standoff post
33. Turn hub
34. Entrance hub
35. Can follower
36. Transfer lever
37. Turn hub spring
38. Solenoid/driver assy. (when lock is electrified)
39. Solenoid Spring for above
40. Spring retainer for above
41. Retractor for above assy.
42. Cyl. anchor assy.
43. Electrified lock bushing (for electrified lock)
44. Lock case cover
45. Case cover screws
46. Lock handing screw
47. Dead bolt (when applicable)

Figure 18-11 Mortise Lock Assembly with Parts Identification. Courtesy: Schlage Lock Company, Fairfield, NJ.

some of the weight of the door. Pivot hinges can be either offset or center hung, and unless controlled by a stop, tend to be double acting. A center-hung pivot installation places the pivot in the center of the door's top and bottom rail, approximately 2 ¾ inches from the edge of the jamb. Offset pivot installation places the top and bottom hinges ¾ inches to 1½ inches off the face of the door and has a short arm for attachment to the top and bottom door rails.

There are full mortise pivots available with ball bearing knuckles, and reinforcing pivots are used on doors subjected to excessive wear and tear. Olive and executive pivots are two knuckle hinges made of brass with stainless steel pins and are used where aesthetics are a consideration, such as on boardroom doors or in executive office areas. There are, of course, other types of hinges such as fully concealed, strap, colonial "H and L," butterfly and paumelle that are not frequently used.

Problems occur with hinges for two basic reasons:

The hinges are too light for the service intended.
There are too few hinges installed.

Commons problems with hinge installations can be traced to one of the following:

1. Screws work loose caused by faulty installation or when the door is hung so that it binds.
2. Reswaging (swaging is the slight offset of the hinge leaf that allows both leaves to come together). Reswaging, attempting to modify the hinge's manufactured swage, will only be a temporary measure and will cause the hinge to wear rapidly.
3. Excessive wear of nonball-bearing hinges caused by underestimating the frequency of door use. This condition can be easily corrected by replacing these worn hinges with ball-bearing types.
4. Bending or deformation of the hinge when it is too light for the application. If bending occurs when solid brass, bronze or aluminum hinges are used, switch to steel or stainless steel.

Closers

A door closer is a device consisting of a body (either cast iron or aluminum), a piston, pinion, control valve, hydraulic fluid and an arm assembly. When a door with a closer is opened, the pinion turns and forces the piston to compress against a spring. When the door is released, the hydraulic fluid in the body cushions and delays the closing against the force of the spring. Adjustment valves on the closer can regulate, increase or slow down the closing speed of the door. Where there are strong latching or locking devices on a door, such as those on an exit door, closers must be regulated to close firmly during its final travel toward that latching–locking device.

Closers can be either floor or overhead mounted. When mounted in the floor, the closer is recessed below the floor surface, but when the closer is mounted overhead, it can be mounted in a regular manner, top-jamb mounted or parallel-arm mounted. Regular mounting places the closer on the pull side of the door with the foot bracket attached to the face of the door frame above the closer body. Top-jamb mounting takes place when the closer body is mounted on the frame above the door on the push side, and the foot bracket is fastened to the door slightly below the body. Parallel-arm mounting is called a "head knocker" inasmuch as it is mounted within the opening of the door.

Back checks regulate the arc of the door swing and will allow a door to open from 60 degrees to 85 degrees. Not intended to act as a door stop, damage can occur to the closer, door, frame or hinges if the door is extended beyond the arc established by the back check. Hold-open devices mounted on closers should be used to hold the door open and some are adjustable from 90 degrees to 180 degrees.

Exit Devices

Fire-exit devices and panic hardware both operate when pressure is applied to a horizontal bar or push pad. They differ in that panic devices can be manufactured with a "dogging" feature, which allows the latch to be withdrawn and held in that position by a cylinder key, a hex wrench or tool supplied by the manufacturer. Although some fire-exit devices do have a dogging feature, it is controlled electrically, not mechanically, and is meant to be connected to the building's fire alarm system. Although the latch might be withdrawn permitting the door to operate like a push–pull, when smoke or fire is detected in the building, the alarm system will automatically release the dogging device and the door will become latched.

Panic devices are available in four standard set-ups:

Rim—Surface applied to the door, operating with a push mechanism that activates a single-latch bolt.
Mortise—Surface applied but operates a single-latch bolt that is mortised into the door edge.
Surface vertical rod—Surface applied push mechanism that activates a surface-mounted vertical rod that controls a top and bottom latch.
Concealed vertical rod—Similar to the surface vertical rod, except that the vertical rod is concealed within the door.

Panic or fire-exit devices are operable from the push side of the door by any of these options:

Dummy trim—A pull or rigid knob that allows door to be pulled open when it is dogged.
Night latch—A pull with a lock requiring a key to open the door from the pull side.
Thumb piece—Similar to night latch except that the latch once unlocked is operated by a thumb piece.
Knob or lever—Same as night latch and thumb piece except a knob or lever is fitted.
Turn lever—Found on vertical rod panic devices. A turn lever can be furnished locked, or unlocked by inserting a key. When unlocked, the lever retracts the vertical rod.

Blank escutcheon—No cylinder control, but the attached lever or knob is operable at all times.

When Trouble Occurs

If the hardware itself is not defective look to the following installation problems:

1. Improper fit or alignment between the door and the frame.
2. Wrong lock or case installed.
3. Incorrectly mounted strike.
4. Door or frame or both improperly prepped for this hardware.
5. Hardware not mounted level.
6. Latch case not aligned properly.
7. Vertical rods not aligned nor catching in an overhead or floor receptor.
8. Wrong fasteners are installed and are too loose or too tight.
9. Operating trim is binding.

Protective Hardware

When doors can be subjected to damage from impact, there are a number of hardware items that can protect these doors. Kick plates available in thickness from ⅛ inch to ¾ inch, from 6 inches to 12 inches high and 1½ inches to 2 inches narrower than door width are meant to be mounted on the push side of the door to protect its lower portion. Stretcher plates are mounted in conjunction with kick plates but at the striker plate level to protect doors from impact from double-tiered carts, often attached to both sides of double-acting doors. Armor plate can be mounted over the entire lower portion of a door to protect against severe impact from carts, dollies, hand trucks and so forth. Armor plates of steel, aluminum, plexiglass, lexan™, brass or bronze can be seen in such diverse settings as hospital operating room doors or shipping and receiving room doors. Mop plates are installed on the pull side of a door, near the bottom rail to keep mop water, detergents, and floor wax from splattering on the face of the door. Door edgings made of .050 metal or plastic protect the edges of wood and plastic-laminate doors. These edge strips can be either surface applied or mortised into the door edge and can be purchased in L shapes or C shapes.

Hardware Finish Designations

When referring to finish hardware specifications, there are many confusing abbreviations, some of which designate what is called United States Standard Finishes. These U.S. designations are listed in the following:

US1B	Bright Japanned
US1D	Dead black
US2C	Zinc plated (commercial)
US2G	Zinc plated (government specifications)
US2H	Hot-dipped galvanized
US3	Bright brass

US3A	Bright brass, no laquer on brass metal
US4	Satin brass
US10	Satin bronze
US10A	Satin bronze, oxidized, laquered
US10B	Satin bronze, oxidized and oil rubbed on solid bronze metal
US14	Nickel plated, bright
US15	Nickel plated, satin
US17A	Nickel plated, imitation, half polished iron oxidized and relieved
US20	Statuary bronze
US20A	Statuary bronze, dark
US26	Chromium plated, bright
US26D	Chromium plated, satin
US28	Aluminum metal, satin, anodized
US32	Stainless steel metal
US32D	Stainless steel metal, satin
USP	Primed for painting or staining

In addition to these U.S. standards, various hardware manufacturers have developed their own unique finishes and given them designations that pertain only to their particular product.

19

Curtain Walls—Glass and Glazing

The Glass and Glazing portion of construction projects includes the following systems:

Curtain walls
Windows
Framing systems
Storefront work
Entrances
Overhead glazing

CURTAIN WALLS

A curtain wall can best be described as a nonbearing exterior wall that is independent of the building's structural system. Curtain systems can be constructed of glass, both translucent and opaque, stone, metal panels (either aluminum or steel), ceramic, coated substrates, fiber-reinforced cement products or any combination of these materials. The design of curtain-wall systems takes into account a number of considerations other than aesthetic, and those considerations will affect the final design, especially when energy conservation is of major concern to most clients.

Maintenance-free cladding is to be desired—Anodized aluminum tubing and panels, once considered the last word in maintenance-free finishes has been replaced by fluoropolymer finishes that promise long-term antifading and antichalking qualities or by relatively thin, lightweight sections of natural stone or composites.

Energy flow through the walls—Face panels backed with insulating materials such as isocyanurates or factory-formed sandwich panels provide various degrees of thermal resistance through the panel itself. However the same degree of insulating qualities must be met or exceeding in the other components of the system such as tubing, seals and glass.

Resistance to condensation—Condensation resistance factor (CRF) can predict the relative thermal performance of windows with respect to condensation. The higher the CRF the better will be its resistance to condensation—an important factor in curtain-wall design.

Resistance of the system to heat loss and heat gain—The selection of materials and their orientation in the curtain-wall system, along with the proper selection of glass, can be a contributing factor to satisfactory heat loss–gain within the building.

Air infiltration—Leaks through the joints of the curtain-wall system must be kept to a minimum, and design plus quality of construction can play an important part in the performance of the system. Air leakage can be caused by cracks in the system amplified by air pressure differences across the wall.

The Role of Glass in Curtain-Wall Performance

The thermal performance of glass is dictated by its shading coefficient and its "U" value. Curtain-wall design considerations will include:

- Summer solar heat gain through the windows, which can be reduced by selecting a glass with a lower shading coefficient.
- Winter conducted heat loss through the glass, which can be offset completely by solar heat gain if the correct shading coefficient has been selected.
- Daylight can be used to reduce lighting requirements and therefore reduce cooling loads when the correct glass has been selected.
- Building orientation, geometry and siting will have a direct bearing on solar heat gain, daylight patterns, and the impact of wind pressures on infiltration through the system.
- Expansion joints and anchorage must be designed to anticipate building movement, both vertically and horizontally to keep stresses on the glass within tolerable limits.
- Thermal stress caused by the sun and heating sources create differential temperatures between the center of the glass and its edges. Light colored framing systems with low heat capacity will greatly reduce the potential for edge stress. When stresses become too great, the risk of glass breakage increases. Heat traps, particularly behind spandrel glass can be severe at times, and unless some form of ventilation can be provided, thermal stress will occur.
- Weep systems must be designed to prevent the accumulation of moisture within the system.

A WORD ABOUT GLASS

Glass, a mixture of silicon, sodium and calcium (sand, soda and lime) is manufactured by two basic processes: float and plate

Float—A manufacturing process developed by a British firm, Pilkington Brothers, in which molten glass is floated over a bed of liquid tin and seeks its own level to create the required thickness. Approximately 95 percent of all glass produced in the United States today uses this method. When float glass hardens it retains the same optical qualities as plate glass without the need to be ground or polished. Float glass is manufactured colorless, tinted or coated. The purpose of coating is to provide reflectivity, which helps in reducing solar gain.

Plate glass—Glass that is cast, ground and polished. Sheet glass is manufactured by pulling a ribbon of glass vertically from the furnace on rollers, while plate glass is drawn in its molten stage between rollers to the required thicknesses.

Glass is a brittle material although it does possess tensile strengths as high as 1,000,000 psi. Failures in glass generally occur at its edges, where surface imperfections have occurred during the cutting process or at imperfections created during the manufacturing process. Large lights of annealed float glass have been known to break under the following conditions:

In path of sonic booms that create 6,000 psi pressures upon the glass.
When wind loads exceed 5,500 psi during a 10-second gust.
When wind loads exceed 4,000 psi during a 1-minute interval.
When glass has been subjected to 3,000 psi loadings over a period of several hours.

Although there are only two methods of manufacturing glass, there are many variations to the basic product.

Annealed glass—Glass that is cooled slowly as it comes off the float line thereby minimizing internal stress patterns.

Heat-treated glass—Annealed glass that is reheated to just below the softening point and cooled faster than normal. During the cooling process, the interior of the glass is subject to tension while the outer surfaces go into compression. Heat-treated glass will usually have a bow or warp to it depending on whether it was manufactured in a vertical or horizontal position.

Tempered glass—A heat-treating process that increases resistance to impact. When shattered, the glass breaks up into small shards. Tempered glass cannot be cut in the field and must be manufactured to size.

Herculite™—A registered trademark of PPG Industries. This form of glass is 500 percent stronger than annealed glass and is made by first cutting annealed glass to size, heating it close to its softening point and then rapidly cooling it with air.

Spandrel glass—Glass that is heat treated by either a tempering process or by a heat-strengthening process. A colored ceramic coating is then permanently fused to the interior side of the glass rendering it opaque. This glass is most often used in curtain-wall systems.

Wire glass—Wire mesh, generally not less than 24-gauge thick, is embedded into the glass as it is being rolled.

Laminated glass—Two layers of glass with a vinyl sheet laminated between them. Some forms of laminated glass have a UV ray absorption film inserted between the glass layers to reduce the passage of UV rays into the building interior.

Burglary-resistant glass—A form of laminated glass ranging in thickness from $\frac{9}{36}$ of an inch to $\frac{9}{16}$ inch, typically used in shop windows, jewelry cases and museum display cases.

Bullet-resisting glass—Yet another form of laminated glass incorporating multiple layers of glass and plastic film interlayers in various thicknesses depending on the degree of resistivity desired.

1 3/16" thick	Resistive to 3.8 automatic pistol
1 1/2" thick	Resistive to .357 Magnum
1 3/4" thick	Resistive to .44 Magnum
2" thick	Resistive to 30-06 rifle

Insulating glass—An assembly of two or more panes of glass with a sealed air space between each layer. The air space may range from 1/4 inch to 1 inch (hence the designation 1/4 insulated glass or 1 inch insulated glass.) "Evacuated glazing" is a form of insulated glass where a vacuum is formed between the glass layers and maintained through an edge seal. An insulated glass panel that has been "aerogeled" is one with its air space filled with a highly transparent form of silica gel, which greatly increases its "U" value.

Double glazing—Not to be confused with insulated glass. This method places one pane of glass over another with an air space in between, but there is no attempt to seal the two panes together.

Triple glazing—A single pane of glass placed in front of an insulated glass assembly. Most often used in residential windows.

Low-E glass—Low emissivity glass is a form of insulating glass where an ultrathin, transparent metallic coating has been applied to the inside face of the glass light before the panel is assembled. In some cases the space between the two panes is filled with inert argon gas. Low-E glass is designed to keep out summer heat but retain winter heat.

Coated glass—Sometimes refered to as reflective glass. The film applied to the inside face of Low-E glass is just one of many types of coatings that can be applied to glass to provide shading while maintainting architectural design criteria. Coatings are available in such colors as silver, pewter, gold, gray, several shades of blue, green and copper. Soft coatings are applied after the glass has been manufactured by placing the glass in a vacuum chamber and using a process called "sputtering." Cold coatings can also be applied directly to the surface of the glass in film form. Hard coatings are sprayed onto the glass while it is still hot and being floated so that this type of coating is actually baked right onto the surface of the glass.

Decorative glass—A form of rolled glass, made in small batches, often in various solid or variegated colors, often referred to as art, opalescent or cathedral glass and used in the manufacture of stained glass windows.

Plastic glazing materials—While not grouped under glass classification, a number of clear or tinted plastics such as acrylics, polycarbonates, polyvinyl chloride and fiberglass reinforced polyesters are often used as glazing materials when the glazing material will be subjected to impact. Skylights, sloped glazing applications, segmented or curved barrel vault ceilings are frequently glazed with plastics. Polymer top coatings can be applied to these plastic materials to improve weatherability and resistance to abrasion.

A Glossary of Glass and Glazing Terms

Single strength glass—Glass that is 3/32 inch thick.

Double strength glass—Glass that is 1/8 inch thick.

Opaque glass—Glass that has been etched, frosted, painted in such a manner as to render it nontransparent.
Relative heat gain—The amount of heat gain through a glazing system using a complex combination of figures—summer "U" value, shading coefficients and solar-heat gain.
Shading coefficient—The ratio of solar-heat gain through a window to the solar-heat gain through a single pane of ⅛ inch clear glass. The smaller the number the better the glass will be at stopping heat from entering.
Solar energy transmittance—The percentage of UV, visible and infrared energy that passes through a window.
Solar energy reflectance—The percentage of solar energy that is reflected from the surface of the glass.

WINDOWS

Windows for commercial and residential use are manufactured of steel, aluminum, wood and plastic materials, and can vary in the way they open and close, but they all have one thing in common—nomenclature. Figure 19-1a identifies the various components of a wooden double-hung window, but be it wood, steel or plastic, a stile is still a stile, a rail is still a rail and a stool or sill is still a stool or sill.

Window configurations can be double hung where both top and bottom sash are operable in a vertical position, or single hung where only the lower sash can open and close. Beyond these common types there are a multitude of others. (See Fig. 19-1b).

Wood windows create a warm presence, and when insulated glass is installed in the sash, will produce an assembly with excellent thermal qualities. Weather and seasonal

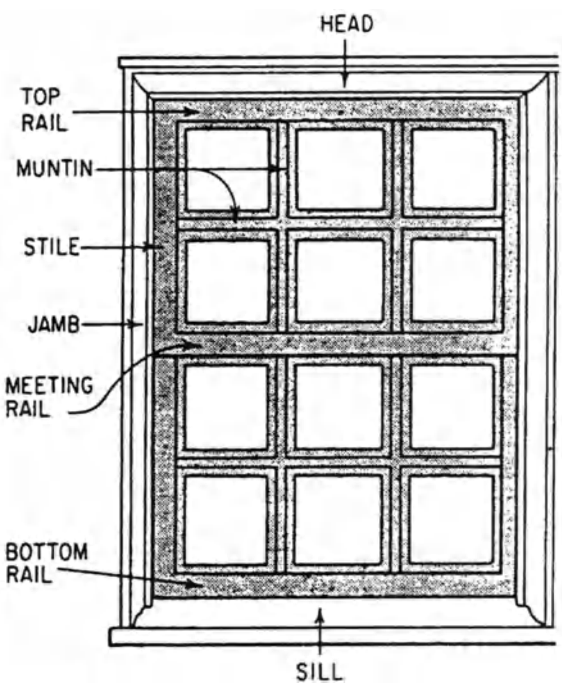
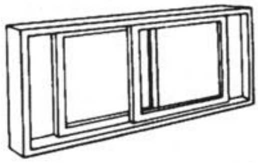


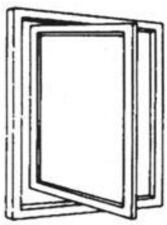
Figure 19-1a Nomenclature of Typical Window Components.

Sliding windows



Vertical sliders are called single- or double-hung windows. Horizontal sliders typically consist of two units providing 50 percent ventilation area by sliding horizontaly in front of each other.

Pivot windows

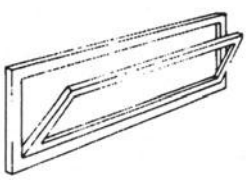


Pivot windows contain a single sash that can be rotated either 180 or 360 degrees vertically or horizontally. They offer ease of cleaning as their prime advantage.

Casement windows

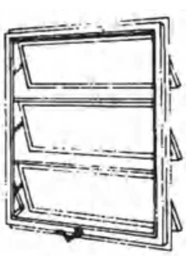
The sash in casement windows is hinged or pivoted on one side so as to swing outward when cranked open to a 90 degree angle in most cases.

Bottom Hinged(Hopper) Windows



Often included in a fixed light window, the bottom hinged sash will open for 30 to 60 degrees for ventilation.

Top Hinged (Awning) Windows



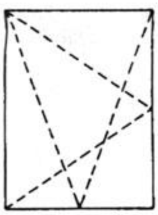
Whereas the hopper sash projects out in such a fashion as to trap water when it rains, the awning window provides ventilation while keeping the elements out.

Figure 19-1b

Project Out Windows

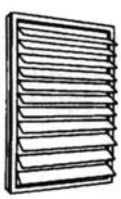
Project out windows are similar to top hinged windows, but they sometimes include a hopper window within the frame.

Tilt and Turn Windows



This casement configuration allows the sash to turn and operate as a casement window, or tilt and operate like a hopper window. Ease of cleaning with this type of double-hinged sash is an advantage.

Jalousie Windows



The multiple vents of the jalousie provides good visability and allows maximum ventilation. The seal between one glass ventilator and the other does not provide a weather-tight seal in colder climates.

Figure 19-1b ***(continued)***

temperature changes can have an adverse affect on wood windows unless the wood has been treated and sealed with a paint or stain. Maintenance costs can be quite high unless a protective metal or vinyl cladding has been attached to the outer surface of the frame, and these types of windows are more frequently used in residential and light commercial construction.

Steel windows are manufactured in four basic grades: residential, standard intermediate, heavy intermediate and custom heavy. Grade depends primarily upon weight per lineal foot:

Residential—2.0 pounds per linear foot minimum.
Standard intermediate—3.0 pounds per linear foot minimum.
Heavy intermediate—3.5 pounds per linear foot minimum.
Custom heavy—4.2 pounds per linear foot minimum.

Because of the inherent high strength of steel, these windows can support large glazed areas, and steel window frames tend to expand and contract much less than aluminum windows. One drawback to steel window frames in the past has been higher maintenance costs even though protective coatings such as PVC and other bonderized coatings had been applied. The more sophisticated finishes in the marketplace today make steel frames attractive for some applications. Galvanized steel decreases the potential for high maintenance and steel windows find acceptance in many specialty applications such as prison or security windows where its high strength is of prime importance.

Aluminum windows are competitively priced, easy to install and with some of the fluorocarbon polymer finishes, will be maintenance free for many years. But aluminum can corrode if left unprotected in certain environments, and corrosion may be accelerated when aluminum joints are welded and the flux has not been thoroughly removed. Aluminum is an excellent conductor as witness its use in electrical cables, and it requires a thermal break frame in order not to trasmit cold to interior surfaces.

Vinyl, fiberglass or polyvinyl chloride windows are tough, durable, and weather resisting and are manufactured in sizes and shapes aimed primarily for the light commercial and residential market.

Framing Systems

Exterior building wall envelopes can be built with spandrel panels between floors made of architectural precast concrete, metal panels, brick or block or a variety of composite panels. The infill between these spandrel panels, which may be attached to the structure rather than tied back to the structure in the case of curtain walls, will be some form of individual window or a series of glazed openings secured within the framing system. The most widely used framing system is composed of aluminum extrusions either manufactured and assembled in a factory, or cut and built in place in the field by a glazing subcontractor. A typical example of a built in-place assembly of window wall components is shown in Figure 19-2. Other types of window-wall assemblies can be put together in the field using unitized factory assembled components snapped together and fastened in the window opening as shown in Figure 19-3.

These window wall assemblies can be constructed with intermediate mullions, vertical support members, or the glass in the windows can be installed with what is known as a "stopless" system or by securing the glass vertically to the top and bottom track with butt glazing. Glass can be sealed within the framing system by any one of three glazing methods:

Wet system—Sealant applied to the glass and the framing member taking advantage of the natural adhesion qualities of glass.

Dry system—Preformed neoprene and EPDM gaskets acting as compressible sealants between glass and frame.

Wet/dry system—The gaskets provide inner moisture protection, while a silicon wet seal provides strength.

Stopless glazing systems, also called structural glazing, use high modulus silicon sealants to secure the glass to the structural framing member when applied to the exterior surface of that framing member. The concept eliminates an exterior metal framing member that would otherwise be used to cover the area where two lengths of

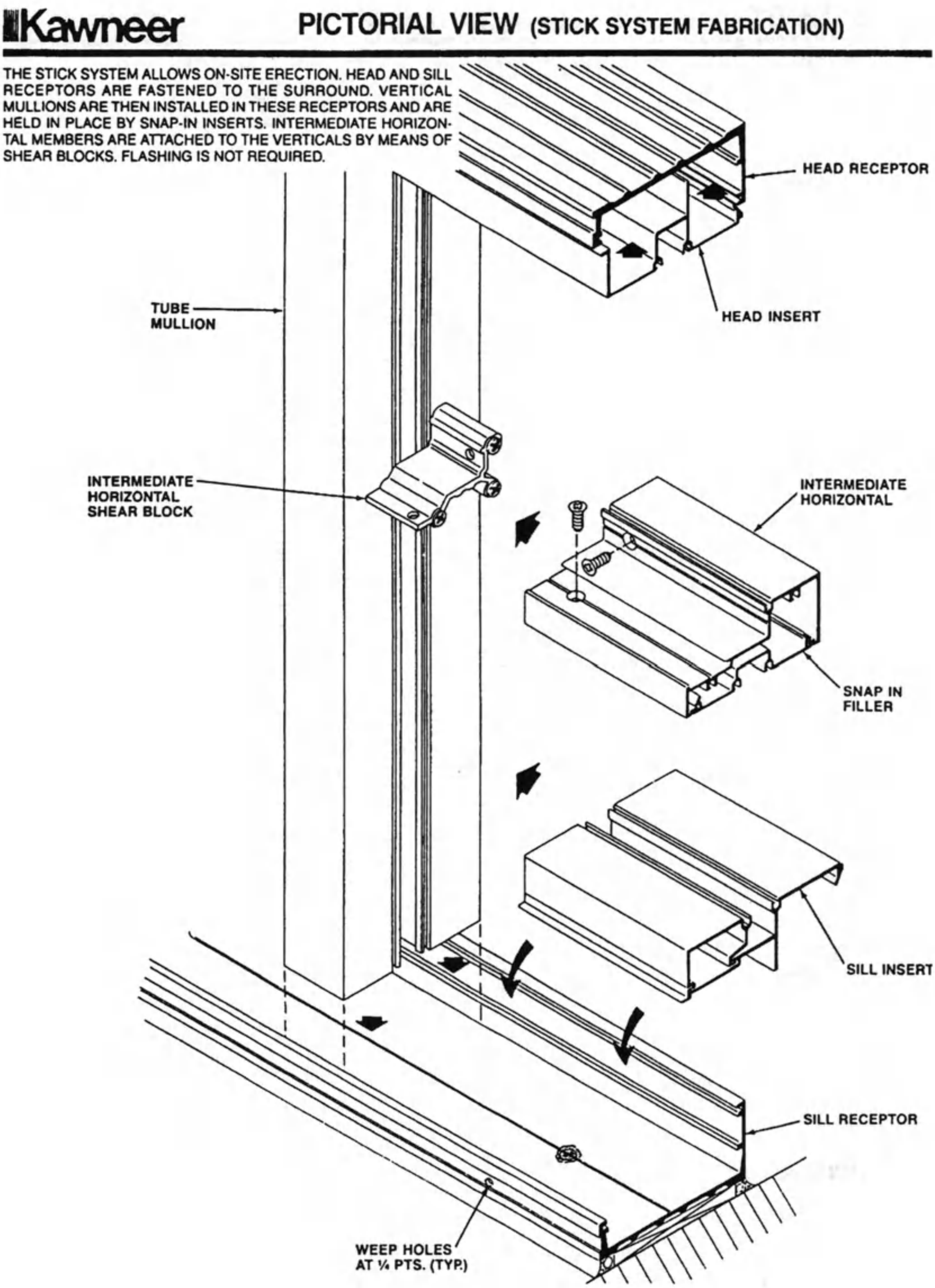


Figure 19-2 Components of a Built-In-Place Window Wall Assembly. Courtesy: Kawneer Company, Inc., Norcross, Georgia.

Kawneer **PICTORIAL VIEW (SCREW SPLINE FABRICATION)**

THE SPLIT VERTICAL IN THE SCREW-SPLINE SYSTEM ALLOWS A FRAME TO BE INSTALLED FROM UNITIZED ASSEMBLIES. SCREWS ARE DRIVEN THROUGH THE BACK OF THE VERTICALS INTO SPLINES EXTRUDED IN THE HORIZONTAL FRAMING MEMBERS. THE INDIVIDUAL UNITS ARE THEN SNAPPED TOGETHER TO FORM A COMPLETED FRAME.

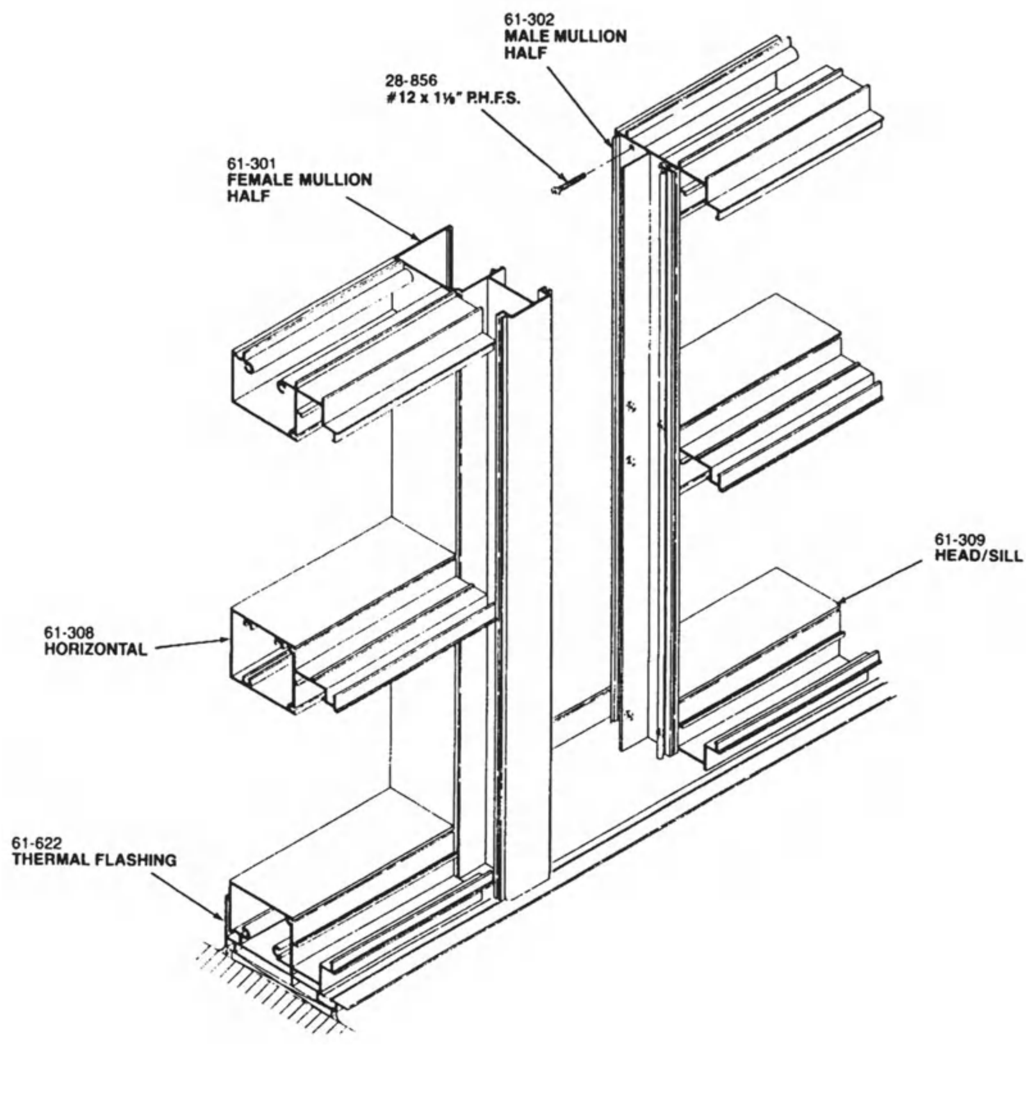


Figure 19-3 Components of a Factor-Assembled, Field-Erected Window Wall Assembly. Courtesy: Kawneer Company, Inc., Norcross, Georgia.

glass come together. Structural glazing provides an architect with more design freedom since it achieves a mullionless, uninterrupted glass surface. Along with design implications, structural glazing can substantially reduce the risk of thermal breakage and it also reduces the potential for air and water infiltration.

Butt glazing is created by eliminating vertical support members at the joints of the glass panes and filling these joints with high-modulus silicon sealants. The glass is still secured in the top and back track of the metal frame, but the silicon at the joint provides structural integrity between the vertical edges of the glass lights.

Common Causes of Window Leaks

1. Installation performed at low temperatures where sealants will not bond. (Many sealants will not perform below 40 degrees, silicon, is an exception. Acrylic based sealants require temperatures above 60 degrees unless they are warmed before use.)
2. Glass installed in frames that are out of square and out of plumb.
3. Failure to properly seal all frame joints, both butt and mitered.
4. Dirt and debris remaining in any rabbeted frame sections.
5. Damaged extrusions, bent rabbets.
6. Improper installation or absence of proper setting blocks.
7. Failure to bed and cushion glass thereby allowing it to walk or shift in the frame.

Storefront Work and Entrances

The term "storefront" originally applied literally to the front facades of retail establishments, but in today's construction terminology it means building entrances that incorporate exterior pedestrian doors and quite often includes a vestibule acting as an airlock to keep out summer heat and keep winter warmth inside. The components of typical storefront and entrance work can be seen in Figure 19-4 and the different parts of the assembly are identified as follows:

1. Framed sidelight
2. Mullion
3. Sidelight mullion
4. Meeting stiles at the pair of front doors
5. Head rail (sometimes refered to as a head mullion)
6. Transom mullion
7. Sill
8. Door head rail
9. Door bottom rail
10. Door stile

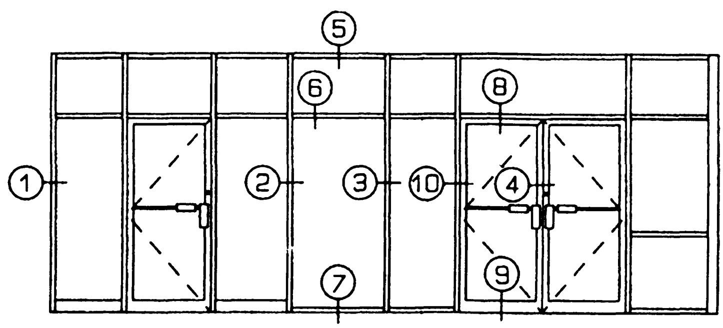
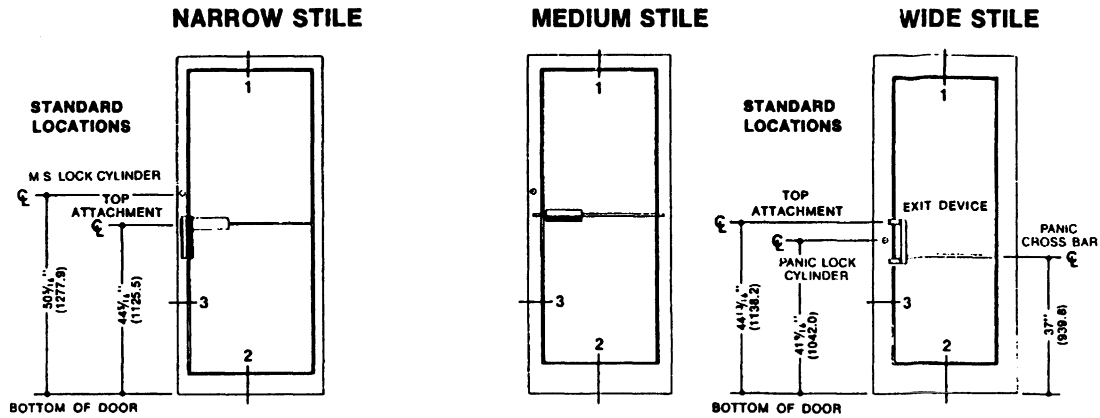


Figure 19-4 Typical Storefront Assembly.



