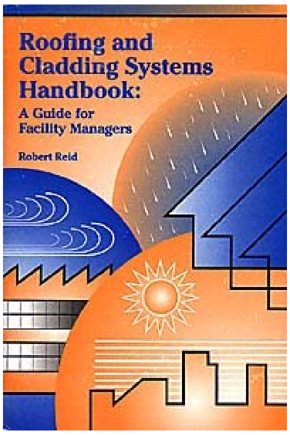
Roofing and
Cladding Systems
Handbook:
A Guide for
Facility Managers
Robert Reid

Roofing & Cladding Systems

A Guide for Facility Managers

By Robert N. Reid

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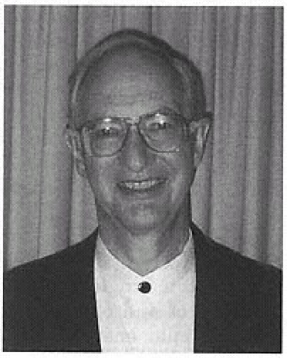
For Katherine, Dierdre, Samuel, Nathanael and Rebecca Reid. May they live, work and play in houses that are warm, safe and dry.

The Advisors



Richard L. Fricklas is an author, journalist and educator. He recently retired as Technical Director of the Roofing Industry Educational Institute, a position he held since 1979. Prior to that, Dick was the director of BURSI, also an educational forum on roofing technology. He is a graduate chemist, holding a Bachelor of Arts degree from Hofstra University and a Master of Science degree in physical chemistry from Rutgers University.

Dick is co-author of *The Manual of Low Slope Roof Systems*, published by McGraw Hill (1996), and is a contributing editor for The Roofing Specifier and Roofing Specifications Institute magazines.

Mr. Fricklas has received the James Q. McCawley award from the Midwest Roofing Contractor's Association and the Walter C. Voss Award from the American Society of Testing and Materials for his contributions to education in the construction industry. He holds honorary memberships in The Roof Consultants Institute and the Institute of Roofing and Waterproofing Consultants.

Dr. Heshmat O. Laaly is an internationally acclaimed Certified Professional Roofing Consultant and analytical chemist recognized as a world expert in the fields of plastics, rubbers, and roofing and waterproofing materials. He has authored and presented technical papers to roofing professionals in both the United States and Canada and has made presentations at international conferences worldwide as an invited speaker. Holding a Ph.D. in Chemistry from the University of Stuttgart in West Germany, Dr. Laaly has worked as an Associate Research Officer at the National Research Council of Canada Division of Building Research for 13 years. Presently Dr. Laaly is a Certified Professional Roofing Consultant in Los Angeles, California where he has consulted for the past 14 years. He is the author of *The Science and Technology of Traditional and Modern Roofing Systems* (published by Laaly Scientific Publishing of Los Angeles, California) which combines over 30 years of research and experience into two huge volumes known internationally as the **Roofing Bible.** He is also the inventor and patent holder of a photovoltaic single-ply roofing membrane which combines the qualities of and effective waterproof roofing membrane with an efficient solar energy collecting system.

*For additional information Dr. Laaly can be reached by telephone or faxed at: (310) 559-6090.

Contents

Preface

Roofing and Cladding Systems: A Guide for Facility Managers is designed for the facility manager wanting the very latest information on roofing systems and building envelope technology. For facility managers who face a critical repair/replace/tear off and recover decision, this book provides the manager with the tools and information needed to make the decision quickly and in the best interest of the facility.

Roofing systems continue to change rapidly and a roofing system decision made as little as 5 years ago, can be obsolete in today's new market. Changes in single ply materials, in design and acceptability standards, in understanding of wind and corrosion theories have revised the materials and the methods for modern roofing. In addition to new and improved roofing methods, materials and standards, the cladding of building shells has seen dynamic changes. New Exterior Insulated Finish Systems (EIFS) are extremely competitive with more traditional cladding materials. In addition, better understanding of adhesives and thermal expansion and contraction play an important role in decisions of building cladding and sidings.

This book shows facility managers how to conduct system assessments and how make essential decisions on where, when and how to get the most out of the roofing system at the minimum cost.

Since the roof is one of the most essential parts of the facility, if it leaks, not only is the structural integrity of the building at risk, but the people and products contained within the facility are at risk as well. By providing a building envelope that protects what is inside from the elements outside, the facility manager reduces liability risk, lowers insurance costs and may reduce overall costs to the facility.

Roofing and Cladding Systems: A Guide for Facility Managers has been designed to give the facility manager the tools needed for management of this portion of the building system. The book has been specifically designed for today's busy facility manager. It seeks to simplify a manager's role by breaking building envelope technologies into a logical, manageable tasks. The book starts with an assessment of an existing roofing system and proceeds logically through the series in a purposeful directed action.

Steps include assessment, data surveys to determine conditions, wind and weather elements and how they relate to the facility envelope decisions, types of roofing systems and how they interface with other components, cladding and how both cladding and roofing work together as one system to protect the contents from the elements.

Not only does this text inform the facility manager about the physical elements of the building, and it's weather protection, but the book also informs decision makers about people who can provide the best information to the manager. What materials are on the market and how to operate a facility while it is being re-roofed are discussed. Data on warranties and service life of the various systems are provided.

The book provides the latest information on energy and insulation systems and shows how energy use is calculated. Tips are provided to analyze the cost effectiveness or adding insulation when reroofing and how the government will assist a facility when reroofing by providing tax incentives to decrease energy consumption. The handbook tells how to get the most from the roofing maintenance budget. Information needed to protect the facility from costly lawsuits stemming from failure of the roofing membrane or from unsafe worker or contractor actions are also provided to help the facility manager minimize facility risk.

Vapor barrier and dew point humidity is discussed from a practical standpoint including guidance in estimating these critical points in a building's envelope.

The book provides a number of case histories to illustrate specific examples of the results of facility decisions. Where beneficial, forms have been included to help make the facility manager's job easier. Tables, charts, and photographs are included to explain and clarify the text.

Finally, this roofing and cladding systems guide provides the facility manager's staff with needed information to schedule and plan a major reroofing project and information needed to establish a preventive maintenance program to protect the facility investment. For the student of facility management, it is an excellent guide into the facility management process.

Introduction

New Trends

Recent facility surveys indicate that one of the most rapidly changing technologies in the buildings and management industry is in the building envelope. Advances in understanding scientific properties of thermal and moisture barriers continues to cause a technological revolution in development of new types of building envelope (roof and wall) systems. In addition, these same advances continue to refine some of the old systems by incorporating new science. Since new materials have been accepted by the real property loan industry and by insurance agencies, modern facility managers are now *deluged* with myriad decisions about roofing, cladding, and building envelope questions never before faced by so many managers on such a grand scale.

Roofing and Cladding Systems: A Guide for Facility Managers is created specifically for facility managers. It presents, in non-technical terms, what a manager needs to know to be able to make the correct decisions to enhance the facilities' value. By breaking down the science of roofing and cladding systems into components, this handbook takes the guesswork out of the roofing system equation. The handbook speaks to all of the new materials and systems in a rapidly changing market.

Discussion of building moisture protection systems like modified bitumen, single ply roofing and sprayed polyurethane foam have found their way into the corporate board rooms. Not only does the facility manager have to make the right decision quickly, but he or she must be knowledgeable about the other systems on the market to be able to defend the decision.

Surveys indicate there are over 1200 separate roofing systems currently on the market, and that roofing is a $19 Billion dollar industry in the United States alone.

A Huge Choice of Systems and Types

In a 1996 survey of roofing contractor's, the National Roofing Contractor's Association reported that roughly 1/2 of all roofing projects involved reroofing of low sloped roofs. This means that commercial and industrial facilities account for nearly half of all the roofing projects in the country.

Almost 8% of the cost of the facility is tied up in the roofing system and the entire value of the contents of the building are at risk if the roofing decision is a bad one. Roofing and reroofing decisions affect every facility manager at one time or another. In fact, the roofing industry business continues to grow at 13% per year, a rate above the growth rate of facilities. Hurricanes in the southeast, and extreme cold winters in the northeast and midwest have taken a toll on roofs, causing membrane and insulation failures, and in some heavy snow or high wind areas, the entire structure fails ruining the building and its contents. Such events are often widely reported on the news. Roofing, reroofing, and building envelope modifications will be one of the decades' top priorities for facility managers.

Depending upon facility size, contents, age, condition, weather, and local roofing contractors; the facility manager decides how to manage this component of his building system. In addition, real estate professionals report that one of the highest user problems leading to occupant turnover is a leaky roofing system.

Not only is the roofing decision costly, it affects ongoing operations at the facility as well. Fire, safety, insurance, and space planning are all affected when reroofing. Recent trends in hazardous waste management can also affect the facility manager's roofing decision.

Roofing and Cladding Systems: A Guide for Facility Managers leads the facility manager step by step through the process of maintaining and upgrading the facility's exterior. Beginning with weather conditions and how they vary throughout the country, exterior systems are chosen for service and economy. Facility manager's choose among various types of roofing systems, shapes and materials. This book provides the FM with the information he or she needs to make sure a designer makes the correct recommendations for the facility.

Life Cycle Costs

Further into the process, the facility manager is concerned about the cost of removal of old roofing systems. This book explains how disposal costs can become a significant factor in replacing a roofing system. Other environmental factors relative to roofing and reroofing are also discussed.

Cladding

Cladding and wall systems are included. While non-technical, the book addresses masonry, glass, wood, metal siding and sheathing. The book includes extensive discussion of the new Exterior Insulated Finish Systems, called EIFS by the industry. What EIFS do and their advantages reveal why this new cladding system is becoming so popular. Names of the industry associations are provided for this fastest growing area of building envelope construction.

Structure. The handbook provides general information on building structure, to show facility manager's when to bring in a structural engineering consultant. In older buildings, a roofing failure sometimes leads to structural failure, something to be avoided at all costs because of the liability both to occupants and building contents. The handbook's discussion of structure is geared toward the interface between roofing and cladding systems and the main structure, explaining how and why some roofing types won't work with some structure types. For many facilities incompatibility between the roofing or cladding system and the structural frame limits facility remodeling options. It can even affect the overall life of the structure.

Energy Consideration. Since so many of the roofing systems include energy insulation, the handbook extensively covers insulating systems. The material explains how the roofing membrane and the thermal insulation work together to curb rising energy costs. In addition, many re-roofed facilities experience problems with moisture condensation on the inside walls, ducts or plenums. This handbook explains this problem and tells how to eliminate it. Energy costs and tradeoffs for increasing thermal insulation are shown, along with methods to determine life cycle insulation costs. Case studies are provided as examples of how facilities successfully achieved energy retrofits and reroofing projects at one time.

Fasteners

Since some roofing system failures are a result of failures of the fasteners, the book discusses fastening and membrane attachment methods. It shows what facilities can do the minimize fastener problems.

Membranes

The handbook addresses primarily low slope roofing systems since these are the ones with problems most often faced by facility managers. Each of the types of waterproofing membranes is presented along with the latest trends for each type of system. Discussion includes single ply roofing which has steadily gained favor in the low slope industry over built up roofing. The handbook covers bituminous built-up, modified bitumen, plastic and elastomeric membranes and sprayed polyurethane foam. There is an extended discussion of metal roofs often used in metal buildings but now also used for other types of construction. The interface between metal roofs and insulation is discussed.

Since many roofing system problems are the result of punctures or tears in the system that result from roof penetrations like HVAC units, plumbing, electrical conduits, antennas and so on, a complete chapter is dedicated to roofing projections and methods to prevent them from leaking.

Project Management

Next, a chapter is dedicated to reroofing project management. Beginning with initial surveys and following through design drawings and specifications, the chapter leads the facility manager through the bidding, and contract management process. The discussion includes information on what to do with the building's contents and the people who have to work inside while the roofing is being torn off and replaced. This discussion should prove beneficial to the facility manager since many roofing texts do not go into the details of how to manage a roofing or reroofing project

Maintenance and Warranty

A complete chapter is dedicated to maintenance and warranties of roofing and cladding. Tables provide guides for life cycle costing and for roofing estimates based upon material and labor costs. The discussion also addresses roofing safety and provides steps to protect the facility from liability. Several sample wavier forms are included.

An appendix provides a comprehensive reference to roofing industry trade associations. This can help the facility obtain additional data for field or consultant assistance. A glossary is provided to help the facility manager better understand some of the roofing terms and conditions while dealing with architects, engineers, roofing consultants, contractors and vendors.

Since it is imperative to have a leak proof roof, understanding of how vicious and aggressive nature's elements are that attack the roofing system starts on the next page.

Chapter 1— Weather Effects on Roofing Systems

Introduction

Imagine for a moment, that you aren't inside. You don't have a roof over your head nor walls about you. The burning sun beats down upon your head, wind whips your papers around. Dust swirls about you as you try to read this. You can't concentrate, it's too hot or too cold. Insects bother you. Raindrops soak your papers, and your computer.

Well you get the idea. The roof and cladding systems, i.e. roof and walls, protect you from the elements, constantly, around the clock. When it rains, it keeps out the water. When it's cold, it keeps in the heat. In the frozen north, the roof keeps the snow out. In the Pacific Northwest, the roof protects from rain. In the South, thundershowers; in the Southwest, the desert sun.

Roofing and cladding systems protect building contents and people from the outside elements. The success of the system is the result of the designer's successful choice of materials, the builder's competency in installation, and the facility manager's maintenance of the system.

Wind–One of the Roof's Worst Enemies

Winds are one of the roofs biggest problems. Hurricanes and tornadoes bring winds beyond the roof design tolerance. Hurricane Andrew in Florida destroyed mostly roofs, the succeeding rains finished off the building's contents. Some roof failures result from poor installation, fastener failures, loss of adhesion, become apparent when the winds increase and the whole roof is blown off.

For each building a 'design wind' is selected. This wind force is determined from weather data, historical records and building location, size and height.

Historically, building designers rely upon various building standards that were accepted based upon previous experience. If a roof fell in it was obviously a poor design, because it had not considered the factors of weather. Over the past 50 years, more science has been applied such that winds and wind effects on buildings are better understood. Today, for tall buildings or buildings of unusual shapes, models are created and placed in wind tunnels to confirm theories of the building behavior under varying wind conditions.

Many, many roof failures are attributed to the roof being damaged or blown off entirely by the wind. Sometimes, the roof itself is a good design, but the elements that hold the roof to the walls or beams, pull out or are pulled apart by forces from the winds getting under the roofing membrane and lifting the assembly. Eventually these forces can tear the roof away from whatever structure is below it.

Design for wind resistance has made great progress in the past years. The evidence is that buildings can be built today that are larger than 50 years ago. Understanding the elemental forces that act on the structure during its lifetime, roof design will continue to get better and better.

Wind design of roofing and cladding systems are based upon weather data collected by the United States Weather Service. Figure 1-1 shows typical wind velocities in various areas of the United States. Similar graphs are prepared in other countries. Winds and moisture records are tabulated in various areas and compiled in a huge database. With satellite imaging and better data processing, understanding of weather patterns will continue to improve. Building designs will change to accommodate it.

Not Only the Wind, but What's in Wind Can be a Problem

The wind carries sand, dust, debris, vegetation, and the spores and seeds of many plants. These particles carried by the wind get onto the roof and inside the walls. Dusts and sands can wear away portions of buildings. The great sandstone arches of the southwest's national parks are examples where sands carried by high winds carved out huge amounts of stone. Granted it took

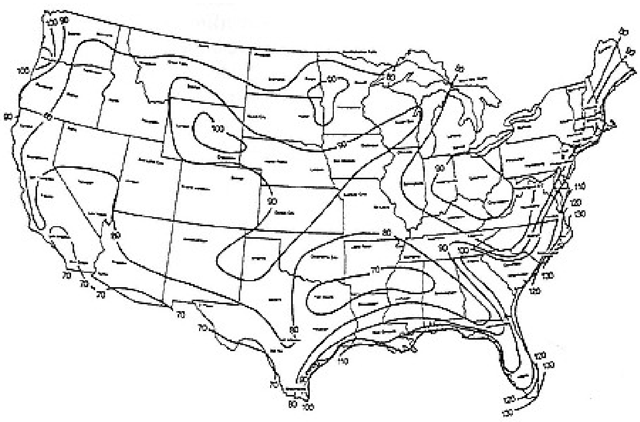


Figure 1-1
Several organizations publish diagrams with expected wind velocities and pressures. Factory Mutual Bulletin 1-25 shows expected wind velocities in miles per hour 30 feet above the ground. Worst case every 100 years.
Reprinted courtesy of "The Science and Technology of Traditional and Modern Roofing System" *by Dr. Heshmat O. Laaly.*
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hundreds of years, but today, in some areas wind borne sands peel the paint off buildings and wear out roofs in the same way.

In some buildings microorganisms carried by wind penetrate the roofing membrane and get into roofing insulation. Provided the microorganisms have enough moisture, they grow and can degrade the building envelope. A common growth on a roof includes moss, which if unmanaged can build barriers on the roof that capture dirt and the seeds of larger plants. Degradation of wet roof insulation may result in objectionable odors which may migrate into the indoor air and result in complaints of nausea, vomiting and respiratory ailment.

The Sun and Its Energy

Energy for wind and weather results from the sun's solar radiation heating the air and water from the seas. Since the rays strike the earth directly at the equator and glance off because of lesser angles at the poles the air is cooler at the poles. The warmer air near the equator rises and is filled in by cool air flowing in below it from north and south of the equator. Hence warm air flows toward the poles at high altitudes while the cooler air flows across the earth at lower elevations. Hence the cold north winds in wintertime. Since the earth also rotates, the earth moves under the pattern of air. The result is that winds tend to blow from the Northwest in the Northern Hemisphere and from the Southwest in the southern hemisphere. Land masses, mountain ranges and other obstacles slow down the winds or channel it through mountain passes.

Locally, infrared light in sunlight raises the temperature of objects. Dark objects absorb the energy while light colored objects reflect some of the energy. A dark object or patch of land is warmer on a sunny day causing the air above it to rise and cooler air flows into the area from adjacent space. At night this flow reverses. The dark object cools more quickly than a light object and air flows in the opposite direction. This and other types of local air movement creates winds and gusts.

Since dark objects absorb more infrared energy than light objects the temperature of dark items increases. For a roof or cladding system this heat, which can reach 170F, causes the material to expand. In addition to heat, sunlight includes ultraviolet light which breaks down long organic molecular chains found in plastic and asphalt substances. Hence the roof must withstand the winds, heat, cold and degradation from sunlight to prevent cracks or breaks.

Temperature Extremes

In addition to the general problems of winds and heat from sunlight some areas are subject to extreme summer or winter temperatures. Death Valley, California, is one of the hottest places in the country with regular summer temperatures of over 110 degrees Fahrenheit. The highest recorded temperature in the world was 136.4 degrees Fahrenheit in the Libyan Desert in 1922. Likewise low temperatures are observed in the northern areas of the United States. The lowest recorded temperature in the lower 48 states was minus 70 degrees Fahrenheit at Rodger's Pass, Montana, in 1954. Alaska temperatures are lower with minus 80 recorded at Prospect Creek Camp in 1971. The materials on the roof must withstand not only winds, but the differences from these temperature extremes. Roofs and walls can be even warmer or cooler when energy is absorbed from sunlight in addition to the high ambient temperature. For cold conditions wind chill can lower the roof or wall temperature below even these low figures.

The roof and walls in these extreme temperatures have to do the same job: protect the clients and building contents from the weather, in both the extreme heat of summer and the extreme cold of winter.

Not Only Hot and Cold, but Water Too?

Like temperature, moisture in the atmosphere is the result of the sun's energy and the earth's rotation. Water, picked up from oceans and freshwater lakes, changes temperature and falls back to the earth as rain. In cold weather the moisture freezes as it condenses and it falls as either snow, hail, or freezing rain.

Moisture, in the form of vapor, rain, snow and ice are the third enemy of the roofing system after wind and sun. Sometimes wind and sun crack the membrane then moisture penetrates into the insulation or even into the structure below it. When rains fall, the roof needs to hold it until it can run off through roof drains, eaves, gutters or scuppers. During heavy rains or snowstorms, the deck must carry the additional weight of the water until it can drain or be removed. A roofing system must hold water during spring thaw conditions when ice dams form that can block the normal drainage flow. Ice dams are a common problem in areas were temperature patterns fall below freezing, then warm, then freeze again.

The roof must channel off the water, or at least be strong enough to hold the weight of the water until it runs off. In cold weather climates it must also carry the weight of snow or ice buildup.

Ponding. Flat roofs must withstand a phenomena called 'ponding' where the roof sags slightly either from its own weight or poor design. Water collects causing it to sag more, which allows it to hold still more water. A poorly designed roof can collapse under these conditions.

If hail falls onto the roof, waterproofing membranes must withstand the forces of impact of the hailstones, otherwise holes punched into the roof will leak after the hailstones melt.

In some areas of the country rain water may be slightly acidic, a phenomena known as acid rain. If roof materials aren't compatible, the acidity can dissolve some roofing elements. Acid rain corrodes metal roofing and flashings, allowing winds or other forces to tear or pull up the membrane. A good roof system should resist these corrosive reactions.

Another roofing problem is that moisture can become trapped inside the structure. High internal humidity can cause the inside walls to become wet with condensation creating corrosive problems on the inside. Moisture trapped underneath a waterproofing membrane can vaporize and expand under hot summer conditions. If the expanding moisture cannot escape from underneath the membrane blisters will form on the roof. Blisters eventually break creating holes which allow more moisture under the membrane.

The method to prevent this problem results from calculating the "dew point" inside the roof membrane and being able to determine where in the cladding or roofing assembly the dew point will occur. The dew point is the temperature at which water will condense out of air. Dew point calculations are included in Chapter 6 along with sample calculations.

Humidity can also enter into roofing materials and during winter freeze thaw cycles expansion and contraction of the moisture can crack or break up the roofing membranes.

If humidity permeates within the roofing or wall membranes and is not able to escape, fungal or microbial growth can begin. Occasionally resulting in unpleasant odors and complaints from building occupants.

So What's the Next Step?

Fortunately, people have been putting roofs over their heads for as long as man has wanted comfort. The initial roof materials were natural materials local people found worked best. Huts of sticks and straw, still used in some poor areas of Africa and South America, was no doubt invented by some fellow who figured out it was drier standing under a bush or tree than standing out in the open. So he picked some of the brush, tied it together and put it up on the building frame to carry off the water. The point is that history has led builders and facility managers to select inexpensive local roofing materials compatible with the local environment.

It would be odd to see the steep roof with heavy beams common to alpine areas, i.e. the classic ski lodge, in a Caribbean island setting. This is because this sturdy type of construction is not needed in a tropical setting.

Likewise, a thin reedy structure acceptable on a desert island would be out of place at a mountain ski resort where heavy snows and cold weather extremes would render the slight structural materials into nothingness in a short season.

The problem a facility manager has with the roof is that weather and moisture conditions change throughout the day, seasons and locations. Out on the plains, one type of design is acceptable while just a few miles away in the mountains, a more sturdy structure is needed because of heavier snowfall. Where high winds exist a structure must be stiffened to resist the winds.

Local Building Codes and Standards

Accordingly, communities utilize local building codes written specifically for the weather and seasonal patterns in that area. The local code is a minimum requirement, while cost of the structure is the other limiting factor. Hence the pressure is on the builder or owner to minimize the cost while meeting the code. In northern climates, snow building up on the roof tends to make the beams and deck more sturdy. In coastal areas, designs are modified to resist coastal winds and even hurricanes.

Local codes are supported by industry and trade associations who try to keep regulatory officials informed about the state of the art of the various building systems and components. And builders who are used to one code sometimes have difficulty when the code is changed or when relocating to another area of the country where another code is in effect. For facility managers roofing membrane systems are rapidly changing. Structurally, frame members are becoming lighter, allowing the use of less materials. This requires the weight of the roofing system be reduced so that the roofing does not overload the structure.

For structural conditions, the American Society of Civil Engineers (ASCE) publishes national recommended standards for design. These standards take weather loads like rainfall, wind and snow into account, along with other considerations like earthquake potential. The building is designed for the 'assumed' conditions that are agreed upon by these building professionals.

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is studying weather maps and data to provide temperature and rainfall information to designers and builders throughout the United States. ASHRAE works closely with the United States Weather Service to compile weather data throughout the country.

There are a number of other professional associations who participate in the development of codes. Most of these are mentioned in Chapter 14. One of the most significant with regard to the roofing industry is the National Roofing Contractor's Association or NRCA. The NRCA has approximately 4000 members and represents professional roofing contractor's and the manufacturer's of roofing assemblies throughout the country. NRCA is headquartered in Rosemont, IL.

For buildings outside the country the professional associations work with similar associations from other countries. The primary difficulty working across international boundaries are the differing weather conditions from country to country. Keflavik, Iceland is going to have vastly different building standards than Kingston, Jamaica.

However, most major cities of the world, lie in a moderate temperate zone between these extremes and buildings in Mexico City are going to be similar, although not exactly the same, as in New York City. While roofs and claddings throughout the world will vary with local conditions, many types meet the local standards of both warm and cool climates and are acceptable to local codes in many areas. Single-ply roofing and Exterior Insulated Finish Systems (cladding) meet the codes throughout the United States and many areas of the world.

In the USA, the United States Weather Bureau keeps track of rainfall, temperature and pressure data. Their reports are routinely published in journals, society papers, and government records. Professional code associations look at the government information and use this data to recommend changes to local codes in the various states and regions. This happens after severe heavy rainstorms, earthquakes and hurricanes. Professionals are called in to examine buildings after the event and with careful study of the damaged and undamaged buildings try to determine if the way buildings are designed or built can be changed to make them more sturdy.

In addition to government and professional associations, the insurance industry is continuously evaluating roofing systems and roof system failures. These numbers are evaluated against the dollar value of the insurance risk. If a certain type of failure occurs too often, insurance associations post bulletins informing the insurers that their risk is increasing. The insurance companies then adjust facility premium rates accordingly and may require modifications to the system or design.

One organization that monitors roofing performance is the Factory Mutual Research Corporation (FMRC) in Norwood, Massachusetts. The organization tests varying types of roofing assemblies and publishes a list of approved systems. By approval, the FMRC is indicating they have tested the system and found it acceptable within the standard conditions set up by the test. Roofing assemblies are reported in a publication titled "Approved Roofing Products" by the Factory Mutual Research Corporation, 1151 Boston-Providence Turnpike, Norwood, MA 02062.-

An agency that reported on roofing system performance in the past was the National Roofing Contractor's Association "Project Pinpoint" which provided performance experience of commercial roofing systems in the United States. Unfortunately "Project Pinpoint" has been discontinued by the NRCA.

In conclusion then, the facility manager wants a roofing system that will protect the building from the harsh extremes of weather. The roofing industry, professional associations, designers, contractors, and manufacturers are constantly working together to provide structural materials, insulation and waterproofing membranes that will resist the elements at the minimal cost to the facility. Local and national government work with the professional associations to establish codes for construction based upon estimated or historical weather patterns. Finally insurance industries log and track roofing system failures and problems to minimize insurance and facility risk.

Understanding where a single roof fits in with all these parameters is in the next chapter, understanding your roofing system.

Chapter 2— Understanding Your Roofing and Cladding Systems

What Kind of Roof Do You Have?

Before the facility manager can make adequate decisions about their roofing and/or cladding system, they must know what type of system they presently have. The shape of a building is a function of where it is located, what activity takes place within the walls, and the materials used in the basic structure. A building can have a steep roof as opposed to low slope roofs. Depending upon use, different types of ceilings are required which can affect building design. Sun, wind, rain and weather in the region where the building is constructed affect building shape and roofing materials. Owner and designer preferences, experience, and budget affect the building's size and shape.

Costs of various types of roofing materials play a large factor along with use of the building and its expected life.

Sizes and Shapes

For a large building, shape and size may be the result of what is to be housed within the building or of the flow of materials through the building. A factory may have several floors that allow materials to flow down through the various levels as the materials are changed. Another type of factory may have long conveyors that move material from one station to another which allow the product to be modified at each step. Hospitals have patient wards and treatment areas, schools have classrooms and exercise areas.

Walls and roofs encompassing these various areas are a function of what takes place inside and environmental conditions inside and outside. The type of materials used to enclose these areas depend upon the use of the space to be enclosed.

Land values can also make a difference in the shape of a building. Buildings in areas with high land value will be multi-story while areas of low land value would have large single or two story structures. A manufacturing district will have large individual buildings with large floor areas and lots of land adjacent to the perimeter to allow trucks or rail cars to deliver and ship products.

So how does this information apply to the facility manager? A manufacturing assembly facility with a large flat roof requires more maintenance than a small commercial building with a steep sloped roof. A multi-level or multiple story building has a smaller roof area per square foot of floor space than a single story. This means the proportional roofing expense will be smaller and the impacts of a roofing failure less than it would be in a building with a large single story area. Multi-story buildings have a higher cladding to roofing ratio so cladding and glazing become more important to these type facilities.

For a hospital or school, the surgical suites and the class room areas would be higher priority for maintenance than storage or custodial areas. The facility manager wants to consider how the customers are affected by the roofing and cladding systems being maintained.

Size as a Function of the Construction Materials. For residential and commercial buildings the length and width of a building and its roofing and cladding systems are often multiples of two feet. This is because building codes require a frame member every two feet to provide strength. If a designer draws plans with a single foot dimension, such as 39 feet, the builder will use the same amount of materials as would be used in a 40 foot dimension, he just cuts off the odd foot and discards the materials. Therefore, a building dimension with an odd number, such as 39 feet, is rare and the cost for a 39 foot wide building would be nearly the same as a 40-foot-wide building.

In a similar manner sheet construction elements like plywood, veneer, insulating boards, and gypsum come from the manufacturer 4 feet wide and either 8, 10 or 12 feet long. For builders it makes economic sense to design the building to minimize the cutting and the waste of many end pieces.

Roofing and cladding insulation materials also are made in even foot numbers, again to minimize the cutting and fitting during installation. Rolled roofing goods are often furnished in even foot widths.

Building Structural Materials

For large buildings materials are affected by the same 2-foot dimension. In the case of a concrete building, the forms are made from wood or "standard" concrete forms that come in even sizes. If a designer puts a one foot jog in a building, for example, it has to be made from pieces that come from the factory in 2-foot widths.

Steel framed buildings are made from standardized structural shapes bolted or welded together. These types of buildings have floors and the roof decking made from cold rolled steel formed with stiffening ribs to resist deflection so that they can bridge between joists or purling. See Figure 2-1. Figure 4-5 on page 72 shows this roof deck material from below.

Because decking materials and beams act as an elastic material under most designs, they "flex" under various design load conditions. That is, the shapes deflect slightly under their own weight after being placed. A roofing or cladding system should take this deflection into account when the overall structure is designed. The walls of steel buildings usually rest upon clips attached to the steel frame. Therefore, a cladding system for a steel framed building must be capable of being clipped to the structural frame. A deck for a steel framed building is attached to the frame with bolts, screws or by welding. The roofing system must be flexible enough to move with the frame as it flexes during the life of the structure. If this flexibility isn't taken into consideration when the roofing system is designed, the roofing membrane can rip or tear, causing a roofing system leak or increasing the chance the wind could get under it and blow it off.

Concrete, another basic framing material, is used as well as steel. In a building with a basic concrete frame a form is built of metal or wood. Steel reinforcing bars are placed in the forms before the concrete is poured. For a concrete frame, the walls of the building can be concrete, or another cladding material can be used and attached to beams and columns with clips similar to cladding systems used for steel buildings.

Concrete is more fire resistive than unprotected steel, although it is more costly to frame up than a steel framed building.

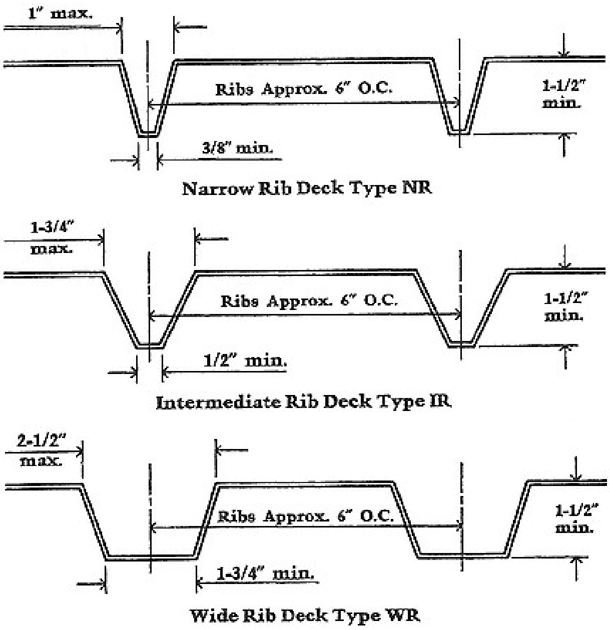

Figure 2-1
An end view of typical steel deck shapes.
Reprinted courtesy of "Roofing: Design, Criteria. Options, Selection"
by R.D. Herbert, III, and Illustrations by Carl W. Linde.