Narrow Stile	Medium Stile	Wide Stile
1. Dimension–2 1/4" ±	1. Dimension–3 1/2" ±	1. Dimension–5" ±
2. Dimension–3 3/4" ±	2. Dimension–6 1/2" ±	2. Dimension–6 1/2" ±
3. Dimension–1 3/4" -2 1/8"	3. Dimension–3 1/2"–3 11/16"	3. Dimension–4 1/2"–5"

Figure 19-5 Variations in Frame Dimensions of Narrow, Medium, Wide Stile Entrance Doors. Dimensions vary somewhat from manufacturer to manufacturer. Courtesy: Kawneer Company Inc., Norcross, Georgia.

Storefront and entrance work is usually assembled on-site with aluminum extrusions precut at the factory or field measured, cut, fit and built in place using stock lengths of tubing. Entrance and storefront extrusions can assume several different profiles and depths and can be finished in stock anodized colors—clear, bronze or black as well as a wide range of custom and standard paint colors.

Framed aluminum and glass panel entrance doors can be obtained in three standard frame-member widths: narrow stile, medium stile and wide stile (refer to Figure 19-5). These doors can be hinged to operate as single or double acting. Automatic door openers activated by ultrasonics, photoelectric cell, magnetic strip, security cards, recessed floor mat or remote switchs are common to many installations. In these cases provisions are made for automatic by-pass and full manual operation in the event of a power failure. Entrance doors in high occupancy areas are often furnished with pivot hinges since they are stronger and more durable than conventional knuckle type butts. Typical entrance door hardware installation dimensions for both cylindrical lock and panic hardware are also included in Figure 19-5.

Sloped Glazing

Any glazing installed on a slope exceeding 15 degrees from vertical is referred to as sloped glazing. Contemporary architectural designs that bring daylight into interior spaces employ one of several forms of sloped or overhead glazing. Eight typical sloped or overhead glazing designs are shown in Figure 19-6. The various lettered components of each configuration is listed below.

A—Ledger main frame at head
B—Purlin

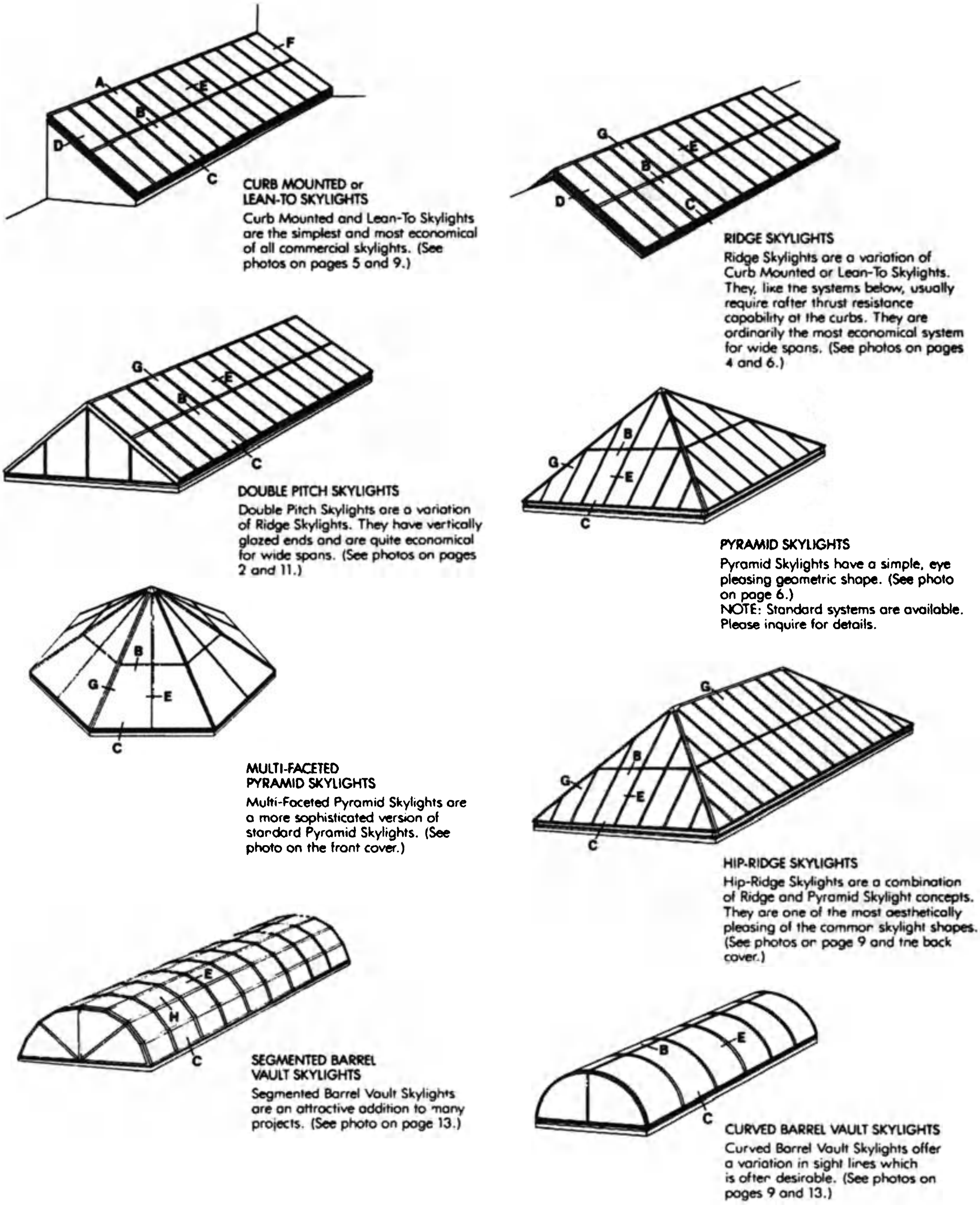


Figure 19-6 Sloped Glazing Designs. Courtesy: Regal Manufacturing Company.

C—Self flashing main frame at sill
D—Self flashing main frame at jamb
E—Rafter or joining mullion
F—Ledge main frame at wall
G—Supported hip or ridge

The insulated glass in sloped or overhead glazed structures is usually annealed or heat-strengthened laminated glass available as clear, tinted or reflective. However, plastic glazing materials such as polycarbonates, Lexan™ and fiberglass products are infrequently installed. The use of overhead glazed structures will place a high demand on a building's cooling system even in the colder climates and quite often power-operated blinds or drapes are retrofitted to the interior structural members of the assembly.

20

Interior Partitions, Ceilings, Wall and Floor Finishes

INTERIOR PARTITIONS

Partitions can be defined as nonbearing walls that serve to:

1. Provide delineation of space within a building.
2. Provide resistance to the spread of fire from one area to the next.
3. Provide control over sound transmission thereby affording privacy in the workplace.
4. Provide an enclosure for specialized equipment operations.

Partitions can be fixed in place, movable, demountable and relocatable. Although the construction superintendent will become involved in the installation of demountable and relocatable partitions from time to time, the fixed-in-place partition will be present in almost every construction project and discussed in detail in this chapter.

In residential construction and some light commercial projects, wood studs are used with regularity as partition framing members, but by and large, steel studs represent the overwhelming choice of most commercial and industrial contractors.

Steel Framing Components

Studs and Runners. Channel-rolled, corrosion-resistant coated steel studs are available in three standard metal gauges and with five nominal section depths:

20-gauge—2½″, 3⅝″, 4″, 6″
22-gauge—2½″, 3⅝″, 4″, 6″
25-gauge—1⅝″, 2½″, 3⅝″, 4″, 6″

These studs are designed for screw attachment and are prepunched to allow stringing electrical cable and small-diameter pipes horizontally through each member.

Load-bearing steel-framed walls such as those used in light-gauge exterior-wall framing assemblies will use steel studs constructed of 14-, 16- and 18-gauge metal available in section depths of 3⅝ inches, 4 inches, 6 inches, 7¼ inches, 8 inches, 9¼ inches, 11½ inches and 13½ inches. These heavier gauge studs are generally welded together in framing assemblies. Runners are U-shaped rolled form members that fasten to the floor and the top of the partition to provide the anchorage, alignment and rigidity of frame required prior to the application of drywall.

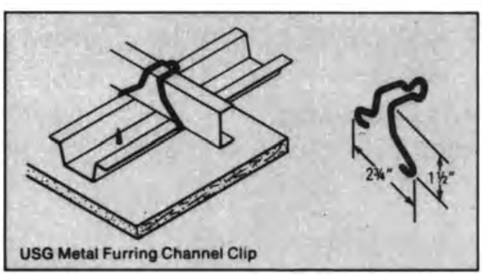
When drywall is to be attached to a concrete or masonry wall, furring strips provide the anchorage for the gypsum wallboard. These furring strips are available in three configurations: channel, resilient channel and zee channel (see Figure 20-1). The channel furring strip can be attached to a vertical wall or it can be clipped to a black iron or cold-rolled steel channels and used to support a suspended drywall ceiling.

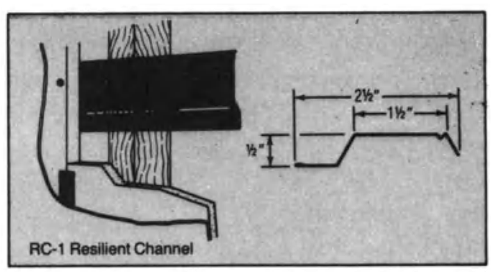
The resilient-channel-furring member, made of 25-gauge galvanized steel, is the economy channel used in wall partition construction, and the zee-furring channel made of 24-gauge hot-dipped galvanized steel is the one to use when rigid foam insulation is to be installed on an exterior wall.

There is an adjustable wall furring bracket that can be used in conjunction with the furring channel. This accessory is used on the inside face of masonry walls and allows adjustment or shimming to compensate for the variations in plane that are inevitable in masonry wall construction.

Framing Accessories

Stress can occur because of expansion and contraction when large expanses of gypsum wallboard partitions and ceilings are being built. When long, uninterrupted runs of drywall are anticipated, a control joint should be installed to prevent future





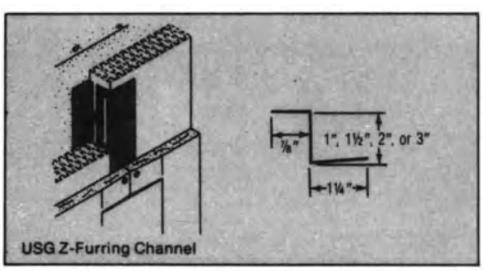


Figure 20-1 Three Types of Sheetrock Furring Strips. Courtesy: USG, Chicago, Illinois.

cracking. Operating much like a bellows (see Figure 20-2) this cold-rolled zinc-coated steel accessory can be installed in all partitions except where fire-rating and sound-transmission considerations must be taken into account.

Because of the nature of the product, drywall edges are susceptible to damage unless protected in some way. There are a number of accessory items on the market that are used to protect the construction of wall corners and also provide a true vertical sight line. Figure 20-3 contains an illustration of a typical cornerbead and three of the most common edge-casing trim pieces used in gypsum wall constructions. These casing beads are available in electrogalvanized metal or rigid vinyl.

Gypsum Drywall

Made of a fire-resistant core of essentially gypsum material, sometimes containing fibers that account for 15 percent of its total weight and bonded with a heavy natural finish paper on the face side and a strong liner paper on the back side, sheetrock walls have revolutionized the way interior partitions are constructed. It is the rare project indeed where lath and plaster walls are built nowadays. Gypsum drywall offers many advantages:

Speed of installation and ready availability of product.
Ability to be painted or papered quickly since no other drying time is required other than that needed for taped joints.
Fire resistive construction even when nonrated wall assemblies are installed.
Nonwarping.
Highly crack resistant.

There are certain limitations to drywall installations:

1. The product cannot be exposed to excessive or continuous moisture and should not be installed where the board will be in contact with surfaces exceeding 125 degrees F. (When used as a backer for ceramic wall tile, only water-resistant material should be used.)
2. Maximum spanning of framing members is 24 inches on center for ½-inch and ⅝-inch board, and 16 inches for ⅜-inch and ¼-inch panels.
3. Installation of gypsum wallboard over ¾-inch wood furring is not recommended inasmuch as the flexibility of this thickness will cause already driven nails to

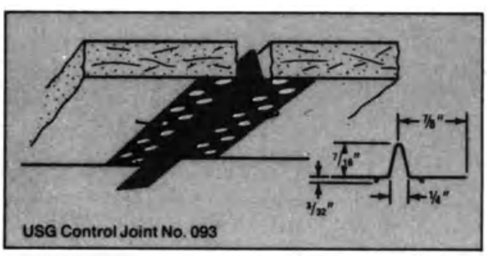


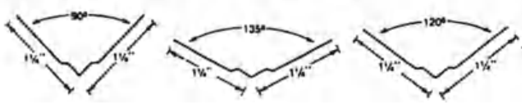
Figure 20-2 Drywall Expansion Joint. Courtesy: USG, Chicago, Illinois.

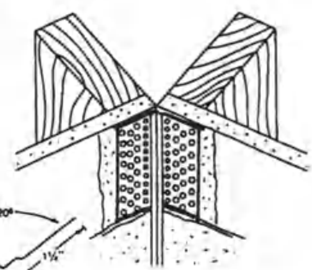
INSIDE ANGLE CORNERBEAD

Inside angle cornerbead is made from electrogalvanized steel and is specially designed to provide a perfectly straight, smooth finish to inside corners without nails, tape or cracking.

Inside angle cornerbead is finished with joint compound. Ideal for both new construction and repair work. Installation instructions included in each box.

Electrogalvanized metals meet or exceed ASTM A591.

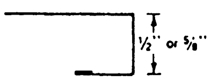


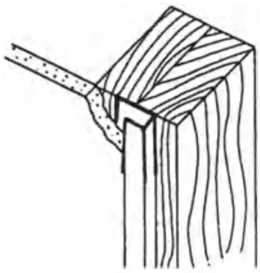


J-BEAD

Reveal-type casing bead provides a finished edge at door and window openings, and can be used where wallboard panels intersect or abut dissimilar surfaces.

Joint compound is not required with J-bead. The electrogalvanized metal meets or exceeds ASTM A591 specifications.

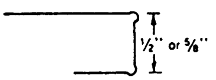


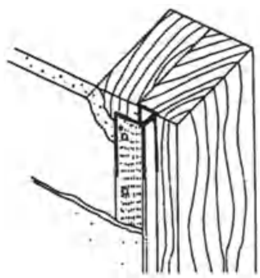


U-BEAD

U-shaped casing bead provides a finished edge around door and window openings. Joint compound is needed to prepare the surface for finishing.

The knurled taping flange and our electrogalvanized metal coating provide maximum joint compound bonding. The electrogalvanized metal meets or exceeds ASTM A591 specifications.

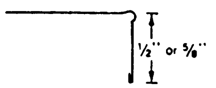


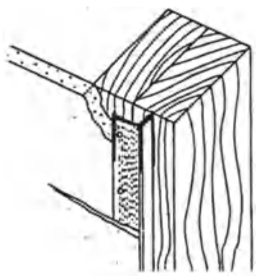


L-BEAD

L-bead trim is used as a finished edge for wallboard stops around door and window openings. Installation is made easier because the back flange is eliminated.

L-bead also has an electrogalvanized metal coating. The electrogalvanized metal meets or exceeds ASTM A591.

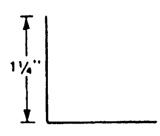




CONSTRUCTION L

Construction L is made from 25-gauge galvanized steel for use in light gauge framing wherever metal angles are required.

Galvanized metal meets or exceeds ASTM A525.



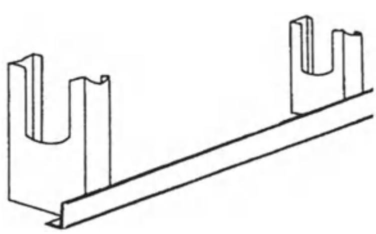


Figure 20-3 Typical Corner-Bead Angles and Illustration of "J" and "U" Bead, "L" Bead And Construction L. Courtesy: Clinch-ON® Products, Mounds View, Minn.

loosen under the impact of subsequent nailing. If wallboard is installed on wood furring strips they should be minimum 2 inches by 2 inches.

4. When gypsum ceilings are installed, the weight of any unsupported insulation shall not exceed 1.3 psf for ½-inch thick panels with 24 inches on center framing 2.2 psi for ½-inch panels with 16-inch o.c. framing and ⅝-inch panels with 24-inch o.c. framing.If these weights are exceeded, objectionable sagging may occur.

Gypsum wallboard panels are available with various factory edge treatments, as in Fig. 20-4.

Although regular gypsum wallboard is noncombustible, there is a fire-rated brand that usually is identifiable by its "X" rating. These fire-rated boards contain additives that enhance their fire-resistivity qualities. "Green board" is the common name for water-resistant gypsum wallboard. The face and back papers are chemically treated to resist moisture and the core is made water resisting by additives placed in the gypsum material.

Foil-back sheetrock is produced by laminating a special kraft-backed aluminum foil to the back surface of regular or fire-rated sheetrock. This foil coating is very effective as a vapor retarder when the foil side is applied directly to the framing member.

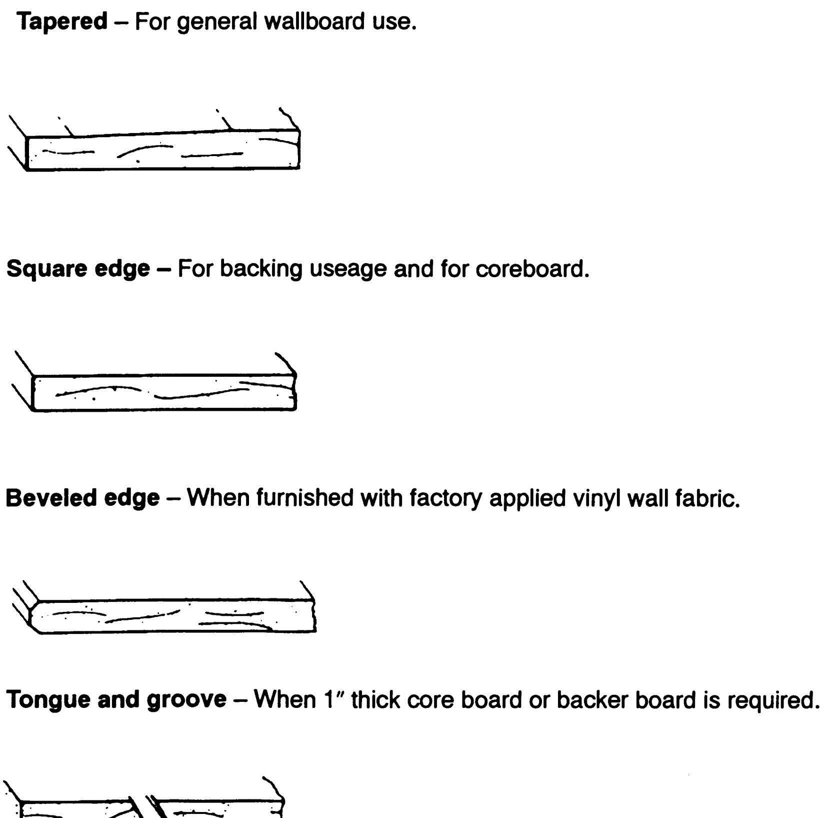


Figure 20-4 Gypsum board factory edge treatments.

Vinyl-faced sheetrock panels in a variety of colors and textures are marketed by several manufacturers, and these panels are meant to be installed as finished wallboard systems. They are often attached to framing members with fasteners colored to match their vinyl surface.

Coreboard is a 1-inch thick gypsum core product with strong gray paper on both sides that makes it unsuitable for use as a finished wall. But with tongue and groove "V" joints, coreboard delivers fire ratings adequate for stair and elevator enclosures.

Exterior sheetrock is a weather-resistant, nonsag board designed for use in exterior soffits, canopies or carport ceilings or as a ceiling material in underground parking garages. Some manufacturers score their sheets so that they can be snapped for quick application.

Exterior gypsum sheathing is a product designed to be installed on the outer face of exterior curtain-wall framing and behind the curtain-wall face veneer. The gypsum core is encased in a special brown water-repellent paper on both sides and along edges. When used on the inside face of a cavity wall with a masonry veneer, the surface of the gypsum sheathing will undoubtedly be punctured when masonry anchors are screwed through to the framing members. Good construction practices dictate that wherever these punctures take place a dab of mastic should be placed over the fastener so that it covers any exposed edges of the punctured sheathing.

Cement board, manufactured by United States Gypsum Company under the trade name DUROCK™ is lightweight, relatively low cost, fire resistant and exhibits superior performance as a water-and moisture-resistant wall panel. Preferred by many builders as a backer for ceramic wall tile, it is also an excellent wallboard for masonry and/or agrgregate veneers.

Lead-lined sheetrock is fire-rated sheetrock with lead linings of 1/64 foot to 1/8 inch bonded to 1/2 inch or 5/8 inch sheetrock. Two-inch strips are provided for installation to each of the joint studs before the sheetrock is installed, and lead discs provide protection where the sheetrock is penetrated by fasteners.

Drywall Fasteners

When wood-stud and drywall installations required nailing, nail "pops" were the bane of the industry. Loss of moisture in the wood framing members would cause it to shrink to the point where the projection of the nail would be visible. The amount of projection was directly proportional to the depth of penetration of the nail. However for those contractors still using ring-shanked nails, recent studies have pointed out other reasons for unsightly nail protrusions:

1. Fractured face paper at the nail puncture.
2. Lack of adequate pressure on the board when the nail is driven home.
3. Board being improperly fitted or wedged into place.
4. Twisting or bowing of a framing member.
5. Nailing from ends or edges toward the center.
6. Improperly aligned studs, plates, spreaders and headers.

7. Wallboard applied over protrusions—pipes, or conduits not recessed into the framing enough.
8. Nails insecurely driven.

Another way to avoid nail pops is to use less nails! With the newer types of adhesives on the market, the use of an adhesive greatly reduces the number of nails required to secure the board in place.

Drywall Screws

Self-drilling, self-tapping corrosion-resistant screws allow greater production of wallboard installation with less headaches for the contractor. The bugle head screw in a variety of lengths for various wall thicknesses is standard in the industry, and there are a number of special-use screws that fit almost any use (see Figure 20-5).

Joint Treatment

The quality of the taped sheetrock panel joints will probably remain the measure by which the wallboard installation is judged. However there are other factors that enter into this evaluation:

- The angle and type of wall and ceiling illumination.
- The type and finish of the paint being applied.
- The level of joint finish specified.

Down lights shining close to the surface of a gloss-finish painted wall will spell trouble, so will joint treatment of only two coats when a very thin wallcovering is to be applied. Several trade organizations have gotten together to establish recommended specifications for levels of gypsum wallboard finishes.

Level 0—No taping, finishing or accessories required. This finish will generally apply to temporary construction.

Level 1—All joints and interior angles are to have tape embedded in joint compound. Surfaces to be free of excess joint compound. Tool marks and ridges are acceptable. This finish will be used for plenums or in areas where the wall assembly will be concealed or in service areas not open to public view.

Level 3—All joints and interior angles to be taped with joint compound and two separate coats of compound to be applied over all joints, angles, fastener heads and accessories. All joint compound to be free of tool marks and ridges. This finish will be used when a heavy- or medium-texture finish is to be applied or where a heavyweight grade of wallcovering is to be applied.

Level 4—All joints and interior angles shall be taped and embedded in joint compound and three separate coats of joint compound are to be applied over all joints, angles, fasteners and accessories. All joint compound shall be smooth and free of tool marks and ridges. This finish will apply where lightweight wallcovering is to be used or flat paints that are applied out of the range of

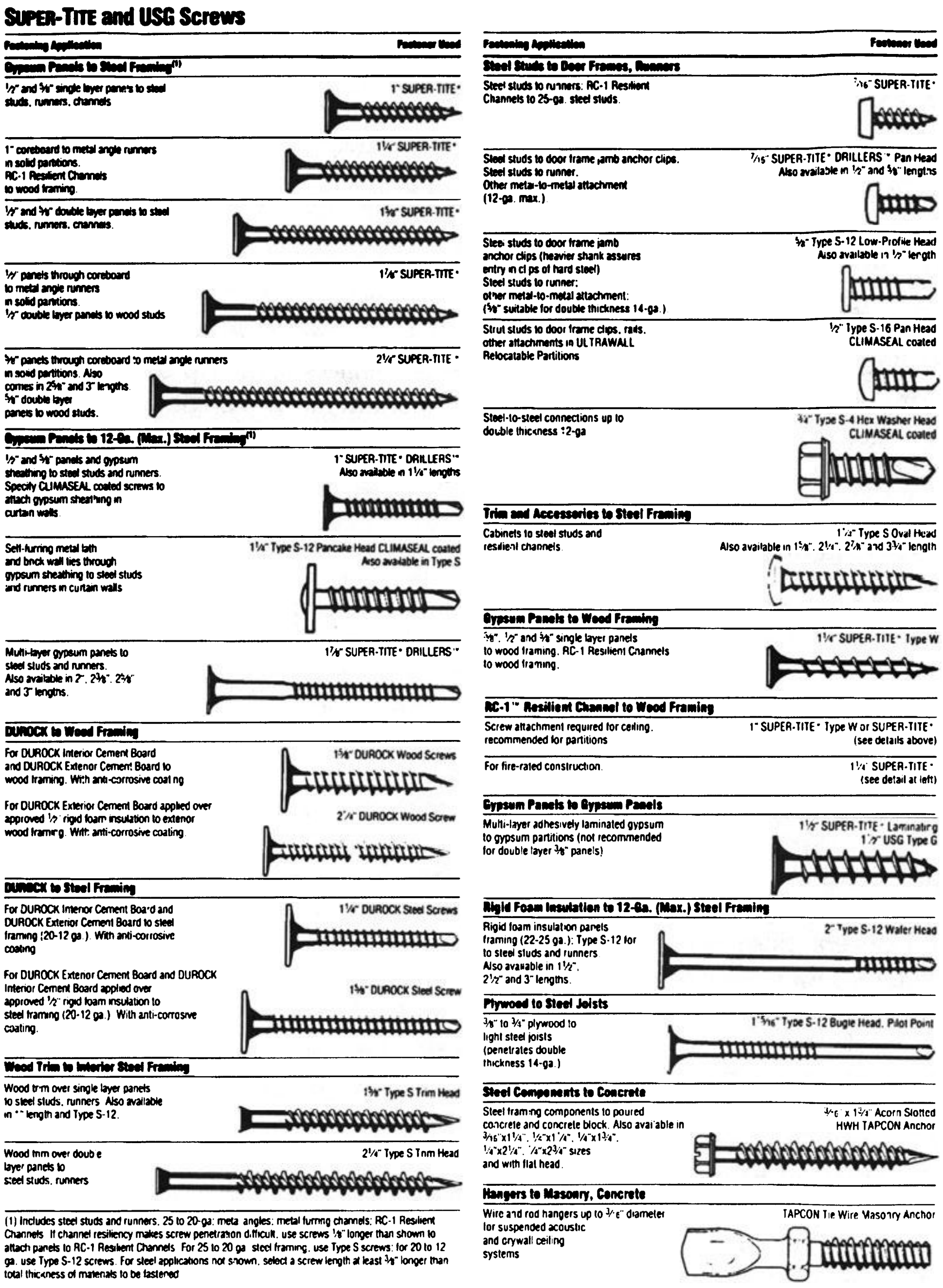


Figure 20-5 Drywall Fasteners for Various Applications. Courtesy: USG, Ghicago, Illinois.

critical lighting areas. Gloss, semi-gloss and enamel paints are not recommended over Level 4 finishes.

Level 5—All joint and interior angles shall have tape embedded in taping compound plus three separate coats of joint compound over all joints, angles, fasteners and acessories. A thin skim coat of joint compound or a material manufacturered especially for that purpose shall be applied over the entire wall surface. This level is recommended for gloss, semigloss and enamel paint finishes or where non-textured flat paints will be applied under critical lighting areas.

Typical Drywall Partition Sound and Fire-Rated Assemblies

Two key elements of a drywall partition are its ability to retard the passage of fire and its ability to retard the passage of sound. Fire-ratings are increased by adding thickness of gypsum wallboard and in particular fire-rated "X" wallboard. By the addition of sound batts, the sound transmission coefficient of the wall, its STC rating, will increase thus making passage of both sound and fire more difficult. Figure 20-6 reveals some of the common wall assemblies and their corresponding fire and STC ratings. But quality sound transmission reduction must incorporate more than just added layers of sheetrock and sound batts, since sound can travel over and under partitions. Better control over sound transmission will occur if sealant (caulking or resilient tape) is placed under the bottom track of the metal wall framing, and if the assembly does not extend above the ceiling to the structure above. A means of preventing sound from escaping over the top of the partition and through the ceiling assembly must also be considered.

Plaster Walls

The fastening of metal or wood lath onto partition framing members followed by a troweled-on coat of a mixture of Keene's cement and alum (one way in which to make plaster!) or lime and plaster of paris is a dying art. Gypsum–cement interior plaster walls are expensive to build and tricky for an inexperienced tradesman to apply, but the hard, durable, polished look of a plaster wall will be difficult to match when it comes to a wall finish.

Plastering is done in either a two-coat or a three-coat application. The three-coat process starts with a first, binding coat called a "scratch" coat. The second coat is known as the "brown" coat, and the third coat is the final or finish coat. In a two-coat application, the "scratch" and "brown" coats are combined into one coat with the second coat being the finish. The first coat is applied to an expanded metal lath, or strips of wood (lath) or lathing board, a solid or perforated plaster sheet measuring ⅜ inch or ½ inch by 16 inches wide and 48 inches long.

Exterior cement plaster wall construction has all but given way to the new synthetic resin coatings manufactured by such firms as Dryvit, Sto, Insulcrete and others. Possibly some new economical form of synthetic plaster interior finish approximating the look of plaster walls may become popular in years to come.

Ceiling Construction

Gypsum wallboard, suspended from black iron framing, is used frequently in situations where fire ratings are required above the capability of lay-in ceilings. Gypsum wallboard ceilings are also used quite a bit where the architect wishes to create a monolithic ceiling.

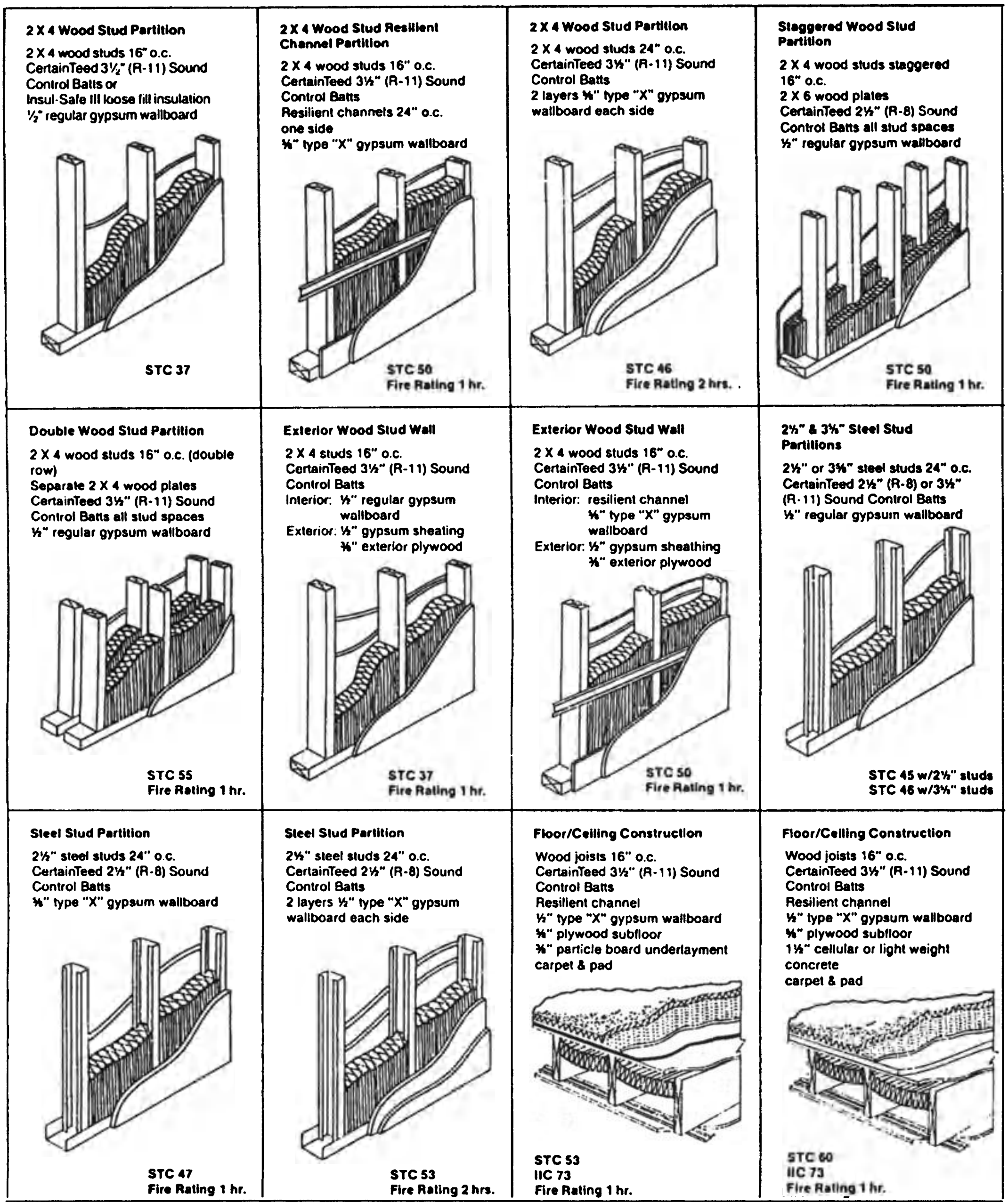


Figure 20-6 Typical Gypsum Wallboard Assemblies for Fire and Sound Rated Partitions. Courtesy: CertainTeed Corp.

Acoustical lay-in ceilings range from most economical to most expensive when custom colored grids are filled with intricately patterned panels, or bright metal strips form a series of linear paths through a room or corridor. When mineral board ceilings are installed, they are suspended in either exposed or concealed framing systems and these suspension systems can be either fire rated or non-fire rated.

Concealed Suspension Systems. These systems require a perimeter channel molding where the ceiling meets a vertical wall surface. Main beams, crosses, tees and tee splines create the effect of a monolithic ceiling while retaining much higher sound trapping characteristics and accessability through the use of strategically placed access panels of the same material and texture. These concealed-spline framing systems can be suspended directly from the structure above or they can be attached to a channel (black iron) framing system.