Concrete has the advantage of being built from sands, gravel and cement while steel requires work in a fabrication shop where sizes are cut to length and clips attached. The beams are shipped to the fabrication shop from the steel beam factory. In the fabrication shop, standard sized pieces are cut, drilled with bolt holes, and plates and clips added to make the steel beams easy to erect at the job site. For this reason, buildings constructed in areas where steel mills are close and the steel members can easily be sent to the job site will favor a steel design. A remote area with good sands and gravels and a good labor force that can build forms may favor the concrete frame over the steel frame.

Finally, some structures favor concrete over steel because the building itself requires more fire resistive construction. A school or hospital which has a large number of people relative to the size of the structure may favor concrete or masonry over steel. However, the steel construction industry has come up with a fire resistive coating that is placed over the steel members that allows the steel frame to be comparable with the concrete.

Roofing professionals shudder at the term "a flat roof." Technically, they call what appear to be flat roofs "low-sloped roofs." The industry agrees that a roof should never be designed perfectly flat because of a phenomena called "ponding." See Figure 2-2. The problem of ponding is that as the roof sags, water ponds, much like a swimming pool. Roofing experts agree that ponding makes for roofing problems and that a perfectly flat roof is the root cause of many other seemingly unrelated roofing problems.

The facility manager's cladding and roofing system design may favor one type of frame over another. For example, a built up roofing system, which is less flexible than a single ply system, will be easier to install on a concrete deck than a steel deck, although both can be used for either purpose. Since a single ply system is more flexible than a built up roofing membrane, a single ply roofing system will integrate better with the lighter, more flexible, structural frame.

Steep Roofs vs. Low Slope Roofs

The roofing industry divides roof designs into low sloped designs and steep slope designs and many facilities have a combination of the two types. Large buildings often have flat roofs because the design requires a significant amount of extra materials to provide the slope needed for a steep roof.

Low slope roofs have a slopes of 1 inch in 10 horizontal feet up to about 2 and 1/2 inches in one foot. Roof slopes in the 1 inch in 10 feet category will have puddles on it after rainfall because it is very difficult to maintain this flat a slope with construction tolerances. Low slope roofs cover large box-like buildings like manufacturing plants, hospitals, schools, warehouses, hangars, and administration complexes.

If a roof evaluation deems it "flat" the roof has an inherent design problem that should be fixed. A flat roof can usually be

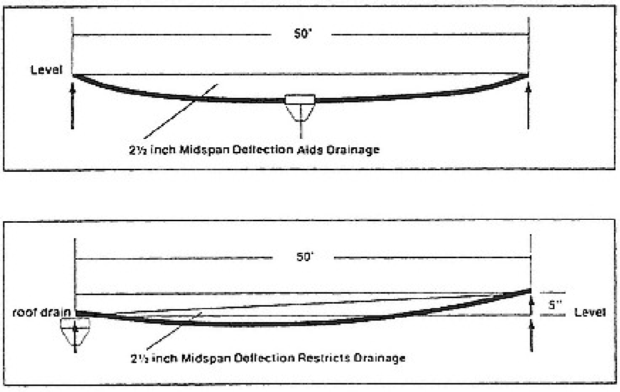

Figure 2-2
Ponding Phenomena. As water collects on a roof, the beams and supports sag under the weight. This allows the roof to collect more water. Drains must be placed correctly to allow runoff and must take the ponding into account.
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corrected by relocating the drains to the low points and/or replacing the insulation with tapered pieces specially designed for this purpose. Insulation is discussed more thoroughly in the next chapter.

The other type of roof, known as **steep roofing**, is more common to residential than commercial types of construction. Steep roofs rely upon water shedding characteristics while low slope roofs must be watertight. Roofs with slopes of 3 to 9 inches vertical to one horizontal foot are common. Steeples and spires have slopes with more vertical rise than horizontal. For example a church steeple could have a slope as high as 3 vertical feet in one horizontal. Steep roofs make for the pleasing architectural touch seen on many public buildings and artifacts. Steeples and spires require a lot more material per square foot of floor space. Hence, these features generate less revenue in the form of leases or rent and have less value. The result is that a spire or steeple is essentially ornamental.

Internal Ceilings

In order to have an effective roofing structure it must be compatible with the inside ceiling as well as the outside. Commercial buildings often have what is called a T-bar ceiling. See Figure 2-3. In a T-bar ceiling, wires are hung from bar joists above forming a grid of metal tees. Within the metal grid, lights and ceiling tiles are placed. The ceiling tiles are usually made from mineral fiber board. These tiles are light, fire resistive, and provide acoustical dampening from traffic on the deck above.

Brown stains on ceiling tiles may be a facility manager's first

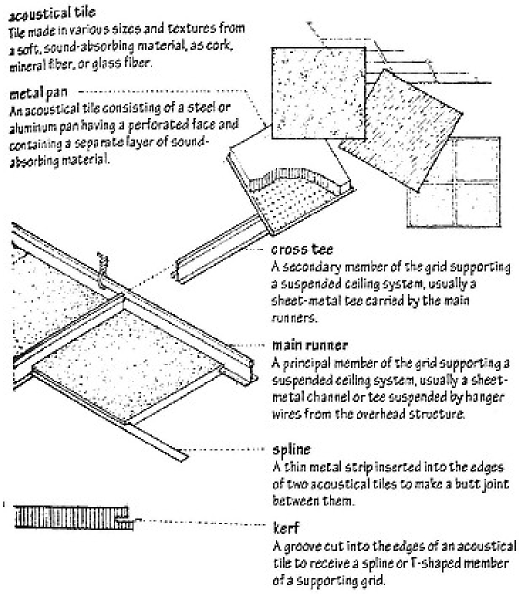

Figure 2-3
The ceiling under the roof deck of many commercial buildings is called a T-bar ceiling. A rack of bars is hung from the above decking and tiles or light fixtures are placed into the racks. The ceiling is called a T-bar ceiling because the rack bars are shaped like an upside down "T."
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sign there is trouble with the roof. Repair of this type of ceiling is easy, just match the ceiling tiles and replace the ones that are stained.

Some ceilings are fully finished. That is, sheetrock or wood is attached to the structure and painted. Facility light fixtures are then attached to the ceiling but they must also attach through the ceiling material and onto the building frame or a structure designed to hold it. One of the most common finish materials is gypsum board. Gypsum board is also called sheetrock or plaster-board in some areas of the country.

Gypsum board consists of gypsum powder that has been wetted and encased between stiff fiber paper. The board comes in sheets either 1/2-, 5/8-, or 3/4-inch thick that are nailed or glued to the frame of the ceiling or walls. After the boards are installed, the joints between the edges are covered with wet applied plaster. Usually several coats are applied and sanded to make the wall or ceiling smooth and seamless. The gypsum will not burn, although sometimes the paper and paints will. This is why gypsum board it is so attractive over wood as a finish material. It is also cheaper than wood.

When a roof deck leaks through to a gypsum board ceiling, the paper will stain as the ceiling tiles will. However, repair of painted gypsum board materials is more complex.

Gypsum board materials lose their strength when they become saturated and the fasteners will not hold the board if it is completely soaked through. Sometimes a roof leak can be repaired from above and the gypsum board allowed to dry. Then the board is sanded and repainted. The most difficult part of this operation is matching the paint to the rest of the ceiling. Since matching the paint is often difficult, a ceiling repair operation usually requires complete repainting of the ceiling.

Sometimes after a leak gypsum board is stained or deformed so much that it must be removed. When this is necessary, the old gypsum boards are pulled down, the fasteners pulled and a new gypsum board placed and repainted. This type of operation is more expensive than replacing T-bar ceiling tiles and some facilities elect to abandon the gypsum board ceiling and hang a new acoustical tile ceiling below it, provided there is enough room for the new ceiling below the old one.

For any finished ceiling, the main frame must provide for attachment of this ceiling. Ideally, the attachment method does not require holes to be punched through the deck to the roofing system above. If it does, then provisions must be made to close up the holes to prevent leakage of water through and onto the ceilings.

Latex paint forms a bubble.

On one project the author arrived to find a leaking roof that had allowed water to penetrate through the deck and into a gypsum board ceiling. The latex paint had enough elasticity that it had separated from the gypsum board and was holding several quarts of water in a large bubble. When a pencil was used to try to puncture the bubble of latex paint, the membrane snapped like a rubber balloon allowing several gallons of water to fall into the room. Fortunately the staff had taken the precaution of removing the books, computer, and furniture before sticking the pencil into the latex bubble.

An unfinished ceiling is often found in warehouses or other storage type buildings. On some buildings, unfinished ceilings leave the building insulation exposed which can pose a problem with insects or dust. An unfinished ceiling leaves the fire protection coating of steel or wood beams exposed to air currents and high humidity conditions. Over time the fire protection material can become flaky and begin to shed. Since fire protective coatings for beams are not designed to work after being soaked, loss of the integrity of the fire protection over the beams can lead to a significant increase in the insurance premium costs for the building.

Wind Problems

The structure must be designed in consideration for the wind the building will face during its lifetime. Hopefully a structure will not have to face the devastating effects of a hurricane but facilities must take this factor into account in design. The roofing and cladding systems should remain intact but the designer might decide that in the most extreme conditions the cladding and roofing systems could be sacrificed without allowing the main structure to fail.

Aside from water failures, almost all roofing system catastrophic failures are the result of winds getting under the roofing, especially at the roof edges, and lifting the membrane, insulation, or the deck. If a section of the roofing membrane is lifted, the membrane becomes a large sail that can strip more roofing from the building.

Architects and designers sometimes use a "wind rose" to determine the conditions of the winds for the building. A typical wind rose is shown in Figure 2-4.

Building Shapes, Colors, Texture

Shapes of the structural members, color and texture affect the final shape of a building. Knowing the building's function and an approximate cost, the designer establishes the basic shape. The type of roof and cladding system are a result of these basic shape

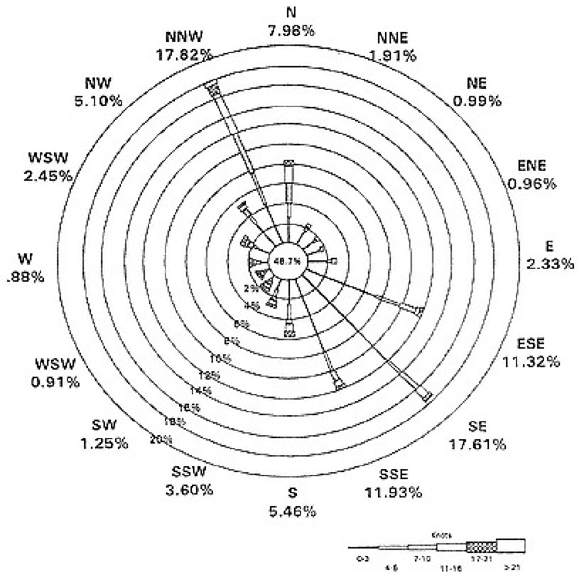

Figure 2-4
When major facilities are designed, a wind rose map can be prepared showing the direction and forces expected in the building location. This wind rose is used by designers to estimate worst case winds and the forces expected on the roof and structure. Wind rose information is usually prepared from weather data or from field measurements at the site. The length of the "petal" from the center of the diagram indicates the relative forces of the wind.
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decisions. Certain types of roofs work well in one application but could be disastrous failures for others.

Final shapes can be the angled roof types discussed earlier or rounded as in the case of the Capitol. Provisions are made to make the shape fit in with the surroundings and the architect chooses colors and textures that enhance that overall design.

For roofing a major consideration is the roof/wall interface which can be a parapet, eave, or cornice. See the Glossary for an explanation of these terms.

Exterior colors are chosen to compare or contrast with an overall theme except where the roof is protected from observation from the ground by parapet walls. In which case the color of the roof is made for energy considerations.

Although not as significant as color, texture decisions are also made. For building cladding, the interface of the exterior finish with windows and doors is an important one.

All total then a facility manager seeks to have an economical building shell and roof that are adequate for intended purpose. Cladding systems are no good if they stain easily and roofing systems are no good if they leak.

Cost Considerations

Of course the facility manager decides how much to spend for his roof. Initially, the designer, architect, or engineer will specify a system and industry professionals indicate that the system chosen is largely a matter of experience. Designers specify roofs that they have had good experience with in the past or one that the owner has expressed a preference for.

Some facility manager's rely upon the manufacturer's claims and guarantees or warranties when choosing a roof system. The warranty life of the roof is selected by the manufacturer. Depending upon the application roofing life is a function of first cost and as a general rule, the higher the initial cost the longer the roof will last. Low slope roofs have guaranteed lives of 5, 15, 20, 25 years. Steep slopes generally have longer lives, 15 to 100 years before replacement.

There are many types of roofing systems for which the facility manager may not be very familiar and which is fully explained in later chapters. Roof systems include the deck and its basic shape, insulation to hold in heat, and a waterproofing membrane that sheds moisture. Most roofing systems are a combination of these elements. In structures the deck is part of the structural frame and the building owner has a choice of building insulation and waterproofing membranes independent of the deck.

Life Cycles of Roofing Systems

Life cycle analysis of roofing systems include all three elements and for most facility problems, if the waterproofing membrane is punctured or tears, water enters into the insulation. When this happens freeze thaw cycles break down the insulation and the moisture reduces the heat holding capability. If enough moisture gets through the insulation it can penetrate into the deck material where the deck itself begins to deteriorate.

This of course becomes a very expensive operational and maintenance project if the roofing system has been allowed to deteriorate to this state.

If the deck is of a solid design like concrete or tongue in groove wood, the deck can be pretty far gone before there are any leaks. When this happens the simple repair job to fix a minor leak grows into major repairs and the facility manager is faced with the classic repair vs. re-cover dilemma.

Doubtless the facility manager wants to make sure he is cost effective with the dollars used in roofing system. Unfortunately, new roofs rarely leak and dollars spent for maintenance in the first years of the roof's life aren't paid back until the end of the roof's life. So the return on the maintenance investment isn't as immediately obvious as it seems.

In addition, facility manager's should be aware that the life of the facility roof and especially the warranty are contingent upon the roof being maintained over its life. If the manager decides to save money by not doing the maintenance in years 10 to 15 then an attempt to obtain warranty service in year 20 is going to be difficult.

Finally, a few roofs might be warranted at a decreased dollar amount, like automobile tires. That is the warranty is decreasing with the life of the roof. If $100,000 is spent on the roof initially and the warranty is prorated over a life of 20 years then the value of the roof in the last year is only $5000. Doubtless, if the building contains $100,000 dollars worth of inventory, the $5000 dollar value of the roofing membrane isn't worth much at all.

Table 2-1 is an indication of the first cost of some of the more popular roof types. Later chapters explain the types and of course roofs are bid by contractor's on fixed price terms. Also the facility manager should be aware that the prices of roofing materials change continuously. For example, asphalt products will follow the petroleum market pricing. The most economical roofing decision today might not be the same in 5 or 10 years and therefore the flexibility of the deck to accommodate various types of waterproofing membranes in the future is a benefit.

Taxes

The facility manager contemplating roofing replacement might want to consult a tax attorney as tax consequences may affect the costs of a roofing decision. The entire cost of a re-

Table 2-1. Roofing System First Costs. Price includes materials and approximate labor for installation. Add insulation cost to roof membrane costs. *Caution: Some membrane types may not be compatible with insulation types.

Type	Approximate Price per Square Foot
Built-up Roofing	
4 plies	$1.45 to $1.93
3 plies	$1.35 to $1.50
Single ply	
EPDM	$1.39
PVC	$1.72
Preformed Metal	
Aluminum	$1.75
Copper	$7.50
Aluminum Shingles	$1.00
Shingles	
Asphalt	$0.92
Slate	$7.80
Wood Shakes	$3.50
Clay Tiles	$7.05
Insulation *Add to membrane costs above.	
Wood fiberboard	$0.85
Polyisocyanurate	
1" to 3-1/2"	$0.70 to $1.30
Expanded polystyrene	$0.55 to $1.11
Composite Boards	$1.02 to $1.41

cover activity is probably going to be deducted from taxes in the year the work is done. A replacement activity, where the old material is removed down to the deck, or even portions of the deck are removed and replaced is considered by the tax man to be an addition to the real property and cost for this work cannot be deducted in the year the work is done. In fact, recent changes to the tax law require that reroofing be depreciated over 39 years. Doubtful that low sloped roofs will last that long.

Replacement of roof and wall insulation can qualify the facility for an energy tax credit. These credits can be significant and any roofing project should consider the value of increasing insulation to save energy costs.

Maintenance/Service. The facility manager should be aware of a new trend in the roofing industry for maintenance organizations. These new contractors sell only maintenance service and keep themselves independent of selling reroofing or recovering jobs. They don't build new roofs, they just provide inspection and patching services. A facility manager may find that this type of service is available in his area and that using this type of contractor may add to the life of the roof. One problem faced by these new companies is how they can maintain the original manufacturer's warranty on systems they did not install. Obviously some details are still to be worked out but the services provided are a boon to any facility manager if he can obtain them.

Environmental Design Considerations

The roofing system is supposed to resist the natural elements discussed in Chapter 1: Wind, rain, snow, sleet, hailstones, sun, insects, molds and fungus. In addition, the roofing system conserves energy used for heating or cooling the building. The roof then has to be economical and last a long time in these conditions.

Aside from a roof wearing out from old age, major roofing failures are of two types, either the roof falls in because the deck failed or it is destroyed because wind gets under it and lifts it off the building. Mostly these failures are attributable to either a design flaw, poor installation, neglect, or extreme weather conditions. Legally the building is designed to meet certain structural codes but no building can be designed to meet conditions encountered in a natural disaster. Codes are designed to make the structure withstand some natural events, storms and minor earthquakes, but these designs are based upon expected events that are predicted by the code associations as discussed in Chapter 1. No one can design for unpredicted events.

Uplift Design. Since winds can carry debris that punctures the roof or wind can get underneath the membrane and lift it off of the building, several technical studies are performed to make sure the roof resists normal wind events. The studies are called "uplift tests" and roofing designs are tested against varying conditions of uplift resulting from wind pressure. Both the roof deck and the waterproofing membrane must be designed to withstand uplift pressures.

While it is doubtful that high winds could get under a membrane that had loose gravel placed on it to hold it down (called a loose ballasted system). The resulting ballast descending to the sidewalk or parking lot below could have devastating effects. The Single Ply Roofing Institute requires loose ballasted roofs to have height limits and parapet walls.

Thus, one of the keys to preventing winds from destroying the roofing system is the method used to attach it to the deck. Some systems are glued with hot bitumen (tar) or sticky adhesives, some are fastened with metal screws or plates, while a few are ballasted with loose stones.

Most systems specify the type and size of the fasteners, stress plates, and the spacing of the fasteners. The number and shapes of flashing and fasteners are integral to that particular roofing system.

Sunlight Deterioration. Sunlight, ultraviolet light and heat from infrared rays will parch the roof and can eventually destroy the membranes over time. Changes in temperature cause the membrane to expand and contract. The expanding membrane can make ridges in the surface and block the drainage of water. One expansion phenomena called caterpillaring is where the material expands in the heat, then contracts when cooled. Factors in the roof system cause the membrane to "grab" instead of shrinking back to the original location. In caterpillaring the membrane essentially "walks" across the roof. This has caused some interesting expletives from the maintenance manager who goes up and keeps pulling the membrane back into place.

If a membrane is completely adhered and stresses are concentrated at points like a deck joint the membrane can split, leaving holes in the membrane for water to penetrate.

Second, the heat from the sun's rays will dry out any volatile materials in the membranes. This drying leads eventually to cracking of the materials because of a loss of flexibility.

Third, within sunlight are ultraviolet rays which destroy some of the long polymer chains in plastic and asphaltic materials. UV light makes the membrane brittle and causes cracks called "alligatoring."

To protect the membranes from heat and direct sunlight waterproofing membranes sometimes have gravel or stone placed upon them to protect the material from these infrared and ultraviolet rays. What the facility manager sees looking at roofing shingles is a layer of fine granules embedded in the top layer of bitumen.

One of the advantages of bituminous type roofing systems used in built up and modified bitumen roofing is the tendency of the material to 'heal' itself. When heated during the day the soft bitumen materials liquefy and flow into tiny cracks left from previous events. This is one reason why this material has been so successful. However, over time, the sunlight destroys the volatile materials in asphalt membranes making them brittle and unable to expand and contract. Hence, maintenance is more important on asphalt type of roofs than on the single ply membrane roofs.

Rain. Next, water gets onto the roof from rainfall and snow. The water can corrode any metal flashings or fasteners. Holes in the membranes allow water into the insulation below.

Humidity. Akin to rainfall but not exactly the same, roofing systems must be designed to accommodate the humidity of the region where they are installed. Facilities with high interior humidity such as food processing and swimming pools must have a roofing system designed in consideration of potential moisture condensation inside building. If the envelope is sealed too tightly by the roof and cladding systems then the building ventilation system must accommodate any extra humidity. Otherwise, the walls, floors and inside windows will have a tendency to sweat. Water droplets form on the inside by condensing just like water will form on the outside of a glass with ice water. Therefore a good roofing system provides a means for trapped moisture to escape. This process is called venting.

Chapter 6 discusses insulating a "vapor retarder" that will prevent moisture from reaching cool surfaces and condensing.

Trapped moisture between the deck and the membrane can turn to vapor when heated under a hot roof. The expanding vapor creates bubbles in the roofing membrane. If the vapor causing these bubbles isn't allowed to escape, then any traffic on the roof can break the membrane at the bubble and allow more moisture inside. More details about venting and moisture are presented in Chapter 5.

Another similar problem with high humidity inside the building is the degradation it causes when the moisture from high humidity condenses in or on the building's insulation. Wet insulation allows heat to escape and defeats the energy retarding purpose of the insulation in the first place. The moisture may result in disintegration of the insulation or loss of bond to the membranes.

Energy. Roofing and cladding systems include insulation designed to retard the flow of heat when outside temperatures are higher or lower than the building's inside temperatures. There are many different types of roof insulation but all work on the principle of trapping air inside membranes and holding it. The air acts as the insulating barrier. Selecting the correct insulation material can reduce energy costs and in some cases facilities replacing insulation can take advantage of energy tax credits for saving energy. This tax credit has a double advantage because not only can the facility take a tax credit for installing new insulation but reduced energy costs will also enhance the facility budget over time.

The facility must be careful, however, to select an insulation material that is compatible with the roof deck, the waterproofing membrane, and the building's inside and outside environmental conditions. Methods of selecting insulation, tax and energy calculations are discussed in detail in Chapter 6.

Environmental Hazards

Recent environmental legislation regulates disposal of industrial and hazardous wastes. The new rules have had significant impacts on the roofing industry, particularly with regards to reroofing. One factor the facility must consider in making the tear off and re-cover decision is, "What is going to happen to the old materials?"

In many cases the old roof represents a large bulk of material that may or may not be hauled to the landfill. Many old roofing systems contained asbestos which was thought to be an inert material but has now been identified as a cancer causing material.

Disposal of these materials during reroofing may pose a bigger problem for the facility manager than anticipated. By carefully evaluating the materials beforehand a potential problem can be eliminated. Additional roofing material disposal costs should be included in a reroofing decision. In varying areas of the country fees are charged at the industrial waste complex for disposal of roofing materials and significant fees and paperwork are necessary for the disposal of hazardous wastes.

A recent trend in the roofing industry has been an attempt to recycle the old roofing materials. Some old roofing can be recycled into to lower grade products. Asphalt roofing can be recycled into paving and PVC can be recycled into lawn furniture. Recycling has the added benefit to the facility manager of making the facility friendly to the environment.

In addition to the problems of disposal of the old roofing materials, a reroofing or re-covering operation could lead to complaints from neighbors or building occupants from the smell of the roofing materials. Some systems are sprayed or hot mopped onto the roof. The odor from this type of operation may indicate pollutants that could result in a challenge from the surrounding community or even the building occupants.

If a roofing contractor has decided to direct his staff to wear protective clothing, including respirators to protect the workers from fibers in the insulation or from fumes in the waterproofing membrane, what is the public going to think watching the operation from the next block over? The facility manager wants to make sure his contractors and designers are checking into the impacts of any hazardous material decisions they make.

Some roofing systems are spray applied. The facility manager wants to make sure that these chemicals don't over spray onto adjacent properties or onto cars in the parking lot. Care should be taken to protect building occupants and members of the public from the sprays and subsequent odors.

Material Safety Data Sheets

One of the most effective ways a facility manager can determine potential hazards from a reroofing project is to examine the manufacturer's Material Safety Data Sheets (MSDS) provided with the materials the contractor proposes using. The MSDS is a quick way to determine any environmental hazards from a proposed new roofing material. Chapter 13 on safety discusses Material Safety Data Sheets in greater detail.

Fire Ratings. A building fire is potentially a tremendous threat to the community. When a building catches fire, not only are the occupants lives at stake, the contents of the building and the building itself are also at risk. Since fire is such a threat, roofing and cladding systems are extensively tested to measure fire resistance.

Agencies which publish standards for fire and flame test roofing systems include the National Fire Protection Association (NFPA), the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI). The Factory Mutual Insurance Corporation (FM) and Underwriter's Laboratories (UL) test roof assemblies and list and rate various roof types in their approval guides. FM and UL publish pamphlets where the different types and classes of roofing systems are listed. In many areas the building code requires the listing of the roofing assemblies by one of these two approving standards.

Each association either publishes standards or performs tests used to evaluate the fire resistance of roofing and cladding components.

Fire science technology is complex and requires much independent study. In addition several different kinds of tests have to be conducted on a roofing system and the results of the tests establish ratings of either the entire assembly or one or more materials. The burning brand test, for example, is an Underwriters Laboratory test to determine if the roofing system will catch fire from flying burning patches from an adjacent building. Another test called the flame exposure test subjects roofing to a flame for a limited time. For a third test Underwriters Laboratories exposes the roofing materials to a flame at the edge to see if the flames spread over the roofing sheet.

If the material passes all three tests then it is qualified to have the Underwriter's Laboratories Label and it is rated either Class A, effective against severe fire exposure; Class B, effective against moderate fire exposure or Class C, effective against light fire exposure.

In addition to external fire exposure, roofing systems are rated for their resistance to internal fire exposure. For internal fire, the Factory Mutual Insurance Company gives a rating of either Class 1 or Class 2. These ratings are complex with Class 1 being more fire resistive than Class 2. Several tests determine which Class the roofing system meets including construction of a mock roof assembly that is then subjected to extensive flames and fires. If the assembly meets time vs. temperature criteria and flame spread criteria then it is given an approval rating and it is listed in Factory Mutual's Approval Guide.

Cladding Systems Designs

Simply stated, cladding is the skin of the building that makes up the exterior walls. Just as the roof provides the weather and environment resistance to protect the occupants, cladding provides weather and wind resistance on the exterior walls.

Today modern cladding systems may or may not provide structural strength. Current building design practice is to provide a roofing system over a skeleton frame. The cladding system is attached to the sides of the frame while the roofing system is attached to an upper deck.

Early structures used natural materials like stone or wood to make walls. The walls then held up structural members like beams that made up the roof. Later designs did not require the walls to have this same strength. Hence it became practical to reduce or eliminate the structural wall materials. Cladding was needed to provide enough environmental protection in the walls to protect occupants from weather.

Without having to provide strength these cladding systems became thinner and utilized many new technologies for color, texture, cost, moisture resistance, thermal barrier-and maintenance. As with the roofing system, cladding provides an enclosure and environmental protection at the most economical cost.

Trends in cladding systems are changing even more rapidly than in roofing. In more and more cities, facilities are deciding to replace or repair the cladding of older structures. There has been a trend to sandblast the masonry of many historical buildings to remove stains and grime built up over the past 100 to 150 years. In a few installations, the old cladding is being removed and replaced with newer more energy efficient materials.

Cladding then is a thin weather proofing material erected over or attached to the initial frame of a building.

Sheathed Structures with Siding. For a typical siding system sheathing is nailed over the frame. While sheathing can be of several forms the most common consists of a light fibrous board nailed to the exterior. To the sheathing, several types of exterior skin finishes can be attached. Sidings are designed to be attractive and meet requirements for color, texture, and cost. Most of these systems are commonly seen in residential service and use has not been attractive for commercial or industrial construction because wood frame and wood sheathing usually won't meet the fire code requirements for commercial service. In addition, wood framing becomes very expensive compared to steel for taller multi-story buildings.

Insulation for sheathing type cladding systems is attached in batts behind the sheathing and between the framing members.

Other exterior claddings include brick, vinyl and metal siding. Each is acceptable and attractive and are erected by a small field crew with minimal tools. In addition, wood siding is sometimes used as a finish material but it is expensive and requires more maintenance than the brick, vinyl or metal systems. None of these systems has inherent strength on it's own. Hence it is often called veneer.

Masonry. Building cladding includes a variety of stone surface materials that fall into the category of masonry. As a cladding, masonry does not provide the main structural strength which is instead carried by a framing system of steel, concrete or wood. Masonry cladding includes systems of blocks, bricks, natural stone, cut or quarried stone and assemblies of stones such as mortar cemented brick. Cladding not included in this masonry category are precast concrete panels which is discussed separately later in this chapter.

For masonry cladding, the system must be carefully attached to the main frame. This is especially true of brick veneers which can pull away from the basic frame and then crumble/slump and fail. Masonry has good thermal and moisture resistance although some masonry will stain from water runoff and hence care must be taken at the roof to prevent water from running down the face of a masonry cladding system.

Facility managers should recognize that all of the cladding elements have to work together to provide weather protection. As such the exterior finish, attachments used to hold the cladding to the frame, sheathing, flashing, insulation, and sealants, should work together to provide a uniform assembly preventing the natural elements, air and water, from entering the structure.

Brick. One of the very earliest of the exterior structural systems that graduated to become a building cladding was fired clay bricks. Originally, the bricks were stacked and held together with mortar to provide the strength in the wall. The wall then held up beams that supported the roof. Since about the 1950s or so, design practice changed in favor of steel or wood framing systems that held up the beams and the brick became a filler material between the columns. As the brick wall had better insulation characteristics when cast in two wythes (courses) with an air space in between the wythes, builders found it cheaper to abandon the inner wythe of bricks in favor of a wood or metal curtain.

The curtain then held the interior finished wall, the insulation between the frame members, and the exterior brick facing. The brick acted as the weatherproofing material that resisted the natural elements of wind, water, rain and snow.

Brick facings come in many colors from light gray to dark red. In the past, used brick has been a popular cladding material as well. Bricklayers can also create patterns and images from varying the colors of the brick as they are placed in the wall.

Most veneer brick walls are stacked on a sill or base. For a tall wall, an additional sill must be placed to carry the weight of the bricks above. Otherwise a tall wall can over stress the bricks at the base and crush them.

Figure 2-5 shows a typical brick veneer cladding system over stud framing.

Block. Similar in many ways to brick, block can be used either as a structural wall or as a cladding system. Figure 2-6. In addition to exterior cladding, a common application of block is to form a fire barrier between zones in buildings. Block is made from cementious materials poured into molds and allowed to harden. Common block materials have large air spaces that make excellent thermal insulation barrier. Like brick, individual blocks are bonded together with mortar to hold the blocks in place and prevent wind and water from wicking between the blocks. Block is more porous than brick and is generally less costly to install. However, common block is not used as a finish material and because of the porosity of the brick materials, most structures that have block as an outside wall, place a veneer over the outside or inside to reduce wind leakage through the wall.

Care must be taken with block veneers to allow water that gets into the wall to evaporate or to escape. The natural action of freeze and thaw will destroy the base of a block wall that has not had provision for water to wick out of the block and allow drying.

In order to increase the strength of a block wall, some of the block voids are filled with concrete and steel reinforcing. This

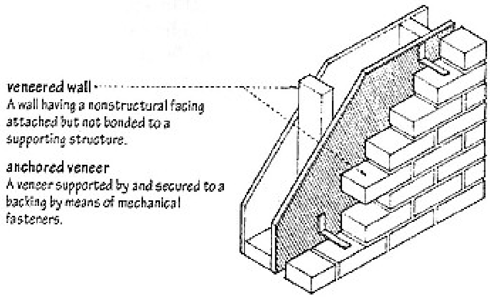

Figure 2-5
A common cladding material, brick veneer over a framed wall.
The brick veneer must have weep holes to allow moisture out,
otherwise water can freeze in the mortar and cause the wall to fail.
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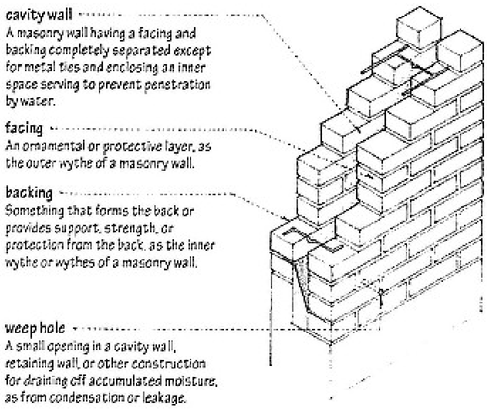

Figure 2-6
For block walls, a brick veneer is also installed to enhance the
beauty of the building's front. Veneer must be attached to the
block wall and weep holes must be provided to prevent
moisture from breaking and eroding the bricks in cold winters.
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effectively forms a structural column within the wall giving it a significant increase in strength. Many building codes do not allow the main structure of walls to be made from unreinforced masonry (block, brick or stone) since an earthquake can cause the wall the crumble. Hence masonry walls must have some form of material, usually steel, to hold it in place when "shaken."

The height of block walls is limited by the strength of the blocks themselves since the weight of the blocks above are carried by blocks below. Higher walls can be built but require detailed engineering analysis to assure they are structurally sound. Support for brick and block veneers can be a concrete foundation or angle clips anchored to the structural frame.

Block is sometimes the main element of the structural frame and in some instances block is left exposed, covered with a brick veneer, or painted. Block is an ideal structural material for commercial buildings in that it combines high fire resistance with comparatively minor expense.

Since block is heavy compared to other fire resistive materials it is not used as cladding between rooms or areas of tall buildings. Lighter materials like fire stopping, gypsum boards and other systems can be used.

Block is also used below ground and coated with a waterproofing membrane like asphalt or tar to make it water tight. In some areas of the country, use of block for structural foundation is not allowed, code officials opting for concrete foundation walls instead.

Finally block comes in various colors although for the cost, one of the other exterior types is often selected because it is considered more attractive.

Stone. Similar to the brick and block walls, stone is another masonry material used for exterior skin. Historically the stone was, of itself, the main strength of the wall but as methods of construction improved, the tendency has been to reduce the thickness of the stone and have it act as the exterior weathering material while internal insulation and sheathing provide more of the weather resistance. A stone veneer can be small 9-inch by 9-inch tiles held together with mortar. Often this type of stone is also used on interiors as decorative finish for fireplaces, entrance halls, and fountains.

One attractive cladding system used for tall buildings is the attachment of thin sliced limestone, granite, or slate. These systems again simulate the look of large monolithic blocks when in fact they are much lighter. Construction with these thin veneers is difficult because the natural sliced material may have weaknesses not apparent without close examination.

Some stone veneers are sliced thin enough to admit light but care must be taken when attaching these thin sheets to the frame. Many building codes require large factors of safety for installing thin stone sheets which makes them expensive compared to glass or concrete panels. However, advancement in technology, notably computer modeling, and non-destructive testing methods are allowing thin stone to be used more often. Some stone veneers are actually synthetic materials made from fiberglass, or tile, but have been specially designed to imitate the look of natural limestone or granite.

One of the most important industry associations that develop standards for brick and block is the National Concrete Masonry Association headquartered in Herndon, Virginia.

Glass. One of the most attractive cladding types for commercial multi-story buildings is glass. See Figure 2-7. In the glass wall, the building is framed with metal members, and glass panels are attached to the frame with clips. In some systems, the glass is enclosed at the edges within a metal frame, usually anodized aluminum and sealed within the metal frame with adhesives as sealants.

Glass also still comes in blocks, and although this type of cladding was popular in the 1930s it has seen continued use and has even seen an increase in use in recent years. Several codes address the use of glass block in interior and exterior wall, and the size of the glass block area is limited by the code.

Glass material used as cladding for windows comes in several forms. Sheet glass is used for windows while sheet, plate, and float type glass are used for cladding. Colors, thicknesses, and varied frames are many of the options available with glass or glazed cladding.

Most exterior glass is sealed into panels which are then erected and clipped to the structural frame. Important coordination is required for glass systems since the metal, glass, adhesive and sealants must all work together to hold the glass in the wind and earthquake loading conditions. One advantage to the glazing concept is that natural light shining through the glass can be used to light the interior of the building, reducing the need for a large number of lighting fixtures.

Glass curtain wall systems are often performance specified.

Figure 2-7
Some modern buildings use glass panels set in metal frames for the cladding system. Photo by author.

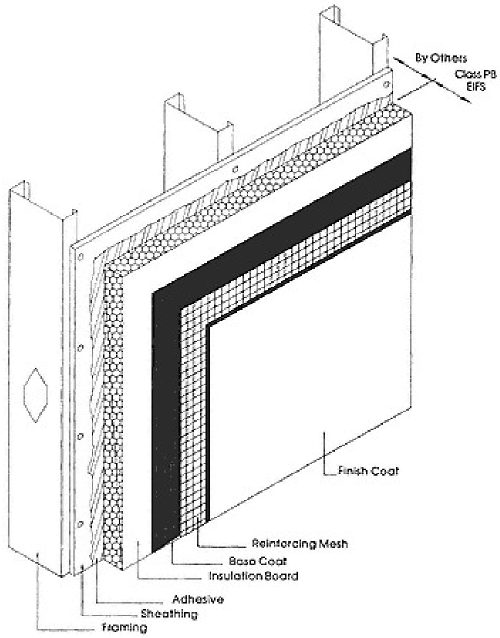
This means that the environmental and operational conditions are spelled out and the glass system is supplied by a combination of manufacturer and erection specialists.

For glass cladding the adhesives are important and care must be taken to make sure the correct sealant is used. Glazing sealants must meet required strength tests, and the sealants must not deteriorate by adjacent materials or weathering. One sealant manufacturer is the DOW Corning Company of Midland, Michigan.

Exterior Insulation Finish Systems or (EIFS). Beginning in the late 1940s when the first Exterior Insulated Finish Systems were imported into the United States from Germany, this type of cladding system has seen continuous growth and development and is currently one of the most popular cladding systems.

EIFS are a manufactured system specially designed as cladding for attachment to building frame.

The exterior insulated system (Figure 2-8) consists of a plywood or synthetic sheet called a substrate attached to a rigid insulation board. Over this a base coat of weatherproofing is placed with an embedded fiber reinforced mesh. A finish coat is applied over the fiber embedded base coat.



Note: Minimum required Insulation Board thickness is 3/4" (19 mm).
Maximum thickness is 4" (100 mm)

Figure 2-8
Details of an Exterior Insulated Finish System. These EIFS have been used in Europe for over 40 years and are becoming very popular within the United States as well. They offer an economical, attractive exterior.
Courtesy: EIFS Industry Members Association, Clearwater, FL.

EIFS can be installed either in panel form directly over the exterior frame or they can be "laid up" by attaching the insulation boards to the frame, then the membrane, reinforced mesh and final finish coat applied in successive layers. EIFS have been subjected to a large number of field tests and their use in the USA is growing at about 10 percent per year.

EIFS are purchased as a "system" from an EIFS supplier that is a member of an industry association dedicated to the manufacture of exterior cladding systems.

Advantages of EIFS include an improved thermal insulating characteristic. By using EIFS insulation on the outside of the structure instead of on the inside wall, the frame is not subjected to the thermal loads of increasing and decreasing temperatures throughout the structure life. In addition, interior insulation systems like fiberglass batts have a tendency to leak because they have to be cut in places for electrical boxes and interior elements. Gaps in batt insulation allows a migration path for the escape of thermal energy.

EIFS are now accepted by the three major code associations, the International Congress of Building Officials (ICBO), the Building Officials Congress Association, (BOCA) and the Southern Building Code Congress International (SBCCI). In addition, EIFS meet the criteria for wind and weather resistance, do not stain, and are less costly than the brick, block, and glass systems previously discussed. Tests of EIFS included salt/spray resistance, mildew/fungus resistance, freeze/thaw adsorption, impact resistance, and an extensive battery of fire resistance exams.

Metal Wall Panels. Another type of cladding system used for buildings are metal wall panels, sometimes called metal sandwich panels. These metal panels, available from a few manufacturers, are a polystyrene insulation material enclosed within two thin metal skins. Averaging 2 to 3 inches thick the panels erect on a metal frame quickly and easily. Usually the metal is a thin gauge aluminum but steel is also used. The exterior of the metal panel is pre-finished with paint. Joints in the metal panels are specially constructed with adhesive in a tongue in groove assembly and adhere to each other readily. The panels have a high thermal resistance and an acceptable fire rating.

One field problem with erecting metal panels is cutting/notching them. The notches have to be sealed with flashing to protect the insulation board from weather attack. Metal sandwich panels probably see more industrial application than commercial. Figure

2-9 Shows a cross section of a metal wall sandwich panel.

Patching damage to these metal panels requires application of waterproofing and then a seal plate is flashed over the penetration. However the metal panels are quite strong and capable of withstanding extreme wind and weather conditions. On one project the metal panels were used for the roofing deck as well. No other roof assembly was needed.

In addition to metal sandwich panels, cladding systems include corrugated metal panels. This type of system requires separate insulation, usually fiberglass batts attached on the inside of the metal panels. This is the common insulation method seen in metal buildings used for warehouses and factory buildings in many parts of the country. These metal walled, metal roofed buildings are adequate for many installations although they don't work well for office type construction because the interior requires extra work to finish. Metal buildings often have a liner panel installed on the inside up about 10 feet from the floor to protect the batt insulation from labor activity at the lower level. Above 10 feet the batt insulation is clipped to the metal skin. Usually the insulation has a plastic skin on the interior to protect the friable fiberglass material from flaking off into the room. Insulation methods and types are discussed in more detail in chapter 5.

Metal wall panels, like sandwich panels must be flashed if cut to accommodate wall penetrations like pipes or light fixtures. Figure 2-10 are photos of typical metal buildings.

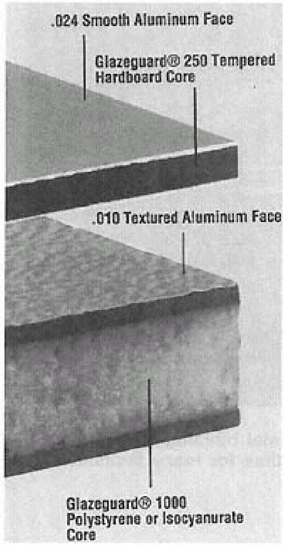


Figure 2-9
On some buildings a metal panel with a foam interior is used for an exterior skin. These panels erect quickly and provide insulation with a finished interior and exterior wall after simple erection over a steel frame. Reprinted courtesy of Citadel Architectural Products, Indianapolis, IN

Figure 2-10
Photo of an economical metal building. These buildings offer low cost and rapid erection time for many facilities. Photo by author.

Summary

Roofing and Cladding systems come in many forms, shapes, colors, and textures and vary in cost depending upon the expected life and visual attraction of the structure.

The choice of roofing and cladding is usually made by an architect or engineer working for the facility manager. Each of the varied systems has special application and repair procedures and some of the systems aren't compatible with some of the building designs.

For claddings, masonry, glass, metal and the more sophisticated EIFS, a facility manager faces a significant number of choices but not all claddings fit with every type of building frame. The same general application applies to roofing. Low or steep slopes, bitumens, single plies, shingles or tiles have to be coordinated with the proper building frame. Given information about the basic frame the facility manager can make exterior finish, thermal and weather proofing decisions carefully. A discussion of the structural conditions and the relationship to the building envelope systems is presented in the next chapter.

Chapter 3—
Building Envelope and Roofing Structure

Replacing Your Roof: Where to Start?

Any roofing project starts with an understanding of the structural frame and decking, that is, what is holding up the present roof. This analysis is especially difficult if there is an existing roof and it has problems. This is because the insulation, waterproofing membrane, and any ballast in place, make it difficult to determine the exact condition of the substructure. However there are a few basic considerations that the facility manager needs to know before even going up onto the roof. This starts with an understanding of what the industry expects and what is required by local codes.

Frame and Deck

The insulation and membrane are placed over the deck which is placed on the structural frame. Usually, beams are placed between the columns and then smaller beams (sometimes called purlins or joists) are placed across the large beams. The distance between columns and beams is determined from the architectural design and is a function of what is inside the rooms. If for example an office is constructed, the partitioning of the office allows the placement of many columns that can be hidden by the office partition walls. On the other hand if the facility is a large hangar for airplanes the roof must be free standing without any columns between each outside wall. The distance between columns is called the span.

As spans become longer it requires larger and larger beams to hold the longer span. For very long spans some other structural techniques are used including trusses, which do the same thing beams do.

In a building, the beams are covered with the decking on top and are usually hidden from below by the ceiling of the finished rooms.

The main beams span between the columns or for some types of structures, between bearing walls. Smaller beams called joists span between the main beams. Across the joists the roof decking material is placed. Figure 3-1 shows columns, beams, and decks.

Some buildings use designs that eliminate the grid of beams and use long straight trusses placed closely together across load bearing walls. These trusses are placed close enough together that decking can be placed directly across the trusses.

The decking is the final structural element in the roofing system. It is placed upon the joists or trusses and is what the balance of the roofing system attaches to. The decking must be strong enough to support the insulating and waterproofing membranes above and there must be enough strength and stability in the decking that the men and the materials work upon the roof without risk of falling or damage to the structure. Remember if all the roofing material is stacked in one spot, the weight can be too much for the beams below.

The deck must also be attached to the outside walls with enough strength to keep the roof from separating under wind or uplift pressures. The roof/wall interface must allow for either pins, nails, bolts, or another bonding method.

Accessibility

For construction of the roof and for later maintenance the roof must be accessible, however, the roof shouldn't be easily accessible because only personnel authorized should be allowed on the roof. Many facilities accomplish this with a small room on the roof called a penthouse. The penthouse is then only accessed from the inside of the building, allowing the facility manager to control access by keys.

The roof has to be accessible to allow the roofing contractor to get to it as well as any maintenance personnel. If any other items are on the roof such as satellite dishes; communication antennas or weather monitoring stations; heating, ventilating or air conditioning equipment; access must be provided to the roof in order to

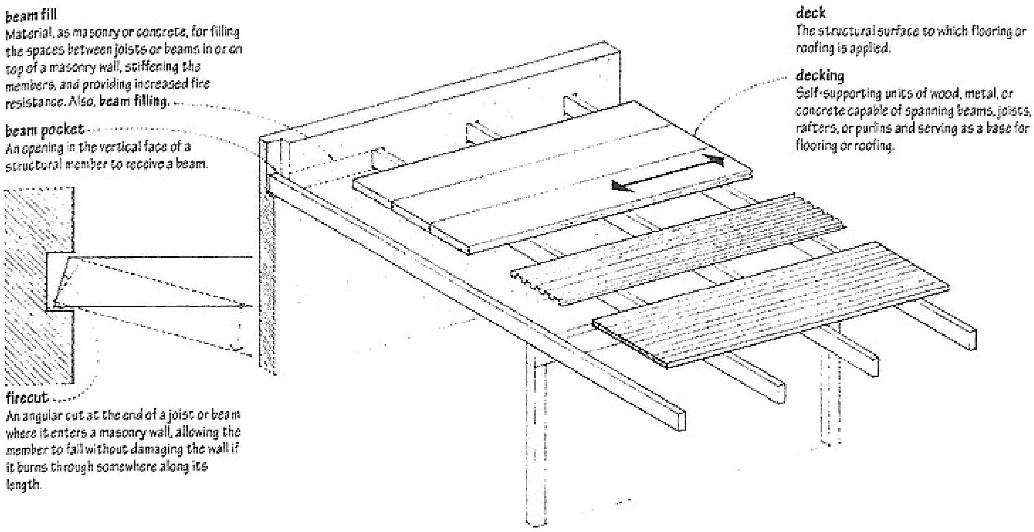


Figure 3-1

The roof substructure is comprised of beams, purlins and joists. Together they from the structure that holds the deck. Reprinted from: *A Visual Dictionary of Architecture* by Francis D.K. Ching service this equipment as well.

Building Codes

The building codes tell designers what minimum loads are to be expected for a building and for small structures these codes provide general rules of thumb. Tables for roofs indicate what spans can be accommodated with certain types of materials. For example, the Uniform Building Code specifies the width of span to be accomplished with lumber 2 inches wide by 10 inches deep on 2 foot centers.

Facilities should be cautious because the Uniform Building Code (UBC), published by the International Conference of Building Officials has been adopted by most western and Midwestern states. In the south most communities use the codes by the Southern Building Code Congress International (SBCCI) and in the Northeast the codes are administered by the Building Officials Codes Association (BOCA).

When a structure is more complex, and most of the ones for facility manager's reading this book are, the code adopts standards from industry. For example steel structures are administered by the American Institute of Steel Construction (AISC) who publish a volume which defines the loads, pins, spacings etc. for steel beams. These codes and the interpretation of them in building design are read and interpreted by civil engineers.

An authorized civil engineer has a license from the state in which the building is built. This license requires the civil engineer to have a degree, at least 4 years of practical application experience and a series of tests that determine his or her ability to determine the application of the codes. The evidence that the engineer has a certification is a stamp or seal that is placed over the engineer's signature on design drawings. The engineer's registration seal has a number on it. This number can be checked for validity by the facility manager by contacting the state board of registration with the license number and asking if the registration is current. The state keeps the records of the engineers qualifications and the results of his/her test scores.

For concrete structures the American Concrete Institute publishes a Manual of Standard Practice sometimes called the ACI code. National associations provide input to codes for other materials such as wood, trusses, decking, sheet metal, etc. Many of these associations addresses and phone numbers are included in Chapter 14.

The Code Associations like ICBO or SCCBI then accept a manual of practice like the ACI concrete code and incorporate it into their code by reference. In turn the code from the model code agency like ICBO or SCCBI is then adopted by the local government, the city, town, or state. This then makes the code a legal requirement. However, not all communities adopt all of the code because of local conditions or local understanding of conditions. This discrepancy between the national code and local code is an area where facilities sometimes run into problems because the company or its managers relocate from one region of the country to another. For this reason designs are often certified by a locally registered professional engineer or architect.

In a small community a city building inspector will look for the engineer's stamp, since the inspector himself may not be qualified to determine if the design meets the code. For unusual or unique structures, the building inspector may forward the plans to an independent engineering firm working for the city or the city may have an engineer who reviews unique plans. The process of local government review cannot be rushed. Plan review is usually is processed through the city planning and zoning department, city building department, or town council.

Building Loads

Dead Load, Live Load, Environmental Loads, Uplift, Seismic

While most of the forces acting on a building are the result of the weight of the construction materials, other forces also affect the structure. These forces include the weight of furniture, people and equipment. In addition, wind pressures, rain, snow and ice also affect the design of the structure. Designers call all of the forces acting upon building, loads. Design of buildings must address all of the loads that are expected in or on the building.

Building codes guide the designer by providing expected loads the building will be subjected to during its lifetime. Roofing systems must support whatever loads occur.

Dead Load. Loads are a combination of what are called the dead loads and live loads. Dead load is the weight of the structure. The roof must be capable of supporting its own weight, hence dead loads are the weights of the beams, deck, roofing, insulation and ballast.

Different materials have different weights and engineers usually make an estimate of the weights, perform a trial design, size all of the beams, deck, etc., then go back and check the weights again. The are many factors to be estimated at this initial stage and sometimes designers estimate several cases. Most engineers use 'rules of thumb' for estimating the weights and, having years of experience, these rules of thumb are adequate.

Dead Loads include any fixed equipment items in the building.

Estimating dead roof loads is a trial and error process, the weights are estimated, the beams and decks and equipment are sized, then the weights are calculated, and then beams and decks sized again. For most buildings this trial and error process only takes a couple of runs because the results of the initial guesses usually prove satisfactory. For unique structures the trials may take longer and for very complicated structures like skyscrapers the study may take several weeks. Designers often use computers with design software containing tables of code requirements. With a computerized system beam sizing goes fairly fast. The engineer uses the computer to look up the correct sizes in the tables after giving the computer program the loads or forces.

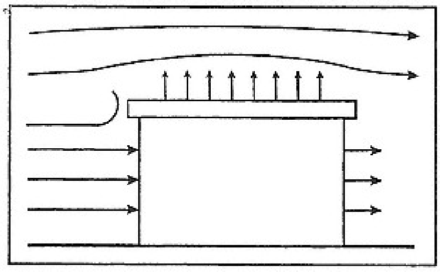
Environmental Loads: Winds, Snow

To the dead loads the designer adds building environmental loads. These loads are also specified by codes. For example the loads from the Uniform Building Code for one region of the country is: 20 psf. This means the load is estimated at 20 pounds per square foot. Loads in other areas of the country are primarily a function of the snow and wind that acts on the structure.

Snow Loads. In cooler areas of the country, snow, rain and ice can build up on a roof to the extent that the roof collapses. The designers estimate snow loads from codes for that area and the estimate is usually a function of the elevation as well as the location. As an example the building codes dictate the design snow load is 30 pounds per square foot for Salt Lake City, Utah.

Wind Loads. Because winds approach from multiple directions these loads are estimated slightly differently. The effect of winds on structures has been studied extensively and what the engineer does with wind loads is estimate the worst case of several different scenarios. Winds are assumed to only act upon the structure from one direction at a time.

Like the snow loads winds are usually estimated with some guidance from the codes. In addition to the lateral force of wind loads, the wind has an uplift effect where the force draws the roofing membrane upward. Figure 3-2 shows how wind loads affect a flat roof.



Wind force striking a building structure

Figure 3-2
Wind on a sloped roof creates an uplift force. The membrane and deck must be heavy enough or attached firmly enough to keep the roof from lifting up. Reprinted from *Drilling and Anchoring Systems Design Manual* by the Rawlplug Company, Inc. New Rochelle, NY.

Live Loads: People, Moving Materials, etc.

Engineers are familiar with the live loads required in their areas. One of the things that engineers do is look at other structures to check their own designs. If a mountain ski resort has wood beams all 4 feet deep and the calculations reveal that the beams for a facility in a similar area have beams two feet deep there may be a load condition the designer hasn't considered. This problem is reduced by having the designer submit the plans to the city or community for review before construction. This way, public officials review the design loads that have been estimated by the engineer. Live loads are added to the dead load since they both act downward.

Seismic Loads

Finally, designers estimate seismic loads. Like the loads from snow and winds, seismic loads are estimated based upon the region. Obviously there is greater change of seismic activity on the west coast than in the Midwest. Seismic zones are estimated from information on a chart like the one shown in Figure 3-3. These seismic loads are figured as a horizontal force, similar to wind load. The force is estimated as a result of ground motion at the base of the building. The method is to put a load on the building horizontally at each floor based upon estimated seismic (earthquake) forces.

Seismic analysis from the codes is fairly complex involving ground motion, wave duration and a host of other factors. With seismic design there is still a lot of theory which engineers are trying hard to validate with results from past earthquakes. Structures that have failed are examined after earthquakes to see what assumptions were wrong. Then the engineering society publishes technical papers to discuss their findings and recommendations are made to revise the codes. Builders sometimes oppose the recommendations because the changes almost always increase the costs of the building. In areas of the country where seismic codes have been revised, many governments have had to deal with either a seismic retrofit or abandonment of buildings because new seismic criteria reveals old structures may not withstand the forces of a major or even a minor earthquake.

Again, once the designers estimate the loads, computers are used to estimate the sizes of the members using tables in a computer database. The weights are checked and the design is finalized.

Ponding

For roofing the designer calculates the deflection of beams in the long spans. As mentioned in Chapter 1 deflection is an important element in low slope roof design because of the ponding problem. As the beams deflect, water is collected. As more water ponds, the weight increases, increasing the deflection more, allowing more water and so on until the roof eventually either stabilizes or collapses. Long span beams, or any low slope roofing structure is checked for ponding. In the American Institute for Steel Design ponding has its own chapter to be addressed by designers before the engineer can give his stamp of approval to the design. Under the combined loads then, the dead and live

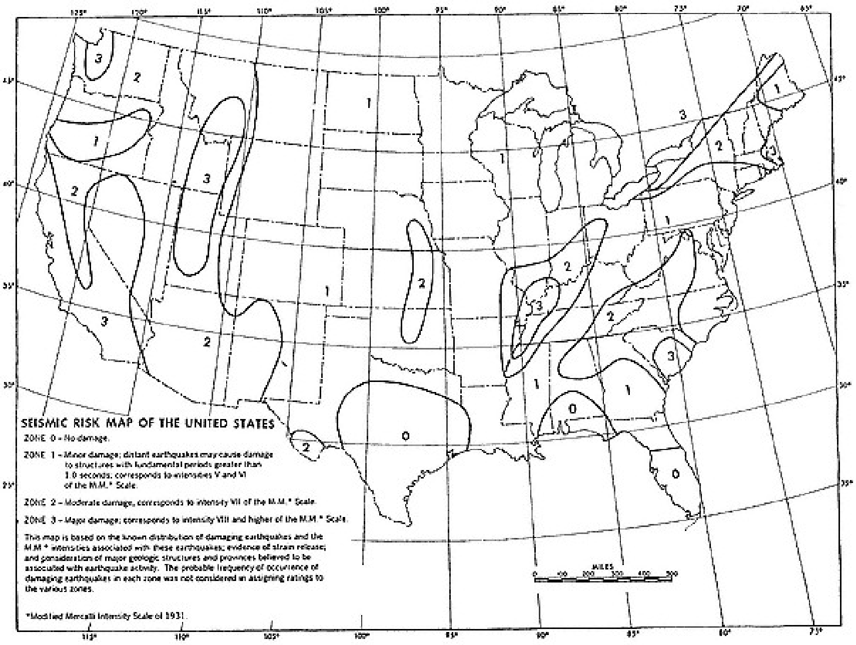


Figure 3-3
Another structure force is the result of earthquakes and are called seismic forces. The building frame is designed to take seismic forces into account. Seismic forces are determined in part from expected earthquake activity from a seismic map such as the one shown here.

loads, seismic loads and ponding, the shapes and sizes of the columns, beams, purlins and decking is calculated. The largest beams from the worst case are chosen. Then the designer may go back and estimate the dead loads again, etc. Most designers know how long it will take them to run through these calculations and with computers the task is much easier.

Drainage/Slopes

Low sloped roofs need to be designed to discard water and a flat roof that does not allow the water to run to the drains will have problems. Because of the deflections in the beam from the building's own weight, no roof slope is going to be exactly flat anyway.

Therefore all roofs should be designed with a slope to provide for drainage even if it is a very low slope. The requirement can be frustrating to the facility manager who has a flat roof because resloping the roof increases the cost considerably.

Some types of roofing systems lend themselves more readily to a change in slope than others. Slope changes can be accommodated by using cant boards underneath the insulation (see Figure 3-4). Another method to provide slope to roofing is by tapering the insulation boards attached to the deck under the waterproofing membrane. Both are acceptable methods in drainage design.

A third option is to erect a sloped roof above existing roof decking. However this option can be expensive since the materials to provide the slope require added design calculations and may involve an upgrade to the beams and columns. One recent trend has been to use metal frame and standing seam metal roofing to make flat roofs into sloped roofs. The metal system is light, compared to other types and can often be accommodated by building frames constructed under older codes. When adding structure to the roof, it is important to check and verify the new roof doesn't increase the loads over allowable limits and verify the modified system does not affect the Factory Mutual rating.

Placing Roof Drains

Often, to the frustration of roofing contractors, the roof drain is placed close to a beam in order to hang the drain pipe from the beam. This design decision places the drain on the roof near the high point at the beam, instead of at the low point midway between the beams. A good design indicates where the low point of

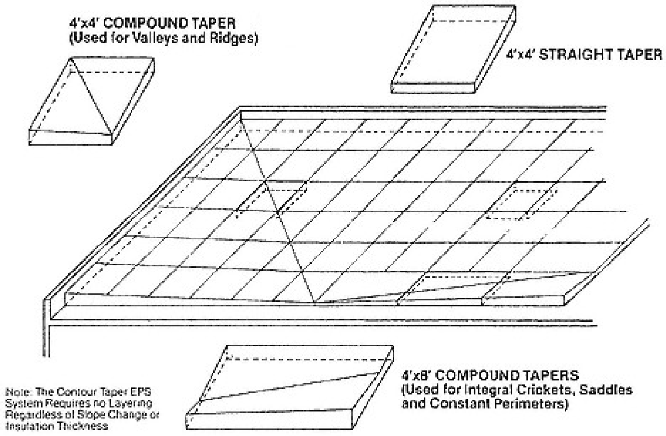


Figure 3-4
Tapered insulation prevents sharp bends in roofing membranes and help the roof to drain.
Courtesy: The Science and Technology of Traditional and Modern Roofing Systems,
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the roof is and indicates the roof drain will be placed at that point.

Aside from the many problems roofs have as a result from weather, wind, rain etc. the most significant is roof drainage.

Ponded water allows the growth of insects, fungi, mold, or mildew. Also, ponded water can penetrate the seams of the roofing system causing minor leaks. Other kinds of leaks get through the waterproofing membrane and allow water into the insulation.

Although no visible water leaks into the finished areas of the building, wet insulation allows heat to escape and reduces the energy efficiency of the structure.

For a low sloped roof two drains are recommended for every 10,000 square feet of roof area. Roof drain maximum spacing should be less than 75 feet. Ideally drains run to inside the building which keeps the plumbing piping inside and helps to prevent ice buildup in the piping. The size of the drain pipe is a function of the area being drained and the estimated intensity of rainfall. The drain has a strainer that keeps large debris particles out of the pipe. Most commonly roofing drains are 3- to 6-inch pipe.

When specifying pipe size a slightly larger pipe diameter allows debris to pass through it more readily.

Case Study: Concrete Beams Pose Construction Problem with Integral Deck

A building with a concrete deck was being constructed where the roof was designed to slope at 1/4 inch per foot to allow for drainage and to keep water from the decking. The roof was planned to be covered later with a sprayed polyurethane roofing system. The interior concrete finish had to be strong and smooth so the architect chose a reinforced concrete system to be the deck and ceiling. Beams were to be cast monolithically with the roof deck. However because the top of the roof deck was sloping the beams required reinforcing bar stirrups throughout the beam length. As the beam and floor were integrally cast, each stirrup had to be a different height to accommodate the sloping roof. This meant that each of the stirrups, shop fabricated, had to be tracked individually on the job site in order to make sure the right height of stirrup went in the correct location. This led to a lot of running around on the job site because the men installing the reinforcing bars were not told each stirrup was only for one location. The problem was compounded when there were multiple beams for different floors all with different stirrup sizes to accommodate the slopes of roofs and floors. Delays resulted from not being able to locate the correct number of the right height of stirrups. For the next project the architect committed to a beam of a constant depth and the sloping deck was allowed to sit on top of the beams. The deck was reinforced with wire mesh.

Case Study: Roofing Failure Leads to Replacement of Building and Equipment

A warehouse constructed in 1947 housed a water tube steam boiler used for heating a complex of buildings with steam heat piped underground throughout the complex. The firebox of the boiler was fire brick. Lack of preventive maintenance of the building roof and a heavy snow load led to the failure of a large old wooden truss immediately over the boiler. The truss cracked and allowed the roof to pond. A leak developed in the roofing membrane over the boiler. When the weather warmed, the ponded water ran through the cracked membrane into the building in a steady stream that ran into the boiler brick. Water eventually penetrated into the boiler firebox and turned to steam, pressurizing the water within the brick, destroying it. The boiler was shut down but attempts to dry the brick were abandoned when inspection revealed the steam heating of the bricks had fractured nearly every brick in the entire firebox. The building along with the boilers was abandoned and had to be replaced along with a down-turn of activity in the entire complex because of cold conditions and minimal heat being provided. The staff attempted to make do with electric space heaters throughout the complex but the old wiring would not support much of the additional heating equipment.