Exposed Suspension Systems. At one point a client could have any color grid system as long as it was white, but that has changed. Exposed grids are now available in a multitude of colors including aluminum and reflective metal finishes and the standard $^{15}/_{16}$-inch flange width has been joined by a slim line measuring only $^{9}/_{16}$ inches. Exposed grid systems are made in both fire-rated and non-fire rated assemblies.

Mineral Board and Metal Ceiling Panels. Several manufacturers market a product line of mineral board panels in many different colors and textures. By rabbeting the edges, these panels take on a three dimensional look as they extend down beyond the grid system. And with intermediate routing or grooving, a conventional 2 by 4 panel can assume the look of a 2 by 2 or 1 by 1 pad. Although embossed-metal ceiling squares approximating the look of turn-of-the-century tin ceiling tiles are used in downtown restoration projects, an entire product line of polished stainless steel panels, baffles, grid systems and linear metal strips have transformed many dreary showrooms, offices and lobbys into bright new modern spaces.

Fire Safing

Holes, cracks, voids in fire-rated partition, ceiling and floor assemblies must be sealed or safed off with approved materials so that their fire ratings can be preserved. Local and state fire codes may permit flutes in metal decks to be stuffed with fire retardent batts to safe-off the space between the rated partition and the structure above. Some local authorities may require that these batts be held in place with some sort of restraining material. Low-melt-point glass-fiber batts have proven to be less effective than originally perceived, and there are specific types of insulation available in the marketplace just for fire-safing applications.

Irregular openings in concrete floor slabs or cast-iron pipe penetrations through these floors are best filled with concrete or mortar. But pipes and conduits made of materials that can melt at temperatures generated during a fire, and penetrate rated walls or floors, must be filled with an intumescent material (one that expands when subjected to heat). Intumescent caulking in tubes is available along with intumescent putty in cans and foam in aerosol cans. These materials, when subjected to fire can expand as much as 1,000 percent to choke off the spread of fire and smoke when pipes collapse.

FLOORING

The first flooring material could well have been earthen, smoothed and compacted by primitive man and possibly followed shortly thereafter by wood after the Iron Age man who fashioned crude axes and adzes and learned to use them as tools. It is known that the ancient Egyptians crafted ceramic tile, but it was not until the Middle Ages that ceramic tile began being manufactured in Italy and became a technologically crafted product. The twentieth century brought forth synthetic materials that are the backbone of the carpet and resilient flooring industry today. There are cementitious flooring materials in limited use today such as terrazzo, a marble-aggregate concrete that is cast in place or precast and then ground smooth to create a smooth, shiny stonelike floor that is rich looking and maintenance free. But we will concern ourselves with the four most popular types of flooring today: ceramic, wood, carpet and resilient.

Ceramic

Perhaps a better designation for this type of flooring material would be "burned clay" because that would encompass not only ceramic tile but bricks, pavers and quarry tile. These types of flooring materials are usually installed over a concrete substrate and are set in either a bed of mortar or thin-set with latex-Portland cement mortar or epoxy mortar.

Tile is divided into five categories according to the type of traffic that it will bear.
Residential—Normal residential foot traffic.
Light—Light commercial traffic.
Moderate—Normal commercial or light institutional use.
Heavy—Heavy commercial use.
Extra heavy—Highest commercial use—food prep areas, industrial work areas, hospital kitchens.

Ceramic tile is available in two classes: glazed and unglazed. Unglazed tile is used for flooring since the possibility of slipping is considerably less than if a smooth glazed product is used. Another form of ceramic tile, crystalline, often seen in small squares in mosiac patterns is also recommended as a flooring material inasmuch as its irregular surface produces antislip qualities. While most ceramic tiles are made from porcelain materials, natural clay is used in the manufacture of earth tone quarry tile. Brick pavers are also formed of clay and shale; however, some can be made of porcelain.

These kinds of flooring materials are layed with open joints, and these joints are filled with grout, a different formulation for each use:

Dry set—Portland cement shake. Used when pavers with thin joint patterns are installed.
Portland cement grout—Sometimes fortified with a latex bonding agent and used for many flooring applications where pavers of ¾ inch to 1½ inch thick are set in mortar.
Epoxy grout—Provides a chemically resistant surface and also creates high bond strength.
Mastic grout—A one-part material that is flexible yet stain resisting.
Silicon grout—Resistant to moisture, steam, humid indoor conditions and is mildew resistant.

Furan grout—Contains furan resins and is used in industrial flooring applications where high resistance to chemicals is required.

Wood Flooring

The installation of wood flooring is not confined to residential use. Architects have been and will continue to specify wood flooring in certain selected areas within commercial buildings. And superintendents involved with schools and performing arts projects will more than likely find requirements for wood flooring in gymnasiums and on stage floors.

Wood flooring, either strip or parquet can be installed over wood-joist construction or over concrete slabs that have been prepared for nailing by the installation of plywood underlayment or wood sleepers. When installed over wood joists, the subfloor should be constructed with ¾ inch by 4 inch or 6 inch boards—kiln dried. No. 1 or No. 2 pine or equivalent is preferred, laid diagonally and spaced ¼ inch apart. The subfloor should be nailed with 10d common or cement coated, ring-shanked nails twice at every bearing point. Plywood can also be used and it should be exterior grade, not less that ½-inch thick.

Wood floors installed over concrete should first have a 4-mil minimum polyethylene vapor barrier applied to the concrete deck. If plywood subfloor is used, it must be exterior grade, at least ¾-inch thick with spacing of ¼ inch to ½ inch between panels and ¾ inch at each wall line. A nailing base can also be created by installing chemically treated wood sleepers at a 90 degree angle to the direction the flooring will be laid. The end joints of the sleepers should be staggered with ends lapped 4 inches. These sleepers should be embedded in a troweled-on coat of cut-back asphalt floor mastic and then a layer of 6-mil poly ought to be laid loose and lapped over the top of the sleepers.

The typical wood species used for wood flooring applications and their respective grades are set forth as follows:

Oak—Either quarter sawn or plain sawn. Available as Clear (clear with an average of ⅜ inch of bright sap). Select (may contain sap, small streaks, pin worm holes, burls, slight imperfections), No. 1 Common (may contain heavy streaks, worm holes, knots, minor imperfections) and No. 2 Common (contains many character marks, contrasting appearance—used for economy reasons).

Birch, beech, hard maple—First Grade (free of all defects except natural color of wood shall not be considered a defect), Second Grade (will contain tight, sound knots, slight imperfections but may lay without any waste), Third Grade (must be of such a character that it will lay and provide a good, serviceable floor.

Pecan—First Grade (practically free from all defects), First Grade Red (same as First Grade except face shall be all heart wood), First Grade White (same as First Grade except that face will be all bright sap wood), Second Grade (allows tight sound knots, pin worm holes, streaks, light stain and slight imperfections), Second Grade Red (same as Second Grade except face to be all heart wood), Third Grade (must be such a nature as to lay a good serviceable floor).

Prefinished hardwood floors are graded differently. The top grade of oak will be graded Prime Grade, followed by Standard & Better Grade, then Standard Grade and lastly, Tavern Grade. Prefinished pecan and beech flooring is graded Tavern and Better.

Common Problems with Wood Floors

Cracks are the most common problem, and wood flooring will shrink as it dries. Hairline cracks are to be expected in strips 2¼ inch wide or less. Cracks in floors not related to moisture are generally caused by settlement of the subfloor, whether it be wood or concrete; overdrying if the flooring has been placed over forced air or heating pipes or coils; improper subfloor materials where nailing has not been effective; and heavy vehicular movement especially during a move-in, when heavy loadings will cause the flooring to shift.

Cupping of floors is caused by excessive moisture being absorbed on the underside of the wood causing expansion, which will raise the edges of the plank. Crowned floors are created when the flooring loses its excess moisture and shrinks on the underside, thereby flattening and leaving the topside edges lower than the center of the plank. Proper precautions during on-site storage, such as storing wood flooring materials in a dry, well-ventilated area and allowing the wood to climatize, will reduce the possibility of cupping or crowning.

New advances in wood-floor finishes permit tough acrylics to become impregnated into the wood by the use of vacuum or pressurization processes. In some cases a liquid monomer is forced into the cells of the wood where it is transformed into acrylic plastic when bombarded by gamma rays. These impregnated coatings contain long wearing colors and sealers and provide the warm, stained glow that makes wood flooring so appealing.

CARPETING

Although the choices in patterns and colors can be bewildering, the make-up of commercial carpeting is rather straightforward. Carpet is made of wool, synthetic fibers or a combination of both, and carpet is made by a process whereby hundreds of stitchlike placements of yarn are embedded in a backing material. This process is called "tufting" and while all carpets produced before 1950 were woven, 95 percent of all materials produced today are tufted. The method by which the yarns are locked into place creates the surface texture of the carpet (see Figure 20-7). Level-loop carpet has both ends of the loop anchored into the carpet backing, making the surface smooth, level and long wearing. Multilevel loop pile is made with face yarns of different heights and gives a sculptured look to the carpet. Cut pile is created when the top loop of the looped pile is cut so that two individual yarn tufts are formed.

Velvet and plush carpets are made in this way, so are saxonies (where tuft ends are twisted together and heat set) and frieze, pronounced free-zay, a carpet made from tightly twisted low pile yarns to create a nubby effect. There are also cut-and-loop pile carpets containing a mixture of both types of yarn.

Wool carpets are luxurious and good performing, and are more expensive than synthetics. Approximately 97 percent of all carpets produced are made with man-made fibers, and nylon represents 80 percent of all pile fibers used by U.S. carpet mills.

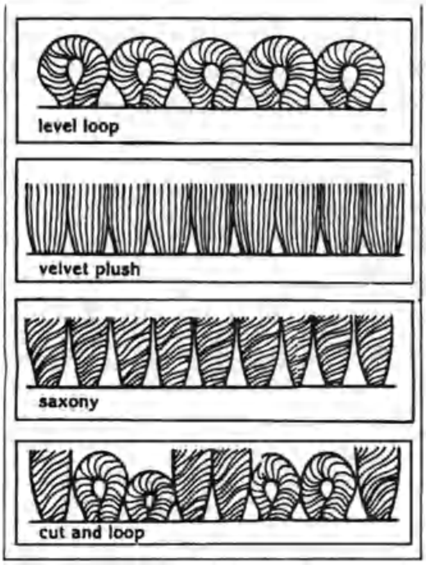


Figure 20-7 Yarn Configuration that Determines Carpet Type.

Nylon is available with built-in static control, and this fiber produces a carpet that is outstanding in terms of abrasion resistance. Nylon is resistant to water-soluble stains and can be cleaned easily. Olefin (polypropylene) yarns are strong, easily cleaned, resistant to permanent soil and stain, moisture and mildew resistant. Polyester carpets are noted for their soft "hand" or feel, offer excellent color clarity, can be readily cleaned and resist water-soluble stains. Acrylic fiber yarn, often found in velvet and level-loop carpet construction offers the feel and appearance of wool but at lower cost. This yarn is moisture and mildew resistant and resists absorption of water-soluble stains.

Quality carpet is judged by density (the amount of face yarn in the carpet), twist (the winding of carpet around itself), and heat setting. By bending the carpet in an inverted "U" shape, the closeness or density of the individual tufts can be determined. Quality carpets will display ends that are neat and well defined and do not blossom open. Heat setting of a 2-, 3- or 4-ply yarn will enable the yarn to hold its twist through many cleanings.

Carpet weight is expressed in ounces per yard, so the designation "32 ounce" carpet means that it weighs 32 ounces per square yard.

An important factor in carpet make-up is its backing. The primary backing of tufted carpet is made of jute, cotton or woven synthetics. When a carpet is "double backed" it contains a secondary backing made of jute, woven fabric or possibly a foam or another cushioning material. Carpet can also be installed with a separate padding layer made of jute, foam rubber or plastic, or felted cattle hair.

Resilient Flooring

This type of flooring material can be subdivided into vinyl composition tile (VCT), backed-sheet vinyl, homogeneous-sheet vinyl, slip-retardent tile and rubber tile. Vinyl composition tile replaced the asbestos bearing VAT tile years ago, and VCT is classified in two types; Type I, Smooth Surface, and Type II, Embossed Surface. Both types are produced in 12 inch by 12 inch squares with a nominal thickness of ⅛ inch or 1/16 inch. The tile itself is made of a blend of thermoplastic binders, generally PVC or copolymerzing vinyl chloride in combination with fillers and pigments. Color finish and patterns are wide and varied.

Solid vinyl floor tiles are also available in two types and three classes:

Type I—Smooth Surface:

- Class A—Monolithic, constant composition throughout.
- Class B—Multilayered with a layer of binder stabilized against heat and light or fillers and pigments or a transparent or translucent vinyl plastic.

Type II—Embossed Surface:

- Class A—Monolithic.
- Class B—Multilayered.
- Class C—Class A or Class B with a protective coating.

Solid vinyl tiles are manufactured in 12 inch by 12 inch squares and in thicknesses from ⅛ inch (3.18mm) to .100 inch (.254mm), .080 inch (2.03mm), .050 inch (1.27mm) or .039 inch (1.27mm). Again, colors and patterns are plentiful.

Sheet Vinyl, Backed Vinyl and Homogeneous Material. Available with backing or as solid vinyl material, solid-sheet vinyl flooring forms the basis for most commercial work, while the foam-backed product is used primarily in residential construction. Backed-sheet vinyl has a wearing surface of tough vinyl adhered to a backing of fibrous composition. This form of sheet goods is also available in a slip-resistant finish. Slip-retardant sheet vinyl is constructed of three layers: a fibrous composition backing, a vinyl base layer and a wearing surface containing mineral aggregate discs. Homogeneous sheet vinyl is a nonlayered, nonbacked, solid vinyl product suitable for the most demanding use.

When these floorings are installed over new concrete slabs, a curing or drying time of 4 to 6 weeks must be attained before the flooring is installed. The concrete slab should have been steel troweled to a smooth surface and any depressions, score marks or grooves should be flash patched before flooring installation proceeds. When these materials are installed over old slabs, the concrete must be clean and free of oil, grease, wax or dust, and any existing oil-based paints removed, preferably by the use of a drum sander followed by a thorough rinsing with water. The concrete must then be allowed to dry.

Installation over wood floors with previous tile surfaces can be achieved if all tiles to remain are solid and fully adhered to the substrate, and if the substrate is free of springiness. However a better installation will occur if the new tile is laid over a sound, smooth underlayment of ¼-inch hardboard or underlayment grade plywood.

Other forms of resilient flooring are:

Linoleum—A composition of oxidized linseed-oil binder, and ground cork or mineral fillers with a backing of asphalt-impregnated felt. Good resistance to grease and abrasion. Made in residential and commercial grades.

Rubber tiles or sheet goods—Generally nonlayered and nonbacked, specifically those known as "radial" tiles offer excellent wearing characteristics along with slip-resistant qualities.

Cork tile floors made of granulated cork heat sealed in a resin binder, offer first-rate resilience but poor resistance to abrasion.

PAINT AND WALL COVERINGS

To paraphrase Green Bay Packer's Coach, Vince Lombardi—"Surface Preparation isn't the most important thing—it is the only thing." Most paints and wall coverings in the marketplace today are fairly sturdy materials when applied in accordance with the manufacturers suggested uses and installation, but trouble does occur when the substrate has not been prepared properly. Not only must the correct primer be used, but the surface must have been properly cleaned, made free from dust, oil, grease and other materials that prevent the proper bonding of the paint to the substrate.

Depending upon the level of finish desired, imperfections, dents, dings, and gouges must be filled in and properly sanded. Surface contaminants, particularly on ferrous and nonferrous metals must be removed by sanding or wire brushing by hand or with power tools, or wiping with a solvent or other chemical, or in extreme cases by sand blasting. After substrates are cleaned they must be coated with the proper primer.

A Surface Preparation Checklist

Metal Surfaces. The minute pores in metal surfaces provide anchorage for paint, but when these pores are clogged with dirt, rust, grease or oil, proper adhesion will not occur. New galvanized metal must be wiped clean with mineral spirits to remove any remaining film, after which a special galvanized metal primer must be used. Weathered galvanized metal should be cleaned with a wire brush or by sanding, and terne metal surfaces must be slightly abraded with steel wool or fine abrasive paper. Bare aluminum exposed to the weather will corrode, and this corrosion must be removed by rubbing with steel wool and then wiping with mineral spirits; severe pitting will require sanding.

Drywall and Plaster Surfaces. Patch all cracks in plaster and cut out deep ones before refilling. Plaster patches should be spot primed after being allowed to dry for at least 15 hours since these patches will tend to absorb more paint than surrounding areas and plaster walls should have less than 15 percent moisture content before painting. Drywall tape joints and spackled nail heads must be dry, sanded and free from dust particles.

Concrete and Masonry Surfaces. Oils from concrete forms must be removed from the surface of new concrete, and the longer concrete cures, the less chance there will be for cracking, flaking and peeling of the paint surface. Laitance, that weak slurry of water and cement that sometimes appears on the surface of concrete when excess troweling has taken place, must be removed with a 10 percent solution of muriatic acid and water. Efflorescence on masonry walls must also be removed by washing the surface of the wall with water or acid and then followed by a clean water rinse. If moisture still exists in the wall, efflorescence will continue and any paint will more than likely peel off. Concrete floors should be etched with muriatic acid followed by a clear water wash. This will give the paint a better grip on the surface of the concrete.

Wood. Decorative wood should be fine sanded, and when open-grained woods such as oak, mahogany or walnut are being finished a filler–sealer will close up the pores of the wood to create a "free from pin holes" appearance.

Chronic peeling of exterior wood surfaces generally results from moisture becoming trapped behind the surface of the paint. Excessive interior moisture that cannot vent itself to the outside or possibly wind-driven moisture penetrating the exterior through open joints are the causes of most exterior paint failures.

Paint Composition, Paint Finishes and Paint Types

Paint is made of three components: pigments that provide the color; binders that give the paint hardness, adhesion and wearability; and solvents that control the viscosity and ease of application. Paint finishes are determined by gloss range, and gloss level is obtained by using more or less pigment. High-pigment levels create a flat, rough finish while low-pigment levels produce a glossier surface. The five basic gloss levels and corresponding gloss ranges (per ASTM D-523 standards) are:

Gloss Level	Gloss Range
Flat or soft lustre	Below 15
Eggshell	5 to 20
Satin	15 to 35
Semigloss	30 to 65
Gloss	Over 65

Types of Paints

Alkyd. Made by mixing synthetic materials with vegetable oils such as linseed, soya and tung. The more oil in the paint, the lower drying time will be as the oil oxidizes and the solvents evaporate. Alkyds have almost entirely replaced oil-based paints because they dry faster and have better color-retention qualities.

Latex. Composed of latex particles (styrene, styrene butadiene) suspended in a water base. These paints can be used on interior or exterior surfaces and have low odor, are more resistant to blister and peel, dry faster and make clean-up much easier. Since latex paints are water based, they must be kept from freezing and should not be applied on exterior surfaces when temperatures drop below 50 degrees during the day.

Vinyl Acrylic Latex. Provides excellent washability and its fast drying cycle permits the application of two coats in one day. This paint does not raise the "grain" of drywall fibers but has poor wet adhesion and water resistance qualities. Used mainly on interior wall surfaces.

Acrylic Latex. Superior to alkyd, oil and vinyl acrylic latex paints in color and gloss retention. Used on interior trim, exterior wood and masonry.

Epoxy Ester Coatings. Epoxies modified with oil to produce a coating that dries by oxidation, and has properties similar to alkyd resins. It has poor gloss retention, but higher resistance to chemical fumes and marine environments.

Catalyzed Epoxy Coatings. Two-part mixtures: one containing the epoxy base and the other the hardener. When mixed together the chemical reaction creates a coating that is extremely hard and tough. These coatings have outstanding resistance to chemicals and provide a glazed wall-tile-like appearance.

Polyurethane Finishes. Isocyanate copolymers that create a coating with extreme hardness and durability. The most common types are oil-modified urethanes, a blend of urethane, drying oils and alkyds, and catalyzed aliphatic polyurethanes, a two-component paint with outstanding gloss and color retention capabilities as well as very good resistance to abrasion.

Wall Coverings

Vinyl and cloth wall coverings are made with a mildew-and fungus-resistant cotton fabric base combined with either decorative paper, polyolefin or natural fiber fabric or polyvinyl chloride facings. These materials are generally manufactured to comply with local and state fire codes, and they should exhibit a 15 flame spread, 0 fuel contribution and 25 smoke development to meet a Class A fire rating.

Vinyl wall coverings fall into one of two weight classifications: Type 1 and Type 2. Type 1 is a lightweight wall covering with a total weight per square yard of 7 ounces to 13 ounces. Type 1 wall coverings should be used in low-traffic areas such as office walls, hotel rooms and nursing home rooms. Type 2 wall covering includes those materials with a total weight per square yard in the 13 ounce to 22 ounce range, and these heavy gauge materials are suitable for high traffic use such as in office corridors, lobbys, schools and restaurants.

The "weight" designation of vinyl wall coverings can be confusing. When a construction specification stipulates vinyl wall fabric to be 19 ounces, for instance, this generally refers to its weight per *linear yard*, and most wall coverings are available in two roll widths, 27 inch and 54 inch. These linear foot weights can be converted to square yard weights, but never the twain shall meet. It is important in discussions with wall covering suppliers and wall covering specifiers to make certain that both parties are referring to the same unit measure when specifying and ordering the materials. The correlation of the two weight computations can be seen in the following table.

	Spec'd Weight per linear yard =	**Weight per square yard**
A 54-inch wide roll of wallcovering	12 ounces	8.0 ounces
	15 ounces	10.0 ounces
	19 ounces	12.7 ounces
	20 ounces	13.3 ounces
	24 ounces	16.0 ounces

Some wall coverings are manufactured with various top coatings meant to increase their resistance to stains and usually construction stains can be wiped off with a damp cloth. When fabric wall coverings are installed, removal becomes a little trickier since saturation of the fabric with a solvent could reactivate the adhesive in the product therby setting the stain. Most manufacturers can furnish stain-removal procedures, and it is best to remove these stains quickly rather than let them dry and become more difficult to remove.

21

Elevators, Dumbwaiters, Escalators

The modern multistoried commercial and industrial building must provide vertical transportation for its occupants and the equipment and supplies they require in order to operate in an orderly, efficient manner. The elevator is not a new invention. In 236 B.C., Archimedes invented a vertical lifting device using a system of ropes and pulleys, and the Egyptians employed hoists to lift some of their 20-ton building blocks when they built the pyramids.

Early elevators were operated by ropes, and if a rope broke while passengers were being hoisted to any significant height, the results could be disastrous. The first modern day elevator as we know it was invented by Elisha Graves Otis, a Yonkers, New York, mechanic who, in 1852, devised a safety brake that would keep the elevator from falling if the hoisting rope broke. Five years later, in 1857, the first passenger elevator was installed in a retail establishment in Manhattan.

TYPES OF ELEVATORS

The three common types of elevators are hydraulic, gearless traction and geared traction. The hydraulic elevator uses an electrically driven pump to force oil into a cylinder, thereby extending the piston and raising the cab. When the hydraulic oil is diverted to a by-pass, the elevator will seek downward travel.

A gearless-traction elevator relies on a large slow-speed electric motor to drive a pulley on which hoist cables have been installed to pull the elevator upward and lower it when required. The geared-traction elevator employs a high-speed motor to drive a worm and gear reduction unit to turn the hoisting sheave allowing cables on the sheave to raise or lower the cab.

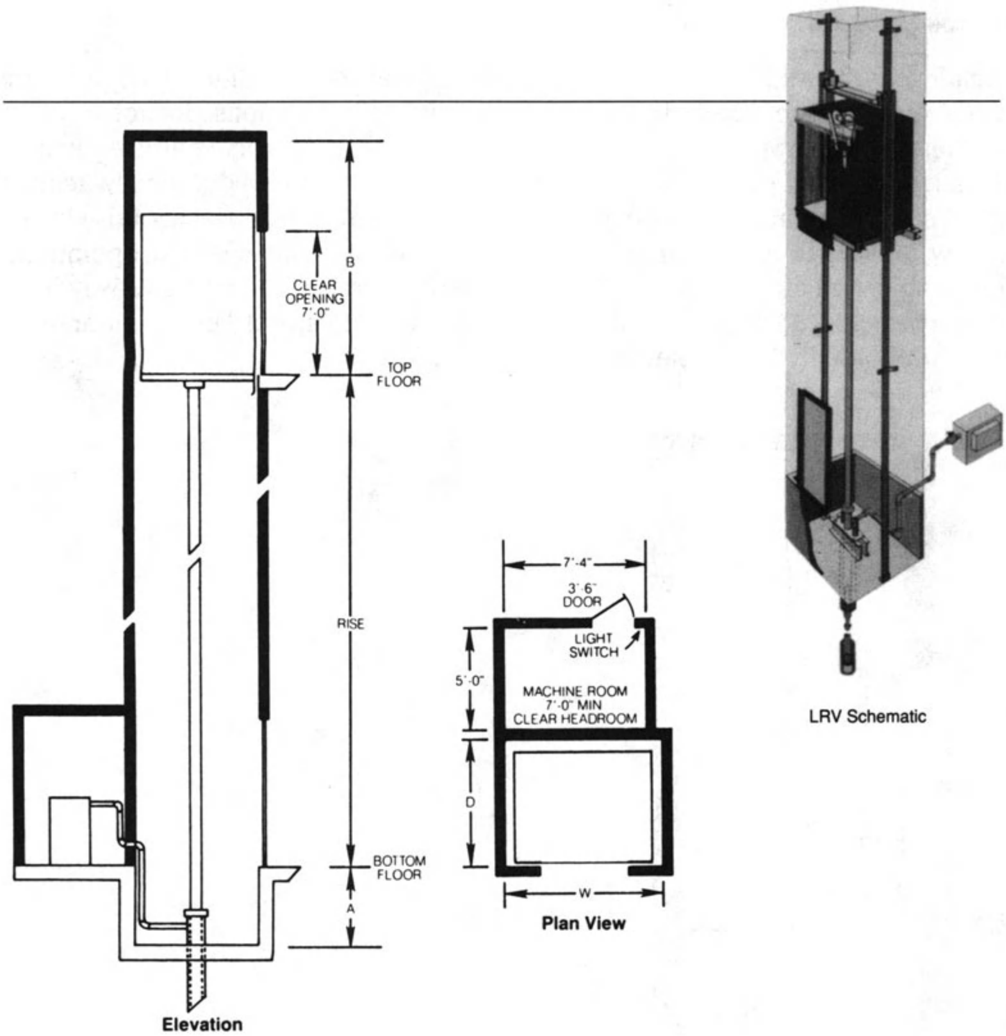
Hydraulic Elevators

Hydraulic elevators are installed in low or mid-rise buildings, and their efficient operating height of about 50 feet to 60 feet will limit their use to structures of five stories or less. Their rate of travel will range from 75 feet per minute (fpm) to 125 fpm, and their top speed is usually limited to 150 feet per minute. Capacities of hydraulic elevators include 2,000, 2,500 pound, 3,000, 3,500 pound and 4,000 pounds as the maximum. Cab platform size can range from 5′ 8″ side-to-side and 4′ 3″ back-to-back to 7′ 8″ side-to-side and 5′ 8″ back-to-back. Hospital size platforms can vary from 5′ wide by 7′ 4″ deep to 7′ 9″ wide by 7′ 4″ deep.

Hydraulic elevators can be installed singly or in banks of up to four elevators. Unlike traction elevators, construction of a hydraulic elevator commences before building foundations have been completed. Since the hole for the plunger, cylinder and casing must be drilled while access to lower levels of the building's interior are still accessible. Waterproof jack-holes are available for locations where underground water may be present.

Hydraulic elevators require a slightly less complicated hoistway than traction elevators require (see Figure 21-1). Remote machine rooms located at the lowest landing are preferable, but if adequate space is not available at that location, the machine room can even be placed in a penthouse. The installation of hydraulic elevators is not a complicated proceedure once the jack-hole has been drilled. After the building shell has been erected, and the roof is watertight, the rear and side elevator shaft walls will be constructed and the rail installation can commence. All of the equipment such as pumps, relays, controllers, starters, and microprocessor systems will start to be installed and hooked up in the machine room once it has been constructed. Cab installation will start once the building's permanent power has been installed, and once the cab platform is operational, hoistway entrances will be properly located and set in place so that the front portion of the elevator shaft can be completed. The following lists some of the hydraulic elevator requirements that an elevator subcontractor requires "by others:"

1. The floor in the concrete elevator pit is not to be poured until the cylinder has been set in place. If the pit has been poured before the jack-hole drilling commences, an opening in the floor of not less than 24 inches by 24 inches must be created.
2. A properly framed and enclosed hoistway, (except for the entrance framing) must be in place, including the vent required at the roof level.
3. Adequate supports are to be installed for guide rail fastening and their vertical spacing should not exceed 14 feet.
4. A hoisting beam at the top of the shaft, capable of supporting 5,000 pounds live load will need to be installed.
5. An enclosed machine room with legal access and ventilation (some codes require ventilation to the exterior of the building).
6. A fixed vertical ladder in the elevator pit will be required, and if installed early on, it will assist all trades that need to work in the pit.
7. Partition walls at the elevator entrance must not be installed until after the cab platform is in place and is operational.
8. Various sill details may be indicated. In some cases a depression in the floor slab at the front entrance to the hoistway will be required while other installations may require a steel angle to be attached to the slab edge.
9. A fused main-line switch for each elevator with a feeder or branch wiring circuit to the controller will be required, and of course, permanent power to the building must be in place by the time the rails have been set in place.



HYDRAULIC ELEVATOR DIMENSIONS

Equipment	Rated lbs.	Capacity pass.*	Speed (fpm)	D (depth)	SW (width)	Rise* (max.)	A**	B	Stops (max.)
LRV 2000	2000	13 | 12	125 150	5'-9"	7'-4"	60'-0"	4'-0"	12'-3"	7
LRV 2100	2100	13 | 12	125 150	5'-9"	7'-4"	60'-0"	4'-0"	12'-3"	7
LRV 2500	2500	16 | 15	125 150	5'-9"	8'-4"	60'-0"	4'-0"	12'-3"	7
LRV 3000	3000	20 | 18	125 150	6'-3"	8'-4"	59'-0"	4'-0"	12'-3"	7
LRV 3500	3500	23 | 21	125 150	6'-11"	8'-4"	56'-4"	4'-0"	12'-3"	7
LR 1500	1500	10 | 9	100 125 150	5'-9"	6'-8"	60'-0"	4'-0" **	12'-3"	6
LR 2000	2000	13 | 12	100 125 150	5'-9"	7'-4"	60'-0"	4'-0" **	12'-3"	6
LR 2500	2500	16 | 15	100 125 150	5'-9"	8'-4"	58'-0"	4'-0" **	12'-3"	6
LR 3000	3000	20 | 18	100 125 150	6'-3"	8'-4"	55'-5"	4'-0" **	12'-3"	6
LR 3500	3500	23 | 21	100 125 150	6-11"	8'-4"	52'-9"	4'-0" **	12'-3"	6

* **CANADA ONLY**: Right hand numbers for passenger capacities reflect Canadian code requirements.

** **CANADA ONLY**: 5'-0" for Canadian Province of Ontario.

Figure 21-1 Cut-Away View of an Installed Hydraulic Elevator with Hoistway Elevation and Machine Room Plan. By Permission of Otis Elevator Company, Farmington, Conn.

10. Some form of heat–ventilating source in the machine room that can maintain temperatures between 60 and 100 degrees F and a humidity level that does not exceed 95 percent must be in place.

Holeless Hydraulic Elevators

Especially handy when an elevator is going to be installed in an older building, or one that has already been built, these kinds of elevator installations do not require a jack-hole. The hoistway for the holeless elevator will contain vertical framework on the rear wall, which will permit the elevator to travel vertically. A hydraulically actuated piston assembly will rest on a concrete slab slightly below the first level of rise instead of below ground in a conventional hydraulic elevator installation. In operation, a telescoping piston attached to a traveling guide mounted on the rear hoistway framework will be activated by a hydraulic pump to raise the cab upward in a manner similar to a conventional hydraulic elevator (see Figure 21-2).

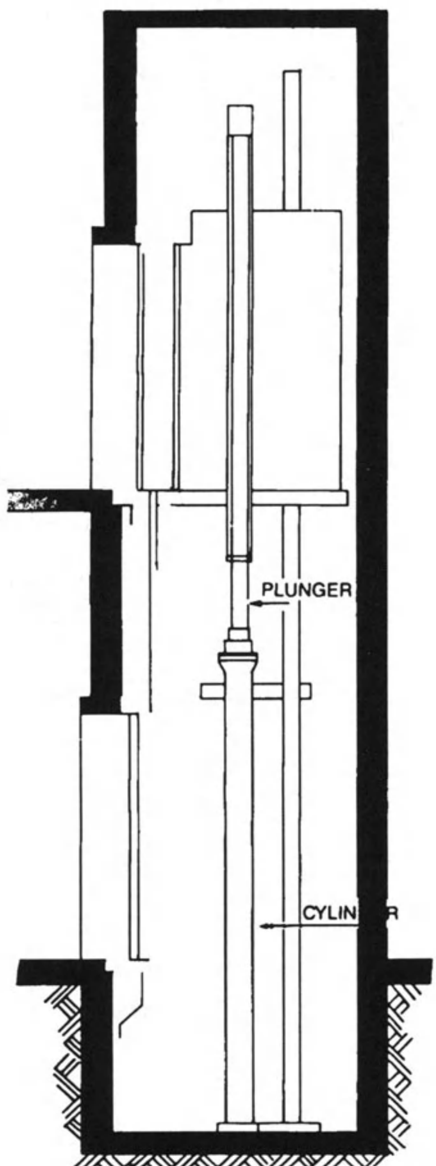


Figure 21-2 Holeless Elevator Hoistway Layout with Piston Resting on Top of Lower Slab.

These holeless elevators have two limiting factors:

Vertical travel is limited to approximately 70 feet.
Cab capacities range from 1,500 pounds to 2,500 pounds only.

Gearless and Geared-Traction Elevators

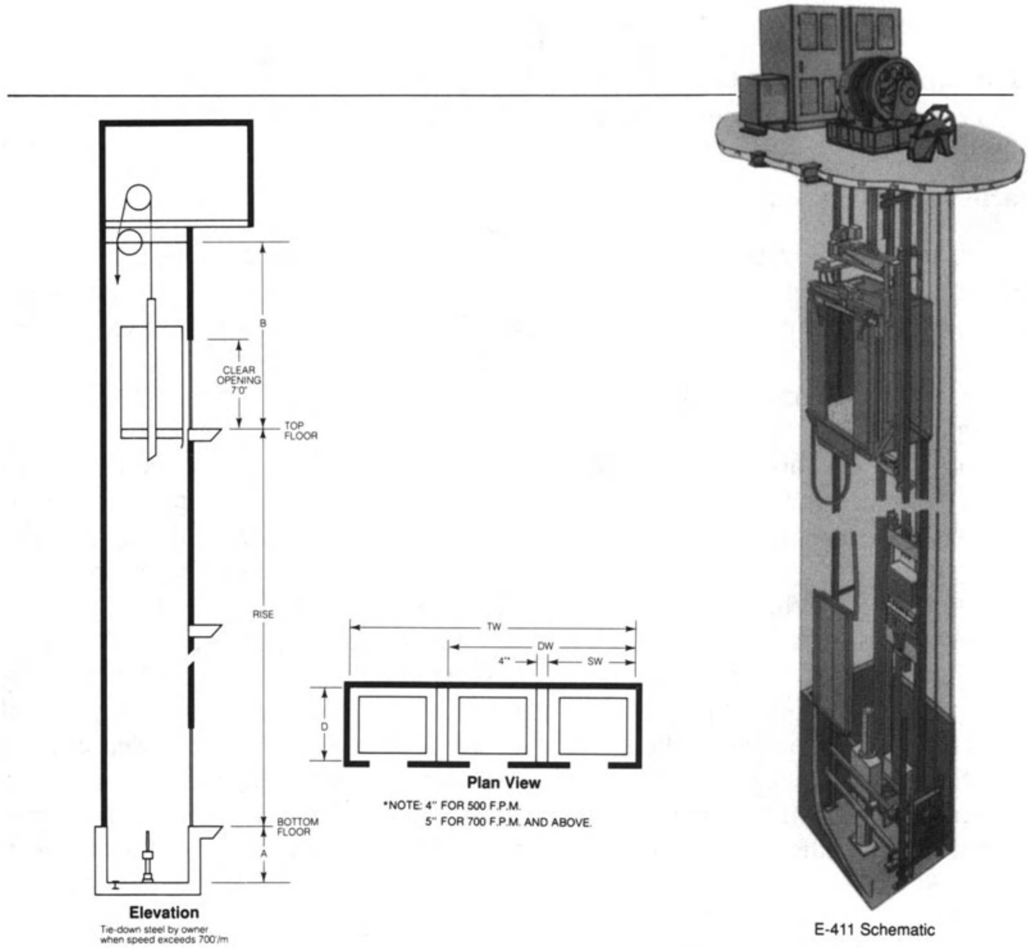
Gearless-traction elevators are used in high-rise buildings over 10 stories to 12 stories high because they are capable of attaining speeds of 400 to 1,800 fpm. Their large, low rpm motors are connected directly to grooved drive pulleys referred to as sheaves (pronounced "shives"). A hoist cable with one end affixed to the elevator cab is then wrapped around the grooves of the driving sheave and attached to a counterweight that slides up and down on its own guide rails, usually at the rear of the hoistway. The full weight of the cab and half of the passenger load is balanced by the weight of this counterweight, which, while going down as the elevator cab moves upward, relieves the motor of the need to lift the full weight of the car and its occupants (see Figure 21-3).

The geared-traction elevator, although it has a high-speed motor is the slower of the two, capable of reaching speeds of only 25 to 350 fpm (see Figure 21-4). Traction elevators are more complicated to install for several reasons. First, they require a machine room at the top of the hoistway. The slab of this room will be configured with precisely located openings for the cable installation, and this slab must be capable of supporting all of the heavy hoisting equipment that will be placed upon it. Second, the installation of the sheaves and the motors require positive anchorage and alignment to ensure a smooth, maintenance-free operation. And third, it is a major time-consuming effort to hoist all of the bulky equipment to this machine room at the top of the hoistway.

A "By-Others" traction elevator lists will read as follows:

1. Supports for guide rails are not to exceed 14 feet for car rails, 12 feet for counterweights.
2. A dry pit is required for buffer equipment. This pit needs a ladder, convenience outlet and light same as hydraulic elevator installation.
3. Hoisting beams must be in place and must support a live load of 4,000 pounds.
4. Sills requirements vary, some elevator subcontractors require recesses, others require steel angles and level floors at the entrance way.
5. Supports for machine room equipment, sheave beams should be in place and any beam pockets grouted in.
6. The slab at the top of the hoistway should not be installed until the equipment is in place.
7. A machine room must be built and ventilation and heater installed.
8. Inside temperatures must be controlled between 45 degrees and 100 degrees F (hydraulic elevator rooms slightly higher minimum temperatures because of the need to control the viscosity of the hydraulic fluid!).
9. Hoistway entrance walls are not to be constructed until elevator entrances are set in place and plumbed.

A typical elevator hoistway and machine room configuration for one or two traction elevators is shown in Figure 21-5.



GEARLESS ELEVATOR DIMENSIONS

Equipment	Rated lbs.	Capacity pass.*	Speed (fpm)	D (depth)	SW (width)	DW (width)	TW (width)	Rise ** (max)	A	B
E-411 3050	3000	20 | 18	500	7'-3"	8'-4"	17'-0"	25'-8"	300'	6'-8"	18'-3"
E-411 3070	3000	20 | 18	700	7'-3"	8'-4"	17'-1"	25'-10"	420'	9'-1"	20'-6"
E-411 3550	3500	23 | 21	500	7'-11"	8'-4"	17'-1"	25'-10"	300'	6'-8"	18'-3"
E-411 3570	3500	23 | 21	700	7'-11"	8'-4"	17'-1"	25'-10"	420'	9'-1"	20'-6"
E-411 3580	3500	23 | 21	800	8'-0 1/2"	8'-4"	17'-1"	25'-10"	480'	14'-2"	21'-6"
E-411 35100	3500	23 | 21	1000	8'-0 1/2"	8'-6"	17'-5"	26'-4"	600'	16'-10"	22'-6"
E-411 35120	3500	23 | 21	1200	8'-0 1/2"	8'-6"	17'-5"	26'-4"	720'	19'-9"	23'-10"
E-411 4050	4000	27 | 25	500	7'-11"	9'-4"	19'-1"	28'-10"	300'	6'-8"	17'-4"
E-411 4070	4000	27 | 25	700	7'-11"	9'-4"	19'-1"	28'-10"	420'	9'-1"	20'-6"
E-411 40100	4000	27 | 25	1000	8'-0 1/2"	9'-6"	19'-5"	29'-4"	600'	16'-10"	22-6"
E-411 40120	4000	27 | 25	1200	8'-0 1/2"	9'-6"	19'-5"	29'-4"	720'	19'-10"	22-6"

* **CANADA ONLY**: Right hand numbers for passenger capacities reflect Canadian code requirements.

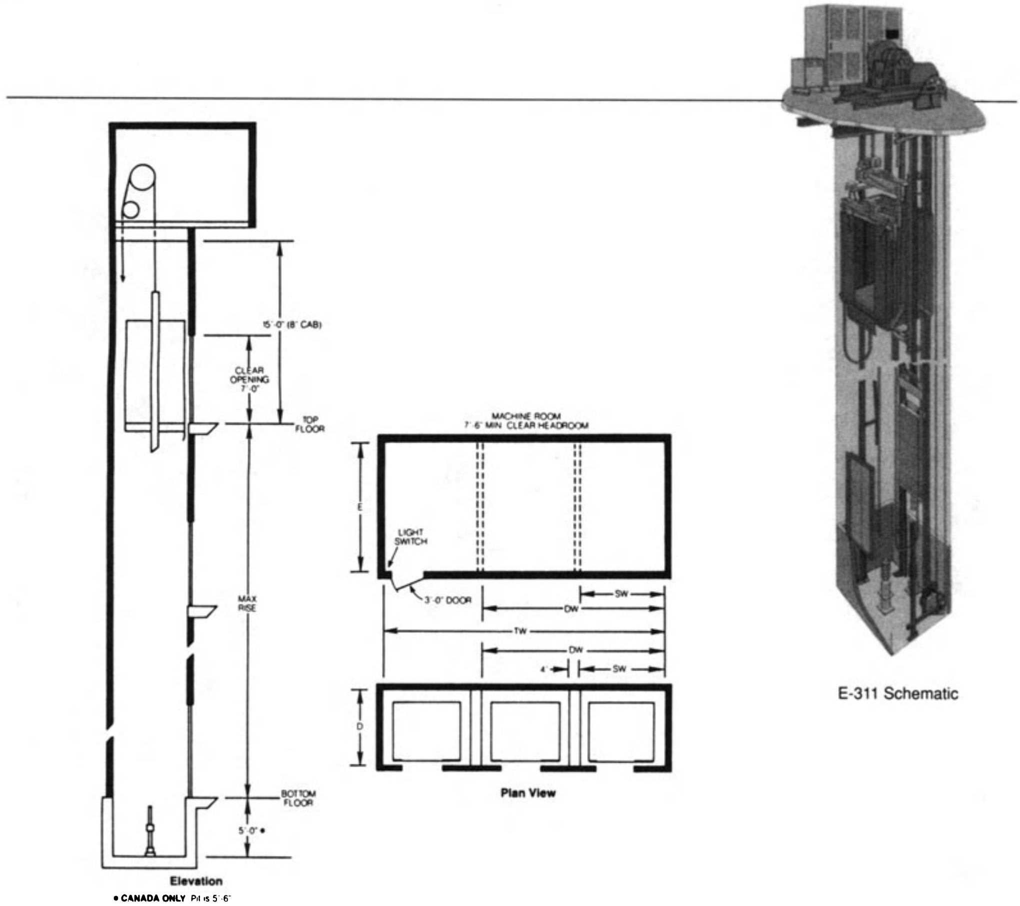
** Subject to elevatoring analysis of proposed building project.

NOTE: Machine room dimensions vary with the type of installation and building conditions.

Figure 21-3 Gearless Elevator Cut-Away Installation, Hoistway Configuration and Placement of Bank of Three Hoistways. By Permission of the Otis Elevator Company, Farmington, Conn.

Elevator Cabs

Elevator-cab platform frames are built of formed or structural steel members, adequately braced to support the platform and the cab enclosure. The platform itself is made of steel with a steel and wood subflooring and some elevator manufacturers separate the cab from the frame with rubber isolation pads. Ceilings in the cabs can be



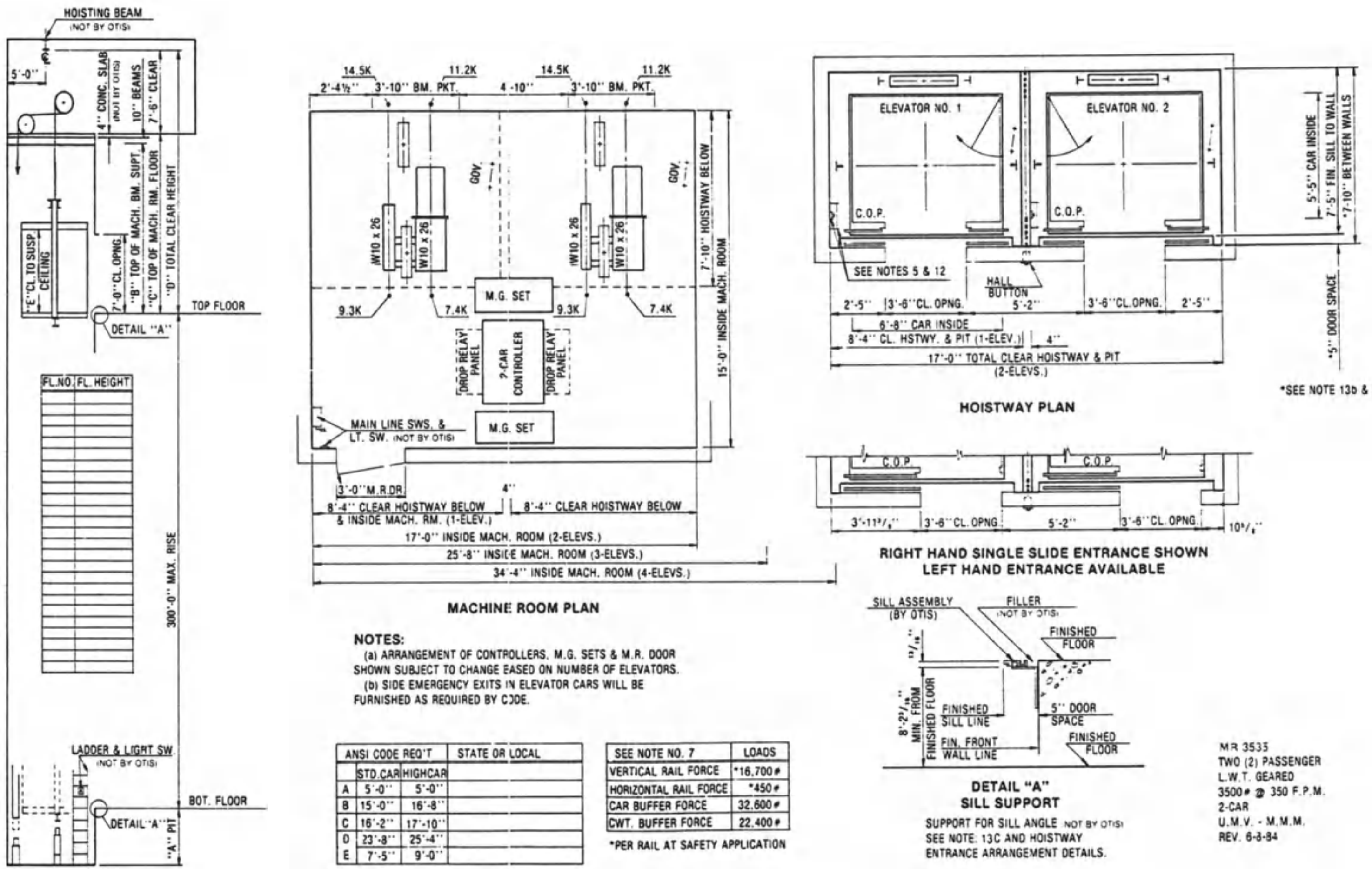
GEARED ELEVATOR DIMENSIONS

Equipment	Rated lbs.	Capacity pass.*		Speed (fpm)	D (depth)	SW (width)	DW (width)	TW (width)	Rise (max)	E
E-311 2040	2000	13	12	400	6'-7 1/2"	7'-4"	15'-0"	22'-8"	300'-0"	15'-0"
E-311 2045	2000	13	12	450	6'-7 1/2"	7'-4"	15'-0"	22'-8"	300'-0"	15'-0"
E-311 2540	2500	16	15	400	6'-7 1/2"	8'-4"	17'-0"	25'-8"	300'-0"	15'-0"
E-311 2545	2500	16	15	450	6'-7 1/2"	8'-4"	17'-0"	25'-8"	300'-0"	15'-0"
E-311 3040	3000	20	18	400	7'-1 1/2"	8'-4"	17'-0"	25'-8"	300'-0"	15'-0"
E-311 3045	3000	20	18	450	7'-1 1/2"	8'-4"	17'-0"	25'-8"	300'-0"	15'-0"
E-311 3540	3500	23	21	400	7'-10"	8'-4"	17'-0"	25'-8"	300'-0"	15'-0"
E-311 3545	3500	23	21	450	7'-10"	8'-4"	17'-0"	25'-8"	300'-0"	15'-0"
E-311 4040	4000	27	25	400	7'-10"	9'-4"	19'-1"	28'-10"	300'-0"	15'-0"
E-311 4045	4000	27	25	450	7'-10"	9'-4"	19'-1"	28'-10"	300'-0"	15'-0"
E-311 4540	4500	30	28	400	11'-3 1/4"	7'-10"	16'-0"	24'-2"	300'-0"	15'-0"
E-311 4545	4500	30	26	450	11'-3 1/4"	7'-10"	16'-0"	24'-2"	300'-0"	15'-0"
SPEC60 2035	2000	13	12	350	6'-7 1/2"	7'-4"	15'-0"	22'-8"	245'-0"	14'-0"
SPEC60 2535	2500	16	15	350	6'-7 1/2"	8'-4"	17'-0"	25'-8"	245'-0"	14'-0"
SPEC60 3035	3000	20	18	350	7'-1 1/2"	8'-4"	17'-0"	25'-8"	245'-0"	14'-0"
SPEC60 3535	3500	23	21	350	7'-10"	8'-4"	17'-0"	25'-8"	245'-0"	14'-0"

* **CANADA ONLY**: Right hand numbers for passenger capacities reflect Canadian code requirements.

Figure 21-4 Gear Elevator Machine Room Layout and Dimensioned Hoistway with Single Slide Doors. By Permission of the Otis Elevator Company, Farmington, Conn.

as simple as fluorescent tubes installed above a metal or polycarbonate egg-crate grill, or it can be a mirrored affair with custom lighting. The front inside face of the car is referred to as the car front, and recessed into this front wall will be the car operating panel with its emergency telephone, key lock-outs, floor indicators, and floor selector buttons. Side and rear panel options include a wide range of plastic laminates, stainless steel, bronze, brass, natural wood, decorative stone, and combinations of any



SECTIONAL ELEVATION

Figure 21-5 Typical Elevator Machine Room Layout and Dimensioned Hoistway with Single Slide Doors. By Permission of the Otis Elevator Company, Farmington, Conn.

of these materials. Flooring, generally excluded from the elevator subcontractor's scope of work, can vary from vinyl composition tile to carpet or stone.

Some of the buttons and lights used in elevator installations are called by names other than "buttons and lights."

Hall lantern—The light outside the elevator entrance that indicates whether a car is going up or down.

Hall station—The pushbuttons in an elevator lobby used to call the elevator down or up.

Hall position display—A locating digital readout or other display indicating on which floor the elevator has stopped at that moment.

DUMBWAITERS AND PARCEL LIFTS

Dumbwaiters are used to transport food trays and carts from lower floors with a kitchen to elevated floors in either commercial and health-care facilities, and they also find use in delivering such items as parcels, mail, books, linens, luggage from one floor to the next without tying up valuable elevator time and space. Dumbwaiters are limited in the weight they can carry (200 pounds to 500 pounds), the vertical distance they can travel (about 40 feet) and the speed at which they can travel (50 fpm more or less). Parcel lifts are basically dumbwaiters with less carrying capacity and are usually limited to an ability to hoist a maximum of 150 pounds and as little as 25 pounds.

Dumbwaiters and parcel lifts are similar to miniature elevators inasmuch as they require a hoistway and they ride on rails in this hoistway. They are lifted and lowered on cables operated by electric motors, and they have cabs and hoistway doors, either biparting, slide-up or swing out. Dumbwaiters are available with manual or motorized hoistway doors, and the controller will respond to both call and send instructions delivered via a bank of pushbuttons. Arrival indicators take the form of an arrival lantern and a gong.

Parcel lifts are powered by ¾ or 1 horsepower motors requiring an 11 amp or 15 amp circuit. Dumbwaiters with their higher lifting capacity will be powered by a 1, 2, or 3 horsepower motors.

ESCALATORS AND MOVING WALKS

Low- to high-rise retail stores, indoor malls, and sports arenas are where escalators will be found, and moving walks are quite often seen in large metropolitan airports. Escalators can be installed where the vertical rise is designed for 30 feet to 36 feet in a single unit, but with criss-crossing and stacked installations, they can rise well above 3 stories. Some manufacturers offer custom escalators with the ability to rise 120 feet. Escalators are designed to move people along at speeds ranging from 90 fpm to 120 fpm.

An escalator installation requires a pit approximately 4-feet deep and slightly wider than the out-to-out dimension of the deck boards. All escalators have safety devices that will cause them to stop in case an object gets caught between the last step and the comb plate, that grooved, fixed plate at the exit run out. Escalators are tied into smoke and fire alarm systems, and when those systems are activated the escalator will slowly come to a stop. A typical escalator profile is set forth in Figure 21-6.

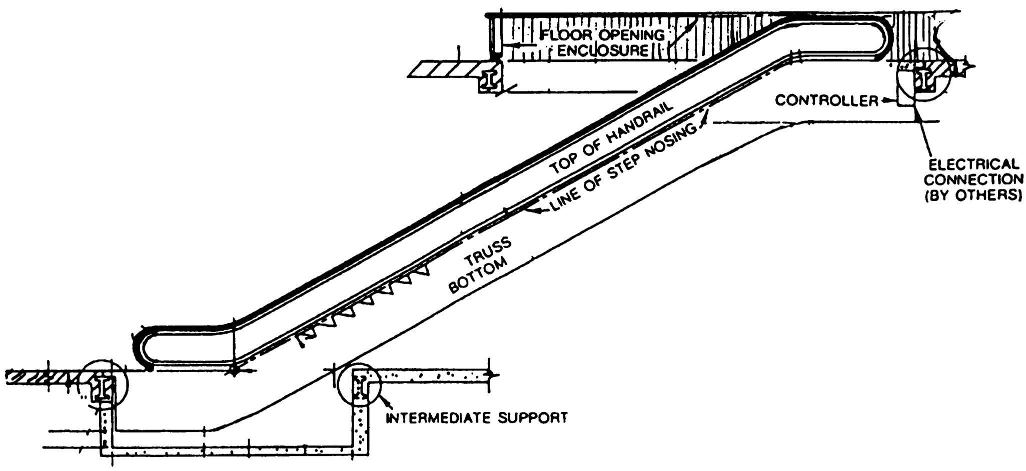


Figure 21-6 An Elevation of a Typical Escalator with Controller Mounted at Top Landing.

Moving walks provide rapid horizontal movement for people at speeds of 80 fpm to 175 fpm on surfaces that are dead level or up or down inclines that do not exceed 12 degrees from the horizontal. These moving walking systems incorporate many of the same features as escalators and are operated by a below-grade chain drive.

AN ELEVATOR CHECKLIST

An elevator inspection and sign off will be one of the more critical items requiring the construction superintendent's attention as a project comes to a close, because the issuance of a Certificate of Occupancy for the building will depend on a successful inspection. Even though individual state codes will vary and other requirements may have to be met, the following checklist will serve as a guide when preparing an elevator installation for an inspection.

1. Ladders in elevator pits should extend 42 inches above the first-floor door sill.
2. Pits are to be clean and dry. Check for light and receptacle installation. Lights should have a grounded wire cage over them.
3. If there is a drain in the pit, it must have a cover.
4. The cap around the hydro jack (applies only to hydraulic elevator installations) must be grouted.
5. All penetrations in hoistway must be patched and hoistway must be of 2-hour fire-rated construction.
6. Permanent lights are to be installed in front of all elevator entrances.
7. Hoistway vent must have been installed. Does local code require steel grid in hoistway vent to prevent fireman from falling through when it is in an open position?
8. Permanent lighting is to have been installed in the elevator machine room with a switch on the strike side of the door.
9. Machine room ventilation should be installed, and a "B" labeled door with closer will have been installed in this room. Door lock opened only by key. All holes in walls, ceiling and floor must be patched.

10. Smoke sensors are to have been installed in elevator lobbies and machine room. Wires to be identified and terminated at the controller.
11. A green-colored bonding conductor at least No. 8 wire is to be bonded to the disconnect switch then brought to the main controller.
12. No equipment is allowed in the machine room or hoistway that does not pertain to the elevator.
13. Emergency communication in the elevator shall have been installed. Telephone with speed dialer to 24-hour manned monitoring desk? Dedicated telephone line to guard service?
12. All edges in the shaftway extending 2 inches are to be beveled at least 75 degrees to the horizontal to prevent a resting place for tools that may fall on someone who is working in the shaft.
13. Elevator cab flooring is to be completed.
14. Emergency circuit and fire alarm tie-ins must be complete and tested before being made operational.
15. Elevator lighting and auxiliary circuits must be identified at the controller termination.

Finally, some states require payment upon completion of a successful inspection, and a check in the correct amount on the job site when the inspector arrives may speed up the receipt of the elevator certification certificate.

22

Heating, Ventilating and Air-Conditioning (HVAC)

The indoor work environment must be controlled for comfort and to ensure the proper operation of the equipment within the workplace. Although people may be able to work temporarily in temperatures that deviate from the normal comfort zone, computers and computerized equipment do not have the same degree of adaptability.

The comfort zone for people in a work environment depends upon two factors: heat (or lack thereof) and humidity. The ideal indoor temperature should range from 65 degrees to 75 degrees F, and relative humidity levels ought to be between 30 percent to 50 percent. When temperatures exceed these limits, excess heat and humidity must be removed by conditioning the air, and when temperatures fall below these acceptable levels, heat and, possibly, humidity must be added to the environment.

Added to these two basic requirements, the quality of the indoor air is of prime importance as anyone who remembers the outbreak of Legionaires disease years ago can attest. All heating and cooling systems require the same components: a source for generating either hot or cold, a means whereby the heat or cold generated can be distributed and a method of delivering and directing the heat or cold where it is needed.

GLOSSARY OF HVAC TERMS

There are some terms used in HVAC work that, if better understood, will help ease the passage through the maze of equipment necessary to achieve a proper working environment.

Air-cooled condensers—Equipment that uses fans, either propeller or centrifigul, to move air over fin-tube pipes to create a condensation effect on the refrigerant gas in these tubes, thereby creating a cooling effect.

BTU (British Thermal Unit)—The amount of energy required to raise the temperature of one pound of water one degree.

Chiller—Equipment using the evaporation of a refrigerant to chill liquid that passes through its tube bundle.

Compressors—Used in refrigeration cycles to pump the refrigerant from an evaporator to a condenser under temperatures and pressures that create a cooling effect.

Condensers—Equipment that removes heat from gas for the purpose of causing the gas to condense to a liquid.

Cooling tower—A piece of equipment that takes advantage of the natural cooling effect of evaporating water. Water sprayed downward from the tower is partially evaporated by a fan drawing air upward over the waterfall.

Dampers, face and bypass—A set of coordinated dampers arranged to direct air through an evaporator, around an evaporator, or partly through or around an evaporator.

Dehydrator—A device containing a dessicant so that it can remove moisture from the refrigerant.

Dew point—The temperature when moisture in the air condenses on a surrounding surface.

Eliminator—Stationary vanes or louvers designed to remove entrained water particles from an air stream.

Evaporator—Equipment within which a refrigerant is "evaporated" or boiled so as to remove heat from another surrounding liquid. Cooling coils and chillers can be called "evaporators."

Face and bypass type of control—A valve or damper that diverts the flow of air over the face of an extended surface evaporator or through a passage around the evaporator.

Humidity—The amount of water vapor present in the air as compared to the maximum amount possible at that ambient temperature. This is called relative humidity.

Latent heat—Energy involved in the change of ice to water or water to vapor.

Refrigerant—Any fluid used to produce a cooling effect when evaporated under controlled conditions.

Sensible heat—Energy required to raise or lower the temperature by a measurable amount, such as that needed to raise the temperature from 20 degrees to 30 degrees.

Shell and tube—A type of heat exchanger consisting of a tube bundle within a shell or casing.

Temperature—We all know what hot and cold is, and there are three ways to measure it:

Dry-bulb temperature—An ordinary thermometer used to measure air temperature.

Wet-bulb temperature—Measured by a psychrometer (a thermometer with its bulb enclosed in a wick that is kept moist). Measures air temperature with moisture to record humidity.

Ton (as pertains to air-conditioning)—The amount of cooling provided by melting one ton of ice over a 24-hour period.

Water-cooled condensers—Water pumped through tubes in the condenser while refrigerant is pumped through a shell surface surrounding these tubes, thereby cooling the water (also known as a shell and tube condenser).

Water make-up—Water that is added to a cooling tower boiler or evaporative condenser to make up for water lost through evaporation or other reasons.

HEAT AND HEATING PLANTS

Heat can be generated by electricity as the resistance to its passage through an element gives it its name—Resistance Heating. Heat can also be derived from solar energy, but as of this date, that source has not proven practical for most commercial or industrial applications. Heat can also be generated by boilers, which is one of the more frequently used heat sources in today's construction projects.

Boilers used for space heating are usually of the low-pressure type (15 psi to 30 psi), generating water temperatures below 250 degrees F. A boiler can be loosely defined as a closed vessel in which a liquid is heated or vaporized by direct application of heat from a source within or external to that pressure vessel. All boilers have a cast-iron or steel heat exchanger, a burner or some other combustion device, a fill valve and controls to regulate its operation. When hot-water boilers are installed, circulating pumps are also installed to move the water through the distribution system. Boilers also require expansion tanks.

The expansion tank is a critical part of the system since it allows the increased volume of water caused by heating to flow into this additional space. Open expansion tanks, used only on low-pressure boilers, are vented to the atmosphere while closed expansion tanks are used on either low- and high-pressure boilers that are not vented.

There are three basic boiler designs:

Firetube boilers—A boiler where the hot combustion gases travel through tubes as the water circulates around them. Some firetube boilers pass their combustion gases through the water only one time and are known as single-pass boilers. Those that pass these gases through twice are called two-pass units.

Watertube boilers—In this boiler configuration, the pipes are filled with water and hot combustion gases in the chamber heat the water in the tubes much like a heat exchanger.

Low-mass boilers—A packaged boiler with all wiring, piping and integral controls mounted and in place. These boilers are generally small and have quick start-up times since they quite often hold only one quart of water.

A typical hot-water boiler configuration is shown in Figure 22-1, and although the exact placement of accessory components and controls vary from manufacturer to manufacturer, all boilers contain most of these accessories. These types of boilers can be fired by oil or gas or fitted for interchangeable fuel sources.

A heating system can rely on one large boiler or a row of small boiler modules in some situations. There are several reasons for using a bank of interconnected small boilers rather than one large one. Each of the independent small boilers can be piped in parallel and controlled to operate only when demand requires. If needs are minimal at some point in the day, only one or two boilers may be firing, but at times of peak demand, such as morning start up, possibly the entire bank of boilers, sometimes as many as 10 or 11, are all operational. Should any one or two or more boilers malfunction, they can be temporarily taken out of the line and repaired leaving the others to continue supplying heat.

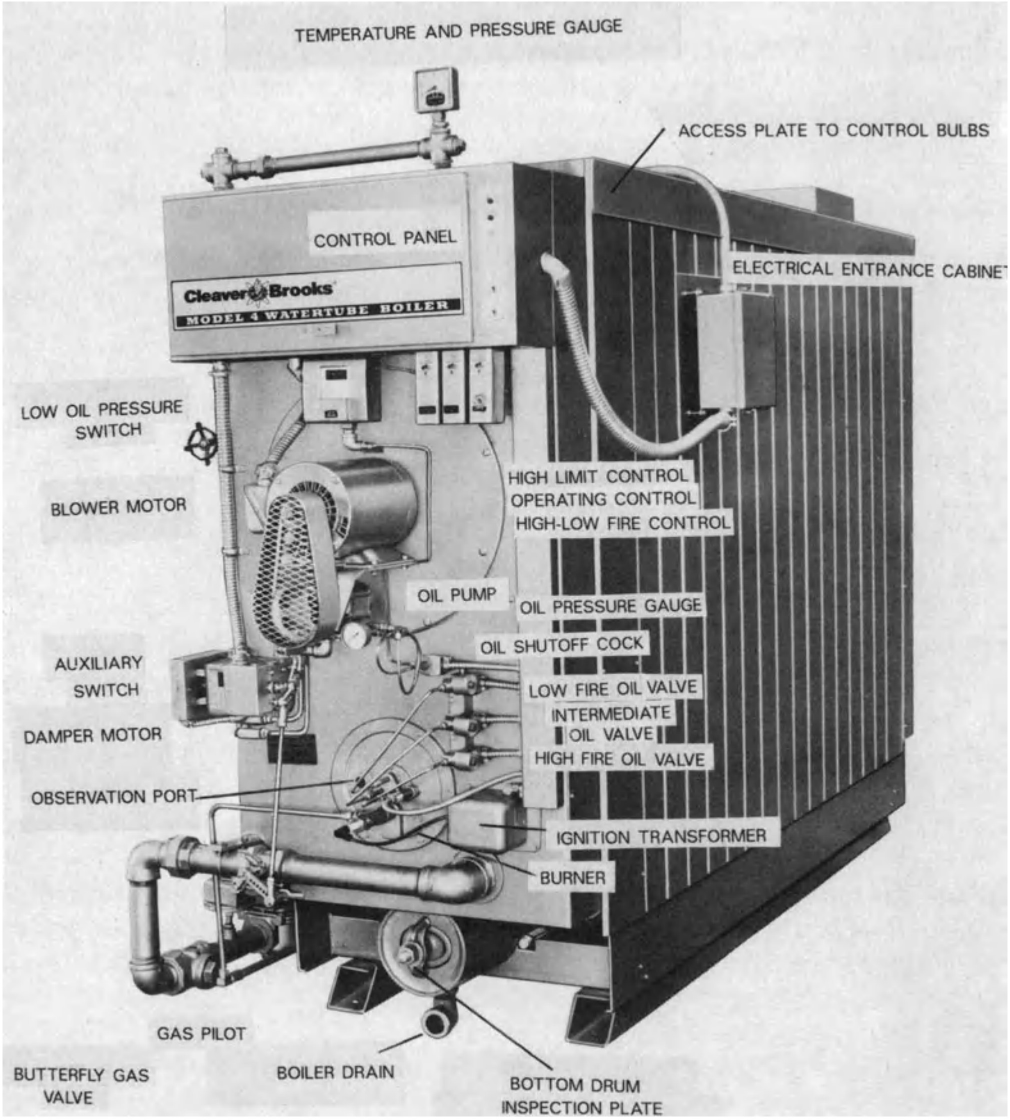


Figure 22-1 Typical Light-Oil or Gas-Fired Watertube Boiler with Accessories. Courtesy: The Cleaver Brooks Company.

Furnaces

A furnace differs from a boiler in that it heats air rather than water. Furnaces have the following components:

- A burner than can be fired by either oil, gas or even electricity.
- A heat exchanger.
- A fan or blower unit to distribute the hot air.
- A filtering system.
- Controls for ignition, fan-on, fan-off, limit switch regulated by stack gas temperatures.
- A draft hood.
- Supply and return ductwork.
- A flue to discharge combustion gases.

Electrically fired furnaces have heating elements instead of burners, and these types of furnaces, in general, are usually relegated to residential, light commercial or smaller retail establishments.

Distributing the Heat Generated by the Boiler

Thermal transfer can be accomplished by heating water and flowing it through pipes or generating steam, which will also be conveyed by pipes, or by heating air and blowing it through ductwork.

Hydronic Heat. This type of heating system can be as simple as a one-pipe system that transfers heated water from a boiler via a circulating pump to baseboard radiation or fan-coil units installed at the perimeter of the building's interior, or it can be as complex as a four-pipe system with fan coils, using a chiller and a boiler. This allows some building occupants to have their space heated while others require air conditioning.

One-Pipe Systems. Figure 22-2 depicts a system with terminal units connected to one pipe, which acts as both a supply and return line. When fan-coil units are the terminal units, either hot water or chilled water will be passed through the pipes to which the fan coils are connected so that the system will provide heat when the boiler is running, or when it has been shut down for summer months and the chiller is functioning, air-conditioning is available.

Two-Pipe System. Water, either hot or cold is brought to each terminal unit through a supply pipe. A return pipe connected to the exit side of the terminal unit returns the hot or cold water back to either the boiler or the chiller depending on whether the building is in a heating or cooling mode (see Figure 22-3).

Three-Pipe System. Contains two supply pipes, one for hot water and one for chilled water. The fan-coil unit is equipped with a three-way valve, one with two inlets and one outlet thereby permitting one fan-coil to receive hot water while another one receives chilled water. A common return pipe will cause mixing of high-and low-temperature water unless there is a three-way valve in the return line controlled by the temperature of the return water (see Figure 22-4). When a diverter valve is added, the hot and cold return water can be segregated to the point where it enters either the hot or cold water return after gathering water from terminal units in similar modes.

Four-Pipe Systems. Figure 22-5 shows a schematic design for a four-pipe system that will allow occupants to select either cooling or heating at any time of the year and the hot or cold water entering their fan-coil unit via a cold or hot water supply pipe will exit via a hot or cold water return line back to the source of hot or cold water.