General Design Shapes

Most discussion faced by facility managers will be for roofing of low sloped roofs which account for a large percentage of facility roofs. Steep roofs account for approximately 70 percent of the roofing industry while low slopes account for the other 30 percent. However over half of all roofing problems are attributed to low sloped roofs.

Steep roofs are often used for buildings with shorter spans because the increase in material needed to accommodate a steep roof for long spans adds significantly to the cost of the structural frame.

Low-sloped roofs have beams or trusses that make up the substructure and then purlins and decking to complete the envelope. Trusses are open webbed frames of long span that function like a beam but are deeper than beams and are lighter, hence less expensive. Beams and trusses come in standard shapes from standard industry suppliers. Concrete used as beams can be formed and poured at the job site and the concrete deck is poured integrally with the beams.

Concrete decks have joints as it is not feasible to pour the deck continuously without stopping. Where a "pour" is halted there will be a seam between the old concrete and the new. This is called a cold joint. One thing to note, it is almost impossible to construct a concrete deck slab without small cracks developing. Usually, since the roof has a waterproofing membrane above it and reinforcing steel bars inside the concrete, these small cracks do not matter.

To encourage drainage, low sloped roofs can be partitioned into drainage areas divided with area dividers. Large buildings with flat roofs will use parapet walls to protect the roof from high winds and uplift pressures. The height for parapet walls is between 18 inches and 5 or 6 feet and is a function of the roofing system and sometimes the result of wind tunnel testing. A parapet is an extension of the wall above the roof level.

Other roof shapes include rounded which is complex to roof because of the difficulty of finding a decking material to accommodate the rounded shape. Capitol domes are usually copper clad since this material bends to fit the frame, however, copper is expensive compared to built up roofing membranes. Domes can be covered with shingles, tiles or slate. In addition to domes, rounded roofs include half cylinder. These structures are usually metal erected over a metal or concrete frame.

If water is to be drained from the roof through exterior parapet walls, scuppers are installed to allow the water through the wall. Figure 3-5 shows a brick parapet wall with a scupper. Note that the scupper is designed to carry water away from the wall to prevent the water from staining the brick.

Another structural element encountered in the roof is an expansion joint between two major building elements. The expansion joint allows differential movement between building slabs and it is usually installed to prevent cracking of the building from shrinkage or expansion of the various structural elements. Expansion joints usually project up through the wall

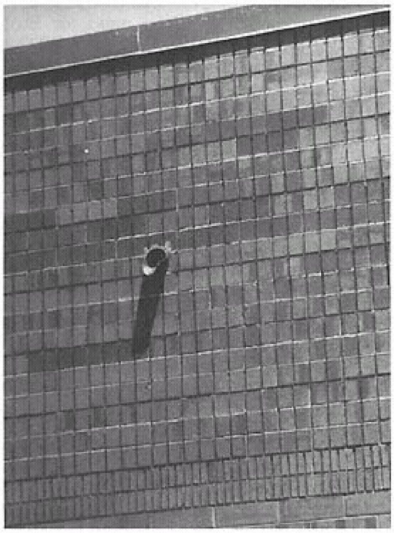

Figure 3-5
Drainage from low sloped roofs with parapet walls accomplished with a penetration through the roof wall called a parapet scupper.
Photo by author.

and have special flashing covering. Sometimes they can be integral with the wall and have a cast in place PVC waterstop and then sealed with bonding sealant. Figure 3-6 is a photo of a flashed expansion joint. Figure 3-7 is a schematic of the flashed expansion joint showing how one is assembled.

Summary

Now that some of the basic shape and regulatory requirements of roofing and cladding systems is known, the next step to understanding a roofing system comes from understanding the limits and possibilities of the main types of construction materials. Some materials will be compatible with a new roofing system, while others will not be compatible without major remodeling. The next chapter discusses the limitations of the frame materials and how they interface with the cladding and roofing systems.

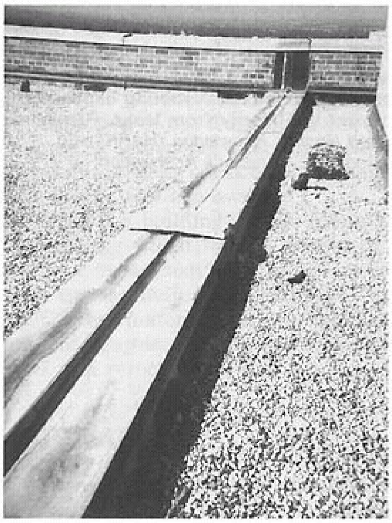

Figure 3-6
A flashed building expansion joint allows the deck and lower structure to expand and contract without affecting the roofing membrane above it.
Photo by author.

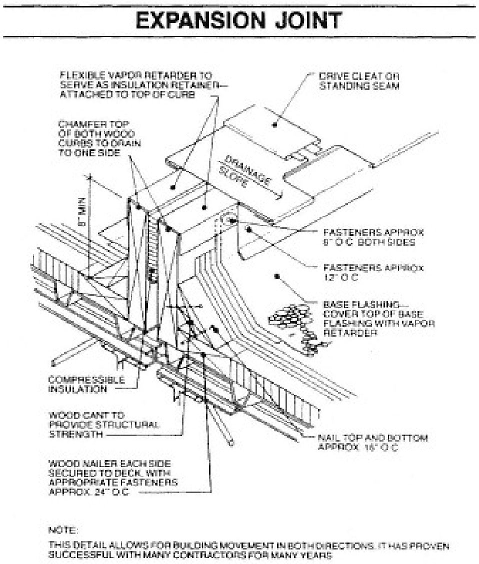

Figure 3-7
Roof decks have expansion joints that allow different portions of the deck to expand and contract. A roofing expansion joint has to be flashed to protect the interior from leaks.
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Chapter 4— Roofing Construction Materials

Framing Problems

In the previous chapter the facility manager was presented with the various types of roofs and cladding systems. Armed with information on what types of roofs and cladding systems there are the facility manager can inspect the facility and determine which type of system he has. However, if a remodel is contemplated and the tear off and replace decision is being weighed against the recover option, the next step is to determine what type of substructure exists for the roof and/or cladding system and determine whether the main frame is sound.

In order to make this determination the facility must conduct an inspection of the framing members described in the previous chapter to determine what the decking material is. In addition the drainage slope needs to be evaluated to make sure water that falls on the roof can escape.

Since the building's main frame plays a significant role in determining which roofing system to use and how the roofing system can be modified, the facility manager will profit from a basic understanding of what types of construction materials are used. These materials support the insulation and membranes of the roofing system and can account for a significant portion of the costs in a reroofing project.

Materials

There are several types of roof framing and decking materials that were touched on in the previous chapter that are used to give the building its basic shape. The cost and useful life of these materials vary but all of the ones mentioned here provide service life of at least 100 years and are light enough to be placed on the roof and strong enough to give the strength needed to provide for the structure. The frame and deck must be sound to carry the insulation and the waterproofing membrane. Several types of systems can be used to protect the waterproofing membrane and the frame and deck must hold all of these in the most extreme and adverse conditions. In addition the deck must be smooth enough to avoid puncturing the waterproofing membrane.

The materials discussed here apply equally well to the deck and the framing members although most of the discussion is oriented to the deck. Failure of framing members, although discussed, is a matter for evaluation by civil engineers.

Wood

One of the oldest of the construction materials, wood provides strength, flexibility and resists pulling apart adequately for many common building applications. Long wood members such as the ones used for beams are difficult to obtain and expensive since a beam made from a single piece of wood requires a large tree and the material must be hauled many miles. Long single piece beams are also difficult to haul to the building site and such, smaller pieces of wood are used and combined to make a system that will hold the loads.

While a complete treatise on wood frame building design is beyond the scope of this text some limited information here will aid the facility manager in making roofing decisions.

Wood framing members are fabricated at lumber mills wherever there is an adequate supply of forested trees. Not all trees however make good framing lumber because some types of trees are not strong enough to provide the necessary strength. Generally, fast growing trees have a large open cellular structure that limits the strength of the wood. Slow growing trees such as oak have a dense structure that makes excellent framing. Softer woods, though still adequate for framing, are certain types of evergreen trees such as spruce and fir. Some types of pine are also acceptable. An added advantage of evergreen woods is their resistance to rot and beetle infestation, both problems that can ruin wood structures.

Standard wood framing members are cut from timber at mills. These members are 1-1/2 inches wide and 3-1/2 to 15-1/2 inches deep. They come in even lengths. An example is a two by four (actually 1-1/2 by 3-1/2 inches) eight to sixteen feet long. And the price for lumber generally increases with the length of the board. For example two boards each 10 feet long will sell for less than one board 20 feet long even though each contains exactly the same amount of wood. These lumber pieces are most often used as joists and they are placed in a structure every 18 to 24 inches. Above the joists the decking is placed. Spans of this type of framing are limited to about 24 feet. Beyond this span, a different type of material is used, either a truss made from wood or metal or a steel beam.

Longer wood beams are made from glued/laminated timber. These beams are usually assembled in the shop where the wood is treated before gluing. Strict quality control is required as the wrong type of glue or improper application of the glue to the wood can weaken the members. Glued laminated beams are much larger, span a greater distance and carry more loads. These kinds of beams can be as much as 12 inches wide by 48 deep and 40 feet long. Solid timbers that are not glued and laminated can also be purchased but they must be specially ordered and it may take several weeks or even months to obtain the wood.

Wood beams and columns are often treated with chemicals to make them resistant to moisture, to prevent their drying excessively and becoming brittle, to prevent fungus, dry rot, mold, and beetle infestation. Sometimes wood is also treated to make it fire resistant, however, both treatments cannot be obtained on the same members.

To have longer spans than can be done with laminated beams, wood trusses are used. Wood trusses are less expensive than laminated beams, Figure 4-1. Wood trusses are assembled from common wood types although for many trusses knots in the framing members are not allowed. Forces in trusses are scientifically analyzed using structural modeling techniques. Trusses are extremely strong and lightweight. As with joists, wood trusses are placed 18 to 36 inches apart and the decking is placed on top of the truss. The most common wood truss is seen framing a residential roof but smaller commercial buildings can also be framed with wood trusses.

It is generally difficult to obtain curved framing members from wood although a few special mills will provide such specialty framed members upon request. To create a curved wood piece, wood is steamed to make it pliable, then it is stretched over a

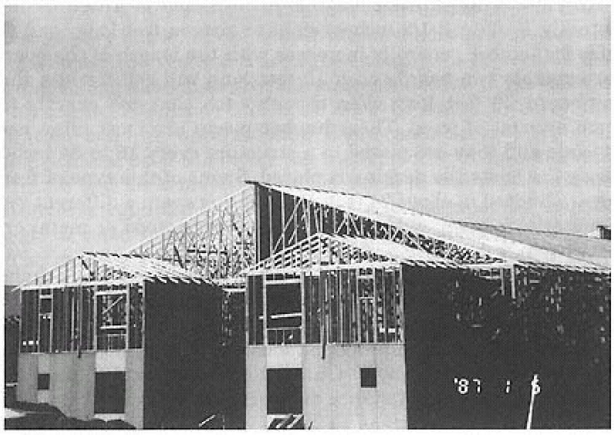

Figure 4-1
A common frame element for commercial buildings is the wood truss.
The wood truss is light, easy to erect and inexpensive.
Photo by author.

preformed metal jig and held in that shape until it dries. This is a time consuming process and it is costly. Other materials work better for this application than wood. Steel, copper and aluminum are better examples and are discussed later in this chapter.

Finally, on occasion a builder will stretch a board and fasten it into a curved shape with nails or screws. However, over an extended period of time the wood will try to spring back to the original straight position, pulling out the nails. This straightening is a problem and requires regular maintenance to reattach the curved boards. In a wet climate the board will eventually relax and stretch to conform with the curved shape, but in a dry climate the board can split or crack. Also, by steaming the boards, some building inspectors and designers believe this weakens the wood and gives it less strength. Therefore they may require thicker, heavier members to accomplish the same strength as straight timber members.

Plywood. For decking, plywood is often used. Plywood is formed by taking thin sheets and layering them together with special glue to form a composite board. Plywood can be obtained with a smooth finish on one or both sides. Most roof decking material of plywood is of three grades, exterior, exposure 1 or exposure 2. Exterior glue is used for roof decking because it is water resistant. Lack of exterior glue can lead to warping the wood if it gets wet and the lamination separates, weakening the deck.

Plywood decking comes in several thicknesses, 3/8 inch, 15/32 inch, 17/32 inch, 19/32 inch and 1 inch thick. The thinner materials are not always used for decking depending upon snow and wind loads. The plywood comes in 4-foot by 8-foot or larger size sheets.

Case Study: Lack of Plywood with Exterior Glue Leads to Construction Fatality

In 1973 on a project in Colorado a contractor was using temporary 1/2 inch thick decking for a platform of a railroad trestle 80 feet above ground. Although the plywood was outside the material did not have exterior glue. Over the winter rain and weather had weakened the deck allowing the lamination in the plywood to soften. When walking on the decking it sagged as much as two inches between the beams. A workman jumped down from one of the rail cars and crashed completely through the deck. He died when he fell onto rocks below the trestle.

Finally, decking can be made directly from wood planks. However, this type of wood use is rare for modern buildings because knots and irregularities in the boards form an irregular deck. Sometimes planks are laid end to end across purling. This leaves a tiny gap to be covered by the waterproofing membrane. Generally, wood plank decking is more expensive than plywood decking. Planking is sometimes laid down with a special notch fitting in a groove in the preceding board. This material is called tongue and groove decking.

Wood is grade stamped at the factory and the stamping is checked by the Engineered Wood Products Association or the Western Wood Products Association. Decking wood can sometimes be inspected from the underside by pushing up ceiling tiles or pulling a hatch cover. Wood that is too wet from the mill has a tendency to twist as it dries, therefore builders are careful to make sure the wood is dry when it comes from the mill. In addition, the wood must be stored properly because allowing to become soaked at the job site can lead to the wood warping as well.

Wood Fasteners. All of the wood discussed can be fastened with either nails or screws although the recent trend has been in favor of screws. For connecting large beams a steel plate is fabricated to carry the stresses from one wood beam to the other. This steel plate is called a gusset which is bolted to the wood beams. On the smaller trusses the gusset is stamped out of sheet metal and it is pressed into place. Nails are used to fasten framing boards together and veneer wood claddings and plywood roofing is often stapled in place. Nails, screws and staples must be the right size for the piece of wood. If the fastener is too large it will split the board. If too small it will not penetrate far enough into the board it is attaching to and it will pull out. Finally, a nail must be large enough around to allow it to be driven in without bending. Many builders now use pneumatic (air driven) guns to drive the nails. Pneumatic guns are also used to drive wire staples for holding decking and cladding.

Building inspectors check to see that the right number and size of nails are being used since the strength of the roof depends not only upon the strength of the wood but upon the fasteners as well. Too few fasteners will allow the decking to work loose from the wood beams. Too many fasteners are a waste of money. The heads of nails, screws or bolts must be recessed into the wood on the roof, otherwise the heads can puncture the waterproofing membrane. Usually framing nails are made from steel. If the

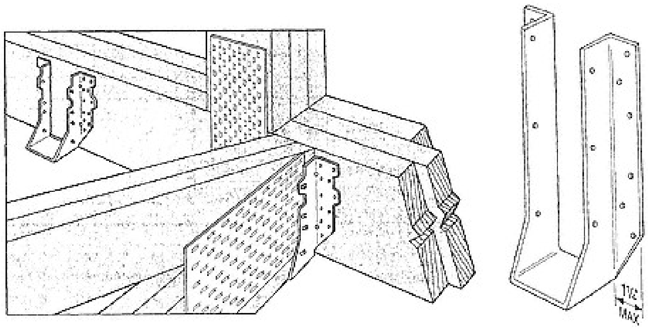

Figure 4-2
Beam and joist clips are used to attach wood framed members together. These clips have proven most effective at allowing the structure to be framed quickly and effective. Moisture can damage these clips over time and result in a significant maintenance cost to the facility to repair. Courtesy: "Wood Construction Connectors" Simpson Strong-Tie Company, Inc., Pleasanton, CA.

nails are exposed to the weather then they are treated with corrosion resistant zinc called "galvanized." Galvanized fasteners will be shiny gray while regular steel fasteners will be dark gray or almost black.

For steep roof decking with plywood members, framing clips are often used. These little metal clips hold the plywood sheets while the nails are driven. "H" shaped clips are used to reduce plywood deflection between adjacent sheets at mid-span. For decks, joist clips are used to hold joists to beams. See Figure 4-2 for an example of a manufacturer's joist clips.

Metals

While wood is an excellent construction material for many of the smaller commercial buildings and it is excellent for residential work, it is not the structural material of choice for larger commercial facilities and industrial uses. Metal members are used in many commercial and institutional facilities.

Metal can be used for the basic frame, for parts of the substructure, for the roof decking, and metal can even act as the waterproofing membrane itself. There are many types of metals: steel, aluminum and copper are the most noteworthy examples. Copper, lead and some other metals are sometimes used on roofs for water shedding but are not strong enough for decking or are too expensive to be used in large sheets.

In addition to the main structural elements, alloys of metals are used for water shedding. Processes are also used that combine metals with other materials to make them more weather resistant and architecturally attractive. Alloyed metals such as zinc, brass, and bronze are occasionally used but for most facilities this type of application is rare.

Steel. Of all of the building materials, steel is the most widely used, although for roofing its inherent problem of rusting requires it to be coated to be used for the outer skin of a building. Tall buildings usually have a structural skeleton made from steel and decks are often made from steel using a Special ribbed metal. Sometimes a metal deck is used in conjunction with concrete to form a composite deck that is both strong and lightweight.

The steel skeleton frame has its main structural members made according to standard specifications written by the American Institute of Steel Construction (AISC). The beams are standard sizes and shapes and are available from standard mills throughout the United States. Structural metal shapes are made in mills by taking the steel and heating it until it is malleable. The metal is then rolled into longer and longer bars and finally rolled into shape through rollers with special dies.

The most common types of steel skeleton members are the H beam and the I beam, so named because of the shape of the end of the beams. In addition, designers also sometimes use pipe (round) or tube (square) shapes for the main members as these are more attractive or meet needs more readily than the H and I shapes. Other structural shapes include channels, "C" shapes; angles "L"; "S" and "Z." The AISC's manual of standard practice is used by engineers throughout the world to specify the sizes and shapes of beams, columns and other frame members used in buildings. Figure 4-3 shows standard steel shapes.

Connecting Steel Beams. Once the sizes of the members are chosen, the designer specifies the method of connection of the various beams to the columns. For tall buildings the connections are either bolted or welded. Like the designs of the beams, the loads are estimated and the connecting methods chosen for strength and simple erection. Bolts are chosen and made in the same way as the beams. Bolts come manufactured to close tolerances from steel and must be tightened to specified parameters. Usually, during construction the inspector checks the bolts very carefully to make sure the correct bolts are being used on the job.

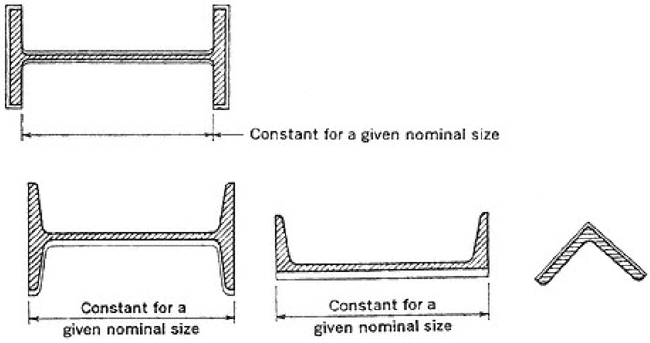

Figure 4-3
Steel framed structures use standard shapes such as H beams, I beams, and channels. Courtesy: The Manual of Steel Construction The American Institute of Steel Construction, Inc. NY Copyright 1990.

Welding. Other than bolting, welding can be used to attach the members together. Welding of structural steels is a special art requiring that the men who do the welding have some training in the welding process. There are many types of welds and welding texts exceed the size of this volume so a complete treatise on welding isn't included here. Generally, if the facility is welding structural steel, make sure an expert advises the facility on the process. Problems encountered with welding include: use of the correct material, qualifications of the welders, application of the weld, length and depth of the weld, voids or cracks, and a host of others.

In a building with welded members, beams are lifted into place with a crane or hoist, then an ironworker climbs up to the connection and tacks the beam into place. Once tacked the beam is then fully welded into place with the same welding equipment. Figure 4-4 shows some types of welds from the AISC manual.

Guidance for welding comes from The American Welding Society, (AWS). Like the AISC, the AWS publishes standards, criteria and specifications for all types of welding in industry and construction.

Testing Welds. For structural welds three types of nondestructive testing are used to make sure the weld has adequate strength. At least one of these non-destructive types is recommended for all welds because many weaknesses in welds cannot be detected by human observation with the naked eye.

X-ray or Gamma ray testing, magnetic particle testing, and ultrasonic testing are all methods used to look for cracks or voids left from the welding process. Each one has advantages and trade-offs. The most effective is the X-ray test, where film is placed behind the weld and a gamma ray camera is used to ex-

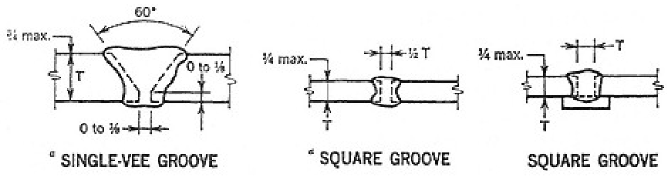

Figure 4-4
Steel frames are either bolted or welded together. Welds are classified according to type and are a significant element of a steel building's frame.
Courtesy: The Manual of Steel Construction The American Institute of Steel Construction, Inc. NY Copyright 1990.

pose the film. After developing, any weaknesses in the welds show up as white specks on the film and the welder then grinds out the weakness, and welds again. The weld is then re-shot with x-rays and checked. For high quality structures the films are kept with the construction documents.

Magnetic Particle Testing uses a film spray on the weld. If there is any crack the spray turns another color revealing a weakness in the weld. Ultrasonic uses a similar method but can penetrate deeper into the weld than the magnetic particle test. Each procedure requires special equipment and training on the part of the tester.

Metal Decks. For decking, steel plates and grating are sometimes used, but these are for decks and not usually for roofing. Plates can be checked or dappled to prevent slipping when walked on. Grating is sometimes chosen because it won't allow snow buildup and it allows visibility between floors in large industrial applications like processing plants and factories. Steel plate is rarely used for the roof deck as it is expensive compared to materials specially manufactured for roof decking. Plating does not have joints suited for the application of a waterproofing membrane and it gets very hot when exposed to the sun, melting or breaking down the polymers in the waterproofing membrane unless insulation is used. Plate also is subject to rusting which is not practical for roof decking material unless it has been galvanized or painted to protect it.

One of the difficulties with constructing steel deck over wood frames is the method of attaching cladding and roofing to the metal frames as opposed to using wood fasteners like nails or screws. For most steel frame applications special clips are attached to the steel and then decking and cladding is attached to the clips. In addition, some beams will have a lighter piece such as an angle bolted to the heavy beam. Then metal screws or bolts are driven into the angles to hold metal decking or claddings.

Fire Protection of Structural Steels. Many structural steel shapes require fire protection to keep a fire from weakening the steel and causing structural collapse. Fire protection can be sprayed onto the surface of the metal with a sticky noncombustible binder or the beams and columns can be protected by enclosure in a non-flammable/fire restive cladding. Sprayed on fire proofing is used for non-exposed members while a double layer of gypsum board is often used as cladding where the sprayed fire proofing is not practical. Not all of the structural steel beams require this fire protection, only the essential ones depending upon the fire resistive characteristics of the building.

One of the most common fire proofing materials sprayed on structural steels in the past has been asbestos. Asbestos is a white, gray, or blue fibrous material that was sprayed on steels and tanks to act as insulation and fire retardant. Because asbestos was thought to be inert and it was a good insulation material it was used extensively in the buildings and construction industry throughout the 1940s, 50s, and 60s. Beginning in the early 1970s asbestos became suspected as a health hazard and standards for exposure to airborne asbestos fibers were published. The removal of asbestos is highly regulated, requiring trained workers and special clothing. Disposal of the material is also rather expensive.

For a more detailed analysis of fire protection of structural members in buildings, the Fire Protection and Prevention handbook in this series is excellent.

Sheet Metal. Like structural framing, sheet metal is often made from steel or galvanized steel. While structural steel is usually 1/4 inch thick or thicker, sheet metals are thinner and lighter and terms of thickness are expressed in gauges. For example 18 gauge sheet metal is 0.0478 inches thick. See Table 4-1. The larger the gauge the thinner the metal. Steels can also be coated with various waterproofing materials to prevent rusting including coal tar epoxy, paint, and galvanizing.

For roofing and cladding, thin metal sheets are rolled or stamped into a waffle shape giving it strength and resistance to

Table 4-1 Sheet Metal Gauges

Gauge	Thickness (inches)
8	0.1644
10	0.1345
12	0.1046
14	0.0747
16	0.0598
18	0.0478
20	0.0359
22	0.0299
24	0.0239
26	0.0179
28	0.0149
30	0.0120

bending. Corrugated sheets were then galvanized to prevent rusting. Today, special shapes are rolled and stamped to fit together snugly to eliminate leakage and they are coated with special acrylic paints or anodized to protect them from water.

One of the newer trends in the roofing industry has been to use metal panels attached to thin metal trusses with clips. The shapes are often referred to as standing seam metal roofs. The standing seam joint is above the plane of most of the roof surface and out of the moisture and water. A figure of a standing seam metal roof panel is shown in Chapter 5, Figure 5-6. Standing seam metal roofing is discussed extensively in the next chapter.

In addition to use of sheet metal shapes for cladding and decking, sheet metal is also used for counter flashing to protect the edges of openings and the ends of roofing membranes.

Fastening. Corrugated sheets are often screwed into place using a special screw with a rubber washer that prevents the hole caused by the screw from leaking. Over time these rubber washers wear out, allowing the roof to leak. In addition to screws, fasteners include nails, and various types of bolts. Fasteners are discussed at length in chapter 7.

Aluminum. Making strides against structural steel, aluminum is being used more and more. Like steel, aluminum can be used as structural members, roof metal, decking, and plating. Aluminum is not as heavy in unit weight as steel and it requires much more careful fabrication than steel to achieve maximum strength. Modern buildings will continue to see use of more aluminum.

Aluminum is also used extensively for the framing of large cladding glass windows. The aluminum is anodized to have a color similar to the glass so that the entire surface appears made from the same material. Anodizing is an electroplating process where the color is infused into the surface of the metal. One of the advantages to aluminum is that it does not rust as iron and steel will. However, it is not as flexible as steel and will crack if excessively flexed. Aluminum is also rolled in flat or corrugated sheets for exterior cladding or roofing.

Other metals. Other metals such as bronze, tin, lead, and zinc have been used in buildings. These metals are most often used as thin sheets used for coating of domes or spires.

One material rarely seen today but used extensively in the past was cast iron. Cast iron was used before the process of rolling structural shapes was fully developed in the early part of this century. Recognized by its dappled surface, preparing cast iron shapes was an art that has been lost in modern times. Cast iron elements were made by making a pattern of the part out of wood, then the pattern was pressed into soft sand and molten iron poured into the pattern left in the sand.

As beams got bigger and bigger it became more difficult to pour the cast iron piece in one pour. Probably one of the most striking structural members known to the author are the trusses used to hold up the dome of the nation's capital. These curved, cast iron trusses were poured and erected in a radial pattern. Capitol visitors are sometimes allowed to go to the cupola by a special stairway hatch and stairway between the inner and outer domes.

Curved Shapes. For unique curved shapes, metal is a more attractive alternative than wood. Thin metals can bend and retain their strength more readily than wood and the welded method of attachment lends itself to fewer fastener pull out problems than are normally encountered in wood. Curved shapes can also be ordered from the mill and for the cost, metal is usually less costly than wood for the same strength.

Trusses and Space Frames

Both metal and wood can be used to create trusses. A truss is an assembly of wood or metal components into triangle shapes to act as a beam for a long span. Many old bridges were constructed of trusses although their use is limited today. For large buildings with long spans, the truss remains one of the most attractive and economical means of providing the structural support needed for the roof decking. Trusses are usually one dimensional, mostly because their design is easy to analyze and they can be stacked and shipped easily. Trusses are made from steel or wood or sometimes a combination of wood and steel.

Like the standard framing elements of steel members and wood members, several truss manufacturers publish catalogs of the trusses they have that are commercially available. Figure 4-5 shows a photo of metal roof framing trusses in a small commercial building. These trusses are ordered, trucked to the job site and erected between the columns as beams or between the beams as joists.

In addition to trusses which are more or less flat, a space frame is sometimes constructed for very long spans such as ball stadiums and sports arenas. Space frames use the individual

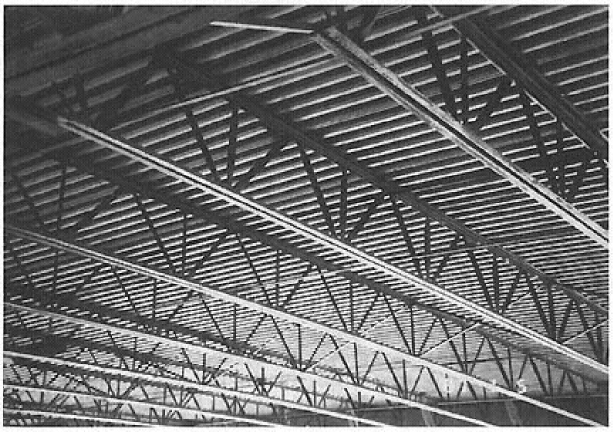

Figure 4-5
In addition to wood trusses for commercial buildings, some designers specify metal trusses. Photograph by author.

members to span a great length in the same way a beam does. Use of space frames is much more complex than trusses but they in effect do the same thing. Engineers use computer modeling techniques to analyze the stresses and strains before the trusses are erected. Trusses and space frames hold the roof deck up and also the ceiling below. For large stadiums and theaters, trusses may be left open and can be examined when attending the event.

Trusses and space frames are subject to the same problems and forces as other structural framing members. Rust, rot, drainage, etc. They can be bolted or welded at the ends. Many long trusses will be pinned or welded at one end while at the other they are fitted into a large complex slot that allows that end to move when heat expands the truss and makes it longer.

Concrete

Like wood and metals, concrete is the third main structural element of buildings. Concrete is a special mixture of cement, sand and stone. By mixing the cement with water and aggregate it is initially plastic and it can be poured. After a setting period of a few hours or days, the mix material hardens and becomes self supporting. The cement dissolves the surfaces of the aggregate and attaches to it making the concrete a uniform hard mass stronger than brick or block. The strength of concrete is determined by three factors.

First, the stones must be strong enough. Therefore certain types of sands and gravel are not acceptable. Second, the proper type of cement must be used. If the cement is of poor quality then the concrete will be weak. Finally, if too much water is used in the mixture, especially if added to make the concrete flow, it weakens the strength significantly.

Concrete has been used since ancient times for the building of structures and since the early 1930s use of concrete with steel bars has become a common construction material known as reinforced concrete. Both concrete and reinforced concrete are used as the structural elements of buildings because of strong weather resistance and resistance to fire. Concrete is also used for slabs in floor and roof decks.

Concrete columns, beams and slabs can be fabricated in a shop and shipped to the job site where they are erected and fastened together, or forms can be erected for holding the soft liquid concrete material until it has set at which time the forms are removed leaving the complete frame in place. As such, concrete is one of the more attractive construction materials for curved shapes since the forms are temporary and the concrete when hardened holds the curved shape.

Fastening. Reinforced concrete uses steel bars to tie the concrete together. For example, in fabricating concrete columns steel reinforcing bars are left projecting out of the top of the column, and are then spliced into the steel bars used for the floor or roof deck. Concrete is then poured for the decking around the bars. When hardened, the whole mass is rigid giving the structure extra strength.

When one pour of concrete is allowed to harden and later a second pour is made next to the hard one, a thin joint is left between the two pours. This thin crack is called a cold joint.

A method other than a cold joint for fastening concrete beams and slabs is through the use of bolts and nuts. When this method of attachment is used the end of the concrete beam has an exposed plate welded to the reinforcing steel. The plate then has the necessary bolt holes or the plate itself can be welded to a similar plate on an adjoining member. As with steel construction, bolts or welding steels used with concrete work require careful inspection.