Steam Heat. The steam generated from a boiler will condense as it travels through heating pipes and cools, forming condensation that must be separated in the lines.

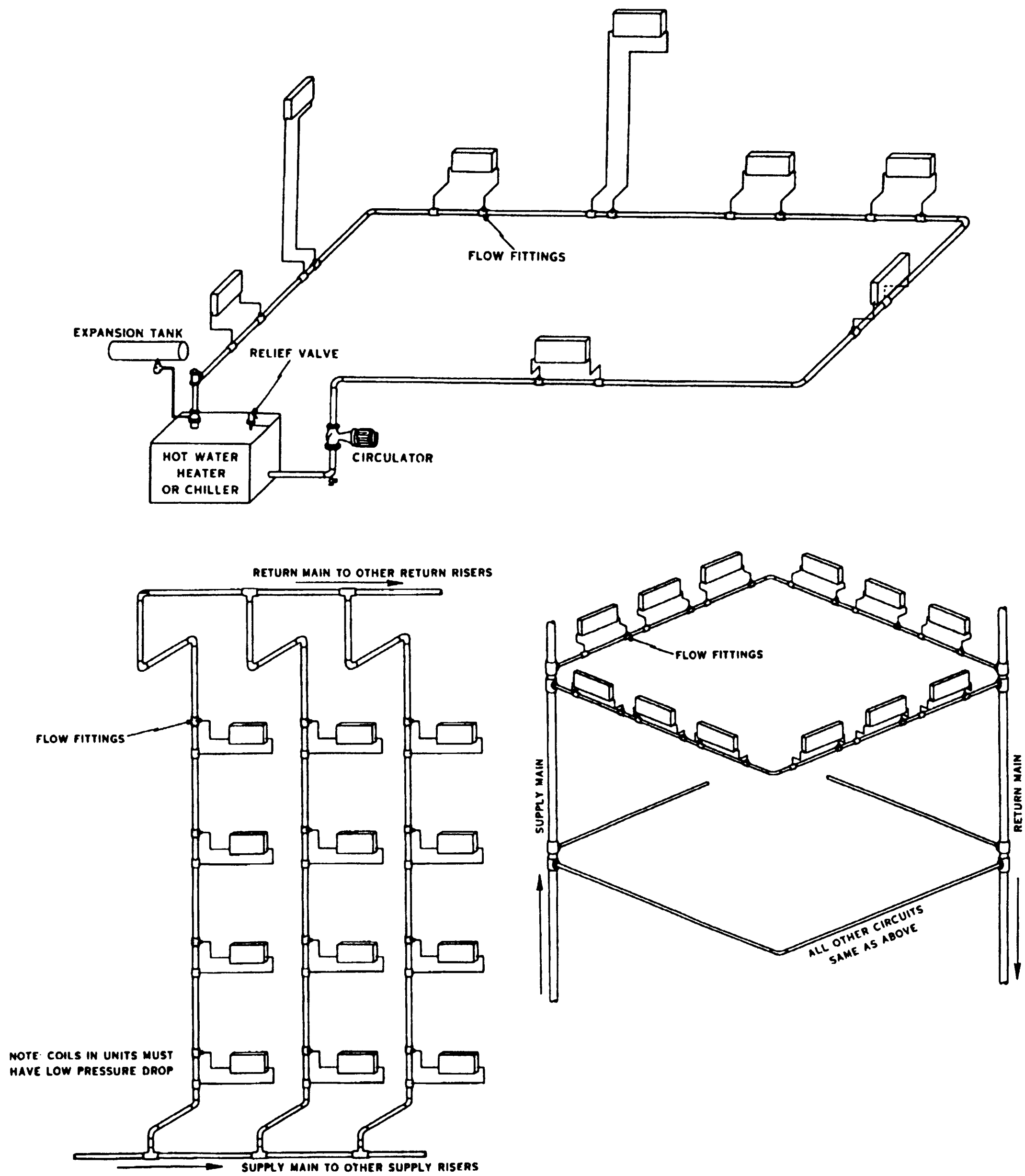


Figure 22-2 A Simple One-Pipe Hydronic Heat–Cool System. Courtesy: The Trane Company, LaCrosse, Wisconsin.

Thermo-mechanical devices called steam traps are installed to collect this condensing liquid and return it to the boiler via a separate condensate line. These condensate lines can flow back to the boiler by gravity or be pumped by a condensate pump. Steam lines can be installed to form either a one-pipe system where steam and condensate travel in the same pipe, or a two-pipe system where one pipe is dedicated to steam and the other to condensate. Return lines located below the boiler water level are known as "wet" lines, while condensate returns above the water level are referred to as "dry" lines.

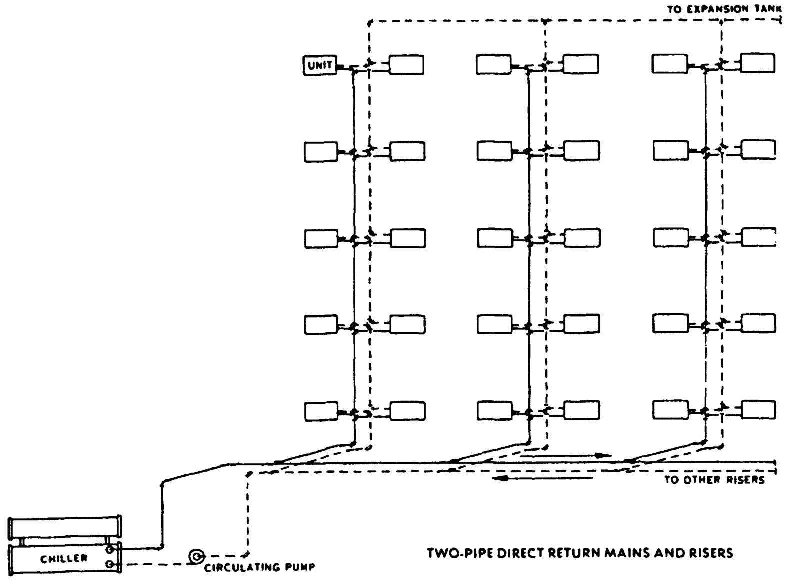


Figure 22-3 A Two-Pipe Hydronic System. Courtesy: The Trane Company, LaCrosse, Wisconsin.

Heat Pumps

Heat can be moved from one place to another, but to do so, it must be absorbed by a substance. This can be accomplished by a refrigerant unit that picks up the heat from a place where it is not wanted and transfers it to another place where it is wanted. Heat pumps perform this function and can pick up heat from air and transfer it to air in another place (air-to-air heat pumps) or it can pick up heat from water and transfer it

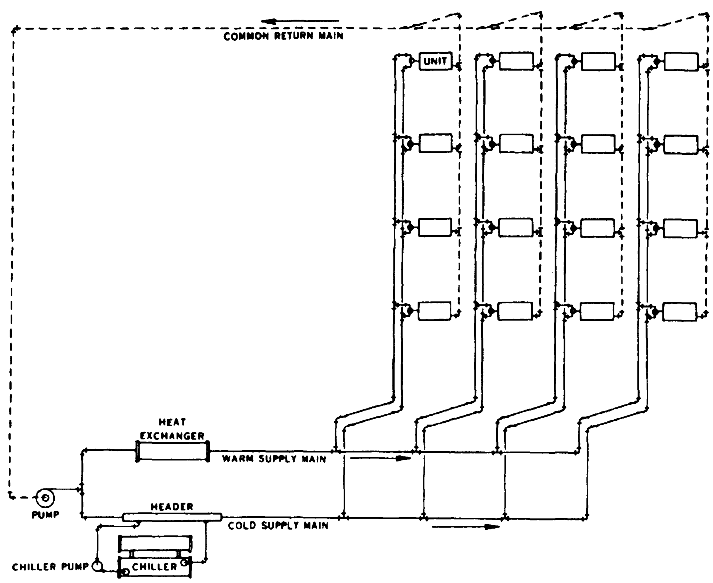


Figure 22-4 A Three-Pipe Hydronic System. Courtesy: The Trane Company, LaCrosse, Wisconsin.

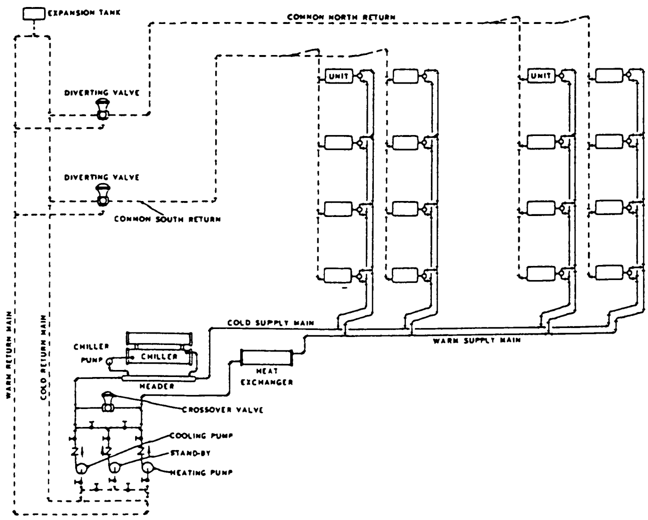


Figure 22-4 ***(continued)***

back to water flowing in another location (water-to-water heat pumps). There are also air-to-water, water-to-air, earth-to-air and earth-to-water pumps. Heat pumps can be further divided into room, unitary, and field assembled. Room heat pumps contain a compressor, evaporator, condenser, fan, filter and controls and are easily recognizable as a through-the-wall or window unit quite often installed in motels. This type of heat pump is usually an air-to-air pump. Unitary or packaged heat pumps are also self-contained units, but they are manufactured with much greater capacities than through-the-

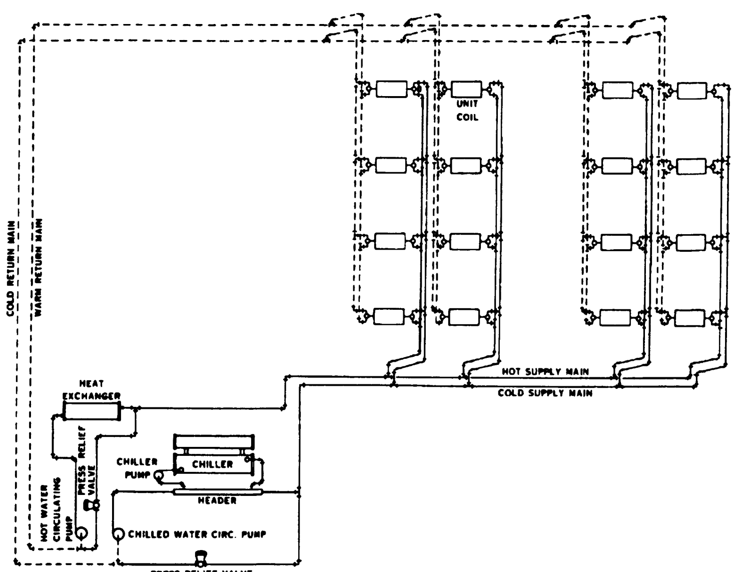


Figure 22-5 A Four-Pipe Hydronic System Courtesy: The Trane Company, LaCrosse, Wisconsin.

wall units. Some of these unitary heat pumps have capacities up to 50 tons and find application in shops, small commercial and retail establishments. Field assembled heat pumps contain components individually selected by the design engineer to meet the specific requirements of a project. But the main components and theoretical operation of all three types are identical.

AIR-CONDITIONING SYSTEMS

A basic air-conditioning system consists of the following components:

A refrigerant unit and related piping.
A heat-transfer unit and related piping.
An air-distribution system, including ductwork and terminal units.
Controls to operate the system.

The Refrigerant Unit

Refrigerants can be defined as any liquid that produces a cooling effect by means of evaporating under controlled conditions. Common refrigerants are air, water, ammonia, carbon dioxide, chlorine, fluorine–bromine compounds (more commonly known as freon), propane, methane and ethane. In order to evaporate, condense and compress these refrigerants, a compressor, condenser and evaporator is used.

The evaporator—This piece of equipment extracts heat from water to be chilled as the water is pumped through its tubes, which are submerged in a refrigerant. Heat from the water causes the refrigerant to boil and vaporize, and it is then sent to the suction side of the compressor. Direct expansion evaporators called DX units boil and superheat refrigerant for either air or liquid cooling, and these devices are often installed as coils in HVAC duct systems or air-handling units.

The compressor—Its function is to pump refrigerant vapor from the evaporator to the condensor. It acts basically as a refrigerant gas pump, receiving gas from the evaporator at a low pressure and delivering it to the condensor at a higher pressure.

The condenser—The condensor's job is to liquefy the refrigerant, which became a vapor after being heated by water passing through the tubes of the evaporator. Condensers can use either water or air for this purpose. An air-cooled condenser removes the heat from the refrigerant vapor by transferring the heat to the air surrounding or passing through the condenser, and the water cooled condenser transfers its heat to the water flowing through it.

Chiller Systems

A chiller uses the components of a basic refrigeration system to add cooling and dehumidification to water or steam-heating systems designed to produce air-conditioning all year long, if required. Chillers can use DX coils or circulated chilled water created when indoor air is passed over evaporative coils in the unit. There are reciprocating chillers that use reciprocating compressors, centrifigul chillers with centrifigul compressors and screw chillers with screw-type compressors. Absorption chillers use heat and physiochemical processes to produce the refrigeration effect.

Cooling Towers

This equipment does not create a refrigeration effect but its purpose is to dissipate the heat generated by the air-conditioning process. Air moving through the cooling tower either by natural, induced or forced draft, interacts with water droplets produced in the cooling tower and during the evaporation process, the air is cooled. The effectiveness of the cooling tower is dependent upon the ability of the surrounding air to absorb moisture.

The Ice Machine as a Source for Cool Air

Ice-melting and ice-storage systems are yet another way to produce cool air. The ice melting system consists of a large bunker for the storage of purchased ice. Return water from the air-conditioning system is sprayed over the ice blocks and a pump in the unit picks up the chilled water in the reservoir and returns it to the air-conditioning system. Using lower cost off-peak electricity to produce ice at night, an actual ice producing system can also be constructed to produce ice during off-hours, reducing electrical demand during the day and storing the ice until chilled water is needed during working hours.

Heat Transfer

Every cooling coil and every heat exchanger must have an arrangement whereby the hot or cold fluid being generated can travel from its source to the terminal unit and back to the source again for rejuvenation. When water is the medium, the various piping systems previously described will do the trick. Steam traveling through a system of one or two pipe assemblies will transfer heat, and when a central fan or fans are to be used to distribute cool or warm air, a system of distribution ductwork made of galvanized steel, aluminum, fiberglass or wire-reinforced flexible plastic ducts is needed.

Fans, Ductwork and Terminal Units

Fans. Fans required to move the hot or cold air from the generating source to the terminal unit can be of the centrifigal type that produce low-static pressure and minimal noise or an axial fan where variable flow is required and noise considerations are not so restrictive. Fan drive can be either direct, powered by a single-speed motor available in a limited range of rpms or belt-driven with a wide variety of pulleys or sheaves so that stock motors with standard rpm ranges can provide many more operating speeds. Figure 22-6 reveals a single central fan schematic system incorporating a chiller for cold-air generation and a steam or hot water coil to produce heated air.

The Ductwork. The simplest air-distribution system would be a single-duct, single-zone system where air is supplied at a predetermined temperature throughout the entire space. From this simple idea there are many modifications to the most sophis-

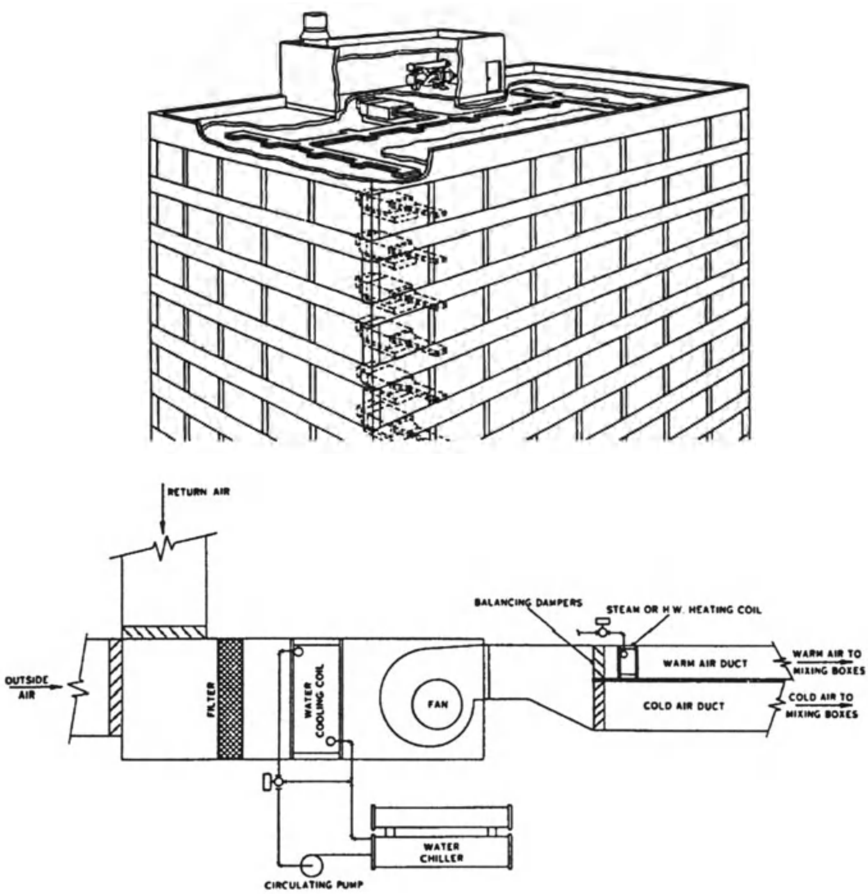


Figure 22-6 A Schematic Drawing of a Central Fan Air-Distribution System with Cooling and Heating Capabilities. Courtesy: The Trane Company, LaCrosse, Wisconsin.

ticated variable air-volume system with elaborate direct digital controls. Sheet metal ductwork is referred to as being either low velocity or high velocity. Low-velocity ducts will handle air moving at 2,000 fpm and is usually configured in a square or rectangular shape. High-velocity duct, one that will move air at speeds up to 4,500 fpm, is usually made as round duct since this shape will permit the use of thinner

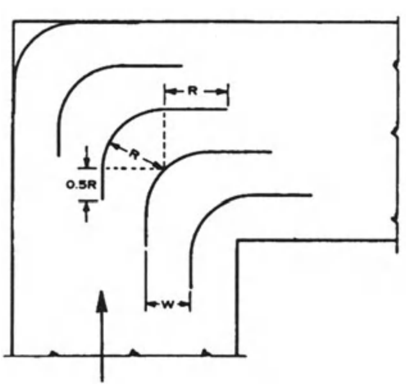


Figure 22-7 Schematic Plan View of Turning Vanes in Ductwork Elbow.

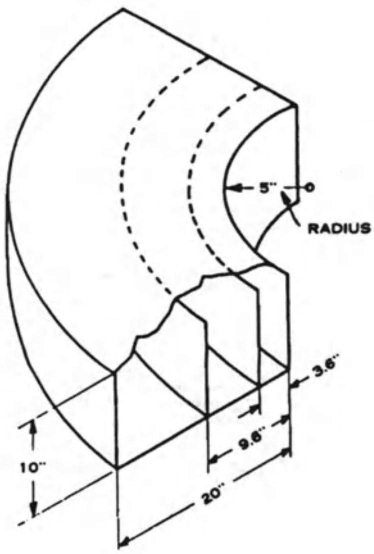


Figure 22-8 Isometric Schematic of a Splitter in a Ductwork Elbow. Courtesy: The Trane Company, LaCrosse, Wisconsin.

gauge metal, won't need reinforcing braces and will create less turbulence. Turbulence and the noise it creates can be a problem in an air-distribution system. To provide an even air flow and reduce turbulence, turning vanes (Figure 22-7) are often used in elbows. When elbows with small radius ratios are installed or they discharge directly into the atmosphere, a splitter should be installed (see Figure 22-8) to reduce frictional loss and help distribute air more evenly. Quite often acoustical duct lining is specified to reduce noise caused by air-flow velocity (see Figure 22-9).

Rectangular ducts of various sizes are constructed of metal ranging in thickness from 16 gauge to 26 gauge and longitudinal seams and transverse duct connections can be made in several ways to prevent air leakage. When fire dampers are installed in ducts,

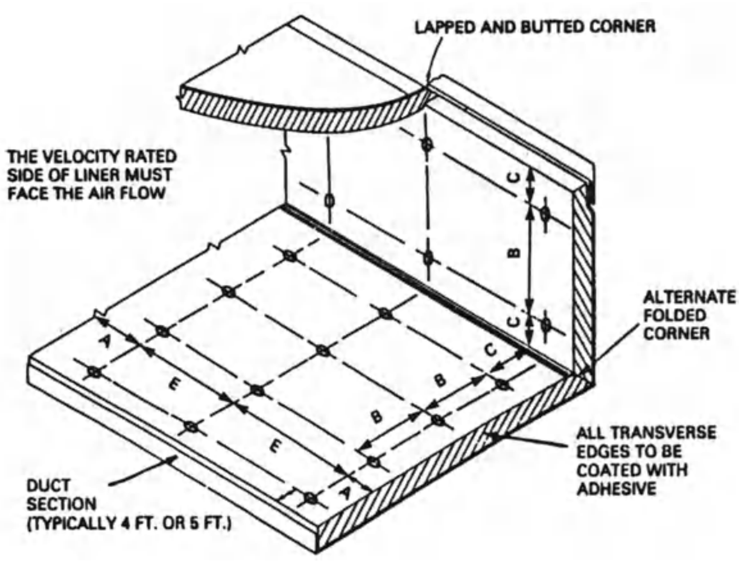
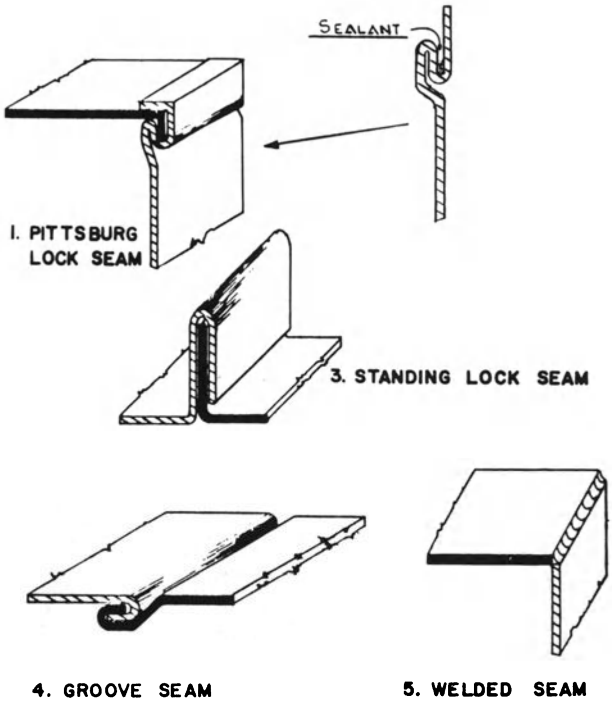
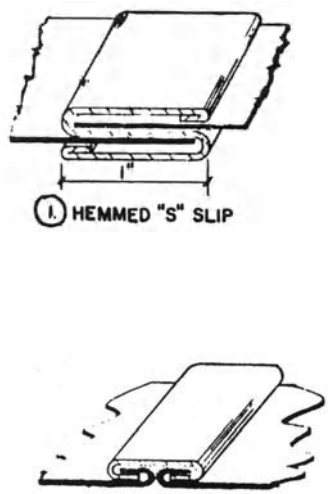


Figure 22-9 Section Through a Lined Duct. Courtesy: The Trane Company, LaCrosse, Wisconsin.



LONGITUDINAL SEAMS



(2) DRIVE SLIP

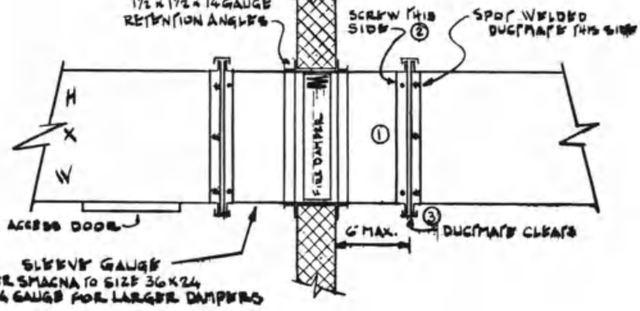


Figure 22-10 Duct Construction Details.

breakaway connections are required to gain access to the damper (refer to Figure 22-10 for these duct construction details).

Terminal Devices. Various fixed or adjustable louver diffusers and grills can be installed in walls or ceilings to admit warm or cool air into the work space. A control system will regulate the temperature of air emanating from these outlets, depending upon the number and placement of control zones throughout the building. In most of today's office buildings more individual control is desired, and the variable volume terminal device fits the bill.

Variable Air Volume. A VAV system can be best described by comparing it with a constant volume system where a fan goes on and warm or cool air is distributed to an area or a zone until a centrally located thermostat indicates that the air temperature requirement has been met. The VAV terminal modulates the volume of constant 55 degree temperature air, and the attached thermostat actuates a mechanism in the VAV box to control the flow of air.

There are three methods by which terminals modulate air flow:

1. A bellows assembly that can be inflated or deflated, thereby allowing air to pass through or decreasing the space for air flow through the terminal unit.
2. An internal damper activated by a thermostatically controlled operator.
3. A modulating air valve where a damper assembly travels within a cylinder with discharge air slots in it.

Some VAV terminal units have electric or hot water reheat coils in them, thereby permitting the occupant to increase the quality of heat from their unit. This may be a requirement for those building occupants with perimeter office space requiring more heat during a cold winter start-up cycle. Fan-powered VAV boxes will provide a constant volume of discharge air at all blending ratios, and are often used in those areas where a constant air flow is desired such as in restrooms, conference rooms and entry ways.

When VAV boxes do not function properly when installed initially, one or more of the following problems may be encountered:

- Inaccurate or erratic air-flow control—May be caused by poor inlet-duct connection, leakage in the duct work, assembly mounted in a no-level position or upside down, controller adjustment dials incorrectly set, low-velocity pressure in the inlet duct, thermostat out of calibration.
- Lack of cooling—Chillers and pumps may be deenergized, check for insufficent pneumatic control pressure.
- Cooling CFM (cubic feet per minute) not up to specified level—Verify CFM at outlet grills, check for crimped air lines, check actuator and crank arm linkage, check flow cross sensor, check controller operation.
- Excessive noise—Check integrity of duct connection, check to see if maximum CFM is set too high.

- Fan motor does not run—Check fan disconnect or circuit breaker, verify supply voltage as being correct. Check to see if bearing or blower wheel is jammed or fan motor is damaged.
- Unit blows cold air, no heat—Verify operation of heat source, check disconnects, fuses, circuit breakers. Air-flow switch may not prove air flow, thermal cut-outs may be tripped, voltage may be too low, heat element or contractor may be defective.

Controlling the Quality of Indoor Air

When outside air is supplied to a building it must be filtered to remove pollen, insects, soot and other air contaminants so as not to distribute them throughout the building. A system of air filtering must be added to the basic air-distribution equipment if it is not an integral part of that equipment. Return air must also be filtered because it will contain contaminants such as cigarette smoke, dust, lint, or residues from normal office and shop pollutants. These contaminants can range in size from 0.01 micron to small leaves, large feathers or even a small bird and they must be removed by some sort of filtering device. Air filters can be divided into three categories: dry type throw away filters, electronic filters or viscous impingement filters.

Dry Type. These filters can be installed in mat form in a stationary position or can be in roll form mounted in a rotating-type drum filter. Dry-type filters are made of fiberglass, cellulose or cotton and are held in place in the air stream with various types of removable filter frames. The rotating dry filter installation permits the disposable filter to be fed from a roller mounted on one side of the airstream to a roller on the other side. When the entire roll of filter element is contaminated it is replaced with a clean roll.

Electronic Filters. Can be of two types. One arrangement will charge dust particles by passing them through an ionizing zone, and the other type of electronic filter uses a charged media to charge the particles and collect them on a plate. When sufficient contaminants have been trapped, the power is turned off and the plates are removed and washed down with water or a solvent. Before replacement these plates are usually given a thin coat of adhesive to ensure that the trapped contaminants will adhere to the plate or plates.

Viscous Impingement-Type Filters. Can be either disposable or cleanable. A viscous filter is so called because of the viscous adhesive coating applied to the surface of the filter media once it has been installed. If the media is of the disposable type, once a new filter element is installed in the frame, it is coated with a viscous liquid such as oil before being placed back in operation. If a permanent cleanable filter is used such as a zig-zag screen arrangement, once it has been removed from the air-handling unit and cleaned, it is also coated with a viscous oil. After allowing the excess to drain off, it is then reinstalled. When a roller-type viscous impingement filter assembly is used, quite often an oil bath is provided under the bottom roller, and as the roller filter media picks up contaminants and passes through the oil bath, these contaminants are deposited there, thereby creating the need to inspect and clean this oil sump from time to time.

Clean Rooms and HEPA Filters

Carrying air-borne contaminant removal to the extreme, the need to create ultraclean environments such as in the manufacture of semiconductors, precision instruments, pharmaceuticals or medical and surgical supplies has caused the development of new filtration technology.

High-efficiency particulate air filters (HEPA) can provide an interior environment with a 99.99 percent efficient filter to remove particles 0.3 micron and larger from the air. And remember one micron is 1/100 the diameter of a human hair!

Clean-room technology has led to the development of air-filtering techniques that were considered impossible just a few years ago. A Class 100 Clean Room, named because its filtering system will result in a particulate count that will not exceed 100 one-micron particles per cubic foot of air was considered quite an accomplishment several years ago. A Class 10 Clean Room, one that does not permit the passage of more than 10 one-micron particules in any one cubic foot of air to pass through was the next commercial breakthrough, but today's frontier is the Clean 1 clean room, which can filter out dust particles 1/10 of a micron in diameter for each one cubic foot of air. Now that's clean!

23

Plumbing

It is believed that the first indoor plumbing system was designed by the Italian Renaissance genius Leonardo Da Vinci in the mid-sixteenth century, and other than the addition of sophisticated pumps on the supply side of an installation and the contemporary design of many of the fixtures today, gravity still plays the major role in the way plumbing systems work. Things still flow downhill.

A building's standard plumbing system will contain the following components:

Incoming water service,
A water distribution system,
Above-ground drainage and vent system,
Underground drainage systems—both storm and sanitary sewers,
Pipes and fittings, and
Plumbing fixtures and trim.

A GLOSSARY OF PLUMBING TERMINOLOGY

It might be best to start off with a glossary of plumbing terminology.

Air gap—The lowest opening of any pipe or faucet supplying water to a tank or plumbing fixture and the level at which the fixture will overflow.

Antisiphon—A mechanical device that eliminates the possibility of a siphon action.

Area drain—A receptacle designed to collect surface water from an open area on grade.

Aspirator—A device through which water passes under positive pressure causing a vacuum. Similar to an ejector.

Backflow preventer—A device installed in a line that prevents backflow of the liquid in the line.

Backwater valve—A valve installed in a sewer pipe subject to backflow that prevents drainage or waste from backing into a lower level drain or fixture.

Ball cock—A water supply valve that is opened or closed by means of a float. Used in toilet water tanks.

Branch—Any part of a piping system that is not a riser, main or stack.

Branch interval—Distance along a waste stack corresponding to a story height, within which the horizontal branches from one floor are connected to the stack.
Branch vent—A vent connecting one or more individual vents to a vent stack.
Circuit vent—Branch vent that serves two or more traps and runs from the downstream side of the highest fixture connection in a horizontal branch to the vent stack.
Cistern—A small covered tank for storing water for residential or farm use.
Cleanout—An access opening in a drainage pipe that allows the removal of obstructions and debris.
Combination waste and vent—A horizontal wet venting of one or more lavatories or floor drains by means of a common waste and vent pipe sized to provide air space above the liquid level in the pipe.
Cross-connection—A connection between two otherwise separate systems such as a connection between a potable and nonpotable water supply.
Dead end—Branch piping from a waste, vent, building drain or sanitary line that terminates at least 2 feet beyond its developed length and is capped off or plugged.
Fixture branch—A drain serving one or more fixtures that discharges to another drain or vent.
Fixture fitting—A device that controls or guides the flow of water into or away from a fixture.
Indirect waste pipe—A waste pipe that does not connect directly with the drainage system but is separated by an air gap.
Individual vent—A pipe connected to a fixture drain that ties into a vent system above the fixture served.
Joints:
- Expansion—A loop or return bend that provides for expansion and contraction in a piping system.
- Flexible—A joint between two pipes that allows one to be deflected without disturbing the other.
- Mechanical—A joint in which compression is applied along the center line of the pieces being joined. Not a screwed, threaded, soldered, brazed or welded joint.
- Slip—One pipe is slipped into the end of another and held in place with special packing.

Loop vent—A circuit vent that loops back to connect to a stack vent instead of a vent stack.
Potable water—Water free from impurities so as to conform to public health drinking water standards.
Relief valve:
- Pressure relief valve—Pressure acting against a spring prevents it from opening until a predetermined pressure level has been exceeded.
- Temperature relief valve—Same as above except it will discharge based upon temperature setting.
- T&P valve—Combination valve that is activated by either temperature and pressure.

Relief vent—An auxiliary vent that allows added circulation of air in or between a drain and a vent system.

Sewage ejector—A device that will lift wastes when activated by a high-velocity stream of water, air or steam.
Side vent—A vent connected to a drain pipe via a fitting at an angle not exceeding 45 degrees to the vertical.
Stack—A general term that refers to a vertical soil, waste, or vent pipe.
Sump vent—A vent from an air-powered sewage ejector that terminates in the open air.
Tempered water—Water in the 85 degree to 110 degree F range.
Trap—A device that provides a liquid seal to prevent the emission of sewer gases.
Trap seal—The vertical distance between the crown weir and the top of the dip of the trap.
Vacuum breaker—Form of backflow preventer installed on openings subject to atmospheric pressure.
Wall-hung water closet—Wall mounted toilet that does not touch the floor.
Water hammer arrestor—A device that absorbs a pressure surge when water suddenly stops flowing.
Wet vent—A vent that receives waste discharge from other than water closets.
Yoke vent—Pipe connected from a waste stack upward to a vent stack to prevent pressure changes in the stack.

WATER SERVICE AND WATER-DISTRIBUTION SYSTEMS

Water-service pipe can be constructed of brass, cast iron, copper, galvanized steel or one of several plastic materials such as ABS (acrylonitrile butadiene styrene), PB (polybutylene), PE (polyethylene) or PVC. Generally a tap-in is made in the off-site water main and brought into the building with one of these water-service piping systems. Installations of incoming mains will be determined by code requirements and the regulations of the local municipality or private water company. At times one main will be tapped into the street source and brought into an underground water-meter pit where it can be subdivided into a domestic water main and a fire main. Backflow preventers are common devices in water-main installations since they prevent any contaminated water in the building from being drawn back into the public water supply. Water meters are another common device frequently installed in the main, and they can be of any one of three types: displacement, compound and turbine type.