Slabs. Concrete slabs can be either poured on the ground in a form and lifted into place or scaffolding can be erected to hold the concrete form and the concrete poured in place. Several advantages are realized by pouring the slabs on the ground and lifting them into place. The most significant is having good quality control of the concrete. Pouring concrete at the job site is difficult because it is hard to get the concrete pumped or lifted up to where the forms are. Many contractors use a crane with a bucket attached, others use a pump truck. In a pump truck, concrete is placed in a hopper and augers force the concrete up through a pipe and out onto the deck. For pump trucks the mixed concrete needs to be thinner than that lifted in buckets.

Prestressed/Post-tensioned Slabs. For pre or post tensioned slabs, the steel within the slab is stretched on a special machine and the concrete poured around the steel. After the concrete has been allowed to set the mechanism holding the stretched steel is released and the concrete within the slab holds the tension within the steel. This pre-stressing of the steel compresses the concrete making the whole slab act as though it were pulled "tight." Pre-stressing allows the slab to be longer and thinner than if it were simply cast in place. Likewise, steel can be "post tensioned" where the steel is pulled tight after the concrete has been allowed to set up. The end result is the same: longer spans with less concrete.

Concrete deck slabs placed next to each other leave a small gap just as planks and plywood sheets do. These gaps are spanned by the waterproofing membrane or they will have a special tape placed over them. In some cases the gap is filled with sealant to prevent leaking into the floor below. Slabs must be even between the joints. If one joint is higher than the other the resulting seam becomes a stress point in the roof's waterproofing membrane and can ultimately lead to failure of the waterproofing membrane.

Lightweight Insulating Concrete for Decks. In addition the reinforced concrete used for slabs, several types of lightweight concrete are used especially for roof decks. These lightweight concretes use light, porous aggregates which are not as strong as concrete made with sand or gravel but are strong enough to support the roofing/waterproofing membrane and other light loads.

Roofing boards and insulation are attached to concrete decks by mopping the deck with bitumen or adhesive, then placing the boards in the wet adhesive. Another method is to use metal anchors designed especially to be driven into concrete. Concrete anchors have a barb or hook on the tip and when the nail or screw is driven into concrete it expands gripping the sides of the hole and making it difficult to extract. Nails or anchors for concrete are tested thoroughly and will generally provide a statement of pullout strength with the anchor.

Fire Resistance. Concrete is often chosen for its fire resistive characteristics. Sand, gravel and cement will not burn. However, concrete and the reinforcing steel inside can be weakened by fire. Heat breaks down the bonds between the elements. If any water is entrained within concrete it can turn to steam when heated. The steam expands and can fracture concrete. This condition leads to what is called spalling. Small cracks appear in the surface and these flake off exposing the internal steel.

Concrete decks and slabs settle and crack over time. These cracks open pores but, provided the embedded steel is intact minor cracks do not necessarily pose a structural problem. However, if cracks allow water into the beam and water then rusts the reinforcing steel this can become a structural problem. The best clue that this is happening is when the edge of a crack has red stains left from rusting iron. Concrete cracks and stains are best left for analysis by experts.

Conclusion

Roofing membranes and insulation attach to the deck which in turn is attached to the frame. For cladding, the materials are also attached to the skeleton with a variety of clips, anchors, or sills. Since fire resistance is a significant choice of the main structure, the roofing system must have fire resistance to be compatible with the frame. Now that some idea of the main structural materials is understood, the next chapter addresses the various types of roofing components, assemblies and cladding systems.

Chapter 5—
Insulation and Waterproofing Membranes

General Roofing Types

Erected over the roof frame the roofing system keeps heat inside and weather outside. Since no one material has yet been completely successful in both waterproofing and insulating, most systems combine the various materials into a single roofing "system."

The facility manager's job is made difficult by the changes in the industry resulting from the development of new and improved insulation types, along with rapid development in new waterproofing membranes. In addition, insulation and waterproofing membranes are not always compatible with each other. This incompatibility can lead to failure of the insulation or the membrane and it is a major source of frustration not only for facilities but for specifying architects and roofing contractors.

Having become more familiar with the frame and deck in the previous chapter the facility manager is now ready to be informed about insulation and waterproofing membranes. Insulation is used to hold energy and the waterproofing membrane protects the insulation, deck and frame.

Thermal Insulation

Insulation is a low density material that is specially manufactured and installed with the roofing system to reduce the flow of heat from within the building. Since insulation and the waterproofing membrane work together, roofing contracts have the roofer place the building insulation as well as the roofing membrane. For low slope roofing systems lightweight insulation comes as boards and for steep truss systems it comes loose or in batts.

Insulation can be placed either on top of or underneath the roof deck while the moisture barrier is usually placed above the insulation to carry water to the drains. Insulation can be attached to the deck or it can be loosely laid on the deck relying upon a weighted ballast to hold the material down. When insulating boards are loose laid the moisture barrier is placed over the insulation and weighted with a layer of stones to hold the insulation and membrane in place. The stone ballast (loosely laid stone) also protects the membrane from puncture, rot, and in some cases the sun's ultraviolet rays.

As an alternative to the loosely laid stone ballast, insulation can be attached to the deck with fasteners or it can be glued to the deck with adhesives or bitumen.

Energy Considerations for Insulation Systems

Understanding roofing and cladding insulation begins with a basic understanding of energy use. While an exact understanding of heat transfer is complex and many engineers create sophisticated computer models to understand the theory, this text simplifies the engineering jargon to make insulation understandable from a facility manager's approach.

Energy and heat are difficult concepts to understand because the terms used to explain them are relatively abstract. Heat can be sensed in air, or walls by feel. Outside on a winter day the air is cold while inside by the fire the air is warm. The objective of a buildings insulation and waterproofing membrane is to keep the warm air inside and the cold air outside. However, it is important in a building to move the air around since building sealed too tightly tends to have air quality problems.

Heat Flow. Insulation's primary function is to retard the flow of heat between the inside and outside of the building. On roof decks it has a secondary function to provide a smooth laydown for the waterproofing membrane, protecting it from puncture by irregularities in the deck below and from workers above.

Heat energy travels across a barrier from any warm space to cooler spaces eventually allowing both sides of the barrier to become the same temperature. A good example of this is a warm drink set on a table during a cold day. As time passes the warm drink cools and eventually becomes the same temperature as the air in the room around it. The same thing happens with a building on a cold day. If the building is not heated, the inside of the building will eventually cool to the same temperature as the outside air around it. Fireplaces, furnaces and other building heating systems consume energy to make the air inside the building warmer and counter the energy lost through the walls and roof.

Early buildings were cold and drafty because there was no way to successfully move warm air from room to room. Hence old buildings had a fireplace in each room to heat that room with the fire's radiant energy. Original stone walls and thatch roofs allowed heat to escape rapidly.

As the process of heat transfer became better understood various types of insulation were developed that were lighter and resisted heat flow more readily than wood or stone. Most insulation had a light cellular structure that upon close examination trapped air within the pores of the material. Energy studies revealed that the trapped air is the insulating medium. The material provides cells that hold the air in place.

Heat flow is a function of the area exposed and the amount of differential temperature across the barrier. A large area will loose more heat than a small one and a warm area will lose more heat than a cool one.

Every facility pays for energy to heat the buildings. (Electrical Power cools the building in Summer) Thermal insulation is used to hold the energy inside the building. Insulation slows the rate at which the energy moves from inside to outside. Energy loss calculations and estimates are explained in detail in the next chapter, including an example of how these calculations are performed.

Open Cells, Closed Cells. On a microscopic level insulation has a cellular structure which is either open or closed. The cells trap air inside which is why the insulation is lightweight. Since trapped air is held in place by the cells around the tiny pockets, heat cannot pass very effectively through the materials. An alternate way of looking at this is that in metals, which have molecules very close together, heating the molecules at one end heats molecules next to it which makes the molecules next to them warm until the entire piece of metal is warm. In insulation using trapped air for insulating medium, heat does not pass through it as effectively because the air molecules are physically farther apart.

Another material that conducts heat faster than air but slower than metal is water. In water the particles aren't as close together as they are in metal, but they are much closer together than air molecules are. When insulation to becomes wet, water fills the tiny pockets which are supposed to be occupied by air. The water carries heat through the cells faster than air.

Open cell type insulation allows water to be absorbed. An example of open cell structure is a kitchen sponge. When placed in water the open cell structure of the sponge sops up the water. In contrast, a classic closed cell structure is cork. Cork does not allow water into the cells. Hence cork floats on water and does not absorb moisture.

For insulating, both the open and closed cells types resists migration of heat through them. Open cells will soak up moisture while closed cells will not. Therefore open cells must be kept from moisture.

Insulating Foam Boards Using HCFCs Instead of Air. While air is the most common medium that fills cells in insulating material, chlorofluorocarbons (CFCs) were discovered as a insulating medium that also worked well in many insulating boards. Widespread criticism of CFC use, and the belief that it contributes to loss of ozone in the atmosphere, has led industry to seek an alternate foaming gas with similar properties.

The industry is now using environmentally friendly HCFCs instead. One problem that remains with HCFC insulating boards is a problem called thermal drift. HCFCs can escape from the insulating boards and are replaced with air, lowering the board's insulating capacity.

Understanding How Insulation Works. Figure 5-1 shows how temperature varies through a typical insulated wall. The wall is a fairly typical one with brick, sheathing, batt insulation, and gypsum board. On the inside of the barrier air is at a normal room temperature, 72°F, while on the other side of the wall the air could be a warm 99°F or a cold 0 degrees F. If temperature were measured at various points through the wall, temperatures would be successively closer and closer to the inside 72°F until the surface of the inside wall the temperature would be the inside temperature. Thus the temperature differential is 72F degrees (72-0)

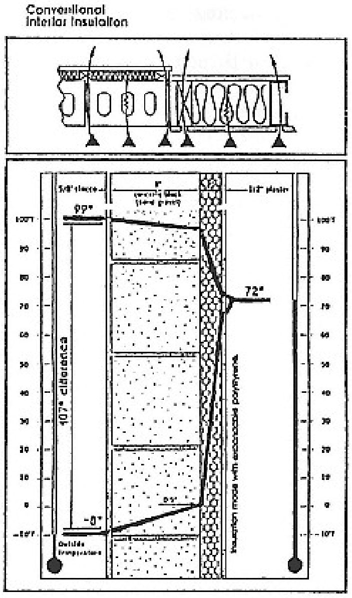

Figure 5-1
Insulation retards the flow of heat through a roof or wall. Experiments have been conducted to plot the temperatures within a wall as the heat migrates through it from the inside to the outside. Figure 5-1 shows the temperature profile through a wall. The higher line is for warm summer conditions while the lower line is for low winter conditions.
Courtesy: Williams and Lampo, Development, Use and Performance of Exterior Insulation and Finish System (EIFS), Copyright 1995 by the American Society for Testing and Materials, Conshohocken, PA.

between the cold outside and warm inside.

Since if it was warmer inside than out, heat would pass from the inside to the outside. If no heat is added heat will continue to pass through the wall until both the inside and outside are the same temperature.

During summer when the outside may be 99F degrees outside while the inside is 72F degrees the temperature differential is 27F degrees but heat flows from outside to the inside.

In each case the heat transferred depends upon three factors. First, the difference in temperatures between to two spaces, second; the total area of the boundary between the inside and outside and finally the time allowed for the heat to move between the two spaces.

If no outside factors intervene, eventually both the inside and the outside temperatures will be the same.

Insulation slows down the flow of heat and the better the insulation the slower the process. Therefore, a building in winter with good insulation loses less heat because it escapes more slowly.

R-Value. The resistance to heat flow through insulating materials is expressed in terms of its R-value (short for resistance value.) To obtain an R-value for any type of material the insulation is tested in a laboratory with special test apparatus. Heat is applied to one side and after a fixed amount of time temperatures are measured on the other side. This determines the amount of heat that flows through that type of insulation. Several tests are conducted in order to obtain an average that the manufacturer then uses when selling his product. In general the higher the R-value the more resistive to heat flow it is. Therefore a high R-value material will let less energy escape than an insulation with a low R-value.

R-values are also used for calculating energy losses through buildings. This energy loss is used to compute the building's fuel or electrical bills. R-values are sometimes given for the entire thickness and sometimes they are given per inch of thickness. This is an important item to know because comparing costs of an insulation that is 4 inches thick with an R-value of 7 per inch is much different than comparing a material 4 inches thick with a *total* R value of 11.

By estimating how much energy is lost through the insulation and by estimating different temperatures throughout the year it is possible to prepare an energy budget. A complete sample calculation showing how this is done is included in the next chapter.

Thermal Drift

One problem with insulation R-values and especially with the chlorofluorocarbon foams used for insulation has been with a phenomenon called thermal drift. What happens to some of these materials is that their closed cell structure has a special gas called a fluorocarbon enclosed within the cells instead of air. The fluorocarbons, being a larger molecule than air molecules, don't transmit the heat as fast and hence these insulations obtain higher R-values per inch of thickness than insulating materials that have air enclosed cells.

What happens to these insulation types over time is that the chlorofluorocarbons migrate out of the cellular structure and are eventually replaced with air. Over a period of years, the R-value drops to a lower value compatible with air in the cells instead of Freon. Once this lower value is attained it remains fairly constant.

For example, a polyisocyanurate board may have a published R-value of 7.2 per inch of thickness. After a period of years, the special gases in the enclosed cells seeps out and are replaced by air. After this the R-value my be reduced to 5.6 per inch of thickness. Part of the insulation value then is lost.

Unless this *thermal drift* has been accounted for in an economic analysis of insulation system retrofit, a facility could be losing money by paying for more energy that it initially thought. The thermal drift problem is still being argued between the various manufacturers but lab data has confirmed its occurrence. Facility managers can ask manufacturer's for test results of polyisocyanurate boards with high r-values per inch what the aged R-value is after 10, 15, or 20 years.

The inverted roof.

In extremely cold climates the Inverted Roof Membrane Assembly (IRMA) was invented to reduce thermal shock and extreme temperature fluctuations (stresses) to the waterproofing membrane. Also by placing the membrane below the insulation, stresses resulting from hail, UV and infrared light, and foot traffic were minimized. This system is also sometimes called a Protected Membrane Roofing system (PMR.) The PMR system was developed in Canada for the more extreme weather conditions in that country. A PMR system costs more than a compatible roof system initially but roof life and reduced maintenance have led to the increase in application of this type of system, especially in cold climates. See Figure 5-2.

Thermal Shock

Roofing membranes are subject to a problem called thermal shock. Simply stated, thermal shock is the result of rapid heating or cooling of a roofing membrane resulting from changes in weather conditions. When a summer thundershower sprinkles rain on a hot roofing membrane the rapid cooling of the membrane can cause severe stresses. Some roofing systems reduce the amount of insulating materials in order to modulate temperature changes in the membrane. However, this reduction isn't practical from an energy standpoint and would not be necessary if the forces of thermal shock were better understood.

Thermal Bridge

Insulation and R-value are only good when they block the path of heat escape from a structure. Thermal bridges occur when

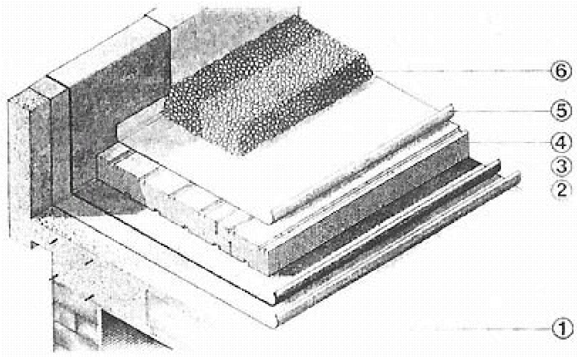

Figure 5-2
An Inverted Roof Membrane Assembly places the waterproofing membrane next to the deck, with the roof insulation on top. This method limits the temperature cycles on the waterproofing membrane and is designed to help the membrane last longer than on conventional roofing systems.
Courtesy: The Science and Technology of Traditional and Modern Roofing Systems, Copyright 1992 Laaly Scientific Publishing, Los Angeles, CA.

nails, metal studs, open joints or metal projections have penetrated through the insulating material. As metal carries heat more readily than insulating materials, whenever a roof design allows beams or fasteners to pass through the insulating layers, heat follows the metal to the outside, bypassing the insulation.

A classic example of thermal bridging can sometimes be seen in cold climates where building studs have frost on them making vertical or horizontal lines on the side or roof of a building. To prevent thermal bridging, the deck is placed on the structural members, then the insulating boards form a continuous barrier. For extreme cold weather areas, a double layer of boards is placed with the joints between the boards staggered. This staggering prevents migration of heat (thermal bridging) and holds heat within the envelope.

Boards, Batts, Loose Placed, and Sprayed on Insulating Materials

For low slope roofing systems insulating boards are usually used between the deck and the waterproofing membrane. Insulating boards are specially manufactured and can be tapered to slope the surface of the deck in order to get the roof to drain properly. Some boards are placed directly on a metal deck or they can be placed on wood or concrete decks as well. The boards are usually fastened to the deck with special screws or nails that have a large flat head or special plate. The ideal board is inexpensive, lightweight, and has a high resilience to rough handling and foot traffic.

Old fire codes required some boards, made from foam, to have an underpayment of 1/2" of gypsum to act as a fire retarding material however, modern manufacturers have found a new fire resistive material that eliminates the fire retarding underlayment. Table 5-1 is a summary of some common types of insulating boards.

Loose Laid Insulation Materials. In roofing systems with trusses, loose insulation is placed between the ceiling of the floor below and the waterproofing membrane nailed to the deck above. This type of insulation is more commonly encountered in residential applications but small commercial buildings and some of the ancillary buildings on a large complex will have this type of insulation. Loose laid insulation includes cellulose, vermiculite, and rock wool. Loose laid insulation is usually applied by blowing it into the areas where it is being applied using a low speed air system. The bulk material is placed in hoppers and the workmen spray the material loosely throughout the structure.

This loose application only works where the roof deck is above the insulation as any winds will carry the material away before the waterproofing membrane can be applied. Loose insulation is an especially good choice in areas that do not lend themselves to batt insulation.

In the past, asbestos was used as a fire insulation material but it is now banned for new applications because of its cancer causing properties. Destruction and demolition operations occasionally encounter loose or sprayed on asbestos which has very strict rules for removal.

Batt Insulation. Rolled fiber batts are also used as an insulation material in both low and steep slope roofing systems. The most common of the batt insulations is fiberglass. Fiberglass batts are made from long spun strands. The glass strands form a mat that traps air and holds it preventing the migration of heat. Usually fiberglass batts are backed with foil or paper to allow them to be placed more easily and to reduce fiber dust during

Table 5-1. Common roofing insulating boards used in low sloped roofing systems and wall cladding systems. Courtesy: R.D. Herbert "Roofing-Design, Criteria, Options, Selection" Copyright 1989 R.S. Means Company, Inc. Kingston, MA.

Characteristics of Various Roof Insulation Materials

	TYPE OF INSULATING BOARD								
Characteristics	Polyisocyanurate Foam	Polyurethane Foam	Extruded Polystyrene	Molded Polystyrene	Cellular Glass	Mineral Fiber Glass	Phenolic Foam	Wood Fiber	Glass Fiber
Impact resistant	G	G	G	F	G	E	G	E	F
Moisture resistant	E	G	E	G	E	G	E		
Fire Resistant	E				E	E	E		E
Compatible with bitumens	E	G	F	F	E	E	E	E	G
Durable	E	E	E	E	E	G	F	E	E
Stable "k" value			E	E	E	E		E	E
Dimensionally stable	E	E	E	E	E	E	E	E	G
High thermal resistance	E	E	E	G	F	F	E	F	G

(table continued on next page)

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Characteristics of Various Roof Insulation Materials

	TYPE OF INSULATING BOARD								
Characteristics	Polyisocyanurate Foam	Polyurethane Foam	Extruded Polystyrene	Molded Polystyrene	Cellular Glass	Mineral Fiber Glass	Phenolic Foam	Wood Fiber	Glass Fiber
Available tapered slabs	Y	Y	Y	Y	Y	Y	Y	Y	Y
"R" value per in thickness*	7.20	6.25	4.76	3.85-4.35	2.86	2.78	8.30	1.75-2.00	4.00
Thicknesses available	1"-3"	1".4"	1".3½"	½"-24"	1½"-4"	¾"-3"	1"-4"	1"-3"	¾"-2½"
Density (lb./ft.3)	2.0	1.5	1.8-3.5	1.0-2.0	8.5	16-17	1.5	22-27	49
Remarks	Prone to "thermal drift"	Prone to "thermal drift" Note"A": Should be overlaid with a thin layer of wood fiber, glass fiber or perlite board, with staggered joints.	Somewhat sensitive to hot bitumen & adhesive vapors Note"A": Should be overlaid with a thin layer of wood fiber, glass fiber or perlite board, with staggered joints.	Somewhat sensitive to hot bitumen & adhesive vapors Note"A": Should be overlaid with a thin layer of wood fiber, glass fiber or perlite board, with staggered joints.			Prone to "Thermal drift" relatively new & untested.	Expands with moisture—holds moisture.	Prone to damage from moisture infiltration.

E = EXCELLENT

G = GOOD

F = FAIR

*from ASHRAE 1985 Fundamentals Manual

application. Tears in the foil detract from the material's R- value and allow air to flow through the insulation allowing heat to escape.

Sprayed-in-Place Insulation. Similar to blown in loose insulation, a number of sprayed-in-place insulation systems can be used. Sprayed-in-place applications are attractive for rough uneven surfaces. However, except for the sprayed in place polyurethane foam system discussed later in this chapter it is difficult to apply an adequate waterproofing membrane directly over a sprayed in place insulation system.

Sprayed in place insulation is often applied to the underside surface of decks and many systems combine fire retardant and insulation in one step. Sprayed in place foam is more often used for fire protection and energy conservation than for roofing systems.

Foam Boards

The following are some of the foam boards used for low slope roofs.

Polyisocyanurate Foam Board. One of the more attractive foam insulating boards on the market the Polyisocyanurate Foam Board which combines high thermal resistance, light weight, and low cost. Its aged thermal resistance value "R" is approximately 7.2/inch which is one of the most effective. It is fire resistive and comes backed with a glass fiber mat. A couple of drawbacks to this type of board are its thermal drift and its recent entry into the market. It is one of the younger insulation boards. Thermal drift is the tendency of the R-value to decline after a few years.

Phenolic Board. Another high thermal resistance board used in the past, with an R-value of 8.2, phenolic foam was thought to be an excellent lightweight insulating system. Phenolic foam boards had good fire resistance and did not require a gypsum underlayment when placed directly on steel decking. With a density of 2.5 pounds per cubic foot it is not as light as some of the other boards but because of its high R-value per inch, the boards were be thinner to compensate. These boards have been taken off of the market as a result of corrosion and friability problems. However, they were used on some roofs.

Polyurethane Foam Board. Similar to the Phenolic Foam Board, the Polyurethane Foam Board was also used. Although its thermal resistance was not as high as the polyisocyanurate at 3.5/ inch, it was an attractive lightweight insulating board. Factory

Mutual required this type of board to have a fire resistive underlayment of 1/2 inch gypsum if placed directly on a steel deck and newer boards with better fire resistive characteristics have replaced this type of board in the marketplace.

Polystyrene Molded Expanded Foam or MEPS. The expanded polystyrene foam board comes in varying densities and has an R- value of about 3.8/inch. It cannot be used with hot asphalt or coal tar membranes because the high temperatures required to apply the asphalt or tar can melt the polystyrene. This material is often chosen for ballasted single ply waterproofing systems but care must be used to make sure that the ballast is placed soon after installation as winds can get under this very light material and lift it during construction.

Extruded/Expanded Polystyrene Board or XEPS. Slightly more dense than the Expanded Polystyrene, Extruded Polystyrene is used in similar applications. With a higher R-value at 5/inch it is still less attractive than the polyisocyanurate board systems. It cannot be placed directly on a steel deck and it is often used in inverted roofing systems.

Cellular Glass Boards. Cellular glass boards are made of closed cells within a glass matrix. Their R-value of 2.8 is lower than the other foam boards and as such it is not specified as often as it once was. It has good fire resistive characteristics, but has a high density compared to the newer foam boards. Because of it's tight closed cells it has high moisture resistance but does not perform well in freeze thaw cycles.

Mineral Board. Also called perlite board. Mineral fiber board has a density higher than most of the other boards and a lower R-value at 2.8/inch. It is mostly used in combination with the other high density boards as a base fire resistive material.

Wood Fiber Board. Wood fiber board is used as a combination decking/insulation material but it has a low R-value (2.00-2.80 per inch) that makes it unattractive as an insulating material. However it is often used in combination with one of the foam boards to make a composite board that is strong and lightweight. This combined board works well for hot applied waterproofing membranes.

Glass Fiber Board. Glass fiber board is used in a similar manner to the other insulating boards. Its R-value is better than wood fiberboard at 4/inch. It is fire resistive but it is not as stiff at the wood fiber board and it is prone to moisture damage. It is also heavy at 49 lbs per cubic foot.

Other Insulation Types

The previous discussion was devoted primarily to the insulation boards used for roof and wall systems. A few other types of insulation are mentioned although they don't act integrally with the roof waterproofing system the way insulation boards do.

Fiberglass Batt Insulation. Fiberglass batt insulation comes in bundles and is installed under metal or wood roofs or above ceilings in many commercial facilities. The batts for installation under metal are held in place with straps or battens attached to the structural members. Batts are also placed between the trusses or in walls between either metal or wood studs. They are surfaced with either plastic or paper.

Case Study: Steam Boiler Plant Saturates Fiberglass Batt Insulation in a Metal Building

Many metal type buildings have been used as mechanical equipment enclosures. In one project the designer left the method of insulation to the metal building supplier. The supplier, experienced in providing metal buildings for warehouses and for other commercial use was not informed that a steam boiler plant would be inside. The boilers, poorly controlled, would vent low pressure steam inside the building. Over time, the wet heavy steam completely saturated the fiberglass insulation, it became too heavy for the battens that attached it to the ceiling and the pieces pulled apart and fell loose. Enough attachment kept them from falling to the floor but their insulation value was lost. The fiberglass batts were replaced with a closed cell foam board that had a high resistance to water saturation.

Rock Wool. Another loose insulating fiber, rock wool was used in the past but has not seen much recent use. Rock wool was blown in place. A loose fibrous material it is seldom used today.

Cellulose. Cellulose was used as a substitute for fiberglass and rock wool however, since the base constituent of cellulose was wood and paper products which have an open cell structure, it was prone to moisture intrusion. Treatment of the fibers as they are being prepared has increased its fire resistive characteristics, its resistance to insect and mold infestation, and its moisture resistance.

Asbestos

Although it is no longer used, asbestos is discussed here because it was used extensively in the past. Over the past 15 years, industry and facilities have gradually removed and changed out asbestos roofing insulation materials because there is an inherent cancer risk resulting from inhalation of loose fibers. The exact reason the fibers cause cancers is not yet well understood and consequently, the standard for airborne asbestos fibers, currently 0.1 fibers per cubic centimeter, is based upon the state of the art of the detectors. Managers of older facilities want to use caution if asbestos is suspected. Removal is extensively regulated and expensive. Sometimes asbestos can be encapsulated in place.

Facings

In addition to the boards and batts, many insulating boards or batts have a facing of a glass mat, asphaltic or non- asphaltic membranes or roofing felts. The facings on the boards allows easier application of the various roofing membranes which are explained later in this chapter. Facings also make the boards easier to handle on the job site.

Waterproofing Membranes

In addition to the insulation systems that hold the energy inside, a roof must prevent moisture from penetrating the insulation. Therefore a waterproofing membrane is installed on top of the insulation/deck. As with the insulation systems, waterproofing membranes come in a variety of types which will be explained here. Most roofing problems stem from holes in or the failure of the waterproofing membrane, but keep in mind that overall the system has to perform together in one unified process to successfully keep out the elements.

Waterproofing membranes fall into six broad categories:

a. Built Up Roofing (BUR) system of asphalt, coal tar, or pitch combined with layers of felts;

b. factory coated bituminous systems of polymer modified bitumens;

c. single-ply membranes such as rubber or plastic sheets;

d. metal standing seam systems;

e. shingles of tile, slate, asphalt, or other mineralized fabrics;

f. Sprayed in-place polyurethane foam and coating.

Figure 5-3 shows the various percentages of the various types of waterproofing membranes.

Built Up Roofing Systems and Modified Bitumen Systems use sophisticated materials resembling tar or pitch. This black sticky

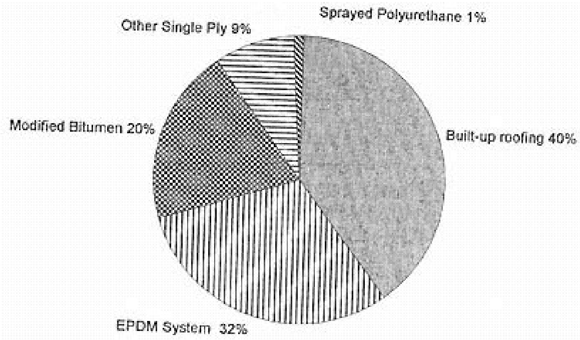

Figure 5-3
Percentages of roofing system types. Original Artwork prepared by the author with data provided by the National Roofing Contractor's Association.

substance is chemically quite complex. The bitumens are combined with fabric called roofing felts which hold the tar/sticky material in place.

Facility managers should be cautious, aware that the mixing of bitumens and felts requires some knowledge. Indiscriminate combinations of roofing felts with bitumens can lead to premature failure of the roof system.

Bitumens-Asphaltic and Coal Tar Cements

What is Bitumen? Bitumen is the generic name for heavy black or dark brown hydrocarbon mixtures used in surfacing roads and roofing systems. Bitumens are divided into three major classes: natural asphalt, petroleum asphalt, and coal tar pitch. Although coal tar pitch and petroleum asphalt differ physically and chemically, they have common attributes: both are water resistant, durable, adhesive, and thermoplastic.

Two elements make bitumens an attractive roofing material. First, bitumens shed water and don't allow it to dissolve or saturate through to the materials below. Second, some bituminous materials inherently seal themselves because they will cold flow into any tiny cracks or blisters, resealing. The bitumens are sticky when applied so they hold roofing felts, which bitumens are combined with, into a water repellent mat.

Over time, ultraviolet rays, water, oxygen, cold winter temperatures, and summer heat drive off the lighter, more volatile organic components in the bitumen, leaving the less flexible particles behind. When this happens the membrane can crack instead of stretching. The felt holds the bitumens in layers, minimizing the cracks. Bitumen is the main ingredient in the built up and the modified bitumen roofing system.

On average the life of the built up roof is a function of the number of plies placed. A four ply system should last 20 years. A two ply system may only last half that time.

Asphalt Types

Asphalt cements used in built up roofing systems come in five grades. Each is specially manufactured for the temperature when the material beings to soften. Table 5-2 shows the various grades. In general the lower the softening point the flatter roof pitch must be for that type of asphalt.

The equiviscous temperature is the temperature at which the bitumen material flows best for application on a roofing system. The higher the Asphalt grade the stiffer the roof membrane will be when the roofing system is completed. A roof with a bitumen that has a low softening point is easier to apply but is prone to soften on warmer days. A roof with a high softening point temperature may become brittle on cold winter days.

Although built up roofing membranes are an excellent waterproofing membrane, weather and moisture slowly break down the bitumens in the membrane. Extremely low temperatures can crack its surface. Hence, proper maintenance is the key to longer roof life.

Type II asphalt can be used for everything except flood coats on poorly drained roofs and for adhering flashing. With its 158°F to 176°F softening-point range, Type II asphalt can serve as an insulation adhesive by hot mopping type II asphalt onto insulation boards. Type I asphalts, thinner and more runny than Type II will potentially bleed through deck joints. With a lower equiviscous temperature than Type III Asphalt, Type II asphalt reduces the threat of interply voids (bubbles) and generally poor adhesion posed by the faster congealing Type III asphalt. Type II is generally strong enough to withstand normal expansion and contraction.

Table 5-2. Roofing Asphalt Properties. Courtesy: C.W. Griffin & R. Fricklas, Low Slope Roofing Manual. Reprinted with permission from McGraw-Hill Book Co. New York, Copyright 1996.

	Asphalt*								Coal tar pitch**			
	Type I		Type II		Type III		Type IV		Type I		Type III	
Property	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Roof slope (in./ft)	0	¼	¼	1	¼	3	¼	6	0	¼	0	¼
Softening point, °F (°C)	135(57)	151(66)	158(70)	176(80)	185(85)	205(96)	210(99)	225(107)	126(52)	140(60)	133(56)	147(64)
Flash point, °F (°C)	475(246)		475(246)		475(246)		475(246)		374(190)		401(205)	
Penetration (*tenths of mm*):												
32°F (0°C)	3		6		6		6					
77°F (25°C)	18	60	18	40	15	35	12	25				
115°F (46°C)	90	180		100		90		75				
Ductility, 77°F, cm	10		3		2.5		1.5					
Specific gravity,*** 25/25°C									1.22	1.34	1.22	1.34

*Per ASTM D312-95.

**Per ASTM 450-91.

***Asphalt specific gravity, although not limited by ASTM, generally runs around 1.03 for roofing asphalt.

The higher type asphalts, type III, have higher equiviscous temperatures. This material is stiffer and is more common on roofs with steep slopes. Hence Type III asphalt is sometimes called "steep" asphalt. Steep asphalt is refined for longer times than Type I or Type II. During manufacture of the asphalt, air or oxygen bubbles are pumped up through asphalt while it is heated to about 500°F. As this process continues, asphalt gets tougher and less fluid. The base asphalt, called flux, can produce roofing asphalts, from Type I (softening at 135°F) for dead-level roofs, to type IV (softening at 225°F for steep roofs.)

Type III to Type IV asphalt has a higher softening point making it "stiffer" when in use on the roof. This allows these types to be used on steeper roofs. However, they are less durable, less waterproof, and more susceptible to voids than Type I and II asphalts. In addition, longer cooling times make mopping and felt-laying more critical for Type III and Type IV asphalts. Type I asphalts have lower optimum adhesion temperatures than, say, Type III. Because of their disadvantages, it is best to limit Type III and Type IV asphalts to hot climates and steeper slopes.

In fact, Type II might be the best all-purpose compromise, other than, perhaps, for flood coats on poorly drained roofs and adhering flashing. As an insulation adhesive, Type II asphalt also provides excellent service.

Coal tar pitch roofing bitumens are a black or dark brown liquid or semi-liquid condensate derived from heating coal in the absence of air. When reroofing it can be difficult to remove coal tar pitch and, in many cases, unnecessary. Consultants usually weigh the cost to benefit ratio of complete removal of a coal tarred roof against possible incompatibility should the coal tar remain.

Bitumen Properties

Bitumen's condition varies with heat and stress, from a viscous liquid when hot, to visco-elastic solids in normal temperatures, to elastic solids in winter. These physical changes in various seasons make computation of contraction expansion coefficients difficult. Bitumen hardens as it deteriorates losing adhesion, deforming, and cracking. However, oxygen and solar radiation, dissolved aerial pollutants and micro-organisms also affect bitumen's lifetime performance.

Waterproofing

Being non-porous, bitumens have excellent water-resistance, as they absorb only minute amounts of water. Both coal tar pitch and asphalt have this low water absorption feature. As such, bitumen makes an excellent waterproofing membrane.

Adhesion

Loosely translated, adhesion is the stickiness of the various roofing tars. Bitumen's adhesion depends on the nature of the surface and the amount of surface wetting. Low contact angles, for instance, easily spread the material and produce good adhesion, while high contact angles make for bad adhesion. Adhesion is similarly poor on moist, dusty or greasy surfaces. Applied as a liquid, bitumen's temperature in use depends on it's consistency and the temperature of the surface where it is applied. Most bitumens soften at 175°F or less, varying with the nature of the task, the kind of material, and the weather. Because overheating drives off volatile constituents, asphalts degrade above 235 C and coal-tar pitches degrade above 200 C.

The Type I through Type IV roofing asphalts and the two grades of coal tar pitch are hot applied on the roof deck. Usually the roofing contractor sets up a melting kettle either on the ground near the roof or up on the roof itself. The coal tar or asphalt is placed in the kettle where it is heated above the equiviscous temperature before applying it to the roof. Usually the roofing insulation has already been laid down. The asphalt is mopped onto the insulation boards or onto the first layer of felt while it is still hot, a process called hot mopping.

After mopping, successive sheets of felts are placed with an overlap. See figure 5.4.

Felts

For both built-up roofing systems and modified bitumen systems, fabric mats called felts are the other critical element in the waterproofing membrane. Felts of organic, glass, polymer, or other fibers are laid between the bituminous layers to give the membrane strength and ductility. The bitumen hold the felt layers together and also hold the felt and bitumen mat to the deck or insulation boards.

Organic Fiber Felts. Organic felts use fibers derived from wood, waste paper, rags, or other material that has a high cellulose fiber content. This allows the bitumen to impregnate the felt and makes it water resistant. Without treatment with bitumen,

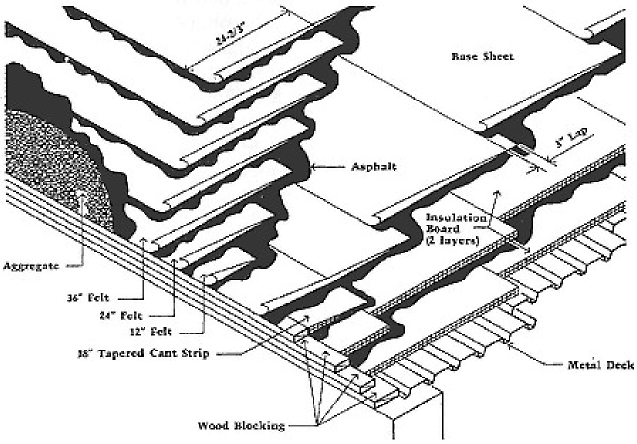

Figure 5-4
A built-up roofing membrane is comprised of layers of felt and asphalt.
Usually the more layers of felt and bitumen the longer the roof warranty.
Courtesy: R.D. Herbert Roofing-Design, Criteria, Options, Selection,
Copyright 1989 R.S. Means Company, Inc. Kingston, MA.

organic felts, when immersed in water, may absorb as much as 80% of their weight. These felts will also expand slightly when wet, more in one direction than the other depending upon which way the fibers run. The quantity of water absorbed, and the degree of expansion vary from one type of felt to another. Felts shrink when they dry, and this shrinkage may be greater than the original expansion. Water and air may make organic fibers subject to rot, fungi and vegetation. Organic fiber felts are rarely used on new roofing systems but were commonly used for many years.

For organic felts, a mineral stabilized bitumen coating, on both sides of the felt greatly enhances its moisture and water resistance. These were called base sheets.

Glass Fiber Felts. Glass-fiber mats have distinct advantages when compared with organic felts. Glass fiber felts are preferred for built up and modified bitumen roofing systems today. Glass-fiber roofing felts consist of highly resistant glass, drawn or blown into fiber, and formed in a wet process much like paper making. A thermoset (heat setting) binder, usually phenol-formaldehyde or urea-formaldehyde is applied and the glass felt mat is cured in drying ovens. The dry mat is then coated with hot asphalt, cooled, and spread with a sand parting agent. The mat is then marked, rolled, and cut into lengths. Much of a glass-fiber felt's strength depends on the length of the glass fibers, and the longer these fibers are, the stronger the felt. Filaments are strongest in long glass-fiber mats. A felt with fibers made according to the standards in ASTM D2178, Type IV, for instance, has three times the strength of a 15 lb (nominal) saturated organic felt.

Because glass fibers do not absorb asphalt, no saturant is needed as is the case with organic felts.

Asbestos. Asbestos, once used as a felt for this same purpose, has fallen into disfavor as a health hazard, though some asbestos made roofing felts may remain on older roofs.

Cold Bitumens

Hot applied bituminous roofing is not always the best application. Sometimes bitumen is dissolved in a petroleum solvent for application on the roof. The solvent evaporates after the coating has been applied. This leaves an adhesive bituminous film similar but usually thinner than a hot mopping. To compensate, cold bitumens are frequently modified with fillers and fibers to control their flow. Cold bitumens can also be produced as heavier mastic cements to produce trowelable material that is widely used for maintenance and adhering flashings.

Compatibility of Coal Tar and Asphalts

Asphalt and coal tar pitch are chemically incompatible, and should not be used in contact with one another. Contact results in one bitumen hardening and the other softening, leading to possible slippage between the felt sheets. Asphalt, coated on pitch, may soften and flow off, exposing the bare pitch, whereas coal-tar pitch, coated on asphalt, tends to harden and crack.

Much depends on roof slope, size, and building geometry. New asphalt placed over old coal tar pitch might, for instance, slide or blow off an outward-sloping roof without parapets. In a few cases, such initial incompatibility disappears with time. In addition asphalt-based sheets and mastic, cause few problems when used for flashing coal-tar pitch roofs.

Now that some of the properties of bitumens and felts are understood the combination of these into the types of roofing systems is the next step.

Built Up Roofing Systems

The oldest low slope roofing system in the country is the Built Up Roofing System (BUR). BUR roofing systems are a combination of waterproofing elements, usually coal tar pitch or asphalt, felts, and a mineral aggregate surfacing.

Not only is this system waterproof, but it is durable, inexpensive and relatively easy to install. Hence the Built Up Roof is still a relatively popular roofing system.

Modified Bituminous Systems

In a modified bitumastic roof (MBR), the asphalt is modified with synthetic polymers to increase its weather resistance and improve it's flexibility and toughness in order to provide a longer lasting roof. Some modified bitumens are cold applied, allowing roofers to apply them to built-up roofs without using a kettle to melt the asphalt. The modified bitumen coating, applied to a reinforcing fabric results in a factory produced flexible membrane.

The modified polymers in a modified bitumen roofing system are commonly atactic polypropylene (APP) or alphapolyolefins (APOs) and styrene-butadiene-styrene (SBS).

Modified bitumen systems are sometimes called rolled roofing because the modified bitumens and base sheets come in rolls and look similar to asphalt shingles in thickness and texture.

Aggregates

A third important element for built up roofing and modified bitumen roofing systems are mineral aggregates placed on top of the final flood coat. Mineral aggregate, i.e. stone, is embedded in the final layer to protect the bitumen from ultraviolet light degradation and improve fire resistance.

Aggregate such as river washed gravels, slag, or stone is spread on the roof. For built up and some modified bitumen systems the roofing contractor places a flood coat over the final felt mat. Then the roofing aggregate is carefully spread over the wet flood coat where the stones sink slightly into the wet bitumen. The aggregates are then considered to be embedded into the flood coat.

The advantages of embedding aggregate into the flood coat are that winds and uplift won't move the small stones around because they are stuck in the bitumen.

The other advantage of the aggregate is that the stone protects the bitumen and felt layer from punctures by foot traffic and the occasional hailstorm.

Aggregate meeting the requirements for roofing systems is specified under standards by the American Society of Testing and Materials. (ASTM D1863) River washed gravels and crushed stone are the two most common types but some blast furnace slag is also used. In many ways, aggregates for roofing systems are similar to aggregates used for road surfacing.

The sizes of the stones are also important. If there are too many large stones, walking on them or putting any weight on them can force the stones down through the flood coat and puncture the roof felt. On the other side of the equation, aggregate with too much sand or dust does not adhere well with the bitumen. The dust coats the stone particles and prevents the aggregate from bonding with the bitumen. Dust will also blow away during application covering windows or cars in the parking lot. Therefore, the amount of dust allowed in roofing aggregate is strictly controlled.

In order to work correctly, aggregate must be the correct size. Like aggregate for other uses, roofing aggregate is separated into different sizes by using a series of screens with holes of different sizes. The screens allow the correct sizes of stones to pass through while filtering out oversize material. Below the oversize screen, an undersize screen holds back the correctly sized aggregate and allows the smaller rocks and dust to pass through.

Another consideration for aggregate is that it sometimes needs to be washed. During the process of shaking the materials down through the screens, dust sticks to the stones. Washing the aggregates after they have been separated removes the dust. The problem of dust can be identified easily by noting a fine white powder, that looks like flour in the material when it is delivered.

Crushed stone, like river washed gravel is an excellent aggregate for roofing systems. Crushed stone, as opposed to river washed gravel has angular faces in the individual pieces. River washed gravels will have these surfaces rounded. Crushed stone is better for the roofing system than river washed gravels, but it can be more expensive since energy is required to crush the stones.

Mineral aggregate for roofing and for other uses is largely a function of the region. Mountainous regions have lots areas where the right types of aggregates are found. Plains regions will be further from the areas where stones are mined. Oceans and beach areas will have lots of washed stone, although sometimes there is a large quantity of sand in some of these materials. Rivers are also a good source of materials.

Most roofing stone is obtained from pits where it is mined and, typically, roofing aggregate can come from the same supplier of concrete aggregates. A facility manager should be cautious using cement aggregates however because the gradation of the particle sizes is not the same. Concrete, of course uses sand in the mix, while roofing aggregate would eliminate sand because of the problems with keeping the bitumen from binding the larger stones.

Conclusion to Built Up and Modified Bitumen Roofs

The most commonly-used roofing and water-proofing membrane is made by combining bitumen (asphalt or coal tar pitch) with organic or glass or other inorganic fiber felts. Bituminous roofing is often used because of its resistance to water. Bitumen's ready adhesion to felts and other surfaces, and easy installation also make it an attractive roofing membrane. However, rubber and plastic modified bitumens are sometimes more suited to some of today's unusual roof designs.

Case Study: Roofing Failures

One of the problems within the roofing industry is the problem of fixing the responsibility of a roofing system failure during litigation. Because the desire of the parties is to be "made whole" the litigants end up settling rather than bringing the issue to trial. In February 1995 a the roof of a large grocery store of a major chain in Salt Lake City, Utah failed and collapsed. Details of the collapse were initially reported in the press but the failure investigation was turned over to insurance adjusters. The matter was eventually settled, but the agreements were sealed preventing the industry from benefiting from the results of analyzing the failure.

Single Ply Roofing Systems

Arriving on the scene at about the same time as modified bitumen systems began capturing some of the roofing market, single ply roofing systems entered the competition. At first it was difficult for the single ply manufacturers to capture the attention of the roofing industry because of the relative reliability of the Built Up Roofing System.

However as buildings continued to become larger and larger and the needs for more economical low slope roofing increased, designers of roofing systems wondered if roofing problems could be solved with a single rubberized or plastic sheet that performed the entire job of waterproofing in a single step. If, a rubber sheet could be used to line a pool or tank, they reasoned, why not use it to protect the roof as well?

Single ply systems are just that. Large rubber like or plastic sheets that are stretched out over the existing decking. Many early single ply systems were ballasted, that is, the sheet was held down by the weight of an aggregate stones placed over it. Later applications eliminated the aggregate in favor of an adhesive material used to stick the entire sheet to the insulation below it. Adhesive systems can be fully adhered where the sheeting is glued to the insulation decking underneath, or some systems are partially adhered, where the material is attached in only certain areas such as to spot plates in the insulation or along seams or welds. Finally, the single ply membrane can be mechanically fastened to the insulation with specially designed fasteners spaced according to designs specified by manufacturers after performing wind and tear tests.

Single ply roofing systems comprise about 40 percent of the existing low-slope non-residential roofing market today. These types of systems are the newest roofing types currently being marketed. Single ply systems were introduced in the 1960's but did not really begin to capture the low slope market until the 1970s. Many of the early single ply systems are now reaching the end of their 20 year life and will require replacement.

Several types of single ply sheeting are available. Single ply roofing methods are one of the most dynamic and rapidly changing elements of today's roofing industry. Single plies are made from rubber sheets, various colors of plastics, and a host of other plastic and/or vulcanized materials.

The new lighter single ply system was initially thought to be a positive benefit because the roof deck could be constructed of smaller, lighter materials. However, problems with the lighter structure included flexing in winds, stretching, cracking and peeling of the membranes.

By revising methods of ballast, adhesion, and fastening, most of the early single ply problems have been resolved. Hence, unballasted single ply systems are lighter than older roofing systems.

Types of Single Ply Systems

There are a myriad of types of single ply membrane systems being produced by various vendors and marketed to facility manager's, roofing contractor's and architects by a large number of salesmen and distributors. Single ply system types can be broken down into categories defined by the materials. The facility manager should be aware that the single ply systems are just that, systems. Each of the elements must work with the other elements in order to assure the system will work. The membrane, insulation and method of fastening all combine into a single system.

The Factory Mutual Research Corporation Part 18 lists hundreds of approved single ply systems in their approval guide. By approved, FM means the system has been subjected to a series of standardized tests including: wind uplift, light, fire and hail. The FM Association gives the roofing system an external fire rating, either Class A, B, or C; an underdeck fire rating either Class I or Class II and wind ratings ranging from Class I- 60 to Class I-180. Class A, B, and C external fire ratings relate to the roof's resistance to an external source. Class A is the most fire resistive and Class C the least fire resistive. For internal or underdeck fire ratings, Class I is the most fire resistive and Class II is less fire resistive.

Wind ratings vary from Class I-60 to Class I-180. Generally the higher the number the more resistant the roof will be to blow off from wind.

Facility manager's should recognize that Factory Mutual Corporation ratings apply to the entire roof system and substitutions are not allowed. The listing requirement depends upon the type of building, who the code officials are, and the insurance company insuring the building.

Plastic-like vs. Rubber-like Single Plies

There are two broad categories of singly ply membranes, thermoelastic and thermoplastic. A broad generalization is:

Elastomeric = Rubber and rubber like material and
Thermoplastic = Plastic and plastic like material.

Table 5-3 is a summary of the trade names and primary material types.

Table 5-3.

Type	*Full Name*	*Type of Material*
EPDM	Ethylene Propylene Diene terpolymer	Elastomeric
Neoprene	Neoprene	"
Butyl Rubber	Butyl	"
CPE	Chlorinated Polyethylene	"
CSPE-Hypalon	Chlorosulfonated Polyethylene	Thermoplastic
PIB	Polyisobutylene	"
PVC	Polyvinyl Chloride	"
ECB	Ethylene-Copolymer-Bitumen	"
EIP	Ethylene interpolymer alloy	"
TPO	Thermoplastic Polyolefin	"
NBT	Nitrile Butadiene Terpolymer	"
CPA	Co-polymer Alloy	"

Elastomeric Membranes

The oldest and most popular of single ply membranes are of the thermoelastic type. These types of membranes have trade names like EPDM, Neoprene and Butyl Rubber. These membranes are rubber like in that they stretch and recover just as rubber bands do. When manufactured they are chemically 'fixed' and while they stretch and bend, fixing makes them difficult to bond at the seams without special chemicals, glues or solvents.

The advantages of this type of single ply material is they are elastic and allow small differential movements in the buildings joints or seams and in wind and thermal expansion and contraction without tearing or puncture. The disadvantages of the rubber like materials are that they are more difficult to install than the thermoplastic membranes because of the difficulty with bonding the seams. The older thermoelastic single ply membranes required a protective coating or ballast to meet fire ratings but newer products are not subject to this limitation.

Thermoplastic or Plastic-like Membranes

The other major category of single ply roofing systems is the thermoplastic or plastic type. Thermoplastic membranes are flexible and waterproof but don't have the stretch strength that the rubber sheets have. Thermoplastic systems are lighter than the thermosetting systems and are the easiest of all the systems to install. The seams in these types are 'fused' with heat guns or special jigs and in these types, the seams are often stronger than the material itself.

Thermoplastic systems are available in various colors and while the rubber like membranes are often black or dark, thermoplastics can be light colored which reflects heat rather than absorbing it. This makes the building easier to cool in summer conditions. Having light colored materials is a major selling point for thermoplastic systems, especially in dry, warm, arid regions of the south and west. Another advantage to thermoplastic membranes is that they can often be ordered in a color specified by the architect, enhancing the beauty of the building.

Finally, chemists who are not content with materials in the thermoplastic or thermoelastic class have gone on to create single-ply water proofing membranes that are a hybrid of the other two class types. Hybrid membranes exhibit the positive characteristics of both the rubber like and plastic like systems. Hybrids, while still in the single ply class of roofing membranes are the newest materials on the market. The drawback to hybrids has been their youth. Doubtless more and more facilities will use them when their life cycles have been proved over longer periods.

Dr. Heshmat Laaly, of the Roofing Materials Technology Corporation has published a list of single ply roofing membrane manufacturers in his authoritative two volume set. A copy of this information is reprinted here with his permission. Table 5-4.

Table 5-4. Some of the single-ply system manufacturers and their phone numbers. Courtesy: The Science and Technology of Traditional and Modern Roofing Systems, Copyright 1992 Laaly Scientific Publishing, Los Angeles, CA.

A & S Building Sys., 639 E. Main St., Ste B-204,
Hendersonville, TN 37075..........(615) 822-4894

Aeroil Products Company, Inc., 69 Wesley Street,
South Hackensack, NJ 07606.......... (800) 338-1418
..........or (201) 343-5200

Alkay Roofing Systems, Inc., 102 South Superior Street,
Angola, IN 46703.......... (800) 552-7762
..........or (219) 665-9794

Allied-Signal Inc., Black Armor Coal Tar, POB 1053R,
Morristown, NJ 07962.......... (800) 221-6490
..........or in NJ (201) 455-5699

Allied Roof Systems, P.O. Box 320347,
Birmingham, AL 35232.......... (205) 591-1010

Alumax, Building Specialties Div, 227 Town East Blvd,
POB 163, Mesquite, TX 75149.......... (214) 285-8811

American Buildings Roofing & Arch Prod,
POB 800, State Docks Rd, Eufaula, AL 3602.......... (205) 687-2032

American Lubricants, 1 227 Deeds Avenue, Dayton, OH 45401.......... (513) 222-2851

American International Building Systems, Inc.,
14603 Chrisman, Houston, TX 77039.......... (713) 449-9000

American Hydrotech, Inc., 303 Ohio St, Ste 2120,
Chicago, IL 60611.......... (312) 337-4998

American Steel Building Co., PO Box 14244,
Houston, TX 77221.......... (713) 433-5661

ASC Pacific, Inc., 211 0 Enterprise Blvd.,
West Sacramento, CA 95691 -3493.......... (800) 726-ASCP
..........or (800) 252-2666
..........or (916) 372-6851

Atlantic Asphalt & Equipment, 146 Railroad Street,
Revere, MA 02151.......... (617) 289-6788

Atlas Aluminum Corp., Iron Run Industrial Park,
540 Snowdrift Rd, Allentown, PA 1 8106.......... (215) 395-8445

Baron/Wheeler, Inc., Construction Mat, 3171
Babcock Blvd, Pittsburgh, PA 15237.......... (412) 367-4277-78-79

Barrett Company, 3422 Old Capital Trail, Wilmington, DE 19808.......... (800) 647-0100
..........or (201) 647-0100

BehStev Corporation, 1 88 S. Teilman Street, Fresno, CA 93706.......... (800) 621-9281
..........or in CA (800) 521-0481
..........or (209) 233-2181

Berridge Manufacturing Comp, 1720 Maury St,
Houston, TX 77026.......... (800) 231-8127
..........or (713) 223-4971

BETCO, Inc., P.O. Box 1 650, Statesville, NC 28677 (800) 654-7813

Bitec, Inc., POB 497, #2 Industrial Park Dr,
Morrilton, AR 72110.......... (800) 535-8597
..........or in AR (501) 355-8585

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Apeldoord, Holland Europe... (011) 31-55-422622

Blackwell Burner Company, 601 Humble Avenue,
San Antonio, TX 78225.. (800) 531-7979
....or in TX (800) 292-7848

Bouras Mop Manufacturing Company,
1330 Doiman Street, St. Louis, MO 63104.. (314) 241-5800

Brubaker-Mann, Inc., 30984 Soap Mine Road,
Barstow, CA 92311.. (619) 256-2520

BTL Weatherproofing Sys, Inc.,
284 Watline Ave, Mississauga, Ont L4Z 1 P4, Canada... (416) 890-4800

Building Protective Industries, 850 Glen Ave,
P.O. Box 392, Moorestown, NJ 08057.. (609) 866-7600

Building Technologies Corp, 2412 Courseview Dr, Ste 400,
Mason, OH 45050.. (513) 573-5200
....or (513) 573-5224
....or (513) 573-5913

Burkeline Roofing Systems, 2250 S. Tenth St.,
San Jose, CA 951124197.. (800) 669-7010
....or (408) 297-3500

Butler Manufacturing Comp, BMA Tower,
Penn Valley Pk, Kansas City, MO 64141 -0917.. (816) 968-3322

Carlisle Syn-Tec Systems, Div of Carlisle Corp,
P.O. Box 7000, Carlisle, PA 17013.. (800) 233-0551
....or in PA (800) 932-4626
.... (717) 245-7000

Celotex Corporation, Roofing Products Division,
P.O. Box 31602, Tampa, FL 33631.. (813) 873-4185

Cleasby Manufacturing Company, Inc.,
1414 Bancroft Avenue, San Francisco, CA 94124.. (415) 822-6565

Conklin Company, Inc., 889 Valley Park Dr.,
P.O. Box 155, Shakopee, MN 55379... (800) 677-7710
or in MN... (612) 445-6010

Consolidated Coatings Corp, 1801 E. Ninth Street,
Cleveland, OH 44114-3178... (800) 321-7886
....o r (216) 771-3258

Continental Rubber Company, 415 Blake Road, N, Suite 1,
Minneapolis, MN 55343... (800) 992-9973

Cooley Roofing Systems, Inc., 50 Esten Avenue,
P.O. Box 939, Pawtucket, RI 02860.. (800) 444-4023
....or in RI (401) 724-0490
....or (401) 724-9000

Curveline, Inc., 1745 Monticello Ct., P.O. Box 4268,
Ontario, CA 91761... (714) 947-6022

Danosa Caribbean Inc., P.O. Box 13757,
Santurce Station, Puerto Rico 00908.. (809) 785-4545

Dibiten USA, 4301 E. Firestone Blvd., South Gate, CA 90280....................................... (800) DIBITEN,
....or in CA (800) DIBITEN,
....or in Canada (800) 527-1123

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DiversiTech General (A GenCorp Co), Bdg Sys Div,
POB 875, Toledo, OH 43696-0875........ (800) 443-4272
........or (419) 729-3731

Domtar Const Materials (NGBM Inc.), 2021 Union Ave,
Montreal, H3A2S9, Canada........ (514) 848-5418

Dunlop Construction Prod, Manitoba Ave, Bdg 63,
Huron Park, Ont. NOM1Y0, Canada........ (519) 228-6564
........or (800) 387-8000

Duro-Last Roofing Inc., 525 Morley Drive, Saginaw, MI 48601........ (800) 248-0280
........or in MI (517) 753-6486

E.G. Smith Construction Products, Inc.,
100 Walls St, Pittsburgh, PA 15202........ (412) 734-6249

ECI Building Components, Inc., P.O. Box 968,
Stafford, TX 77477-0968........ (713) 499-5611

ERACORP/Syenergy Methods, Inc., POB 119,
50B Tiffany St, Danielson, CT 06239........ (203) 774-3354
........or (800) 443-5785
........or in MN (800) 325-0932

Fabral/Alcan Building Prod, 3449 Hempland Rd,
Lancaster, PA 17601........ (717) 397-2741

Fashion, Inc., A sub of Kidde, Inc., 15450 W. 108th St,
Lenexa, KS 66219-1302........ (800) 255-1009
........or in KS (913) 888-8111

Firestone Building Products Co.,
525 Congressional Blvd., Carmel, IN 46032-5607........ (800) 428-4442
........or (317) 575-7000
........or in IN (800) 422-9079

Follansbee Steel Corp, State St, P.O. Box 610,
Follansbee, WV 26037........ (800) 624-6906
........or in WV (304) 527-1260

Foremost Manufacturing Comp, 20941 East St,
Southfield, MI 48034........ (800) 622-4001

GAF Building Materials Corporation, 1361 Alps Road,
Wayne, NJ 07470........ (201) 628-3000

Garland Co., 3800 E 91 St Street, Cleveland, OH 44105........ (800) 321-9336
........or (216) 641-7500

Gedaco S.p.A., 37050 Roverchiara (VR) Italy, via Busse, 23........ (0442) 74500

George D. Wildman, Inc., 17823 Evelyn Ave,
P.O. Box 3130, Gardena, CA 90247........ (213) 321-1660

Globe Asphalt Products Ltd., 380 Tank St.,
Petrolia, Ontario NON1 R0, Canada........ (509) 882-2300

GOA Inc., 121 Railroad Ave, P.O. Box 1205,
Hackensack, NJ 07602........ (201) 343-0181

Goodyear Tire & Rubber Comp, 1144 E. Market St.,
Akron, OH 44316-001........ (800) 922-7663
........or in OH (800) 231-5867

GS Roofing Products Company, Inc.,
5525 MacArthur Blvd., Ste 900, Irving, TX 75038........ (214) 580-5600

HH Robertson Company, 400 Holiday Drive,
Pittsburgh, PA 15220........ (412) 928-7500

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Huls America, Inc., 2 Turner Place, Piscataway, NJ 08855.. (415) 462-5744
....or (800) 782-4857
....or in NJ (908) 981-5300

Hyload Inc., 1006 McKnight Park Dr, Pittsburgh, PA 15237.. (800) 457-4056
....or in PA (412) 376-0633

Imperbel America Corp, 1717 W 13th Ave, P.O. Box 4452,
Denver, CO 80204... (800) 444-9002
....or (303) 892-9002
....or in KS (800) 456-8556

Imperitalia S.p.A., Str. Lanzo 131, 10148 Torino, ITAL...11 /254054

Index SPA Techologie Impermeabili,
37060 Castel d'Azzano, Verona, ITALY.. (045) 51Z33

Inland Buildings, 1 75 N. Patrick Boulevard, Suite 120,
Brookfield, WI 53005.. (414) 792-9292

Intec-Permaglas (US Intec), 5210 N.E. Elliott Circle
POB 1438, Corvalis, OR 97339-1438.. (800) 541-6230
....or (503) 754-7534

International EPDM Rubber Roofing System Inc.,
5110 Angola Rd, Toledo, OH 43615... (800) 248-1558
....or (419) 382-0111

Jesco Iron Crafts, Inc., 201 West Fort Lee Road,
Bogota, NJ 07603.. (800) 524-1142
....or (201) 488-4545

JPS Elastomerics Corp, Roofing Systems Div,
395 Pleasant St, Northampton, MA 01060.. (413) 586-8750

Karnak Corporation, 330 Central Avenue, Clark, NJ 07066... (800) 526-4236
....or (908) 388-0300

Kelly Energy Systems, 325 Thomaston Avenue,
P.O. Box 2583, Waterbury, CT 06723... (800) KES-ROOF
....or (203) 575-9220

Kirby Fiberglass, Inc., 652 E. Industrial Blvd.,
Pueblo West, CO 81007.. (719) 547-3940

Koppers Industries, Inc., 436 7th Avenue, Rm. 2000,
Pittsburg, PA 15219... (800) 558-2706

Limestone Products Corporation, P.O. Box 217,
Sparta, NJ 07871.. (201) 383-2000

LTR, 9302 S. Garfield, South Gate, CA 90280.. (213) 773-4244

Ludwig Building Systems, Inc., P.O. Box 23134,
Harahan, LA 70183.. (504) 733-6260

Manville Sales Corp, Rfg Sys Div, Ken-Caryl Ranch,
POB 5108, Denver, CO 80217-5108... (800) 654-3103

MB Technology, 188 S. Teilman, Fresno, CA 93706... (800) 621-9281

McElroy Metal, Inc., 1500 Hamilton Rd, Bossier City, LA 71111.. (318) 747-8000

Meadows, Inc., W.R., P.O. Box 543, Elgin, IL 60123.. (708) 683-4500

Merchant & Evans Comp, Crossroads Industrial Comm,
POB 1680, Buriington, NJ 08016... (609) 387-3033

Metal Building Components Inc. (MBCI), POB 38217,
Houston, TX 77238... (713) 445-8555

Mineral Fiber Mfg Corp (MFM), 313 S. 6 St,
P.O. Box 356, Coshocton, OH 43812... (800) 882-7663

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....or in OH (614) 622-2645
....or in CA (714) 968-5861

Molenco, Inc., P O Box 2506, Houston, TX 77252.................. (713) 225-1441

Monsey Prod Co (WatPro, Inc.), P O. Box 368,
Cold Stream Rd, Kimberton, PA 19442.................. (800) 523-0268
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Mule-Hide Products Comp, Inc., PO Box 1057,
820 Broad St., Beloit, WI 53511.................. (608) 365-3111