Although copper pipe and cast iron pipe are the more common water service materials, certain plastic materials have attempted to make in-roads into this application when fairly small diameter mains have been designed. However, there have been problems with pipe connections in these kinds of installations as well as the plastic pipe itself. Some plastic piping systems use acetal compression fittings and these fittings can become stressed by the pressure required to make a tight seal. Stress can lead to cracking and cracking can lead to leaks. If polybutylene pipe assemblies are connected to copper or brass fittings the plastic pipe may become oxidized when in contact with either of these two metals and when that occurs the pipe will become embrittled and may crack if subjected to even slight impact. Certain types of plastic pipe expand and contract as much as eight times when subjected to summer sun and subsequent cool underground temperatures after being backfilled. If enough slack has not been provided in the line, an expanded line can snap when contraction takes place.

Plastic pipe requires a sand bed prior to installation, and backfilling operations should take place using a sand cover directly over the pipe before normal backfill materials are used. When water-main pressures in the street main exceed 80 psi, an approved pressure reducing valve may have to be installed in the water service line near its entrance into the building. When the pressure in the street is insufficient to supply potable water to the building in quantities needed during peak operations, a hydropneumatic pressure-booster system or a water-pressure booster pump will probably be required. An elevated water tank can also be used to increase pressure when needed.

Water Distribution Systems

These systems will use copper or brass pipe, chlorinated PVC, galvanized steel or polybutylene materials and distribute both cold water and hot water generated by any one of several means within the building. Potable water mains are disinfected and thoroughly flushed prior to being placed into service and both hot- and cold-water lines are required to be tested and inspected before any insulation is installed and before they are enclosed in the wall system. Quite often water-hammer arrestors are installed in various parts of the system to reduce shock pressure to both hot- and cold-water lines caused when excessive surge pressure is generated if fixtures or appliances are abruptly turned off. Insulation on cold-water lines serves two purposes: prevention of condensation that could start to form mold or mildew within the wall cavity, and, act as an energy conservation medium keeping hot pipes hotter and cold pipes colder.

ABOVE GROUND WASTE AND VENT PIPING

The vent system in a building is necessary to provide a flow of air to or from a drainage system. A venting installation also provides protection of trap seals in preventing siphonage and back pressure. As water flows down a stack or along a pitched drain the cross section of the pipe is only partially filled with liquid. Air is dragged along with the liquid, and if the flow of this air is blocked in any way, flow will slow and stop. The creation of excess pressure in these drain lines must be prevented, and this is done by installing a system of vents. Along with the vent lines and stacks, traps will also be installed. These traps will be designed to maintain a seal in the line so that sewer gases cannot enter into the drainage system after the downward flow of wastes has ended. The object is to provide a balance of air within the drainage system so that neither positive or negative air pressures greater than 1-inch will develop at the trap seal of a fixture. Vent stacks are basically vertical pipes that provide circulated air to and from all parts of the drainage system. Wet vents receive waste discharge from sources other than water closets. The reason for using wet venting, where allowed by code, is that it reduces the piping required for any given installation because the indivual pipes serve two purposes, providing venting as well as waste discharge.

A key component in a building's waste system is the trap installed to prevent sewer gases from flowing back through the waste lines, through the plumbing fixtures and into various areas of the building. Although a trap is a relatively simple J- or P-shaped affair, it has its own parts terminology (see Figure 23-1). The water seal in the trap is the means by which sewer gases are blocked, and when water in the trap seal is reduced to the point where discharge from the fixture sucks the remaining water out of the trap, building occupant complaints will be heard. Trap seal losses can occur when induced siphonage takes place. This phenomenon occurs when pneumatic pressure fluctuations created by the discharge of a fixture other than that to which the trap has been affixed siphons water out of the trap, forcing air back through the trap seal.

Testing Waste and Vent Lines

Waste and vent lines are required to be tested prior to being enclosed in a wall and these systems can be tested with water or with air. When water is used, all openings in the piping system must be tightly closed leaving only the highest one open. Water is then filled to overflowing and all parts of the system are tested with a 10-foot head of water, except the uppermost 10 feet of the system. After having been subjected to the 10-foot head of water for at least 15 minutes, an inspection is made of each pipe and fitting joint to detect any leakage. An air test requires that all openings in the system be sealed and subjected to 5 psi pressure or pressure sufficient to balance a column of mercury 10-inches high. This test will remain on the piping system for at least 15 minutes with no observable loss of pressure. Air tests are usually preferred in colder climates where the presence of water in the lines may causes freeze-ups if these lines cannot be fully drained after testing. Materials of construction for these two systems can be ABS plastic, copper, cast iron or PVC, although galvanized steel pipe is sometimes used for waste and vent lines installed above grade only.

Indirect Wastes

An indirect waste (see Figure 23-2) is one in which there is an air gap between the end of the fixture's waste pipe and the building's waste line. Used primarily in food-service piping systems, the theory behind the indirect waste is that because there is no hard connection between fixture waste line and building waste line, it is impossible for any

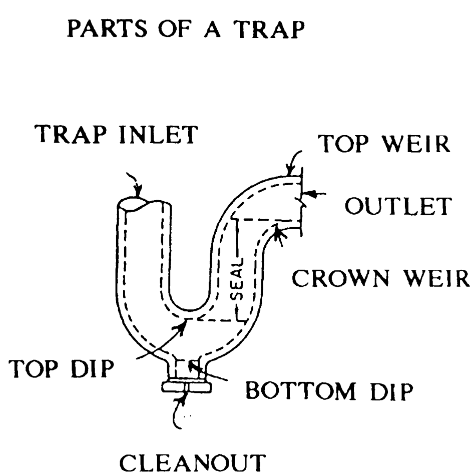


Figure 23-1 Configuration and Nomenclature of a Fixture Trap.

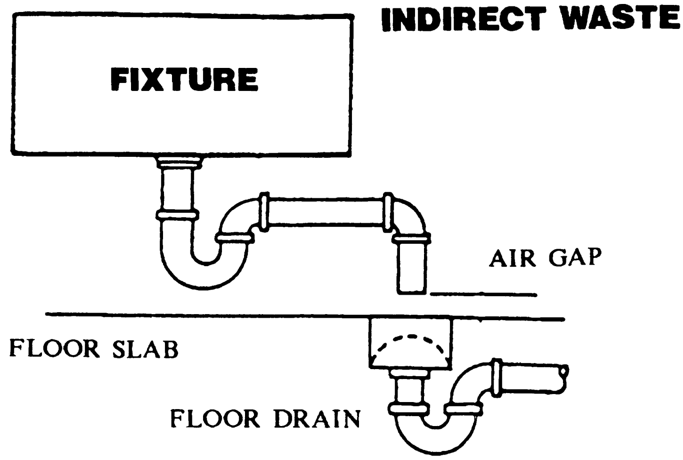


Figure 23-2 Schematic of Indirect Waste Line with Air Gap.

waste discharge from other lines in the building to back up into a fixture where food has been placed. Hospitals use indirect wastes when sterilizers and some laboratory sinks are to be installed into existing waste lines.

Without a hard connection between the two waste lines, odors created by waste matter remaining in portions of the underground pipe can back up into the room unless provisions have been made to install and maintain a trap seal in the underground line. Even though an appliance or fixture with an indirect waste is washed out frequently, the water than remains in the below-grade trap can evaporate thereby eliminating the seal. By installing an automatic primer, water can automatically be fed into those seldom-used traps to maintain seal integrity. An air gap fitting can also be installed on indirect waste lines. This device produces a rigid connection between the fixture and building waste line, and it will create an air gap of at least twice the effective diameter of the drain served thus allowing free circulation of air but preventing contamination from backflow or back siphonage. If no such trap seal device is installed, it may become necessary to pour some nonevaporating liquid such as antifreeze into the infrequently used traps.

Grease and Sediment Separators

A grease separator is used to separate light density oils such as cooking oils, or grease or fat from the waste generated in kitchens. These devices are usually installed below floor level with the cleanout cover at floor level for ease of servicing and maintenance. Double-wall trap partitions that intercept, separate and accumulate grease flowing from kitchen waste lines are available. Grease separators employ the principle of floatation to separate grease globules from waste water.

Sediment interceptors are fixtures designed to retain any solids that could clog a sewerage system. These interceptors are often found in businesses with bottling lines where it is desirable to trap any broken glass that may collect in the waste line, and these devices can be found in barber shops or beauty salons where it becomes necessary to prevent large quantities of hair from entering and clogging the waste lines. These sediment interceptors are equipped with removable baskets or screens to assist in periodic cleaning.

STORM DRAINS

Roofs, paved areas, yards and courtyards collect surface and rain water and disperse it via a storm-drain system using bituminized fiber pipe, corrugated metal, cast iron, concrete, vitrified clay pipe, ABS plastic or PVC pipe. Site storm water enters the storm-sewer system through catch basins, area or yard drains and trench drains while building storm-sewer systems collect rain water in roof and floor drains (see Figure 23-3). Water entering the storm system from parking-garage floor drains is generally required to flow through an oil separator. These oil separators contain a double-wall, deep-seal trap partition and an automatic method of diverting oil that has been intercepted from the storm water so that it can be stored in a tank for future disposal.

Controlled-flow roof drains are designed to temporarily store rain water on the roof, permitting it to drain under controlled conditions into the storm-sewer system. These controlled-flow drains are installed on either dead level roofs or on sloping roofs where pitches are slight, in the range of ⅛-inch to no more than ¼-inch slope to the foot. One way in which modulated flow can be accomplished is by installing roof drains at various elevations above the roof so that predetermined volumes of water are metered into the rain leaders. These drains must be equipped with strainers to prevent the intrusion of debris that could clog the lines. Some designers will also require the installation of scuppers on the roof to avoid the potential for overloading the roof's structural system in case the rain leaders can't disperse the water accumulating on the roof. Various configurations of roof drains are depicted in Figure 23-4.

SANITARY SEWER SYSTEMS

Sanitary sewer systems within the building rely on gravity to remove waste materials from the building through a system of risers or stacks and branch lines. A "waste stack"

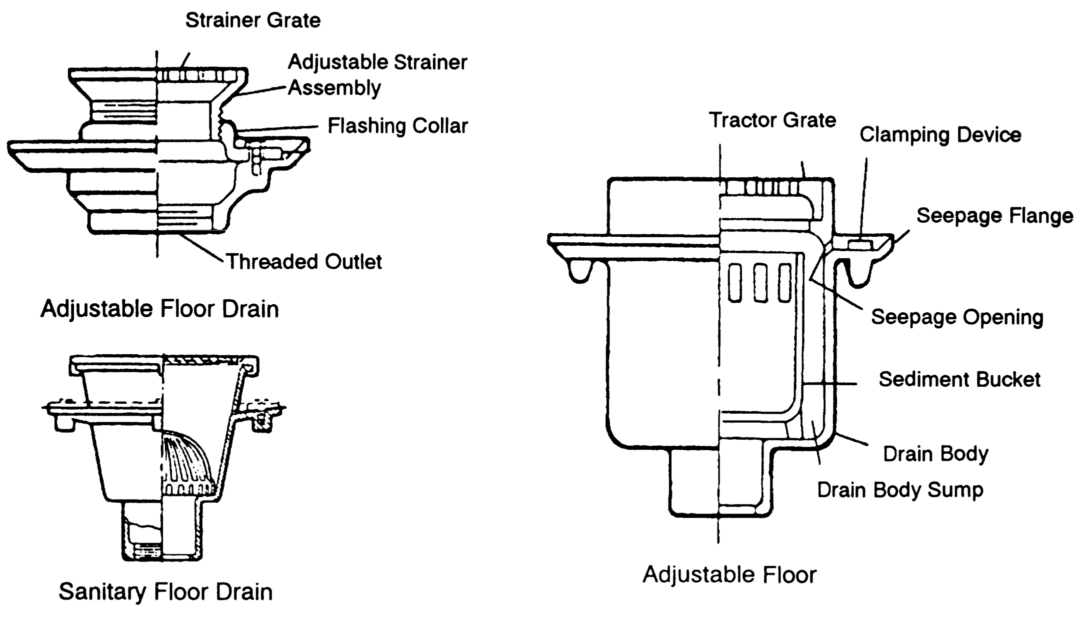


Figure 23-3 Floor Drains.

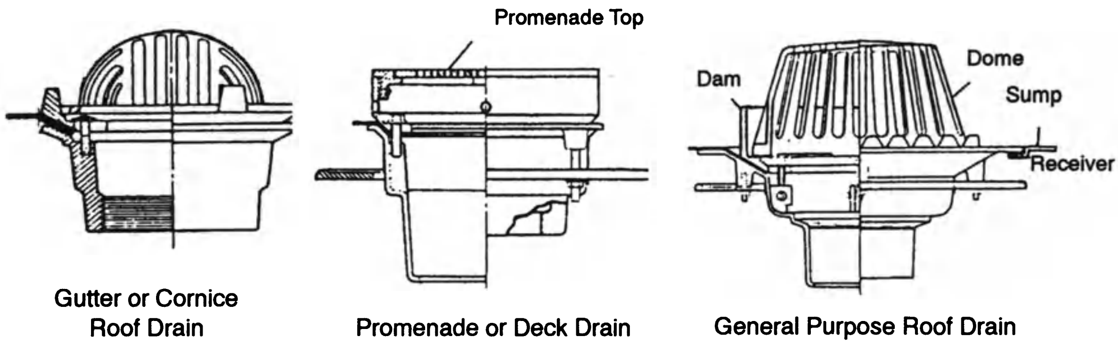


Figure 23-4 Roof Drains

is one that collects waste from fixtures other than water closets and urinals, and a "soil stack" is one that collects waste from toilets and urinals. Horizontal connections to the soil or waste stack are made through a sanitary tee, a long-turn tee-wye, or short sweeps not less than 3 inches in diameter. These fittings are designed to bring waste generated horizontally into the vertical stack with an initial downward velocity. Although it may be thought that the free fall in waste lines continues to accelerate like any free-falling object, friction developed within the riser slows the equilibrium, which may be further disturbed when horizontal lines on lower floors enter the sanitary riser. If the building flow line is lower than the invert of the sanitary connection in the street, a system with a sump and ejection pump must be installed to pump the waste uphill into the city system.

PIPE AND FITTINGS

Plumbing pipe and fittings can be made of a variety of ferrous and nonferrous metals, copper, brass, and their alloys and many different types of plastic materials. The choice of materials is generally limited to code requirements, either local, state of BOCA. Joint connections between similar materials can be either soldered, welded, mechanical, threaded, brazed, caulked or with compression-type fittings, depending on the material of construction of the installed pipe. However, when some dissimilar metals are joined together, precautions must be taken to avoid corrosion of both pipe and fitting. In the event that a dielectric fitting is not installed, the following guidelines should be followed:

1. Copper, copper-alloy pipe or tubing joined to cast-iron pipe—Connections should be made by the use of a brass ferrule or compression joint. The copper or copper-alloy pipe or tubing is to be soldered onto the ferrule, which is then joined to the cast-iron pipe hub by a caulked or mechanical compression joint.
2. Copper, copper-alloy pipe or tubing joined to galvanized pipe—The copper or copper-alloy pipe or tubing is to be soldered to a brass converter fitting or a dielectric fitting, and these fittings can then be screwed onto the galvanized pipe.
3. Cast-iron pipe joined to galvanized steel or brass pipe—Connections are to be made with either a caulked or threaded joint or by the use of an approved adapter fitting.

4. Plastic pipe or tubing joined to another type of piping material—Joints between different types of plastic pipe must be made by approved adapter fittings. When plastic pipe is to be connected to cast-iron hub pipe either a caulked or mechanical compression joint can be used.

All buildings, whether large or small, wood, concrete or steel, tend to move, vibrate, expand, contract and sway, and plumbing installations must be able to move with the building. Hot-water and steam pipes will expand considerably at elevated temperatures, and they will contract when they cool down. Piping hangers and supports must be able to cope with these movements while still providing the necessary support. Large diameter pipe supports are available in various configurations from simple strap hangers to more elaborate roller bearing hangers as shown in Figure 23-5.

FIXTURES

Water closets, urinals, lavatories, bathtubs, showers, drinking fountains and service sinks comprise the bulk of plumbing fixtures in most construction projects. Variations of each of these kinds of fixtures will be based primarily on form rather than function. Mounting heights for normal occupancy use are standard as are the slightly different mounting heights and configurations of fixtures for the handicapped.

The installation of plumbing fixtures is rather straightforward as long as toilets are floor mounted and lavatories are installed in self-supporting vanities or have integrally mounted support legs. When wall-mounted toilets, lavatories and urinals are installed, they usually require some form of support in the wall. This can be provided by some form of carrier. Supports for wall-hung toilets will contain a waste fitting and a support

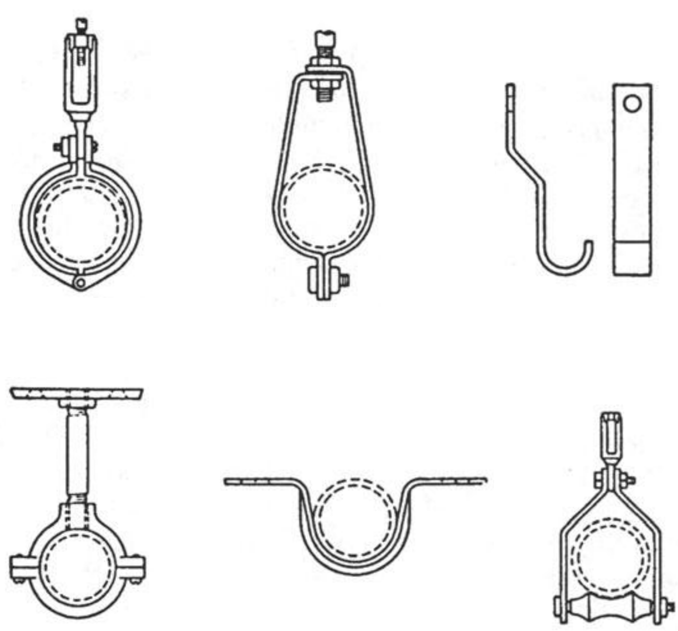


Figure 23-5 Various Types of Large Diameter Pipe Hangers.

assembly (see Figure 23-6). Urinals require a foot or feet for anchorage to the floor slab and an adjustable set of horizontal arms to rigidly support the fixture for normal usage. Lavatory carriers also require feet for anchorage and adjustability for height of fixture installation. Quite often wood blocking is installed in the studs adjacent to this carrier to stiffen the entire wall assembly in case undue pressure is placed on the fixture by someone sitting on it, for instance. Carrier configurations for urinals and lavatories are shown in Figure 23-7.

Along with the regular faucets and trim on toilet-room lavs, swing faucets may be required on service sinks in janitors, closets and special wrist-blade trim may be

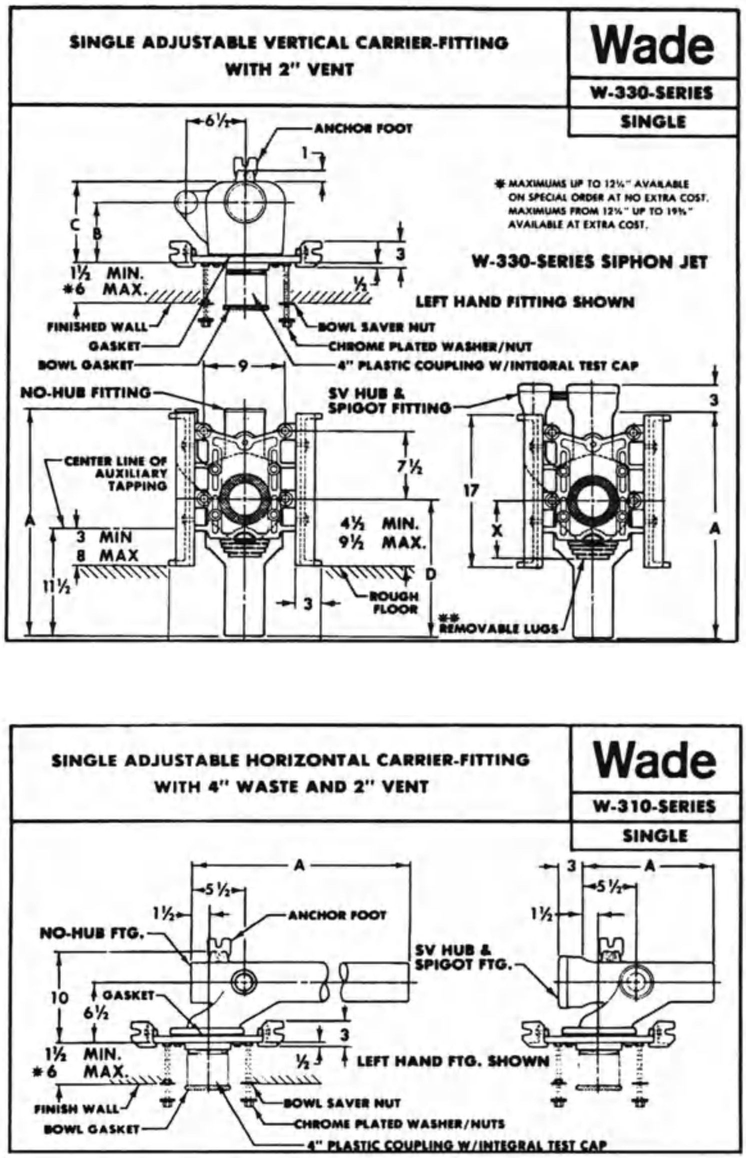


Figure 23-6 Carriers. Courtesy: Tyler Pipe, Wade Div., Tyler, Texas.

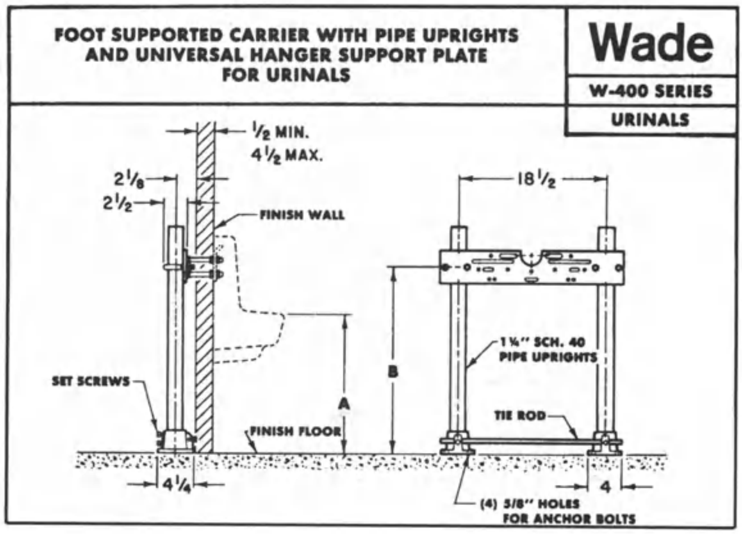
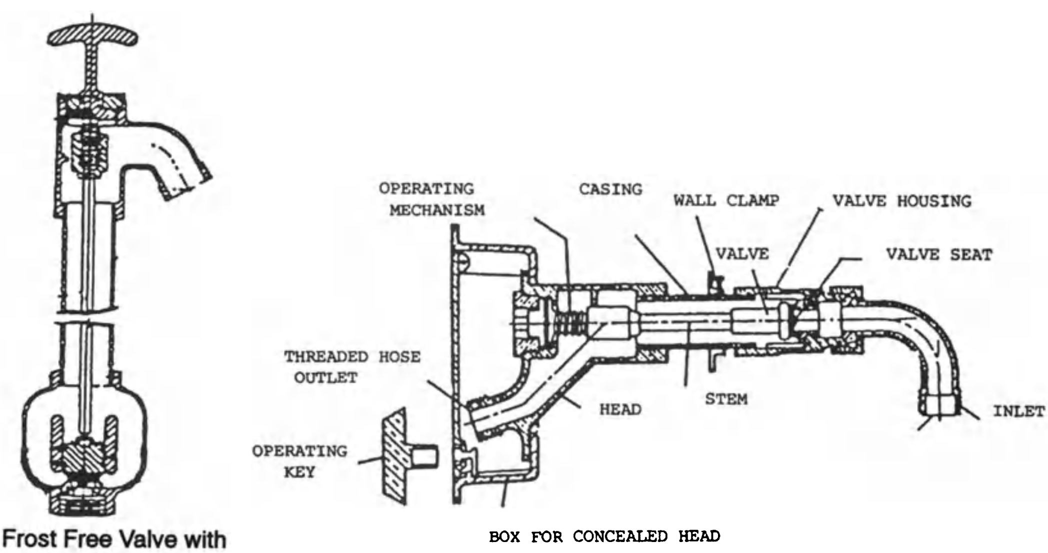


Figure 23-6 *(continued)*

required for special uses such as in hospital construction. Faucets known as "sill cocks," "hose bibs" or "hydrants" are frequently installed on the exterior wall of a building for site wash-downs or lawn-sprinkler connections. If the hydrant or hose bib cannot be installed in such a manner that its water supply is protected against freezing temperatures, a nonfreeze type hydrant must be installed. These frost-free hose bibs can be installed in either exposed position, or concealed within a lockable compartment as shown in Figure 23-7.



Frost Free Valve with Extended Depth Valve Stem

Frost Free Valve in Concealed Lockable Box

Figure 23-7 Frost-Free Hydrants.

HANDY PLUMBING CONVERSIONS AND TABLES

To Convert	To	Multiply By
Atmospheres	Pounds per square inch	14.696
Atmospheres	Feet of water	34
Cubic inches	Cubic feet	0.00058
Cubic inches	Gallons	0.00433
Gallons	Pounds of water	8.33
Gallons	Cubic feet	0.1337
Gallons per minute	Cubic feet per hour	8.0208
Inches of mercury	Inches of water	13.6
Ounces (fluid)	Cubic inches	1.805

Heads of Water in Feet with Equivalent Pressures

Feet Head	Pounds Per Square Inch	Feet Head	Pounds Per Square Inch
1	.43	15	6.50
2	.87	20	8.66
3	1.30	25	10.33
4	1.73	30	12.99
5	2.17	40	17.32
6	.60	50	21.65
7	3.03	60	25.99
8	3.46	70	30.32
9	3.90	80	34.65
10	4.33	90	38.98
		100	43.31

24

Fire Protection—Sprinkler and Halon Systems

In 1874, in New Haven, Connecticut, Henry Parmelee invented an automatic sprinkler system for his piano factory and fire protection for buildings took on an entirely new approach. Over the ensuing years variations on the initial concept resulted in more sophisticated devices to respond to, and deal with, the threat of fire more quickly and with more efficiency.

The widespread use of electronic data processing equipment in commercial and industrial establishments, equipment that could be severely damaged by water, created a new system of fire suppression using a clear, dry, noncorrosive inert gas known as Halon 1301. And in 1967 the first Halon system designed to protect a computer room was installed in Cambridge, Massachusetts.

SPRINKLER SYSTEMS

Sprinkler systems, using water flow to control fire, are usually preset to open automatically at temperatures in the range of 150 degrees F. There are four common types of sprinkler systems: the wet-pipe system, the dry-pipe system, the deluge system and the preaction system

The Wet-Pipe System

In this type of installation, the sprinkler pipes contain water at all times and are connected to a water supply so that when a head or heads open, water in the line flows through immediately and continues to flow until the system is deactivated.

The basic components of a wet sprinkler system as shown in Figure 24-1 are:

1. A water supply. Often augmented by a fire pump to provide the necessary pressure and volume to deliver adequate supplies of water to all parts of the building.
2. A main or riser if a multistory installation is contemplated.
3. Cross mains and branch lines containing "tees" for sprinkler head installation.

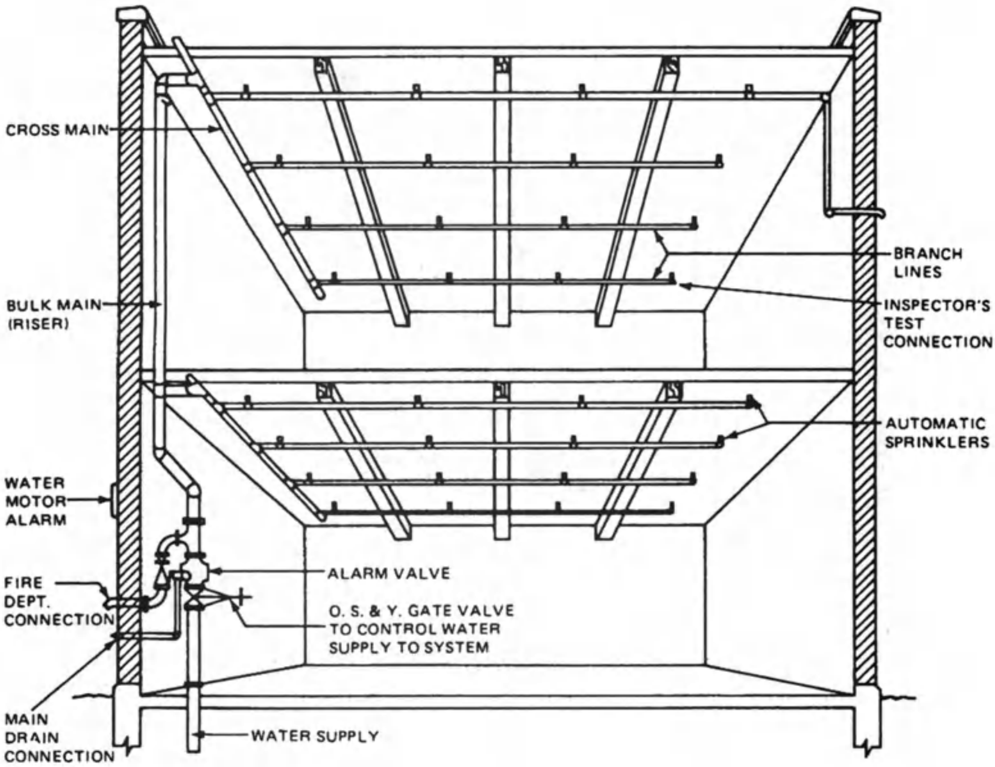


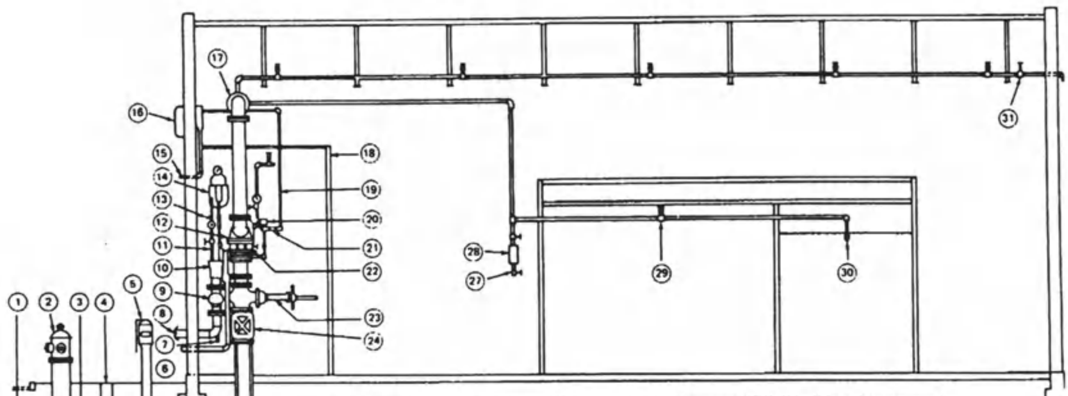
Figure 24-1 Schematic Installation of a Wet-Pipe Sprinkler System. Reprinted with Permission from Fire Protection Systems, Inspection, Test and Maintenance Manual, Copyright© 1986, National Fire Protection Association, Quincy, MA 022690.

4. The sprinkler heads themselves.
5. Various alarms.
6. A connection for the local fire department fire trucks.
7. A standpipe, when installation takes place in a high-rise building or in a high-hazard building.

The Dry-Pipe System

The wet-pipe system can only be installed in a building with heated space, but sometimes sprinklers must be installed in unheated areas, and that's when the dry system is considered. Dry valves in this system allow pressurized air in the mains and branch lines to hold back the flow of water until a sprinkler head opens, therefore this system can be used in unheated spaces and is often seen in underground parking garages. The dry system is not recommended for high hazard areas since the response time of the water flow is considerably longer than that of a wet system. This delay in delivering water requires that a dry system be designed with larger pipe diameters so that a greater quantity of water can be delivered to make up for the delay in response time.

A dry system has basically the same components as a wet system except for the addition of special valves and other devices to control the pressurization of the system (refer to Figure 24-2). The dry-pipe valve is a key device in this system since it holds back the dry air or nitrogen in the sprinkler pipes until a signal is received from the



ITEM	DESCRIPTION	ITEM	DESCRIPTION	ITEM	DESCRIPTION
1	City main	12	Dry pipe valve	23	O.S. & Y. valve (optional)
2	Pumper-type fire hydrant	13	Anti-flood device (optional)	24	Check valve
3	Underground fire main	14	Accelerator (optional)	25	Riser to sprinkler system
4	Key valve and road box	15	Water motor alarm drain	26	Thrust block
5	Post indicator valve	16	Water motor alarm	27	Drain valve and plug
6	Main drain	17	Cross main	28	Drum drip
7	Ball drip	18	Dry pipe valve house	29	Upright sprinkler
8	Fire department connection	19	Water motor alarm line	30	Dry pendent sprinkler
9	Check valve	20	Pressure switch	31	Inspector's test valve
10	Drain cup	21	Alarm line strainer	32	Inspector's test drain
11	Main drain valve	22	Alarm test valve		

Figure 24-2 Dry-Pipe Sprinkler System Layout. Reprinted with Permission from Fire Protection Systems, Inspection, Test and Maintenance Manual, Copyright© 1986, National Fire Protection Association, Quincy, MA 02269.

alarm system to open and allow water to begin flowing through the mains and branchs. A device called an accelerator is often used in conjunction with the dry-pipe valve. Its purpose is to open when the system's air pressure begins to drop at a predetermined rate, such as when a head opens and the air in the pipes under pressure pass through the accelerator to the intermediate chamber of the dry valve forcing the valve to open and flood the system. An air compressor is also part of the equipment needed to operate the dry system, and when an automatic air maintenance device is installed, the need to manually charge the system to overcome small leaks or changes in pressure because of temperature fluctuations will be eliminated.

The Deluge System

In certain special hazard areas where water is the most effective extinguishing agent, a deluge system can be installed. This type of sprinkler system is equipped with sprinkler heads in the open position at all times. Deluge systems are particularly effective when installed in chemical storage areas, in paint shops, over dip tanks and in aircraft hangers or other places where it is important to flood the area when the fire alarm activates the system. When a fire alarm activates this type of sprinkler system, the deluge valve opens and supplies an immediate supply of water to the protected area. The heart of this system is the deluge valve (see Figure 24-3) that can be activated pneumatically, electrically, hydraulically or even manually.

The Preaction System

Preaction systems are similar to dry systems except that the air filling its lines may not necessarily be pressurized. This type of installation relies on a two-stage operation.