Nord Bitumi US Inc., 105 Morris Avenue., Springfield, NJ 07081.................. (800) 445-1337
....or (201) 467-8669

Owens/Corning Fiberglas Corp, Industrial Textile Div,
Fiberglas Twr, Toledo, OH 43659.................. (419) 248-8000

Papler Kingsey-Falls Inc., 6416S. Quebec St., #41,
Englewood, CO 80111.................. (303) 741-3993

Pasvalco, 100 Bogert Street, Closter, NJ 07624.................. (800) 222-2133

Pentameric Corporation, 5401 W. Kennedy Blvd.,
Tampa, FL 33609.................. (813) 287-1173

Performance Building Prod Inc., 701 S. 38th St,
POB 6244, Kansas City, KS 66106-0244.................. (913) 371-7711

Phillips Fibers Corporation, P.O. Box 66,
Greenville, SC 29602.................. (800) 845-5737
....or (803) 242-6600

Portable Heat Burners, Inc., 19011 W. Davison,
Detroit, MI 48223.................. (313) 838-6212

Prospex Rfg Prod Inc., 1275 Eglinton Ave E, # 61,
Mississauga, Ont, CANADA L4W2Z2.................. (416) 629-1014

Protective Coatings, Inc., 1602 Birchwood Ave/
3001 Reynolds St, Fort Wayne, IN 46803.................. (219) 424-2900

Reeves Roofing Equipment, 12042 Leslie Road,
Helotes, TX 78023.................. (512) 695-3567

Republic Powdered Metals, Inc. (RPM),
POB 724, 2628 Pearl Rd., Medina, OH 44258.................. (800) 255-1136
....or (216) 225-3192

Sarnafil, 100 Dan Rd, P.O. 380, Canton Commerce Ctr,
Canton, MA 02021.................. (800) 451-2504
....or (617) 828-5400

Schofield Company; George, P O. Box 110,
Bound Brook, NJ 08805.................. (201) 356-0858

Seal-Dry/USA Inc., 3300 S. Woodrow, Little Rock, AR 72204.................. (800) SEAL-DRY
....or (501) 663-3063

Seaman Corporation, 2170 E. Whittfield Ave,
Sarasota, FL 34243.................. (813) 756-8463

Soprema Rfg & Waterproofing, Inc., 2181 Northlake Pkwy.,
Ste 107, Tucker, GA 30084.................. (800) 543-3085
....or (404) 938-3878

Southwestern Petroleum Corp, P.O. Box 961005,
534 N Main, Fort Worth, TX 76101-0005.................. (800) 877-9372
....or in TX (817) 332-2336

StaFast Roofing Products Comp,
555 Toligate Rd., Ste. G, Elgin, IL 60123.................. (708) 697-5664

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Steelco-MCP, 1887 S. 700 West, Salt Lake City, UT 84104... (801) 973-0911

Steelite, Inc., 1010 Ohio River Blvd, Pittsburgh, PA 15202.. (412) 734-2600

Tamko Asphalt Products, 220 W Fourth Street,
Joplin, MO 64801.. (800) 641-4691
....or in MO (417) 624-6644

Tarmac Roofing Systems, Inc., 1401 Silverside Rd,
Wilmington, DE 19810... (800) 227-7291
....or (302) 475-7974

Texas Refinery Corp, P.O. Box 711,1 Refinery Pl,
Fort Worth, TX 76101.. (800) 827-0711
....or (817) 332-1161

Thermo Materials, P.O. Box 9454, San Diego, CA 92109... (800) 882-7007
....or (619) 272-0061

Tremco Inc., 10701 Shaker Blvd., Cleveland, OH 44104... (216) 292-5000

Tri-Ply / Div. of U.S. Intec, 1250 14 Mile Rd Ste 103,
Clawson, Ml 48017.. (800) 445-9856
....or (800) 331-3007
....or (313) 543-7910

Ultra Seam Association, P O. Box 710, Morganfield, KY 42437. .... (502) 779-2730

Uniroof Corp, P O. Box 160133,801 W. Hwy 436,
Altamonte Springs, FL 32716-0133.. (407) 869-5110

United Steel Deck, Inc., 475 Springfield Avenue,
Summit, NJ 07902-0662.. (908) 277-1617

US Intec, 1212 Brai Drive, P O. Box 2845, Port Arthur, TX 77643.. (800) 231-4631
....or (800) 624-8632
....or (800) 392-4216

Vincent Metals, Bldg Prod Grp, 700-24th Ave SE,
POB 360, Minneapolis, MN 55440-0360.. (800) 328-7772

Weatherford Alum & Roll Forming, Inc.,
1518 Meadors Farm Rd, Florence, SC 29504 WP.. (803) 669-6690

WP Hickman Systems, 29100 Hall Street, Solon, OH 44139... (216) 248-7760

Ballast

Aggregate is also used to ballast single ply and protected membrane roof systems. Ballast is a term for weighing down the roofing membrane, usually with loose stone. Ballast protects the relatively light insulating material and roofing membranes from uplift pressures resulting from winds and from puncture by hail-stones. Figure 5-5 is a close up photo of a ballasted single ply PVC membrane.

Liquid Applied Systems

In addition to the single-ply roofing membrane systems that are installed in sheets, there exist in the fast paced roofing industry liquid chemicals which dry to provide a lasting, tough water-

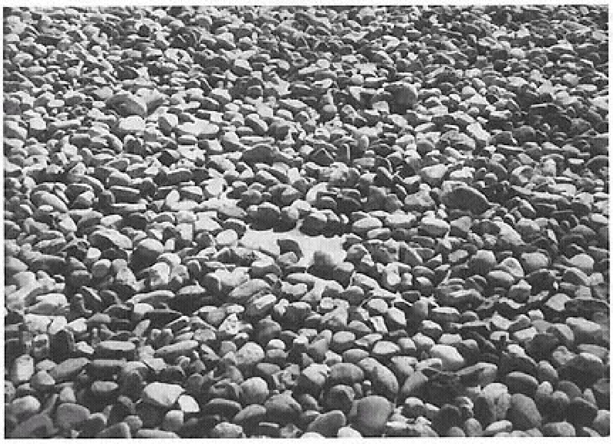

Figure 5-5
A "Ballast" consists of loose laid smooth stones. The weight holds down a single-ply membrane and prevents uplift. Photo by author.

tight membrane. Liquid applied systems can be placed using a variety of methods including brushes, rollers, squeegee, and spray gun. The spray gun used for liquid applied systems is very similar to a paint gun.

Liquid applied waterproofing systems include asphalt cements, acrylic latex, urethane, silicone, neoprene, butyl rubber and epoxies. Depending upon the materials used for the roof deck, the shape of the deck, and the insulation types, varying success is achieved with liquid applied systems. It is very important that the materials used are compatible with the materials they attach to. For example, certain types of insulation does not work well with certain types of asphalts. They will, in effect dissolve each other and this is just the opposite of the desired effect for the roofing system.

Manufacturers of spray applied systems should be consulted prior to application over old insulation or membranes.

The greatest advantage of the liquid applied system is the ability to place them on roofs of uneven shapes or roofs with a lot of projections. A large flat roof without many projections is a candidate for a single-ply membrane delivered in sheets, however, a roof with a lot of small projections, such as for air conditioning vent stacks, antennas, masts, or skylights, requires much cutting and fitting of the rubberized or plastic sheets to make it fit. In addition, each of the projections must be flashed, something discussed more fully in Chapter 7.

The advantage of liquid applied systems is that it can be self flashing because it adheres to the deck and attaches directly to the parapet or gravel stop.

Difficulties with liquid applied systems are pin holing as a result of evaporation of solvent. The systems can vary in thickness resulting in ponding small amounts of rainwater.

Sprayed Polyurethane Foam Roofs

One of the most sophisticated roofing systems is the Sprayed Polyurethane Foam (SPF) roof. By using the techniques of spray application and combining it with liquid applied roofing methods a combined roof insulation and waterproofing membrane is developed that has been very successful in some applications. SPF systems won't work for every type of roof but for many roofs it serves excellent purpose.

The same Polyurethane Foam discussed earlier in this chapter under roof insulation can be manufactured on the roof using a specially designed spray gun that mixes the two chemicals needed to generate a PUF insulation. Applicators walk across the roof deck spraying the liquid which swells on application into the tiny celled foam insulation.

Afterward, the same equipment is used to apply a waterproofing coating over the foam, isolating it and protecting it from ultraviolet light and water.

SPF systems are becoming increasingly popular, but are difficult to apply. One of the many problems with SPF systems are poor quality control in the field while the material is being sprayed. If the deck is not properly prepared, to hot or too cold, or if there is moisture in the deck or if it is placed too thick or too thin then the SPF roofing system can have problems.

Many facilities have had problems with utilizing sprayed polyurethane foam roofing systems not because the product is poor but because the installation of the product was performed by technicians not familiar with PUF application or by application on a deck that wasn't suited for or poorly prepared for the SPF system.

The same fire class problems with sprayed foam apply as with the PUF foam boards. Application is limited to certain types of decks with various materials. Again, the wrong application of foam and decking can lead to increased insurance costs or could be rejected by code authorities for some occupancies.

Finally, the SPF systems have had to be reformulated to comply with new federal regulations against chlorofluorocarbons (CFCs) which are being heavily taxed to prevent their use because of suspected depletion of the earth's ozone layers. The industry has been successful in getting new HCFCs approved and they are being used in lieu of the older CFCs. SPF systems have proved useful and have found a certain acceptance within roofing industry markets. SPF roofing systems will see even greater service in the years to come.

As discussed with the liquid applied roofing membranes, it is important to apply the SPF roofing so that it drains correctly. Low points and voids will eventually hold water that can penetrate into the insulation and break it down under freeze-thaw cycles. Final coats of waterproofing membrane should be applied in layers to form a final dry film thickness of 30 mils or more. One mil equals 1/100 of an inch. SPF systems also have to be applied so that the final foam is strong enough to be walked upon, otherwise, people walking on the deck can tear the waterproofing membrane.

Volatilization

All of the liquid applied systems have a couple of things in common which can be drawbacks if not addressed by the facility manager in charge of the project. Systems that are applied wet have liquids in them which evaporate under a process called volatilization. Usually the volatile compounds are chemical fluids similar to naphtha which can be hazardous if inhaled and which can also be flammable. This would certainly be a consideration if reroofing an occupied building where the intakes for the air conditioning systems were located on the roof.

A facility manager does not want the headache, literally, of having to smell the fumes from the evaporating liquids if he doesn't have to. Neither does he want to have to deal with complaints from angry customers subjected to fumes. Even a harmless vapor that has a foul odor can be troublesome. Hence, the facility manager should consider the problems of building occupancy and fume or odor control when considering use of a liquid applied or sprayed applied system.

Sprayed applications are also susceptible to winds and spraying on a windy day can cause the PUF or the Liquid Applied Membrane to blow onto the cars in the adjacent parking lot or to eating/drinking areas below. Caution should be exercised when considering the application of liquids for these reasons.

Metal Roofing Systems

If all of the previous discussion of polymers and co- polymers and high molecular chemistry is confusing, it is also confusing to many other facility managers. These chemical/rubberized/plastic roofing membranes have their place in the roofing industry. The advantages to using them are the quickness with which they can be applied, their price and long lasting life. However, the metal roofing industry has made great strides in recent years and is now very competitive, price wise, with the elastomeric roof applications.

Metal has advantages in the medium slopes, 3 inches per foot or more but it has also been used in low sloping applications of 1/4 inch per foot. Metal is also very attractive in steep slope applications such as domes, spires or steeples.

Metals

Metals have been used to provide a waterproofing membrane for roofing systems since they were invented, however, as the process of producing metals was expensive, only the cheapest and most mass produced metals were utilized. Buildings have been roofed with gold plates but these buildings don't last very long because someone usually decides to conquer the city to steal the gold. Clearly a case of the wrong application, although not for a technical reason but a social one.

Roofing Metal is chosen because it provides the necessary resistance to water, wind, and sunlight. Historically, metals such as lead and copper have been used. Iron, because it rusts was not used until it could be produced in mass quantity and the technology of painting it to resist corrosion was better understood. Finally more modern metals like aluminum are being used because of their light weight. Most metals are coated either with zinc, zinc/aluminum alloys, paints or special coating applications to protect it. Also for many metal roofing assemblies, it is important to coat the fasteners that hold the metal to the roofing structure.

Lead, as one of the oldest metals, was once used for historical buildings built before 1900. Lead was also used as a flashing material because of its resistance to water and its easy workability in bending, cutting and shaping. However, even though lead is less expensive, it is still very expensive for use in modern buildings.

Copper. After lead, copper is one of the most common of the older roofing metals. The domes of many historical government buildings are fitted with copper sheets over wood decking. The surface of copper turns green in the oxygen that occurs naturally in air. This green sheen over the copper is called 'patina.' The patina forms a protective coating over the metal.

Fasteners. For lead and copper sheeting, fasteners have been made from copper, tin, or zinc coated nails. Some sheets have even been fastened with copper rivets. However most roofing problems with these historic buildings are the result of failures of the fasteners rather than of degradation of the metal itself.

Unfortunately, many cities are now experiencing a phenomena called acid rain where the water is slightly acidic as a result of hydrocarbon pollution from sulfur burning coal. This acid rain is very detrimental to most building materials but especially so to historic metal roofing materials.

Steels. Most metal building roofing covers are thin sheets of coated steel. In fact, all pre-engineered metal buildings have roofs made of coated steel sheets. Metal roofs are also now being constructed as retrofits of older stone or masonry buildings with flat roofs. A new substructure is fabricated that rests on the existing roof deck. The substructure is attached to the old building's frame, then metal roof decking is attached to the new frame. These retrofits change the basic shape of the building's roof and need to be coordinated with the building's drainage plan.

There are a great many types of steels and most building steels are made and installed by sheet metal contractor's instead of roofing contractors. This is because it requires a completely different technology in fastening the sheets to the roof.

Standing Seam Metal Roofs. The most commonly encountered metal roof is the standing seam metal roof with either hidden clips or hidden fasteners. See Figure 5-6. This kind of roofing system comes in sheets up to 40 feet long that have a special edge that forms half of the standing seam. When placed on the roof next to an adjacent panel the other edge completes the other half of the seam.

This type of roof has been successful for the pre-engineered building. However, in areas of high snow combined with a low sloped roof the seam can become submerged. Sealants installed at the ends and side laps prevent leakage. The standing seam metal roof assembly has proven to be an excellent roofing choice, especially when used in conjunction with the pre-engineered metal building design.

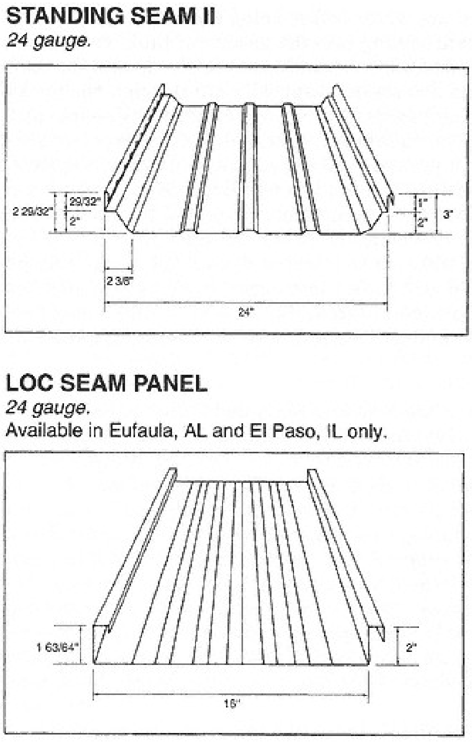

Figure 5-6
Standing seam metal panels are used on buildings.
The standing seam holds the joint between metal
panels up, out of the plane of water.
Courtesy: American Buildings Company Eufaula, AL.

Case Study: Pre-Engineered Metal Building Roof Failure in a Steam Heating Plant

A temporary facility was constructed with two 15,000 horse-power fire tube steam heating boilers burning fuel oil. The plant's steam requirements were used for a process in addition to the building heating loads. The process included steam heating large rolling drums for drying salts from liquid slurry solutions. The steam heating drums were improperly trapped and operators wbypassed the steam traps to allow the direct flow of steam back to the boiler where a tank called a deaerator tank was supposed to hold the condensed hot water before being injected back into the boiler. The live steam coming into the deaerator tank was vented out the stack of the deaerator tank where it fell back onto the roof. Over the years, this live steam eventually ate through the epoxy coating of the roofing panels, destroying the standing seams and the fastening clips. Fortunately an autumn roofing inspection revealed the imminent problem and the roofing system was replaced with new panels within 90 days. The building was only about ten years old at the time. Facility managers reported the roof failure and analysis of the root cause revealed improper processes of bypassing the steam traps on the heated drums. When the correct traps were installed and the system began working properly, the facility energy costs were reduced, the amount of salts being produced was increased, and the damage to the roofing system was eliminated.

Disadvantages to the standing seam metal roof include access for equipment or personnel. Walking on the roofing system and standing on the seams can bend them. Bending can break the seal and allows the seams to leak. It is difficult to have any type of wheeled equipment on the roof, such as refrigerant bottles for charging air conditioning units, and metal seam roofs are difficult to patch if a tool is dropped onto the roof and the metal is punctured. In addition scratched panels are subject to corrosion.

This type of roofing system is very light and the fasteners can pull out under certain wind uplift conditions. Wind damage does not always damage all of the panels however and sometimes the roofing system can simply be folded back down, patched and used for several years.

One of the most significant problems with a pre-engineered metal roofing system is with the fasteners that are used to attach the metal panels to the purlins below. These can be special metal screws are driven through the panel and into the supporting members. Unfortunately, the rubber washers eventually become brittle under ultraviolet light and crack allowing water to seep in. A complete discussion of fasteners in included in chapter 7.

Metal roofing panels are usually limited to a length of about 40 feet. Beyond this length it is difficult to transport them to the job site. This means that the width of the building is limited to 80 feet, that is, with a panel from the gable to the eaves without a joint that runs across the roof. (The standing seams almost always run along the roof. Standing seams that run across the roof are not recommended.)

Like a shingle a seam can be allowed where the lower panel slips under the upper one to prevent drainage problems. With this type of lap joint, the metal roof panels can be extended to even longer lengths and the building can become wider. Generally, if the standing seam panels are going to be lapped, the roofing slope should be enough to prevent ponding water near the seam.

A recent new trend has been to fabricate the panels on site. Mostly this technology is being used today by companies that install roof gutters but the machine used for fabricating gutters can be used for fabricate flashing and even the standing metal panels. A long roll of either metal or aluminum stock on a drum is towed behind a truck with a special set of jigs and tools. For fabricating the panels or gutters, the metal rolling jig is fed the sheet stock and special dies in the jig form the desired shape of gutter, flashing, or panel. A crew of 4 or 5 can install 200 to 300 feet of this material each day. The only limit to the length is the ability to handle the pieces after they come off of the jig.

Finally, metal panels are light and the metal is very thin. Placing them in high wind conditions can be difficult as the winds will bend the pieces before they can be attached to the roof substrate.

Metal Panel Coatings. One of the more complex issues relative to the use of metal roofing panels, and this also includes any type of metal siding panels, are the coatings used to protect the metals from the elements. As previously explained, lead and copper form their own natural coatings in air. In addition, these metals are not subject to degradation and rust in the way that steel panels are.

Steel panels are either galvanized, aluminized, coated with zinc/aluminum alloy or painted. Galvanizing is a term meaning coated with zinc to protect it from rust. Aluminized is a similar term for coating with aluminum. Holes in the panel penetrate the galvanic coating and if this gets wet, rust begins to degrade the metal. Fabrication of irons and steels has improved and rust does not work as fast on steel systems as it once did, however, rust still destroys many metal roofs.

In addition to galvanizing the metal sheets, they can be painted or coated with another material to protect them from the elements. These other methods include baked enamel epoxy, anodized aluminum (several types), porcelain coatings, powdered metal, plastics, acrylic or polyester paints, fluoropolymers, i.e., Teflon@ or Polyvinylidene fluoride (PVF2.) In general the more recent materials provide better weathering characteristics than the older materials.

Paints, while providing rust protection of metal, in general do not adequately seal leaks. Thermal movement that causes metal to move will cause paint to crack along the same lines. Some paint vendors offer a heavy mastic reinforced with fibers that can be dabbed on or even troweled onto joints. About 5 years is all that can be expected from this type of leak repair.

A Few Final Words about Metal Roofing Systems. Metal will continue to grow in popularity. Pre-engineered metal buildings will continue to be chosen by facility managers because they can be erected quickly and they provide one of the best volume per unit cost of any building. For warehouses, storage, vehicle enclosures, and a host of other uses they are very effective. Metal continues to be an attractive alternative to the more conventional built up and single ply sheets. In addition, it is used more and more in the place of shingles on roofs with a slope of 3 inches in 12 or more.

Shingles

More common in residential application but also used for commercial buildings, shingles provide a water shedding membrane on a roof with a greater than 3 in 12 slope. Shingles come in a wide variety materials, colors and thicknesses. Shingle material includes wood, tile, slate, aluminum, and asphalt impregnated glass felt.

Asphalt. The most common roofing shingle is what is called the three tab asphalt shingle. This type of shingle is actually a asphalt embedded glass fiber felt. See Figure 5-7. Commonly used over wood decks on roofs with a slope greater than 3 in 12, asphalt shingles are tacked beginning at the eaves and overlapped with succeeding courses running up the roof. The end of each shingle is displaced by one tab from the course of the proceeding shingle. This prevents a crack or seam occurring in a multiple course.

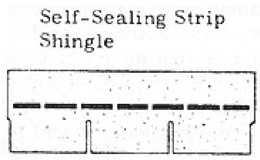

Figure 5-7
The standard three-tab asphalt shingle is used on many sloped roofs. This roofing is used in commercial buildings as well as residential. These shingles are 12" wide and 36" long.
Courtesy: The National Roofing Contractor's Association "The NRCA Steep Slope Roofing Manual" Copyright 1990. Reprinted with permission from the NRCA, Rosemount, IL.

Asphalt shingles are designed such that when the roof is complete there is a layer three shingles deep over the entire roof deck. These three tab shingles are attached with four to six galvanized roofing nails or staples, each long enough to fasten securely to the deck and resist pullout. The asphalt shingles are placed over a single or double layer of asphalt impregnated felt and are of themselves made from a combination of asphalt and glass fiber mat to hold them together. As a top layer, fine granules of stone are placed on the surface of the shingles to protect the bitumen in the asphalt from the sun and UV rays. The three tab shingles have a small spot of adhesive bitumen that softens after the shingle is attached and helps to fasten it to the preceding course of shingle. Figure 5-8 shows a typical three tab asphalt shingle installation.

The length of a shingle roofing warranty is a function of the thickness of the asphalt shingle. Most asphalt shingle systems last between 15 and 25 years. Over time, winds and weather will wear the fine grained stones from the surface of the asphalt. After

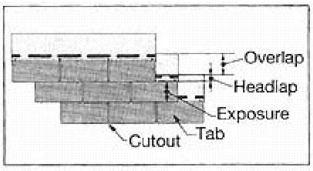

Figure 5-8
Installation of an asphalt shingle roof requires headlap, overlap and exposure for proper installation.
Reprinted from: The Handbook of Accepted Roofing Knowledge (HARK) with permission from the National Roofing Contractor's Association; Rosemount, IL.

this happens the bitumen begins to oxidize out of the glass felt which then begins to curl. The shingles will continue to provide weather resistance when this curling occurs but water begins to penetrate the shingle and even into the wood deck. Once the water penetrates into the wood it can cause the deck to rot. Therefore, if the shingles begin to discolor or curl, it is time to consider replacement.

Fortunately, most roofing systems allow simple re-shingling by placing a new layer of shingles over the former shingles. When re-shingling it is important to use roofing nails long enough to penetrate though the new shingle, the old shingles and into the wood.

Clay Tiles. Clay tiles are used in the south and west and in dry arid climates including the Mediterranean and Mexico. The classic stucco structure with the red clay tiles is a popular combination in arid regions. Clay tile shingle systems can work in wet, rainy climates, but water penetration of the tiles and freeze and thaw cycles have a tendency to break down the tiles.

A typical figure of a tile laying is shown in Figure 5-9 Clay

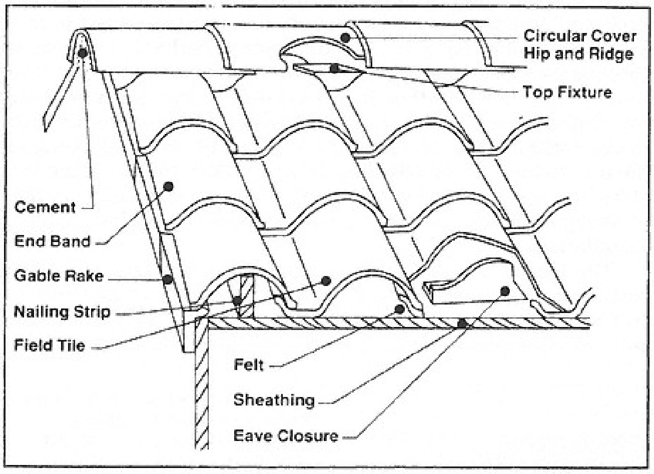

Figure 5-9
Like asphalt shingles, clay tiles are also used on sloped roofs.
Courtesy: National Roofing Contractors Association NRCA Steep Roofing Manual
Reprinted with permission of the NRCA, Rosemount, IL, Copyright 1990.

tiles are one of the more expensive of the roofing materials.

Wood Shingles. Shingles of wood are used in high humidity climates and in wet regions, notably on the west coast. The most common of the wood shingles is cedar. Cedar has natural water resistant oils that protect the wood and the oils also resist mold, mildew, and insect attack. For roofing, cedar shake shingles are placed overlapping similar to the three tab asphalt shingle. Wood shakes are considerably more expensive than asphalt. In addition, wood shingles have to be treated periodically with oil to protect them from weathering. With care, wood shingles can last up 40 years, but wind and weathering sometimes causes individual shingles to split and wobble loose.

Slate. In place of wood shake shingles, slate stone is sometimes used. Applications in the northeastern US are common. The slate is split and nailed to the roof with nails as with all shingles. As the slate is a stone material it will last a long time, up to 100 years.

Roofing manufacturers have begun marketing imitation slate shingles usually made from dense fiberglass. These shingles look like slate but are easier to install. Their long term use has not been fully proved as yet but the market may be ready for this new material.

Aluminum. There are a few manufacturers of aluminum shingling systems which interlock with each other. The shingles are thin metal and are nailed over felt or used in re-shingling applications by nailing directly onto asphalt or felt shingle systems. The nails are driven through the aluminum shingle into the old roof.

Application Problems with the Various Roofing Systems

Each of the previously discussed roofing systems has its own unique set of application problems that must be considered by the facility manager when evaluating which system to use. The fire resistance characteristics of the materials that are used should be evaluated. In fact, one of the elements examined by insurance companies is the combustibility of the roof system in comparison with the value of the materials inside the building.

The most fire resistive buildings are often pubic institutional buildings like schools or government offices. These buildings are designed to outlast the equipment inside and are intended to last over 100 years.

The other problem when evaluating a roofing project is the possibility of the various materials releasing odors during the roofing operation. Built-up roofing systems which are hot applied have the coal tar or bitumen volatilize during application. These materials may occasionally have odors that can be objectionable to the neighbors. On occupied buildings the odors can be drawn into the buildings by the ventilation equipment, resulting in excessive complaints from the buildings occupants.

Single-ply systems don't have to be heated as the built-up systems do or volatilize as liquid applied systems do which is why the single plies are so popular. Some single ply systems cannot be installed over old roofs because of incompatibility between materials or insulation types.

Chapter 6— Energy System Calculations

Introduction to Energy and Roofing System Calculations

The following information provides a guide for the facility manager to see how energy calculations are performed. By following these simple steps it will be possible to estimate the energy use for heating and cooling at any facility. To find the value of a roofing or cladding insulation retrofit, the calculations are repeated with thicker, usually higher R-value insulation to estimate energy use with new roofing and insulation in place. The use of computers with spreadsheet formulas makes the second step easier than it has been in the past.

With the costs for an insulation upgrade estimated, and an estimate of the savings over time, the facility can determine the value of alternate roofing insulation choices.

Creative software vendors are now marketing thermal energy analysis software for facility managers. These systems have templates where data collected from field measurements is input into the program. Some even have databases that estimate winter and summer temperatures.

In addition to estimating energy calculations, this chapter presents information on vapor retarders and how to calculate whether the dew point will be in a wall or roof membrane. When the dew point falls within the wall or roofing system, moisture can condense out of the air and saturate the insulation. Moisture in this instance does not "leak" in from the outside but instead, "collects on" the insulation from the inside. The same problems: fungus, energy loss, fastener corrosion, will occur.

There is a brief explanation of how to estimate simple thermal expansion and contraction of roofing materials. These numbers aid system designers in preventing tearing, ridging and caterpillaring.

Energy Calculations

To be able to successfully prepare an energy budget a facility manager first estimates past season energy costs. Then a few calculations are performed to estimate energy used. This amount is compared to the amount of energy purchased by checking a season or year of utility invoices. This step verifies the calculations. Most utility companies are willing to assist the facility with an analysis if the energy budget is large and the goal is to conserve fuel or power.

As a first step, the facility manager should contact the energy supplier with concerns about energy use. Some suppliers may provide rough energy estimates for little or no fee. If the application is more complex, the energy supplier will recommend the facility contact an appropriate consulting firm to assist in preparing these estimates. These firms, listed under consulting engineers in the telephone directory, provide energy audits and estimates for an hourly fee. In addition, technical roofing consultant firms also provide a similar analysis.

Energy Use

Depending upon how the facility is heated, and what products or services are performed at the facility, energy calculations start out relatively simple and become progressively more complex as the number of services and the intensity of the energy consumed increases. The calculated energy use becomes the basis for preparation of an energy budget.

Preparing for Energy Estimates

Roofing and wall energy calculations can be broken down into a series of steps. Each step is fairly simple and straight forward and when combined with the entire series lends itself well to any type of financial presentation or fiscal accounting process.

Of the two main types of energy loss in a building. The first is called radiant energy loss. This type of energy use is the one that can be adjusted by increasing insulation thickness. A second type of energy loss is called infiltration. Infiltration loss is a result of cracks around windows, doors, and other openings. There is also infiltration loss from opening and closing doors and windows.

The bulk of energy loss is of the radiant energy category. Infiltration loss is controlled by sealing cracks around doors, windows and other openings and by providing double doors at entrances.

Calculating Energy System Costs and the Value of Increased Insulation

The calculation of radiant energy use is important for facilities because so much of the cost of heating and cooling is the result of radiant energy losses. Factors that make energy use difficult to determine include outside temperatures, (warm? cold?) what kind of lighting is used, how many people use the building, what type of activity goes on in the building and daily thermostat settings.

Nevertheless, over a long period of time, the value of good roofing and cladding insulation can be realized. Price changes in the cost of energy also affect the calculations.

Basic Terms

Energy is purchased either as electricity or as a heating fuel. Heating fuels vary throughout the country depending upon the availability of raw materials. In some areas, natural gas or liquefied petroleum fuels are used while in other areas home heating oil or coal is used. For each type fuel the heat generated when it is burned is represented by an energy unit called a British Thermal Unit or Btu. To be precise, a British Thermal Unit is the amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit. A facility buys energy based upon this Btu use.

However, on a facility heating invoice the unit of measure is more often in cubic feet of natural gas, pounds of gallons of liquid propane, pounds or gallons of heating oil, tons of coal or THERMS. It becomes necessary to convert total Btus into one of the other units to calculate energy costs.

For electricity the most common energy unit is the kilowatt-hour, or 1000 watt-hours. Ten 100 watt light bulbs burning for one hour will use up one kilowatt hour of electricity. There are 3413 Btus in one kilowatt-hour.

Energy Units

The energy units most familiar to facility managers are probably kilowatt-hours for electrical power and Btus or THERMS for fuels. In many areas of the country heat energy is supplied by fuels like liquefied petroleum gas, i.e. propane/butane, or fuel oils, i.e. diesel oil or home heating oil. The fuels are delivered in gallon quantities but when burned yield heat energy measured in Btus. Table 6-1 shows some of the more common heating elements and their relationship to Btus needed to heat the facility.