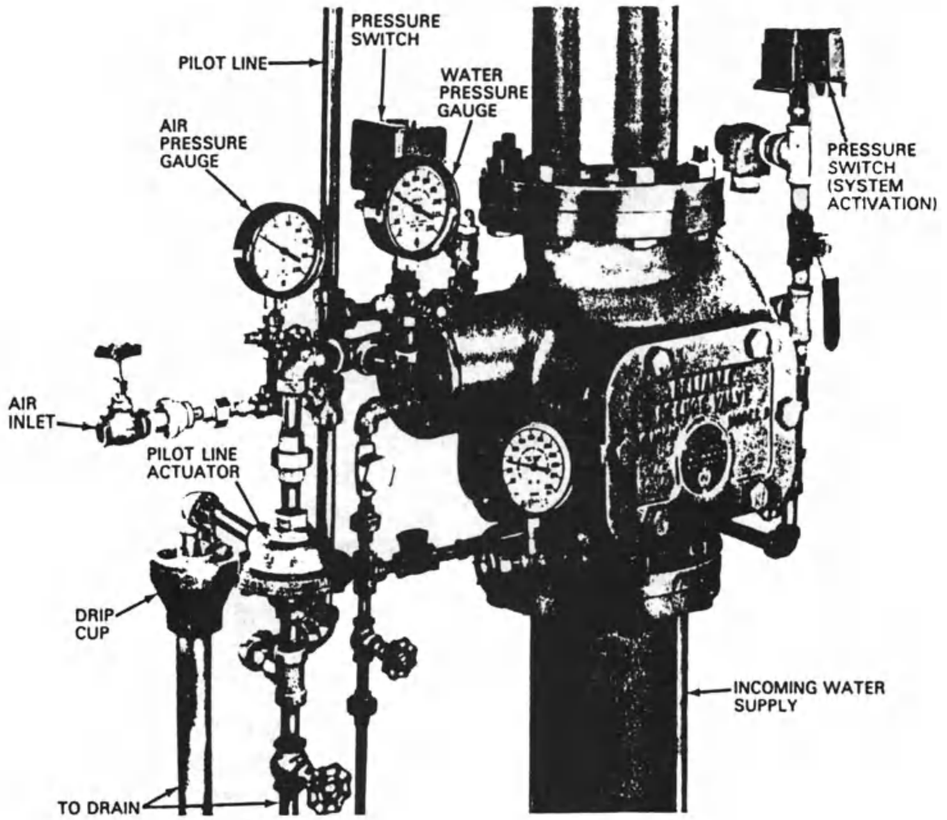


Figure 24-3 The Key Component of a Deluge System—The Deluge Valve. Reprinted with Permission from Fire Protection Systems, Inspection, Test and Maintenance Manual, Copyright© 1986, National Fire Protection Association, Quincy, MA 02269.

When the alarm is activated, a preaction valve fills the pipes with water prior to the opening of the sprinkler heads, and during the second stage of operation the heads open and water is discharged. The preaction sprinkler system relies on a supplemental system of heat detectors with very sensitive sensing devices located in the same area as the sprinker heads. When heat rises above the threshold limit of the detector, a valve opens allowing water to flow to the head. If a sprinkler head is accidentally damaged, the system will not become activated since it relies on the heat detector for a signal to discharge water.

The Standpipe and Related Equipment

A standpipe generally located in the stairwell of a building, is associated with high-rise construction where there is a need to provide an adequate volume of water, under pressure, to the upper floors so that firefighters can attach their hoses to its connections instead of dragging hoses up the many flights of stairs. A standpipe located in a stairwell allows the fireman to attach his hose, floor by floor as he travels up the stairs gaining access to the upper floors.

Most standpipes are installed in wet systems; however, a dry standpipe system can be installed in unheated areas but is limited to occupancies that are not considered high hazard. These standpipes are usually fed from a separate line or upfed by a pump. It is customary to install a hose cabinet or a hose connection at each floor in close proximity to the standpipe. Some local fire departments, however, may prefer to connect their own fire hoses instead of relying on the integrity of a hose that might have been stored in a cabinet for years. Many fire chiefs will request that a valved off threaded connection is installed on the standpipe compatible with the threads on their hose couplings.

Other Sprinkler Installation Materials and Components

The Siamese Connection. These connections allow the local fire department to provide continuing water pressure and volume to the sprinkler system that has already been activated because of a building fire. The pumper truck will connect the inlet side of its pump to the nearest fire hydrant and the discharge side of the vehicle's pump to the siamese connection, assuring that an adequate supply of water is being delivered into the building. Siamese connections can be mounted directly on the side of a building or remotely located as a free-standing capped pipe.

Fire Pumps. Automatic or manually activated fire pumps are often installed in the basement of a building near the fire main entrance to ensure that an adequate supply of water, at the proper pressure, is available when needed. These pumps can compensate for city water fluctuations because of demands elsewhere, and they are frequently tied into emergency generator circuits. A word of caution! A newly installed fire main must be thoroughly flushed prior to the fire pump being connected. Rocks, stones, debris, even a few large nuts and bolts could have found their way into the new main, and these things can raise havoc with the pump impeller upon initial start-up. More than one expensive pump has been severely damaged when proper line flushing procedures have not been followed.

Sprinkler Pipe Materials and Accessory Devices

Pipe and Fittings. Threaded connection Schedule 40 pipe meets all standards for sprinkler pipe installations, but there are thinner wall pipes that meet the ASTM-A135 specification and can be used as well. Certain types of thin wall pipe are lighter than Schedule 40 and make for easier and faster installations. While a 2-inch Schedule 40 pipe has a wall thickness of .154 inch, 2-inch lightweight sprinkler pipe has a wall thickness of .109 inch. Sprinkler piping no longer requires threaded connections since there is almost universal approval of the grooved end system of pipe connections. Special couplings, expansion joints and valves are available for these grooved end piping systems, and when flange to groove adapters are used, many more components become compatible. When Schedule 40 pipe is used, sprinkler pipe fittings are generally cast-iron Class 125 or malleable iron Class 150.

Valves. Preaction sprinkler systems use swing check valves that are rated for maximum pressure service of 250 psi and a minimum supervisory pressure of 1.5 psi. Water check valves are installed in systems to prevent reverse flow and minimize water hammer when closed rapidly. Detector check valves are used to detect leakage or unauthorized use of water intended for the sprinkler system, and these valves are fitted with electric contacts so that any flow will register remotely.

Post Indicator Gate Valves (P.I.V.'s). Are used in conjunction with an indicator post, and display whether a gate valve is open or closed and O.S.& Y valves also give immediate indication of an open or closed position.

Alarm and Supervisory Devices

Although valves are needed at various places within the sprinkler installation, it is critical that valves designated to stay open remain that way, and valves that must stay closed maintain that position. A variety of alarms can be fitted to valves and sprinkler lines to warn of deviations within the system. Pressure alarms are used in dry systems to warn of less than normal pressures, and when the pressure drops to a dangerously low level a contact in the fire alarm system will be activated. Water-flow detectors are vane operated devices and when water flows through a sprinkler line, the vane or paddle moves or rotates thereby activating a signalling device. Supervisory tamper-switch kits mounted on the stem of a valve installed in a standpipe will sound an alarm if anyone attempts to close these critical valves.

Sprinkler Heads

There are many types of sprinkler heads made to suit most of the conditions that challenge the sprinkler system designer. The standard, fusible link sprinkler head depicted in Figure 24-4 is a rather simple device. When surrounding temperatures are absorbed by the solder holding the links together, the solder will melt at a predetermined temperature allowing the links to spring apart and releasing water that will strike the deflector. This type of head is known as a solder type sprinkler head, and is available as an upright, pendent or horizontal sidewall head.

Bulb type heads have a breakable, transparent glass bulb containing a liquid that expands to create pressure capable of breaking the glass and activating the head. The liquid in the bulb is colored to indicate the temperature of the head, and these heads are available in temperature ratings ranging from 135 degrees F to 650 degrees F.

Early-suppression, fast-response (ESFR) type heads are used primarily to protect high-stacked materials. These heads are equipped with ultrasensitive thermal sensors and very large orifices and deflectors to create a heavy sprinkler discharge. Installed in the ceiling of a warehouse where materials are stacked in racks 25-feet high, the rapid response and heavy water flow will greatly reduce damage by fire.

Flush sprinkler heads bring an aesthetically pleasing appearance to office interiors and recessed sprinklers are architecturally pleasing and they also allow the sprinkler system to be installed and tested prior to the completion of the ceiling work. Con-

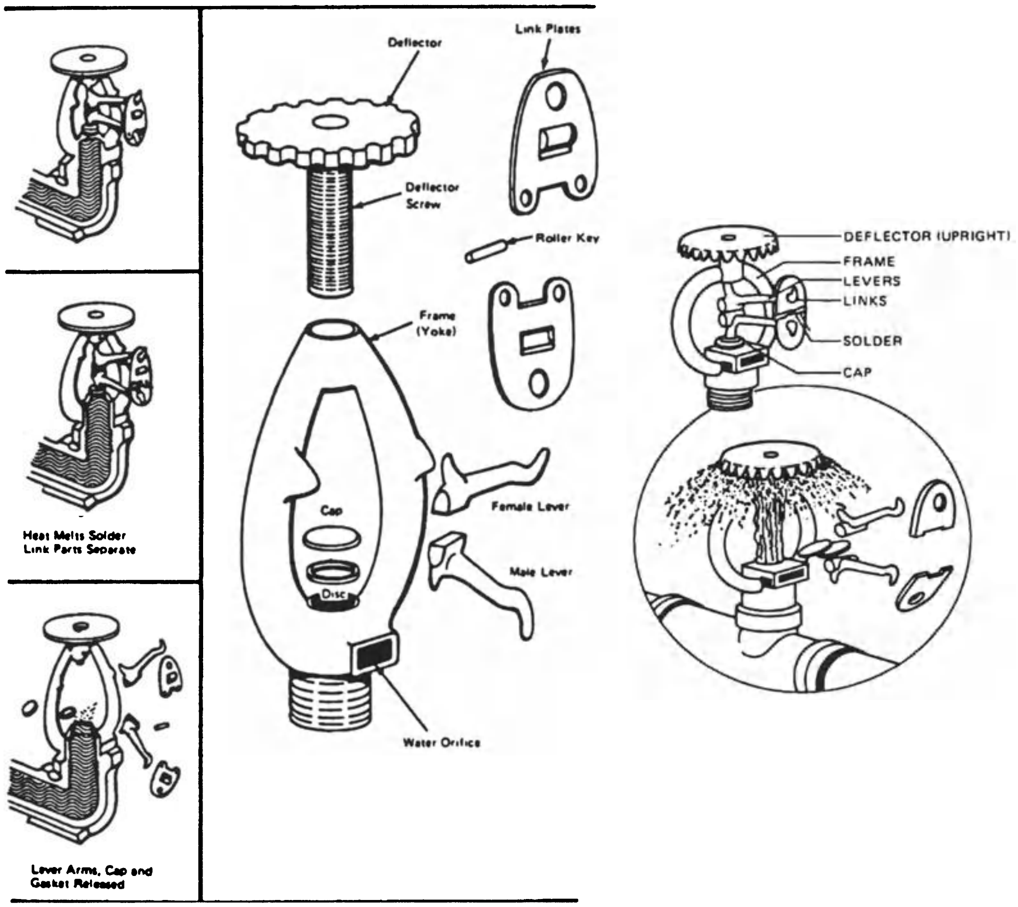


Figure 24-4 Exploded View of a Standard, Upright, Fusible-Link Sprinkler Head, Also known as a Solder Type Head. Reprinted with permission from Fire Protection Systems, Inspection, Test and Maintenance Manual. Copyright © 1986, National Fire Protection Association.

cealed sprinklers carry appearance a step further since they can be equipped with cover plates that match the color of the surrounding ceiling or wall.

Deluge systems incorporate sprinkler heads that are in the open position when installed and some of these heads incorporate very large capacity orifices. Finally, there are sprinkler guards, wire cage affairs that attach to a pendant or upright head to protect it from mechanical damage.

HALON FIRE SUPPRESSION SYSTEMS

Halon 1301 is a compound of carbon, fluorine and bromine and in the heat generated by a fire the bromine separates and prevents the link-up between oxygen and the fuel causing the fire. Without combustion, the fire goes out. This system differs from a carbon dioxide extinguishing system in that CO2 dilutes the oxygen and actually smothers the fire. Although Halon 1301 is classified by the National Fire Protection Association as the least toxic of all gaseous extinguishing agents, high concentrations should be avoided by humans, and the area flooded with Halon 1301 ought to be

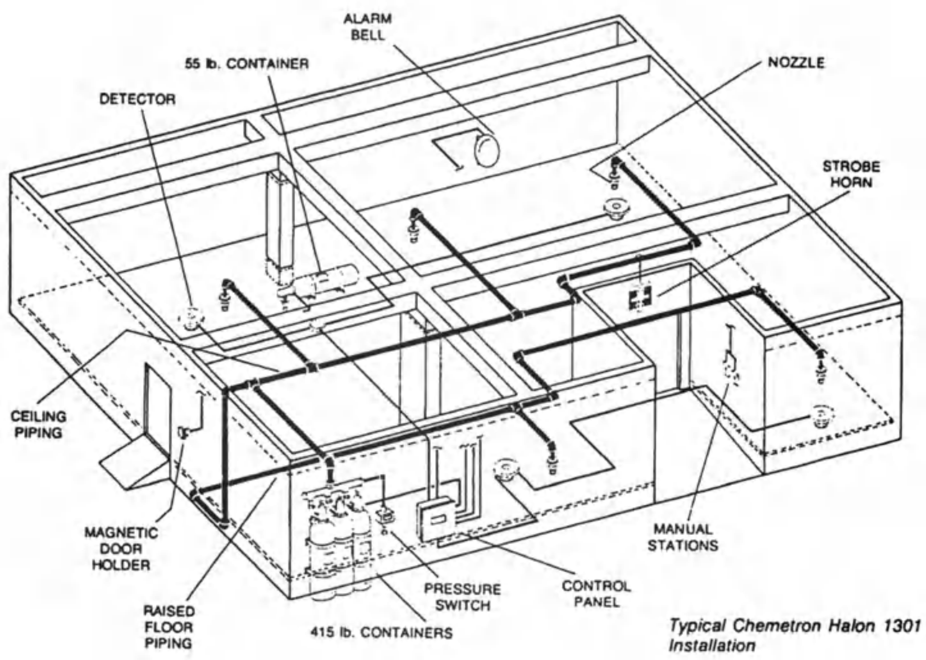


Figure 24-5 Schematic Drawing of a Typical Halon 1301 Fire-Suppression Installation. Courtesy: Chemetron Fire Systems, University Park, Illinois.

evacuated as quickly as possible. A typical Halon 1301 installation is depicted in Figure 24-5. The Halon system uses a cross-zoned detection circuit with ionization type smoke detectors above and below the raised floor. When any one of these detectors are activated, the following sequence of events will take place:

A. Activation of one or more detectors on one of the two zones will cause:
   1. The alarm bell and strobe light to become active.
   2. The respective zone indication lamp on the system's control panel will light up, identifying the zone that has been activated.
   3. This alarm will in turn be transmitted to the building's fire alarm panel.
   4. The relays to shut down the air-conditioning system and damper operations will be energized.

B. Activation of a detector or detector on the other detection loop within the same area will:
   1. Silence the bell and strobe.
   2. Activate the horn and strobe.
   3. Energize the auxiliary relays for equipment power shut-down.
   4. Engergize the 30-second Halon release timer, and Halon will be released in the affected area after the 30-second time period has elapsed.

Activation of the abort button shall cause the horn, strobe to pulsate and the 30-second discharge timer will be reset. Releasing the abort switch will have the same reaction as in B sequence above. A cross-zoned alarm in the above- or below-floor system shall cause the entire discharge of Halon in both above- and below-floor areas.

When any manual release station is activated, there will be an immediate release of Halon, and all delay systems will be by-passed. All bells and horns will become operational and air-conditioning units will shut down, dampers will close and all electrical equipment will become deactivated. All doors and openings in the protected area must be closed when the system is activated and generally these openings are controlled by auxiliary contacts in the system.

FIRE EXTINGUISHERS

Even though a building may be protected by automatic sprinkler systems and Halon systems, one will generally find a few hand-held fire extinguishers filled with either a multipurpose dry chemical, carbon dioxide, Halon 1211 or even water. These extinguishers can be extremely effective in putting out small localized fires, when the proper agent is sprayed on the fire.

There are three basic fire classifications:

Class A—Fires in ordinary combustible materials such as paper, fabric, wood, rubber, some plastics.
Class B—Fires in flammable liquids such as gasoline, oil, grease, tar, paint, lacquers and flammable gases.
Class C—Fires in live electrical equipment such as motors, generators, switches, appliances.

The following guide mates the correct type of extinguishing agent with the type of fire.

Class A—Multipurpose dry chemical is an excellent choice, as is water and Halon 1211. Do not use regular dry-chemical extinguishers nor ones with carbon dioixide.
Class B—Multipurpose and regular dry-chemical extinguishers are excellent choices as are carbon dioxide and Halon 1211. Do not use water.
Class C—Multipurpose and regular dry-chemical extinguishers are excellent choices and carbon dioxide and Halon 1211 will work just as effectively. Do not use water on this type of fire.

25

Electrical

Volts, watts, amps, bus bars, motor control centers. Electrical components and nomenclature can be quite confusing at times, but basic building electrical systems all contain the same elements:

- A service and distribution system—This includes transformers, meters, switchboards, distribution panels, power panels and lighting panels. Conduits and conductors of various sizes are also included in the distribution system, a sort of nervous system that connects the switchgear to all of the devices and equipment requiring electrical power.
- A lighting system to provide illumination to the work space.
- Equipment connections to activate heating, cooling and other building systems.
- Wiring devices to turn lights and some systems on and off.
- Fire alarm systems to warn of fire hazards and perform automatic functions to control the spread of smoke and fire.
- Specialized systems that complement these basic installations such as emergency generators, devices to produce "clean" and uninterrupted power (UPS) and cogeneration equipment.

A GLOSSARY OF ELECTRICAL TERMS

To take some of the mystery out of the electrical installation, a glossary of terms will help pave the way.

Amp—Abbreviation for ampere, a unit of electrical current flow (one volt acting across a resistance of 1 ohm in a current flow of one amp).

Bus—A rigid electrical conductor usually in the form of a rectangular metal bar.

Busways—A grounded metal enclosure containing factory mounted bare or insulated conductors (Bus) which are in the form of copper or aluminum bars or rods.

Capacitor—An electrical condenser placed on a single-phase, small horsepower motor to provide starting torque.

Cablebus—An assembly of insulated conductors with fittings and termination points in a completely enclosed, ventilated, protective metal housing.

Cable tray—A unit or assembly of metal or fiberglass tray sections used to provide a rigid support for multiple runs of electrical cable.

Cellular metal floor raceways—Metal tubes that form hollow spaces in a concrete floor to permit placement of electrical cables under these floors for distribution to work stations.

C.Ts—Current transformers.

Disconnect switch—A switch that will completely disconnect a motor or appliance from its power source.

Flat cable assemblies—An assembly of parallel conductors encased in a flat plastic covering specifically designed for installation in surface metal raceways.

Foot candle—Refers to the strength of the illumination at the light source, not at the surface where the light is required, that is, a desk, (see lumen).

Fused disconnect—An electrical switch that will shut down a certain portion of the electrical system. Contains a replaceable fuse to prevent damage to the piece of equipment.

Kilowatt—1,000 watts (expressed as kW).

Kilovolt—1,000 volts (expressed as kv).

Kilovolt-ampere—The product of the current in amperes and the applied voltage in volts, divided by 1,000 (expressed as kva).

Lumen—The amount of light on a 1-foot square surface 1 foot away from a 1-candle light source.

Motor, capacitor start—A motor with a separate starting winding with an electrical condenser connected to this winding for added starting torque.

Motor, capacitor start and run—Somewhat similar to above except that the capacitor and separate winding remain in the circuit at all times.

Motor, explosion proof—A motor built so that any fire originating within the motor cannot leave the motor housing.

Motor, open—A motor that will allow air to circulate over its windings.

Motor, split phase—An induction motor having a separate winding for starting.

Motor, totally enclosed—A motor that allows heat generated by its windings to dissipate within its casing. These motors may contain little fans to assist in dissipating the heat.

Motor starter, across the line—A starter operated by a magnetic power unit or a holding coil containing overload protection for the motor.

Motor starter, reduced voltage—A starter with the ability to reduce voltage upon starting, and as the motor approaches full speed, allow full-time voltage to be applied.

Overload protection—An electrical device within a motor that will stop the motor if an overload situation arises.

Resistor—A device used in an electrical circuit for protection or control.

Starting torque—The turning effort of an electrical motor upon start-up.

Surge arrester—Protective device for limiting surge voltage by discharging or by-passing the surge current.

Thermal overload elements—An alloy metal within an overload relay that will melt when current demands reach excessively high levels.

Volt—Unit of electromotive force when applied across a resistance of 1 ohm results in a current flow of 1 ampere.

Watt—A unit of electrical power required to do work at the rate of 1 joule per second. (For those wondering what a "joule" is, it is a unit of energy equal to 10 million ergs in the centimeter-gram-second system!)

Wireways—Sheet metal troughs with hinged or removable covers for housing and protecting electric wires.

SERVICE AND DISTRIBUTION SYSTEMS

Incoming electrical power originates at the local utility company and is brought to the construction site via overhead or underground cables. In most cases, the electrical energy provided by the local utility company exceeds the voltage requirements of the project, and transformers are installed to convert their line voltage to that which is required by the new owner. The primary service can be defined as the power and cables installed by the utility company up to the point where their connections terminate at the transformer. Secondary electrical service begins at the termination points on the output side of the transformer and is generally provided by the project's electrical subcontractor. As the secondary service enters the building proper it will be connected to the main fused disconnect, the switchgear, and thereon through various other electrical devices until power is distributed to all points in the building at the design voltage and amperage.

The one-line diagram set forth in Figure 25-1 reveals the standard path of electrical power from transformer through main disconnect and into several house panels and lighting panel. This particular one-line diagram pertains to a mid-rise housing project where several banks of electric meters were required, one for each residence in the complex. In most industrial and commercial projects, multiple meters are normally not installed.

When incoming voltage requirements are more than 23kv and 33kv, the utility company may elect to install a substation on or in close proximity to the property. The substation will contain an enclosure, transformers, switching equipment, metering, grounding and lightning protection. The first stop for the incoming secondary

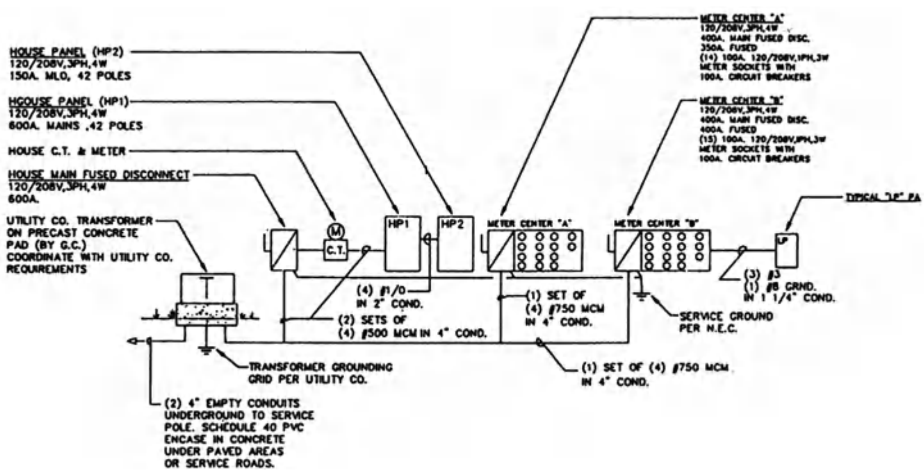


Figure 25-1 Typical 1-Line Drawing Showing Power Distribution.

feeders is the main fused disconnect or switchgear, and this self-contained, free-standing electrical device is custom designed for each specific project. Most switchboards have the same basic components but each one is tailored to the exact needs of the project. Standard switchgear components are shown in Figure 25-2. To accommodate the various individualized components within the switchgear's housing, extended and predrilled bus bars are often provided (see Figure 25-3). Screw type mechanical connections for feeders are standard equipment in many manufacturers' equipment for electrical cable connections (Figure 25-4). Compression-type fittings as shown in Figure 25-5 are also available. Along with fusible switches, molded-case circuit break-

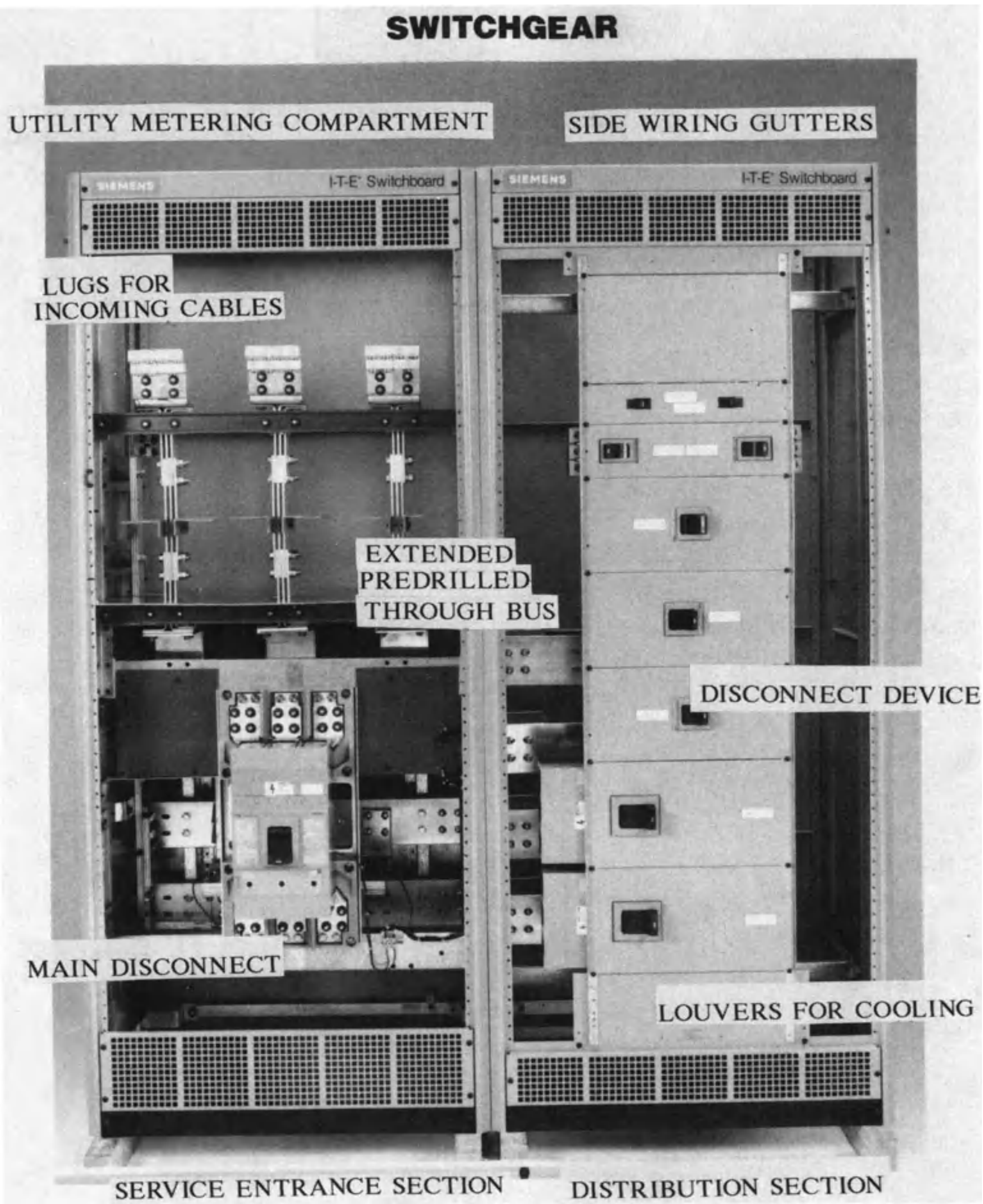


Figure 25-2 Typical Components and Provisions in a Switchgear. Courtesy: Siemans Energy and Automation, Inc., Alpharetta, GA.

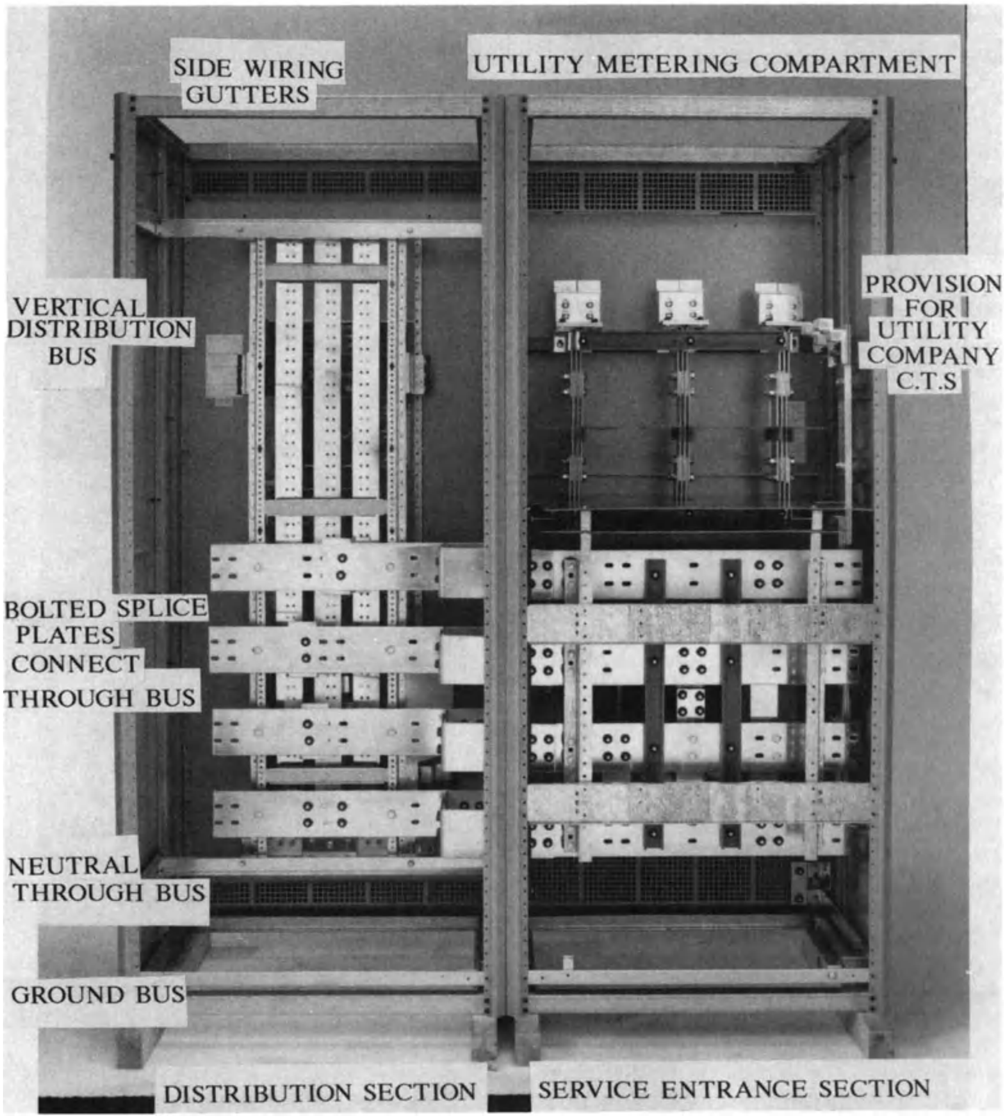


Figure 25-3 Distribution Sections of Switchgear. Courtesy: Siemans Energy and Automation, Inc., Alpharetta, GA.

ers and other protective devices installed in the switchgear, ground fault circuit interrupters are another important device. GFIs are intended to deenergize a circuit or portion thereof when a current-to-ground exceeds a predetermined value that is less than that required to operate the overcurrent protective device on the supply circuit.

Panel boards are the next step in the electrical distribution chain and can be grouped according to function, location or both. Lighting panels installed in electrical closets on each floor of a mid- to high-rise building will contain numerous circuits for that floor's lighting, possibly divided into several separate quadrants. Where there are multiple tenants, it is common to provide separate panels for each tenant. Separate

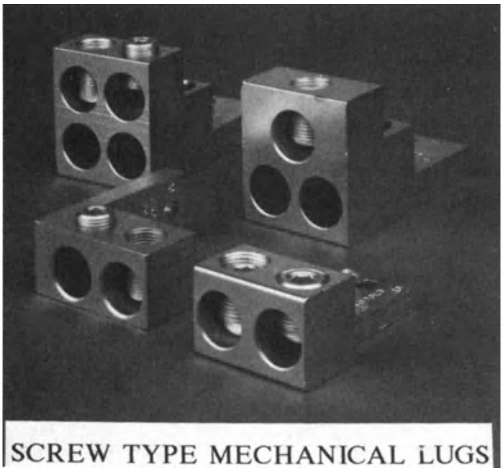


Figure 25-4 Screw Type Fastening Lugs for Electrical Feeders. Courtesy: Siemans Energy and Automation, Inc., Alpharetta, GA.

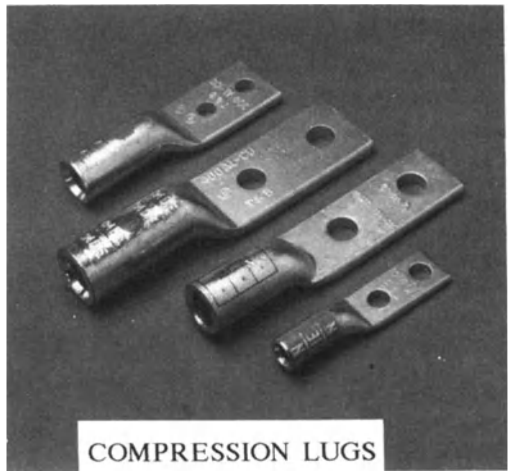


Figure 25-5 Compression Type Fastening Lugs for Electrical Feeders. Courtesy: Siemans Energy and Automation, Inc., Alpharetta, GA.

panel boards for equipment and other appliances are also more or less standard procedure except in very small projects where possibly one or two panels are sufficient to serve both purposes.

Motor Control Centers

Where there are fairly large number of low-voltage electrical motors being installed in a building, it is common practice to furnish and install a motor control center, which is basically a free-standing piece of equipment containing banks of separate circuit-breaker and motor-starter components. Each motor starter, feeder tap units and auxiliary controls can be mounted in their own compartment within one or more motor control centers (MCCs) so that monitoring and supervising these multiple motor operations can be more easily performed in a centralized location. Each one of the motors connected to the motor-control center can be either manually controlled by flipping its breaker on or off, or each motor can be controlled automatically through the building's energy or systems management circuitry.

CABLES, WIRING AND WIRING DEVICES

Cables and wires carry electrical energy from the source to the equipment to be energized and there are many factors that enter into the selection of the proper cable and wire for a particular use. As electrical energy flows through wire and cable, resistance to flow creates heat, and this heat must be dissipated. The proper wire or cable insulating material is to be selected not only for heat and fire resistance but for protection against moisture and dampness. Depending on the length of travel of the electrical current, a certain amount of voltage drop will occur and proper wire selection takes this factor into account.

There are two basic types of conductors: copper and aluminum. Aluminum conductors should not be used when wire sizes #6 AWG (American Wire Gauge) or larger are

Table 25-1. Comparison of Conductivity of Aluminum Versus Copper Wire

Rating in Amperes	Copper Wire Number	Aluminum Wire Number
100	#4	#2
110	#3	#1
125	#2	#1/0
150	#1	#2/0
175	#1/0	#3/0
200	#2/0	#4/0

required. Because the conductivity of aluminum is not as great as copper, the size of conductors will increase when it is substituted for copper. Table 25-1 contains rates of conductivity for both aluminum and copper wire conductors. As AWG numbers decrease, actual size of wire increases, therefore #4 wire is thinner than #2 wire, for instance. The reverse is true of MCM designations;* the larger the number, the larger the size of the conductor. Table 25-2 lists the actual diameter of each conductor within certain selected AWG size cable.

Aluminum has one other unique characteristic when compared to copper wire. It is softer, has a low yield strength and tends to continue to cold flow when compressed in a termination fitting. Many engineers years ago were reluctant to specify aluminum feeders because aluminum feeders would continue to compress and creep after being secured in a screw-type termination device. And if these connectors were not checked and retightened from time to time, the aluminum feeders would become loosely secured, a condition that could be quite hazardous. Newer compression type fittings especially designed for aluminum conductor appears to have cured this problem and eased the engineer's concern.

Table 25-2. Conductor Size and Number of Conductors in Selected AWG Assemblies

AWG Size	No. Wires	Dia. Each Wire*	Dia. Bare conductor*
18	Solid	.0403	.0403
16	Solid	.0508	.0508
14	Solid	.0641	.0641
12	Solid	.0808	.0808
10	Solid	.1019	.1019
8	Solid	.1285	.1285
6	7	.0612	.184
4	7	.0772	.232
1	19	.0664	.332
0	19	.0745	.373
00	19	.0837	.418
000	19	.0940	.470
0000	19	.1055	.528

*Diameter expressed in inches

*The term MCM is an abbreviation for thousandths circular mil area.

Insulating Materials for Wire

The basic materials used for wire and cable insulation must be able to withstand temperatures exceeding 100 degrees C, in most cases required to be flame retardant and resistant to moisture, water, chemicals, ozone and the effects of corona (a discharge of electricity that occurs on the surface of the conductor—sometimes visible). Various thermosetting and thermoplastic materials are used such as polyethylene and nylon, polyvinyl chloride and vulcanized polyethylene.

Types of Wire and Cable in Common Usage According to NEC Designations

Armored cable (AC)—A fabricated assembly of insulated conductors in a flexible metallic enclosure. Suitable for most branch circuit feeders. Commonly referred to as Greenfield or BX.

Electrical nonmetallic tubing—A pliable corrugated raceway with a circular cross section. The conductors are encased in a flame-retardant moisture and chemically resistant covering. Used in concealed walls, ceilings and in cases where there may be exposure to a severe corrosive atmosphere.

Flat conductor cable (FCC)—Contains three or more flat copper conductors placed edge to edge while being separated in a flat insulating material. Used as branch circuit wiring under carpet in commercial buildings to provide power for individual workstations.

Integrated gas spacer cable (IGS)—One or more conductors each individually insulated and enclosed in a loose-fit nonmetallic flexible conduit for use as an underground or direct-burial cable. This cable cannot be used for interior wiring.

Metal-clad cable (MC)—Contains one or more conductors enclosed in a metallic sheath of interlocking tape or a smooth flexible tube. MC cable contains a path for equipment grounding.

Mineral insulated, metal-sheathed cable (MI)—The conductors in this cable are insulated with a highly compressed refractory mineral insulation and enclosed in a liquid-tight, gas-tight continuous copper sheath. Uses for this cable include wet or continously moist environments or where exposure to oil, gas, and corrosive conditions not injurious to its sheathing are to be expected.

Nonmetallic-sheathed cable (NM and NMC)—A factory assembly of two or more conductors encased in a sheath of moisture-resistant, flame-retardent nonmetallic material. The primary use of this cable is in single and multifamily dwellings.

Shielded nonmetallic sheathed cable (SNM)—Manufactured of two or more conductors encased in an insulating extruded core of nonmetallic material covered with an overlapping spiral wound metal tape.

Wire conductors are assigned various letter designations depending on their suitability for use in various environments.

THNN—Annealed copper conductors insulated with a tough, heat-resistant (to 90 degrees C), moisture resistant jacket of polyvinyl chloride over which a nylon covering is placed. These conductors are available in AWG 14 up to 4/0 and 250 to 1,000 MCM.

THW—Soft (annealed) copper conductors encased in insulation that is abrasion resistant, moisture and heat resistant (to 75 degrees C.), and wrapped in an oil-resistant polyvinyl chloride casing. This wire is available in sizes from #8 up to #4/0 and 250 to 1,000 MCM and is used as a feeder or branch circuit wiring when installed in conduit or other approved raceways.

RHH, RHW or USE—Underground service and direct burial cable insulated with an abrasion-resistant vulcanized interlinked polyethylene casing. These conductors can be purchased in AWG sizes #14 to #4/0 and 250 to 1,000 MCM.

XHHW—A high-heat and moisture-resistant conductor that can be used in damp, wet and dry conditions where temperatures do not exceed 75 degrees C. These conductors are encased in a jacket of VIP (vulcanized cross-linked polyethylene) that is abrasion resistant as well as heat and moisture resistant and is available in AWG sizes from #14 to #4/0 and 250 to 1,000 MCM.

Lighting

General lighting can be divided into interior, exterior and task lighting, and along with obtaining the proper degree of illumination, aesthetics and energy considerations will determine both fixture and lamping requirements. Interior lighting requirements have shifted away from the use of incandescent fixtures and toward the use of the more energy efficient fluorescent lights now fitted with electronic ballasts. Incandescent light fixtures are often used for decorative lighting and many types of task lights since the incandescent lamp produces a small point source of light that can be controlled and directed by various types of baffles and lenses.

Lighting has its own particular terminology and a brief glossary will explain some of the more frequently used terms.

Bulb—The glass enclosure of a lamp.

Candlepower—The intensity of light at its source. Measured in candelas.

Efficacy—Ratio of lumens produced by a light source divided by the necessary power to produce them, and expressed as a percentage.

Illuminance—Light falling on a surface and measured in footcandles.

Lamp—The mechanism that converts electricity into light by means of a filament or gas discharge.

Lens—Part of a fixture used to alter or redirect light distribution.

Luminaire—Assembly used to house one or more lamps.

Lux—A metric system measurement used to gauge amount of light falling on a surface.

Fluorescent Lighting

With the advent of the EL, electronic ballast, fluorescent lighting has overcome many of the objections previously leveled against it. ELs use transistors, resistors, capacitors and inductors to transform 60 Hz current to 20,000–60,000 Hz current, which improves lighting efficacy because of greater excitement to the phosphor coating in the tube. With the use of EL ballasts there is less noise, perceived tube flicker is eliminated, and tube life is extended. The reduced wattage required to operated these fixtures along with their cooler operating temperatures create substantial savings in energy costs. Third generation EL ballasts contain integrated chips thereby reducing the number of components in the ballast and providing a variable light output feature. The latest development in fluorescent lighting is the compact ballast lamps (CF) designed to screw into a standard threaded incandescent fixture. These CFs are available in wattage ratings ranging from 7 to 22 and contain a simple reactor ballast with a preheat circuit design. Current is passed through the electrodes for a few seconds to heat them before voltage is applied to the tube so there is a very slight warm-up cycle before full illumination is reached.

Exterior Lighting

Exterior lighting can provide dramatic highlights to building and grounds, lighting for security or public safety concerns. High-intensity discharge lamps using sealed gases and electrodes are favorite choices for exterior lighting because they have a relatively long life and they produce intense light patterns when the proper lenses are fitted to the fixtures. The four most popular HID lamps are as follows:

Mercury—Contains a third electrode used to ionize argon gas, which raises the temperature and pressure in the tube, vaporizing the mercury.
Metal halide—Contains a halide such as sodium, thallium or indium, which produce twice the lumens per watt than a mercury vapor lamp does.
High-pressure sodium—Produces light by passing an arc through a combination of sodium, mercury and xenon. These types of lamps are much more energy efficient than mercury or metal halide.
Low-pressure sodium—Produces light by passing an electric charge through sodium vapor. These lamps require from 7 minutes to 15 minutes to reach full illumination.

EQUIPMENT HOOK-UPS

Electrical connections to elevators, HVAC equipment, pumps, kitchen and data processing and telecommunications equipment can create new demands on the building's electrical system. "Dirty" power for some equipment versus "clean" power for others is becoming an issue, and blackouts, brownouts and voltage surges and sags must be considered when electrical designs are being formulated.

"Dirty" power, power as it comes through the primary and secondary feeder, entering and leaving the switchgear is compatible with all but the most sensitive data processing equipment, however, many pieces of heating, cooling and ancillary machinery will require motor starters in order to function properly.

Motors and Motor Starters

HVAC, elevator machinery components and various types of other equipment, including pumps, may be furnished with motors containing integral starters, but many such specialty motors require an external starter that energizes the motor and provides motor protection. The responsibility for furnishing starters is often not defined in the contract specifications. Many times Division 15—the mechanical specifications does not stipulate that all equipment furnished by that subcontractor shall be provided with starters, and Division 16—the electrical specifications do not require the electrical subcontractor to furnish all starters or to furnish those not supplied by the mechanical subcontractor. The best time to review and resolve all starter requirements is prior to the issuance of a contract to either electrical or mechanical subcontractor. Each subcontractor's responsibilities in that respect must be made crystal clear.

When a motor is a full-voltage across-the-line starting motor, the motor starter will function as a device to connect the motor to the line voltage. There are reduced-voltage motor starters, which will reduce voltage temporarily upon starting and increase the voltage to the motor as it approaches full speed. Starters also provide overload protection to the motor, and when large motors, those larger than 1 or 2 horsepower are being wired, reduced-voltage starters, either magnetic or manual are frequently installed.

A star-delta starter is used on motors that drive high inertia loads with long acceleration times such as those on air-conditioning equipment. Autotransformer starters accept line voltage and the taps on their transformers permit adjustment of the motor's requirements because of starting torque and inrush. These starters provide more starting torque per ampere drawn than any other type of reduced-voltage starter and therefore they are the most popular type. Part-winding starters are effectively used on dual-voltage motors. The first half-winding of the starter will allow acceleration of the load so as not to create a secondary inrush when the second half-winding comes into play, and the full load on both windings normally takes place in less than one second.

Clean Power

Most sophisticated computer installations today require a power source unaffected by external voltage fluctuations and internal disturbances to their electrical fields. Dedicated circuits, circuits that contain no other terminations for equipment other than the electronic equipment, are standard installations. The problems encountered with normal line voltage, even with dedicated circuits, include:

Spikes—High-magnitude split second events that create high-voltage impulses.
Surges—Overvoltages that last longer than one cycle (1/60 of a second).
Sags—The opposite of surges. Multicycle undervoltage conditions.
Noise—High-frequency impulses that ride the normal sine-wave and range in intensity from a millivolt to several volts. Radio frequencies can cause "noise."
Brownouts—Long-term undervoltages, lasting several minutes or longer.
Blackouts—Extended periods of zero-voltage.
Harmonic distortion—Distortions in the normal sine-wave transmitted back into the AC line by other computers, FAX machines, copiers or other devices tied into the AC line.

There are three devices that can be installed to combat each of these conditions:

- A UPS (uninterruptible power system) to protect against blackouts, brownouts and miscellaneous line disturbances with the addition of other devices.

- A line conditioner, containing a ferroresonant transformer to assist in controlling minor brownouts, spikes, surges, sags and noises.
- A plug-in surge suppressor for individual pieces of electronic equipment to control spikes and noises.

Sensitive computer equipment must be isolated not only from slight variations in voltage, but also their power requirements and their support cooling equipment must function without interruption. The UPS, with its lead–acid storage batteries installed between the utility feed and the critical load, assures a full charge until needed. For extended periods of downtime, however, the UPS must be tied into an emergency generator so that it can be regenerated.

Emergency Generators

Diesel, gasoline, propane or natural-gas fired emergency generators are becoming more and more commonplace these days. Many building departments are mandating that emergency generators be installed to meet life-safety requirements in multistoried structures. Hospital and health-care facilities have used emergency generator systems for years to provide back-up for their life-support systems.

Most emergency generators are wired so that they automatically start up when a power failure occurs, and it is not uncommon to include automatic monthly start-up feature to ensure that the equipment is in proper functioning order. Emergency generators, depending upon their size, may have elaborate cooling requirements while operational, while smaller units in the 100kW to 200kW range only need access to an unobstructed outside air source for its radiator to cool the engine properly. These emergency generators come equipped with a 24-volt battery-powered starting motor system and a battery recharger with alternator and voltage regulator. When diesel or gasoline is the fuel source, it is customary to fit the generator with a "Day" tank capable of supplying fuel to the generator for three to five hours. In some installations additional fuel storage may be required for extended running time.

An integral part of the emergency generator system is the transfer switch that automatically transfers the electrical current produced by the generator into the building's emergency circuit when the normal source of power has been temporarily interrupted. Figure 25-6 displays the sequence of operations of a transfer switch as it shifts electrical distribution from line voltage to emergency power circuitry.

FIRE ALARM SYSTEMS

Early detection of fire or smoke is the responsibility of the building's fire alarm system. A basic fire alarm system will contain the following components:

A main control unit,
Detectors,
Standard manual stations,
Duct detectors,
Various lights and horns to alert building occupants of detection, and
A communication link with the local fire or police department, and possibly a 24-hour guard service.

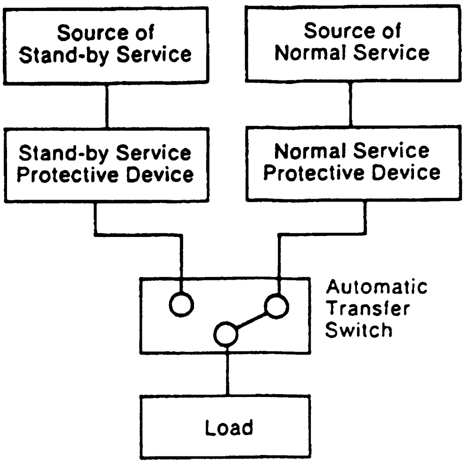


Figure 25-6 Schematic of Transfer Switch Operation from Normal to Emergency Circuit Power.

The main control panel contains the central processing system and ties all of the components into an integrated signal-receiving and action-disseminating center. The control panel receives status changes from the various smoke and fire detectors installed throughout the building and processes the data based on preprogrammed instructions. It may activate magnetic hold-open devices on fire doors causing them to close, signal the presence of fire or smoke in the building, shut down all air-handling equipment, bring the elevators down to the first floor and activate various fire-suppression systems including Halon, sprinklers and carbon dioxide systems. Main or central control panels may contain a visible schematic drawing of the building or buildings indicating in which section fire or smoke has been detected.

Detectors

Smoke detectors can be of the ionization or photoelectric type. Ionization detectors operate on the basis that smoke particles interrupt the flow of ionized air molecules that move between the electrodes within the detector. When this flow is broken, the detector will go on alarm. Photoelectric smoke detectors emit a beam of light via a light-emitting diode. When smoke occurs, the detector senses a reduced transmission of light beam thereby setting off an alarm.

Heat detectors respond to changes in temperature and rely on thermal sensors to detect predetermined temperatures in the air that indicate the presence of a fire. Some heat detectors are know as "rate of rise," ROR detectors, and they become activated when air temperature increases 15 degrees to 20 degrees in a minute or less.

Fire and flame detectors use infrared or ultraviolet light sensors to detect fire, and although they may be the fastest acting detector, the infrared sensor may be activated by the sun's radiation if it has not been properly placed and shielded.

Duct detectors placed within supply or return-air distribution ducts will be triggered by the presence of smoke, and by reporting back through the central control panel, cause the building's air-supply system to shut down and prevent the spread of smoke and fire.

Manual-pull stations represent another form of "detection" device, but they depend on human input for activation. Spotted around the building, these devices allow a building occupant to report the presence of fire or smoke that might not be apparent to any of the automatic detectors. By breaking a glass panel and pulling a bar or lifting an alarm toggle switch, the control panel will activate the system.

Various types of horns and strobe lights will be placed through the building so that occupants can be made aware of an emergency. If there is a separate Halon system in a computer room, it is important that a horn signalling a fire in the data processing area sounds differently than the horns installed for the central system. Communication of the alarm must be made with not only building occupants via flashing lights, horns, and even prerecorded audio instruction, but also the system must be tied into some off-site central reporting station. Local fire departments and police departments offer these services in most areas, and quite often an owner will install a speed-dialer type telephone, which upon activation by the control panel, dials a 24-hour manned station and delivers an audio tape fire-alert message.

26

Automated Building Control Systems

First came the thermostat, and then came the thermostat connected to a clock that could turn heating and air-conditioning systems on and off at predesignated times during the day and night. Microelectronic control of multiple systems within today's modern buildings can perform tasks that would have required a crew of maintenance men directed by a mathematician and a physicist just a few years back.

The term "Smart" or "Intelligent" building can be applied to those buildings that possess EMS and ABC—energy management systems and automated building controls.

EMS—Building energy management systems are concerned with achieving the maximum efficiency with respect to energy consumed. Electrical consumption and efficient utilization of heating/cooling plants will be the responsibility of the EMS installation.

ABC—Sometimes refered to as Building Management System (BMS), is concerned with other building functions such as monitoring of life-safety features, including the fire alarm, the building's security system and even measuring the amount of moisture in the soil to determine when and how long the lawn irrigation system should operate.

THE ENERGY MANAGEMENT SYSTEM

An EMS consists of a program or set of instructions electronically conveyed to a computer indicating what functions are to be performed with respect to the building's electrical, heating and cooling systems. The CPU or central processing unit receives and stores these instructions, which will be passed along through some form of electronic circuitry to the various pieces of equipment to be controlled.

Input—output modules attached to the equipment to be controlled will receive instructions from the CPU and will respond by directing some externally mounted device to carry out these instructions. These systems need a clock to determine when activation should begin and when systems need to be shut down.

The CPU

During the 1970s and 1980s, most EMSs relied on a CPU, the computer, that was programmed with custom-made software to direct every device tied into the system. The CPU acted as the brain and communicated and gave directions and instruction to "dumb" field panels, which provided input to the device or devices they were to control. The control network originated and terminated at the CPU where an operator maintained control and supervised the system.

Today's EMSs use "stand-alone" panels with much more frequency. These self-sustaining units contain their own microprocessors, thereby shifting control from the central CPU to each individual stand-alone panel. A malfunction in the CPU or in one stand-alone panel will have absolutely no affect on the rest of the system.

The Direct Digital Control—DDC

Microprocessor field panels are known as DDCs and they earn their name by being directly in control of the equipment by means of digital electronics. They can control one loop or several loops within the system while remaining an integral part of the overall EMS. The link-up between the DDC and the device exerting control over the equipment can be performed pneumatically or by analog output signals, a fancy term for electrical pulses, generally low voltage. These analog signals operate in the 4–20 milliAmp range, while pneumatic signals require a compressed air supply of 3–15 psig. Pneumatic signals will require a transducer to convert digital electrical input impulses to pneumatic output.

ELECTRONIC CONTROL TERMINOLOGY

Just like every other component of construction, microprocessing equipment, systems and parts have a language all their own so a glossary of computer terms might come in handy right about now:

Analog—A numeric value.

Baud—A unit of signal speed. The speed in baud relates to the number of events per second and if each event equals one "bit," a baud rate equates to bits per second (bps).

Binary—A condition where one or two states will occur—either "On" or "Off."

Bit—Short for binary digit, the smallest unit of information that can be represented.

Byte—Consists of 8 bits and is the amount of storage space necessary to hold one alphanumeric character.

CALI Language—Custom application language: programming language used by the design engineer.

Control point—A software point linking hardware input to hardware output.

Disk, or floppy disk—A 5 1/4-inch plastic disk that stores information and is flexible to the touch.

Diskette—A 3 1/2-inch disk actually in the form of a square performing the same function as the floppy disk but rigid to the touch.

DOS—Disk operating system.

Electric to pressure tranducer—Used to convert an electrical input signal to a change in pressure output.
Field processing unit (FPU)—Interface between relays, transducers, elements and the communication network. The FPU monitors and controls the field equipment when commanded by the CPU.
Hard disk—The drive with data storage capability permanently mounted inside the computer. (Floppy disks, generally containing back-up information, are inserted into the computer and then removed.)
Hardware point—The point where sensors, relays, and other controlled devices are connected to the filed termination board.
LAN—Local area network. A data communications system limited to a confined geographic area.
MHz—Symbol for megahertz, the computer's clock rate.
Normally closed—A controlled device such as a valve or damper that returns to a closed position when the control signal is removed.
Normally open—The controlled device returns to its open position when the signal is removed.
Pressure to electric transducer—Converts a pressure input to an electrical output.
RAM—Random access memory. The temporary storage capacity of the computer. The contents of this RAM is emptied when the computer is turned off.
ROM—Read only memory. Information that is in the computer when purchased. ROM contains the instructions the computer needs to load software and communicates with all of the other pieces of hardware in the system. CD-ROM discs are read only memory disks that look very much like a regular CD. Volumes of books can be stored on just one CD-ROM. Retrieval requires a separate piece of hardware connected to the computer.
Shielded cable—A conductor encased in a metallic sheath to prevent electrostatic or electromagnetic interference between the enclosed wires and external fields.

Energy management systems rely on input and output devices for building control. Sensors that can detect temperature and humidity will relay information back to the stand-alone panel, which can then direct a valve opening or closing, or modulating somewhere in between fully open or fully closed. Depending on the temperature or humidity signals received, duct dampers may be actuated or valves controlling chilled water or hot water opened or closed. When these same sensors report that the predesignated temperatures have been attained, the stand-alone panel will direct other valve or damper openings or closings.

An EMS generally monitors and controls the following functions:

- Indoor and outdoor temperatures to maintain HVAC systems in the most energy efficient manner during normal working hours by interfacing with an outside air-temperature sensor (OA), an air-handling return-air sensor (RA) and a variable speed drive (VSD) for the fan motor.
- Turns off all nonessential lighting (the second highest heat contributor—people are first).

- Unloads compressors and stops supply fans when this equipment is no longer required to operate.
- Resets indoor temperatures downward at predesignated night set-back times.
- Closes any open dampers and stops any running exhaust fans at night set-back time, or at other times as required.
- Delays start-up of morning warm-up cycle until the last minute.
- Keeps heat–cooling at minimum temperatures during normal business closings such as weekends and holidays, and provides for overide mechanism for people chosing to work during those times.
- Duty cycling for certain selected loads such as domestic water heaters, ice makers, indoor or outdoor fountains.
- Diagnostic and alarm functions to alert supervisors when a system is in failure or has failed and advising the supervisor of the reason for failure (for example, burned out circulating pump, damper hung up, compressor failure).

ELECTRONIC CONTROL TECHNOLOGY

Typical applications in the jargon of the control system installer are (in alphabetical order not order or precedence):

Automatic building restart—A restart of equipment after a power failure. This can be a static restart whereby the same equipment running before the failure will restart, or the building can be returned to an operational state as required when the power was restored not when it failed.

Cooling mode purge cycle—Relatively cool outside air for cool-down purposes will be used before the building is fully occupied during the cooling season. Much like an "Economizer" cycle, only the building's supply and return fans will be consuming energy during this period of time.

Duty cycling—Selected equipment is turned off for short periods of time. When several pieces of equipment are providing heating–cooling, the computer may stagger on–off times when in this mode.

Enthalpy optimization—Enthalpy is a term that means total heat content of the air. In conventional HVAC systems control, the volume of outside drawn in is governed by dry bulb temperature. However moisture in the outside air also has an affect on its temperature. With enthalpy optimization, both dry and wet bulb readings are fed into the computer to determine if 100 percent outside air should be taken in or more use should be made of return air.

Load shedding—As electric demands approach the peak point, various pieces of nonessential equipment will be automatically shut down to prevent total building load from attaining peak levels.

Peak-demand limiting—Many utility companies base their rates to commercial users on actual consumption and demand. When the building's peak demand remains at that level for 15 minutes or longer, this peak demand then becomes the basis for determining future energy costs for the company. Working in conjunction with load shedding, the concept behind this function is to predict when peak demand will occur so that load shedding can be instituted automatically.

Start–stop time optimization—Buildings do not normally become fully occupied at one time nor does all of the office equipment in that building become operational at the same time. Some equipment or departments may shut down their operations earlier than others and programmed start–stop times for various pieces of equipment can have significant affect's on energy costs.

BAS—BUILDING AUTOMATION SYSTEMS

Added to all of the functions being performed by the EMS, building managers often require monitoring and control over other critical building functions. Fire detection systems rank on top of the list and it is a rare BAS that does not include monitoring and coordinating over the functions incorporated into the building's fire alarm and fire-suppression systems.

Building security has assumed a higher priority than ever before. Monitoring exterior means of egress will allow the BAS to lock all exterior doors after normal working hours, providing some comfort level to those people working late. Exterior lighting, which may be controlled by time clocks, may need to be folded into the BAS to ensure that power outages and changes from Eastern Standard Time to Daylight Savings Time are taken into account. And it may certainly not be necessary to energize all of those exterior lights on weekends or during holidays. Controlled access to underground parking facilities and control of access to stairs and elevators leading to and from these remote locations will provide early arrivers and late departers a sense of security, as will a centrally controlled TV surveillance system backed up by an automatic videotape machine. Card access to restricted areas within the building or to the building itself is another important function fulfilled by the BAS.

Building automation systems are often used to gather information for facilities management purposes. Useful data can be culled from knowing how and when energy costs accrue, when peak electric, heating and cooling loads occur, when the majority of building occupants arrive and leave, whether the banks of elevators are sufficient for peak loads or whether they, and other equipment, are being underutilized.

Energy management systems and BMS cannot only be monitored and controlled from within the building, but with the addition of a modulator-demodulator, more commonly known as a modem, digital signals can also be transformed into a modulated or analog signal suitable for transmission by a touch-tone telephone. Energy Management System and BAS can now be controlled by facilities managers from any part of the world. And in the construction industry CONTROL IS EVERYTHING!

Appendix A

Industry Trade Group and Related Associations List

Site Work

Association of Engineering Firms Practicing in the Geosciences
8811 Colesville Road, Silver Spring, Maryland
Tel: (301) 565-2733

Concrete

American Concrete Institute (ACI)
P.O. Box 19150, 22400 W. Seven Mile Road, Detroit, MI 48219-0150
Tel: (313) 532-2600

Portland Cement Association
5420 Old Orchard Road, Skokie, IL 60077
Tel: (708) 966-6200

Wire Reinforcement Institute
1101 Connecticut Ave., N.W., Suite 700, Washington, D.C. 20036-4303
Tel: (202) 429-5125

Concrete Reinforcing Steel Institute
933 North Plum Grove Rd., Schaumberg, IL 60173
Tel: (708) 517-1200

National Precast Concrete Association
825 E. 64th Street, Indianapolis, IN 46220
Tel: (317) 253-0486

Precast/Prestressed Concrete Institute
175 W. Jackson Blvd. Suite 1859
Chicago, IL 60604
Tel: (312) 786-0300

Tilt-up Concrete Association
2431 W. Cummings Wood Lane, Hendersonville, NC 28739
Tel: (704) 891-9578

Masonry

International Masonry Institute
823 15th Street, N.W., Washington, D.C. 20005
Tel: (202) 783-3908

Masonry Institute of America
2550 Beverly Blvd., Los Angeles, CA 90057
Tel: (213) 388-0472

Brick Institute of America
11490 Commerce Park Drive, Reston, VA 22091
Tel: (703) 620-0010

Building Stone Institute
P.O. Box 5047, White Plains, NY 10602-5047
Tel: (914) 232-5725

Cast Stone Institute
Pavilions at Greentree, Suite 408, State Highway 70, Marlton, NJ 08053
Tel: (609) 858-0271

Indiana Limestone Institute of America
Stone City Bank Bldg., Suite 400, Bedford, IN 47421
Tel: (812) 275-4426

Italian Marble Center
Italian Trade Commission, 499 Park Ave., New York, NY 10022
Tel: (212) 980-1500

Marble Institute of America
33505 State St., Farmington, MI 48335
Tel: (313) 476-5558

Metals

Aluminum Association
900 19th Street, N.W. Suite 300, Washington, D.C. 20006
Tel: (202) 862-5100

American Institute of Steel Construction
1 E. Wacker Drive, Suite 3100, Chicago, IL 60601-2001
Tel: (312) 670-2400

American Iron and Steel Institute
1133 15th Street, N.W., Washington, D.C. 20005
Tel: (202) 452-7100

Copper Development Association
Greenwich Office Park 2, Greenwich, CT 06836
Tel: (203) 625-8210

Metal Lath/Steel Framing Association
600 S. Federal St., Suite 400, Chicago, IL 60605
Tel: (312) 922-6222

National Association of Architectural Metal Manufacturers
600 S. Federal St., Suite 400, Chicago, IL 60605
Tel: (312) 922-6222

Steel Structures Painting Council
4400 5th Avenue, Pittsburg, PA 15213-2683
Tel: (412) 268-3327

Steel Joist Institute
1205 48th Avenue, N., Suite A, Myrtle Beach, SC 29577
Tel: (803) 449-0487

Steel Deck Institute
P.O. Box 9506, Canton, Ohio 44711
Tel: (216) 493-7886

Wood and Plastics

Southern Forest Products Association
P.O. Box 52468, New Orleans, LA 70152
Tel: (504) 443-4464

Western Wood Products Association
Yeon Building, 522 S.W. 5th Ave., Portland, OR 97204
Tel: (503) 224-3930

American Institute of Timber Construction
11818 SE Mill Plain Blvd., Suite 415, Vancouver, WA 98684-5092
Tel: (206) 254-9132

American Plywood Association
P.O.Box 11700, Tacoma, WA 98411
Tel: (206) 565-6600

Architectural Woodwork Institute
2310 S. Walter Reed Dr., P.O. Box 1550, Centerville, VA 22020
Tel: (703) 222-1100

National Particleboard Association
18928 Premiere Ct., Gaithersburg, MD 20879
Tel: (301) 670-0604

American Wood Preservers Association
P.O.Box 849, Stevensville, MD 21666
Tel: (301) 643-4163

American Wood Preservers Bureau
P.O.Box 5283, Springfield, VA 22150
Tel: (703) 339-6660

Cultured Marble Institute
435 N. Michigan Ave., Suite 1717, Chicago, IL 60611
Tel: (312) 644-0828

Decorative Laminate Products Association
600 S. Federal St., Suite 400, Chicago, IL 60605
Tel: (312) 922-6222

Thermal and Moisture Protection

Institute of Roofing and Waterproofing Consultants
4242 Kirchoff Rd., Rolling Meadows. IL 60008
Tel: (708) 991-9292

Sealant, Waterproofing and Restoration Institute
3101 Broadway, Suite 585, Kansas City, MO 64111
Tel: (816) 561-8230

Mineral Insulation Manufacturers Association
1420 King St., Suite 410, Alexandria, VA 22314
Tel: (703) 684-0084

Perlite Institute
88 New Dorp Plaza, Staten Island, N.Y. 10306-2994
Tel: (718) 351-5723

Polyisocyanurate Insulation Manufacturers Association
1001 Pennsylvania Ave. N.W., Washington, D.C. 20004
Tel: (202) 624-2709

Exterior Insulation Manufacturers Association
2759 State Road 580, Suite 112, Clearwater, FL 34621
Tel: (813) 726-6477

Asphalt Roofing Manufacturers Association
6288 Montrose Rd., Rockville, MD 20852
Tel: (301) 231-9050

Cedar Shake and Shingle Bureau
515 116th Ave., NE, Suite 275, Bellevue, WA 98004
Tel: (206) 453-1323

Single Ply Roofing Institute
104 Wilmot Rd., Suite 201, Deerfield, IL 60015
Tel: (708) 940-8800

Doors and Windows

American Architectural Manufacturers Association
1540 E. Dundee Rd., Suite 310, Palatine, IL 60067
Tel: (708) 202-1350

National Wood Window and Door Association
1400 E. Touhy Ave., Des Plaines, IL 60018
Tel: (708) 299-5200

Vinyl Window and Door Institute
355 Lexington Ave., New York, N.Y. 10017
Tel: (212) 351-5400

Steel Window Institute
1230 Keith Bldg., 1621 Euclid St., Cleveland, Ohio 44115
Tel: (216) 241-7333

Door and Hardware Institute
7711 Old Springhouse Rd., McLean, VA 22102
Tel: (703) 556-3990

National Glass Association
8200 Greensboro Drive, Suite 302, McLean, VA 22102
Tel: (703) 442-4890

Finishes

International Institute of Lath and Plaster
820 Transfer Rd., St. Paul, MN 55111
Tel: (612) 645-0208

Gypsum Association
810 1st St., NE, Suite 510, Washington, D.C. 20002
Tel: (202) 289-5440

Ceramic Tile Institute
700 North Virgil Ave., Los Angeles, CA 90029
Tel: (213) 660-1911

Tile Council of America
P.O. Box 326, Princeton, N.J. 08542
Tel: (609) 921-7050

National Terrazo and Mosaic Association
3166 Des Plaines Ave., Suite 132, Des Plaines, IL 60018
Tel: (708) 635-7744

Acoustical Society of America
500 Sunnyside Blvd. Woodbury, N.Y. 11797
Tel: (516) 349-7800

Ceilings and Interior Systems Construction Association
104 Wilmot Rd., Suite 201, Deerfield, IL 60015
Tel: (708) 940-8800

National Wood Flooring Association
11046 Manchester Rd., St. Louis, MO 63122
Tel: (800) 422-4556

Resilient Floor Covering Institute
966 Hungerford Dr., Suite 12B, Rockville, MD 20850
Tel: (301) 340-8580

National Paint and Coatings Association
1500 Rhode Island Ave. NW, Washington, D.C. 20005
Tel: (202) 462-6272

Wallcovering Manufacturers Association and Wallcovering Information Bureau
355 Lexington Ave., New York, NY 10017
Tel: (212) 661-4261

Mechanical

Plumbing Manufacturers Institute
800 Roosevelt Rd., Bldg C, Suite 20, Glen Ellyn IL 60137
Tel: (708) 858-9172

Air Diffusion Council
111 E. Wacker Drive, Suite 200, Chicago, IL 60601
Tel: (312) 616-0800

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
1791 Tullie Circle, NE, Atlanta, GA 30329
Tel: (404) 636-8400

Cooling Tower Institute
P.O. Box 73373, Houston, TX 77272
Tel: (713) 583-4087

Air Movement and Control Association
30 W. University Dr., Arlington Heights, IL 60004
Tel: (703) 394-0150

Electrical

Lighting Research Center
Rennselaer Polytechnic Institute, Greene Bldg, #115, Troy., N.Y. 12180-3590
Tel: (518) 276-8716

Edison Electric Institute
701 Pennsylvania Ave. NW, Washington, D.C. 20004
Tel: (202) 508-5000

Index