Table 6-1. Energy Units

Material	Fuel Value
Natural Gas	1,080 Btu/Cu Ft.
Propane	90,000 Btu/gallon
Fuel Oil	19,000 Btu/pound
Coal	10,000 Btu/pound
Electric Kilowatt-hours	3,413 Btu/Kilowatt-Hour
THERMS	100,000 Btu

Thermal Resistance, K-factor and R-factor

In a building heat will move from a warm area to a cool area. The walls and roof act as a barrier to slow down the movement of this heat. Materials are tested in a special laboratory and are given a thermal conductivity number (k-factor) which represents the rate that heat will pass through that particular kind of material. For each degree of differential temperature in Fahrenheit, the k-factor represents the number of Btus per square foot that pass through an inch of that material in an hour.

k = Btu-in/hour*ft^2*degree F

Note that a manufacturer will usually have a current k-value for a specific roofing or cladding material.

For example, heat passes through metal fairly quickly (k greater than 20). For wood, heat passes through less quickly (k=1.25) Finally, insulation materials used for roofing and cladding allow even less heat to pass through and this is why these materials are chosen for insulating. (k=0.14 to 0.35)

Thermal resistance (R) is the inverse of thermal conductivity. Therefore:

R=1/k

As the thickness of the material increases, the thermal resistance increases. Three inches of material increases the thermal resistance by a factor of three times.

Rt=3/k

The reason the thermal resistance number is used is that it allows each element of a roofing deck to be *added* to give a total thermal resistance for the entire deck. R values for some typical roofing materials are shown in Table 6-2.

Resistance of Inside and Outside Air Films. In the calculations, the terms f_o and f_i represent the thermal resistance of air film right at the edge of the roof, ceiling or wall. The terms could be ignored but it is not recommended as the inside and outside film resistance makes up a part of the overall thermal resistance of the membrane. Table 6-3 shows estimates that can be used for thermal resistance for inside and outside air films under certain conditions.

Degree Days. The next term used for energy calculations is an abstract one called the degree day. A degree day is a number used by utility companies and engineering estimators. It is a term used to take into account all the variable temperatures over a month or year. What experts do is take the temperature readings over the entire year and tabulate them for their area. The number of degree days can be obtained by calling the utility company and

Table 6-2: R values for some common roofing and cladding materials. R is in hours*ft^2*F/Btu*inch

Material	*Density (lbs/ft^3)*	*Thermal Resistance (R/inch)*	
Cement Fiber Board	120	0.25	
Gypsum Board	120	0.90	
Plywood	34	1.25	
Fiber ceiling tile	18	2.50	
Permeable felt	nil	0.0	
Kraft paper (foil)	nil	0.0	
Fiberglass Batt	0.30	11	for 3 in. thick
		19	for 6 in. thick
		30	for 10 in. thick
Rigid Glass Board	8.5	2.86	
Extruded Polystyrene		5.00	
Expanded Polystyrene	1.0	3.85	
Polyurethane	1.5	6.25	
Polyisocyanurate board	2.0	7.20	
Expanded Perlite board		2.78	
Wood Fiberboard		2.78	
Phenolic Foam (SPF)	2.5	8.33	
Gypsum Concrete	51	0.60	Deck material
Aggregate Ballast	100-120	0.19-0.28	
Planks of Shredded Wood	22	1.67	
Concrete Deck	140	0.80	
Steel Deck	varies	nil	
Plywood Deck	32	1.24	
Mineral Fiberboard	18-23	2.86-2.38	
Mineral Glass Fiber	15	3.45	
Cellulose	2.3-3.2	3.70-3.13	
Expanded Perlite	4.1-7.4	3.70-2.8	
Vermiculite	7.0-8.2	2.13	
Adhered Sheet (Single Ply)		nil	
Cement Fiber Shingles	120	.21	Shingle Thickness
Asphalt Roll Roofing	70	.15	Mat Thickness
Asphalt Shingles	70	.44	Shingle Thickness
Built Up Roofing	70	.33	Applied Thickness
Slate		.05	Shingle Thickness
Wood Shingles		.94	Shingle Thickness

asking them "What were the degree days for October?" or, "What were the degree days for last winter?" Finally, the utility company can also provide the average number of degree days for a particular city for any year. Engineers and roofing consultants also have this number.

In the following example; a 10,000-square-foot roof is covered with a built-up roofing membrane, 1" of perlite insulation, a vapor

Table 6-3. Thermal Resistance of Inside and Outside Air Films. Courtesy of the National Roofing Contractors Association The NRCA Energy Manual Reprinted with Permission of the NRCA, Rosemount, IL Copyright 1990.

	Direction of Heat Flow	Non-reflective E = 0.90	Reflective E 0.20	Reflective E = 0.05
Still Air	R	R	R	R
Horizontal	Upward	0.61	1.10	1.32
Sloping-45°	Upward	0.62	1.14	1.37
Vertical	Horizontal	0.68	1.35	1.70
Sloping-45°	Downward	0.76	1.67	2.22
Horizontal	Downward	0.76	2.70	4.55
Moving Air (any position)		R		
15 MPH Wind (Winter)	Any	0.17		
75 MPH Wind (Summer)	Any	0.25		

Surface films exist on every surface. They are invisible skins of air that cling to the surface and have resistance to heat flow. Outside films will vary in thickness according to wind velocities while indoor films will vary in effectiveness according to the direction that the heat is flowing.

E = Effective emittance of air space

f_o = Resistance of outside air film

f_i = Resistance of inside air film

*Extracted from *ASHRAE Handbook of Fundamentals*, 1985

retarder of foil paper over a wood deck. The building is located in Salt Lake City, Utah, and is heated with Natural Gas that costs: 38 cents a therm. (Remember a therm equals 100,000 Btus.)

Example:

Roof deck:

f_o = Resistance of outside air film (Table 6-3)	....	0.17
Built Up Roofing Membrane (Table 6-2)	....	.0.33
1" of Perlite Insulation Materials (Table 6-2)	....	.2.78
A vapor retarder (foil paper) (Table 6-2)	....	0.00
wood deck (Table 6-2)	....	1.25
f_i = Resistance of inside air film (Table 6-3)	....	.0.61
Total Thermal Resistance	Rt =	5.14

The total thermal resistance of the example roof assembly above is then 5.14.

The thermal conductance (C) is the inverse of the total thermal resistance.

C=1/Rt or C=1/5.14=0.19 Btu/hour*ft^2*degrees F.

The number 0.18 (C) is important but it has to be set aside for a moment while a couple of other numbers are obtained. Once all three are gathered the total amount of Btu's used in a year is the result of multiplying all three numbers together.

For estimating from this book, Table 6-4, is a chart used to estimate degree days for major cities or towns in the USA. The number (degree days) represents the difference in temperatures and number of days (hours when converted) from the established 72 degrees F which is the normal in the US. For Salt Lake City, Utah, the number of degree days is 6050.

Finally, we need the area covered by the roof or cladding insulation. If the particular roof was 10,000 square feet the numbers become:

Total Btus = Area × Degree Days x 24
(Hours Per Day) × C (thermal conductance.)

or:

Total Btus = 10,000 × 6050 × 24 × 0.19
= 275,880,000 Btu.

Unfortunately, heating equipment doesn't work at a 100% efficiency. So, to estimate the heating costs for a year the Btus, or energy, purchased has to be adjusted for furnace efficiency. The facility buys fuel including the fuel of lost efficiency for the furnace. If the furnace or boiler at the facility is 95% efficient, which is a good average, the estimate becomes:

= 275,880,000/0.95
= 290,400,000 Btu

Since one THERM equals 100,000 Btu and a THERM of natural gas in Salt Lake City costs: $0.38/Therm. The cost to heat our facility will be

Cost = 290,400,000/100,000 × $0.38
= $1104 Dollars per year.

Table 6-4. Heating Degree Days for Cities and Towns in the United States. These numbers are used to estimate energy costs. Courtesy of the National Roofing Contractors Association The NRCA Energy Manual Reprinted with Permission of the NRCA, Rosemount, IL Copyright 1990.

Location	Degree Days	Equivalent Operating Hours
Alabama		
Alexander City		1700
Anniston	2600	1610
Auburn		1700
Birmingham	2550	1710
Decatur	3000	1480
Dothan	1800	1830
Florence	3000	1460
Gadsen		1570
Huntsville	3070	1470
Mobile	1560	2070
Montgomery	2290	1950
Talladega	2600	1640
Tuscaloosa	2600	1550
Arizona		
Douglas	2600	1430
Flagstaff	7150	162
Kingman		1470
Nogales		1650
Phoenix	1760	1460
Prescott	4600	760
Tucson	1800	2120
Winslow	4780	1320
Yuma	974	1320
Arkansas		
Blytheville	3400	1490
Camden		1510
El Dorado	2200	1570
Fayetteville	3400	1420
Fort Smith	3290	1740
Hot Springs	3000	1480
Jonesboro	3600	1340
Little Rock	3220	1670
Pine Bluff	2800	1560
Texarkana	2530	1580
California		
Bakersfield	2120	1150
Barstow		1480
Blythe		1720
Burbank	1650	1320
Chico		860
Concord		580
Covina		1660
Downey		1000
El Cajon		1740
Escondido		1280
Eureka	4640	
Fairfield		860
Fresno	2600	1080
Laguna		330
Livermore		930
Lompoc		165
Long Beach	1800	580
Los Angeles	2060	1010
Merced	2400	1340
Modesto	2400	1060
Napa		560
Needles		1480
Oakland	2870	100
Oceanside		380
Ontario		1510
Oxnard		360
Palmdale		1260
Palm Springs		1650
Pasadena	2000	1180
Petaluma		520
Pomona		1500
Redding	4600	770
Redlands		1450
Richmond		102
Riverside		1320
Sacramento	2500	1020
Salinas		290
San Bernardino	2000	1570
San Diego	1460	590
San Fernando		1540
San Francisco	3000	70
San Jose	3000	430
San Luis Obispo		244

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Santa Ana	2000	880
Santa Barbara	2000	310
Santa Cruz	2800	170
Santa Maria	2970	200
Santa Monica	2200	270
Santa Paula		780
Santa Rosa,	3000	620
Stockton	2600	1013
Ukiah		680
Visalia		1250
Yreka	5400	400
Yuba City		900
Colorado		
Alamosa		110
Boulder		250
Colorado Springs		230
Denver		320
Durango		210
Fort Collins	7000	190
Grand Junction	5640	380
Greeley		310
La Junta		850
Leadville	10600	16
Pueblo	5460	580
Sterling		400
Trinidad		450
Connecticut		
Hartford	6230	540
New Haven	5900	560
New London		490
Norwalk	5400	690
Norwich		540
Waterbury		600
Windsor Locks		500
Delaware		
Dover	4600	980
Wilmington	4930	810
District of Columbia		
Washington	4200	
Florida		
Belle Glade		2750
Cape Kennedy		2210
Daytona Beach	880	2170
Fort Lauderdale	200	2690
Fort Myers	440	2770
Fort Pierce	400	2440
Gainesville	1000	2230
Jacksonville	1239	2160
Key West	108	2390
Lakeland	661	2510
Miami	214	2920
Ocala	800	2314
Orlando	770	2410
Panama City	1400	2060
Pensacola	1460	1811
St. Augustine	1000	2020
St. Petersburg	600	2360
Sanford		2390
Sarasota	600	2590
Tallahassee	1480	2080
Tampa	680	2310
West Palm Beach	250	2540
Georgia		
Albany	1800	1990
Americus		2010
Athens	2930	1660
Atlanta	2960	1640
Augusta	2400	1830
Brunswick	1200	2020
Columbus	2380	1840
Dalton	3400	1610
Dublin		1940
Gainsville	3200	1460
Griffin		1640
La Grange		1740
Macon	2140	1770
Marietta	3200	1560
Moultrie	1600	2010
Rome	3326	1610
Savannah	1820	1760
Valdosta	1600	2010
Waycross		2000
Idaho		
Base	5800	350

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Burley	5800	330
Coeur d'Alene	6600	120
Idaho Falls	7200	120
Lewiston	5540	280
Moscow	5800	70
Mountain Home	6400	480
Pocatello	7030	220
Twin Falls	5400	320
Illinois		
Aurora	6600	720
Beleville	4800	1210
Bloomington	5600	900
Carbondale	4200	1250
Champaign/Urbana	5800	1030
Chicago	5880	760
Danville	5400	990
Decatur	5400	1050
Dixon		770
Elgin	6600	650
Freeport		610
Galesburg	6200	840
Greenville		1120
Joliet	6600	790
Kanliakee	6000	850
La Salle/Peru		850
Masomb		940
Moline	6410	730
Mt. Vernon		1230
Peoria	6025	870
Quincy	5400	1025
Rantoul	5800	910
Rockford	6830	630
Springfield	5430	1000
Waukegan		640
Indiana		
Anderson	5400	860
Bedford		1060
Bloomington	4800	1000
Columbus	5400	1000
Crawfordsville		930
Evansville	4430	1200
Fort Wayne	6200	750
Goshen		640
Hobart		730
Huntington		810
Indianapolis	5700	880
Jeffersonville		1160
Kokomo	5600	850
Lafayette	5800	890
LaPorte		700
Marion	5800	780
Muncie	5600	810
Peru		650
Richmond	5400	840
Shelbyville		960
South Bend	6440	640
Terre Haute	5400	1030
Valparaiso		680
Vincennes		1130
Iowa		
Ames		740
Burlington	6110	840
Clinton	6800	690
Council Bluffs	6600	950
Des Moines	6590	790
Dubuque	7380	610
Fort Dodge	7400	700
Iowa City	6400	730
Keokuk	5600	950
Marshalltown	6800	690
Mason City	7600	440
Newton		810
Ottumwa	6400	860
Sioux City	6950	780
Waterloo	7320	560
Kansas		
Atchison		1100
Chanute		1200
Dodge City	4990	1110
El Dorado		1420
Emporia		1270
Garden City		1070
Goodland	6140	880
Great Bend		1310
Hutchinson		1340
Liberal		960

(*Continued*)

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Location	Degree Days	Equivalent Operating Hours
Manhattan		1410
Parsons		1400
Russell		1250
Salina	5000	1260
Topeka	5180	1220
Wichita	4620	1670
Kentucky		
Ashland		1030
Bowling Green		1320
Corbin		1110
Hopkinsville	4000	1370
Lexington	4680	1110
Louisville	4660	1160
Madisonville		1240
Owensboro	4400	1190
Paducah	4200	1230
Louisiana		
Alexandria	2000	1940
Baton Rouge	1600	2010
Bogalusa		1980
Houma		2110
Lafayette	1400	2030
Lake Charles	1400	2160
Minden		1650
Monroe	2200	1710
Natchitoches		1740
New Orleans	1400	1990
Shreveport	2180	1930
Maine		
Augusta		220
Bangor	8000	100
Caribou	9770	
Lewiston	7800	230
Millinocket		110
Portland	7510	150
Waterville		160
Maryland		
Baltimore	4650	1030
Cumberland	5200	900
Frederick	5090	960
Hagerstown	5200	930
Salisbury		980
Massachusetts		
Boston	5630	490
Clinton		340
Fall River	5800	450
Framingham		560
Gloucester		290
Greenfield		410
Lawrence	6800	430
Lowell	6800	480
New Bedford		340
Pittsfield	7580	240
Springfield	6600	490
Taunton		480
Worcester	6970	390
Michigan		
Adrian	6400	670
Alpena	8510	140
Battle Creek	6600	510
Benton Harbor	6200	500
Detroit	6230	500
Escanaba	8480	
Flint	7380	420
Grand Rapids	6890	480
Holland	6400	450
Jackson	6400	550
Kalamazoo	6600	540
Lansing	6910	400
Marquette	8390	80
Mt. Pleasant	7200	350
Muskegon	6700	310
Pontiac		470
Port Huron	7200	450
Saginaw	7000	330
Sault Ste. Marie	9050	
Traverse City		220
Ypsilanti		520
Minnesota		
Albert Lea		470

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Alexandria		260
Bemidji		10
Brainerd		100
Duluth	10000	
Faribault		390
Fergus Falls		270
Mankato		440
Minneapolis	8300	400
Rochester	8200	410
St. Cloud	8800	300
Wilmar		310
Winona		450
Mississippi		
Biloxi	1600	1820
Clarksdale		1460
Columbus	2600	1720
Greenville	2400	1650
Greenwood		1640
Hattiesburg	1800	1870
Jackson	2240	1960
Laurel	2000	1820
McComb		1980
Meridian	2290	1710
Natchez	1800	1880
Tupelo		1480
Vicksburg	2040	1780
Missouri		
Cape Giradeau	4200	1280
Columbia	5050	1160
Farmington		1230
Hannibal	5400	1050
Jefferson City	4800	1150
Joplin	4000	1270
Kansas City	4710	1370
Kirksville		990
Mexico		1090
Moberly		1060
Poplar Bluff		1330
Rolla		1210
St. Joseph	5480	1080
St. Louis	4900	1170
Sedalia	5000	1140
Sikeston		1330
Springfield	4900	1330
Montana		
Billings	7050	190
Bozeman		10
Butte	9800	
Glendive		300
Great Falls	7750	40
Havre	8180	
Helena	8130	40
Kalispell	8190	
Livingston		60
Miles City	7720	370
Missoula	8120	70
Nebraska		
Beatrice		1120
Chadron		570
Columbus	6600	940
Fremont		1040
Grand Island	6530	980
Hastings	6200	920
Kearney		920
Lincoln	5860	1270
McCook		940
Norfolk	6980	810
North Platte	6680	800
Omaha	6610	950
Scottsbluff	6670	490
Sidney		470
Nevada		
Carson City		240
Elko7430	270	
Ely	7730	160
Las Vegas	2709	950
Lovelock		420
Reno	6330	290
Tonopah		380
Winnemucca	6760	320
New Hampshire		
Berlin		150

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Claremont		320
Concord	7380	360
Keene	7400	400
Laconia	7800	310
Manchester	7200	470
Portsmouth	7200	320
New Jersey		
Long Branch	4590	860
Newark	5000	820
New Brunswick	5000	730
Paterson	5400	790
Phillipsburg		810
Trenton	4980	830
Vineland		880
New Mexico		
Alamagordo	3000	1030
Artesia		1370
Carlsbad	2600	1540
Clovis	4200	1100
Farmington		540
Gallup		380
Grants		360
Hobbs	2600	1700
Las Cruces	2800	1560
Los Alamos		250
Raton	6230	430
Roswell	3790	1280
Santa Fe	6200	350
Silver City	3700	530
Socorro		950
Tucumcari		1110
New York		
Albany	6880	520
Auburn		370
Batavia		360
Binghamton	7290	470
Buffalo	7060	330
Cortland		420
Dunkirk		370
Elmira	6400	540
Geneva		460
Glens Falls	7200	270
Gloversville		330
Hornell		280
Ithaca		410
Jamestown		380
Kingston		600
Lockport		280
Massena		160
Newburgh		590
NYC	4810	790
Niagara Falls	7000	360
Olean		290
Oneonta		350
Oswego		230
Plattsburg		140
Poughkeepsie	6200	650
Rochester	6750	380
Roene	7400	370
Schenectady	6650	410
Syracuse	6800	450
Utica		360
Watertown	7200	210
North Carolina		
Asheville	4040	1010
Charlotte	3190	1500
Durham	3400	1300
Elizabeth City	3400	1250
Fayetteville	3000	1550
Goldsboro		1410
Greensboro	3800	1260
Greenville		1330
Henderson		1250
Hickory		1220
Jacksonville	2600	1360
Lumberton		1410
New Bern		1320
Raleigh/Durham	3390	1320
Rocky Mount	3600	1340
Wilmington	2350	1330
Winston-Salem	3590	1270
North Dakota		
Bismarck	8850	310

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Devil's Lake	9900	130
Dickinson		340
Fargo	9220	200
Grand Forks	9800	70
Jamestown		330
Minot	9600	30
Williston	9240	140
Ohio		
Akron/Canton	6040	480
Ashtabula	6400	520
Athens		900
Bowling Green		700
Cambridge		730
Chillicothe	5000	900
Cincinnati	4410	1030
Cleveland	6350	610
Columbus	5660	710
Dayton	5620	790
Defiance	6200	700
Findlay	6200	760
Fremont		650
Hamilton		1000
Lancaster	5200	860
Lima	6000	780
Mansfield	6400	660
Marion		800
Middletown		880
Newark	5600	780
Norwalk	6200	670
Portsmouth		1000
Sandusky	5800	670
Springfield	5600	860
Steubenville		680
Toledo	6490	620
Warren		530
Wooster		610
Youngstown	6400	490
Zanesville		790
Oklahoma		
Ada		1580
Altus -	3000	1570
Ardmore	99	
Bartlesville	4000	1370
Chickasha		1530
Enid	3800	1630
Lawton	3000	1870
McAlester		1560
Muskogee		1910
Norman	3200	1540
Oklahoma City	3720	1670
Ponca City	4000	1580
Seminole		1540
Stillwater	3800	1440
Tulsa	3860	1870
Woodward		1550
Oregon		
Albany		100
Astoria	5190	
Baker	7000	210
Bend		80
Corvallis	4800	100
Eugene	4730	120
Grants Pass	5000	320
Klamath Falls	6400	110
Medford	5010	560
Pendleton	5130	270
Portland	4640	90
Roseburg	4490	290
Salem	4750	90
The Dalles		230
Pennsylvania		
Allentown	5810	710
Altoona	6200	480
Butler		610
Chambersburg	5400	870
Erie	6450	360
Harrisburg	5250	680
Johnstown	5600	520
Lancaster	5400	790
Meadville		400
New Castle		590
Philadelphia	5140	820
Pittsburgh	5970	608
Reading	4940	800

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Scranton/Wilkes-Barre	6250	500
State College	6200	470
Sunbury	5600	650
Uniontown	5200	620
Warren		420
West Chester		820
Williamsport	5930	620
York5400	850	
Rhode Island		
Newport	5800	390
Providence	5950	450
South Carolina		
Anderson		1580
Charleston	2030	1720
Columbia	2480	1710
Florence	2390	1550
Georgetown		1420
Greenville	2980	1480
Greenwood		1700
Orangeburg		1740
Rock Hill		1620
Spartan burg	3000	1470
Sumter-Shaw		1580
South Dakota		
Aberdeen	8600	510
Brookings		470
Huron	8220	660
Mitchell		660
Pierre		610
Rapid City	7340	470
Sioux Falls	7840	630
Watertown	8400	410
Yankton		750
Tennessee		
Athens		1450
Bristol	4140	1100
Chattanooga	3254	1620
Clarksville		1390
Columbia		1460
Dyersburg		1410
Jackson	3400	1360
Knoxville	3490	1340
Memphis	3230	1510
Murfreesboro		1460
Nashville	3580	1440
Tullahoma		1440
Texas		
Abilene	2620	1930
Alice		2860
Amarillo	3980	1260
Austin	1710	2580
Bay City		2240
Beaumont	1000	2000
Beeville		2300
Big Spring		1810
Brownsville	600	2940
Brownwood	2200	2040
Bryan		2290
Corpus Christi	910	2450
Corsicana		1980
Dallas	2360	1940
Del Rio		2070
Denton		1800
Eagle Pass		2300
El Paso	2700	1420
Fort Worth	2400	1870
Galveston	1240	2040
Greenville		1870
Harlingen		2780
Houston	1400	2280
Huntsville		1960
Killeen	2000	1930
Larnesa		1700
Laredo	800	2380
Longview	2400	1820
Lubbock	3580	1610
Lufkin	1800	1810
McAllen		3160
Midland	2600	1810
Mineral Wells		1890
Palestine		1810
Pampa		1410

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Pecos		1980
Plainview		1580
Port Arthur	1450	2030
San Angelo	2250	2060
San Antonio	1550	2360
Snyder		2050
Temple		2130
Tyler		1720
Vernon		1650
Victoria	1170	2390
Waco	2030	1840
Wichita Falls	2830	1990
Utah		
Cedar City		410
Logan		280
Moab		615
Ogden	5600	310
Price		300
Provo		450
Richfield		400
St. George		1130
Salt Lake City	6050	460
Vernal		150
Vermont		
Barre		130
Burlington	8270	210
Rutland	8000	220
Virginia		
Charlottesville	4200	970
Danville	3600	1290
Fredericksburg		1020
Harrisonburg		920
Lynchburg	4170	1130
Norfolk	3420	1280
Petersburg	3600	1260
Richmond	3860	1250
Roanoke	4150	1090
Staunton		900
Winchester		950
Washington		
Bellingham	5400	
Ellensburg		90
Kennewick	5200	340
Longview	5200	40
Moses Lake		230
Olympia	5240	
Seattle	5140	
Spokane	6650	90
Walla Walla	4800	360
Wenatchee		180
Yakima	5940	200
West Virginia		
Beckley		770
Bluefield		640
Charleston	4480	970
Clarksburg	5000	820
Elkins	5680	500
Huntington	4450	1100
Martinburg		1080
Morgantown		640
Parkersburg	4750	910
Wisconsin		
Appleton	7800	290
Ashland		
Beldt	6800	610
Eau Claire	8000	310
Fond du Lac	7600	350
Green Bay	8030	190
LaCrosse	7590	450
Madison	7860	410
Manitowoc		270
Marinette		170
Milwaukee	7630	380
Racine	7400	460
Sheboygan		330
Stevens Point		260
Waukesha		510
Wausau	8400	150
Wyoming		
Casper	7410	160
Cheyenne	7380	110
Cody		50

(*Continued*)

(table continued from previous page)

Location	Degree Days	Equivalent Operating Hours
Evanston		30
Lander	7870	160
Laramie		30
Newcastle		180
Rawlins		60
Rock Springs		60
Sheridan	7680	240
Torrington		340

Degree days are derived from various weather data sources from ASHRAE and the NAHB Research Foundation.

The "Equivalent Operating Hours" listed in the table above were derived from weather data published in the ASHRAE Handbook—1981 Fundamentals. A relationship including latitude and dry bulb temperature was used to determine cooling degree hours. The annual cooling requirements (hours of operation) were then determined as a function of cooling degree hours (sensible load), latitude (solar load) and wet bulb temperature (latent load).

To estimate the value of increased insulation on the 10,000 square foot roof, the same calculations are repeated with R values that result from a new roofing membrane or thicker insulation. Say the 10,000 square foot building was going to upgrade insulation to 2 inches of cellular polyisocyanurate board. Table 6-3 gives this material an R value of 7.2 per inch. Since 2 inches are being installed the R value is 2 * 7.2 or 14.4.

Example Part 2:

Roof deck:

f_o = Resistance of outside air film (Table 6-3)	0.17
Built Up Roofing Membrane (Table 6-2)	0.33
2" of Cellular Polyisocyanurate Materials (Table 6-2)	**14.4**
A vapor retarder (foil paper) (Table 6-2)	0.00
wood deck (Table 6-2)	1.25
f_i = Resistance of inside air film (Table 6-3)	0.61
Total Thermal Resistance	Rt = 16.76

The total thermal resistance of the proposed roof assembly is now 16.76.

C=1/Rt or C=1/16.76=0.0597 Btu/hour*ft^2*degrees F.

Total Btus = Area × Degree Days x 24 (Hours Per Day) × C (thermal conductance.)

or:

$$\text{Total Btus} = 10{,}000 \times 6050 \times 24 \times 0.0597$$
$$= 86{,}684{,}000 \text{ Btu.}$$

Dividing again by the furnace efficiency to account for that energy loss:

$$= 86{,}684{,}000/0.95$$
$$= 91.2 \text{ million Btus.}$$

Using the numbers from above:

$$\text{Cost} = 91{,}200{,}000/100{,}000 \times \$0.38$$
$$= \$346 \text{ Dollars per year.}$$

Hence, by replacing the 1" of perlite insulation Rt = 5.56 with cellular polyisocyanurate Rt = 14.4 the cost to heat the building over winter is reduced:

First Example	Second Example	Savings
$1104/year	$346/year	$758/year

A facility can use this number to budget for energy use and would be able to use this number to justify financing for upgrading roofing insulation.

To restate the effort of calculating the radiant energy losses the following steps are taken:

1. Gather the necessary information. (Building dimensions, openings, insulation materials and thicknesses, etc.) Also, obtain the dollar value for heating fuel purchased, the number of heating degree days for the city or area where the building is located, and an approximate estimate of furnace efficiency.

2. Calculate radiant energy use for one type of building insulation or system by adding up the Thermal Resistance (Rt) of all the roof components, multiply the Rt by the Area of the roof and the number of degrees days of heating or cooling for building and divide by the furnace or heating system efficiency.

3. From the energy estimated calculate the fuel or electricity used for one year.

4. Repeat steps 2 and 3 for alternate roofing or cladding choices.

5. Tabulate the results.

Tax Consequences of Thermal Insulation Retrofits

Some parts of a roof-recover operation may entitle the facility to a tax credit. Depending upon how business has been in the past, this type of credit can be a real boon to the facility in the initial years.

While the tax accounting is beyond the scope of this text, facility managers may benefit from an evaluation of the possible tax consequences. From the previous example where 1" of perlite was replaced with 2" of polyisocyanurate board saved the facility $758 per year in estimated energy costs.

A potential tax credit may make the retrofit more attractive. If 50% of the cost of the project were credited, an initial cost of $28,000 would be reduced to $14,000 by the credit. Over an estimated 20-year life of the polyisocyanurate roof covered with a Built Up Roofing Membrane a savings of $15,160 could be realized.

Other factors to consider include the interest rate on funds required for the roofing project and the potential increases in energy costs over the next 20 years. Chapter 9, Roofing Project Management, discusses these terms more adequately.

Vapor Retarders and Dew Point

Understanding vapor retarding barriers and moisture dew point problems are relatively new for facility managers. As little as 25 years ago radiant and infiltration energy losses reduced the chances of dew point condensation in buildings. Today's thicker and more effective insulation and fewer infiltration losses lead to more moisture condensation problems.

Under certain climatic conditions, roofing and cladding systems need a vapor retarding barrier to prevent naturally occurring moisture inside the structure from saturating the insulation. Moisture inside a building is the result of cooking, bathing and people breathing. Facility activities like processing chemicals also increases inside moisture.

For buildings in areas with cold winters and high humidity a vapor barrier is recommended to prevent moisture from condensing inside the structure. Figure 6-1 shows the relative humidity

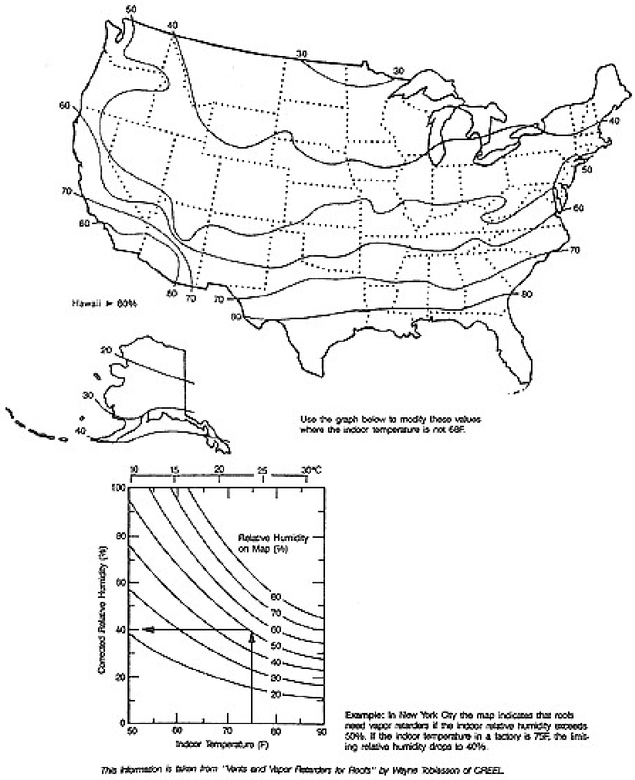

Figure 6-1
Areas in the United States where a vapor retarder is recommended with high indoor relative humidity. Courtesy of the National Roofing Contractors Association The NRCA Energy Manual Reprinted with Permission of the NRCA, Rosemount, IL Copyright 1990.

for areas of the country where moisture dew point is a potential problem. Use of a vapor retarding barrier in these roofs and walls prevents moisture from condensing inside.

A vapor retarder is usually a plastic or foil sheet installed within the membrane to keep moisture out of adjacent insulation.

Humidity and Dew Point

While all air contains moisture, it is mostly water vapor which cannot be seen. When the temperature decreases the moisture in air wants to drop out and it will condense and form rain or dew. Once the humidity reaches 100 percent, any more reduction in temperature results in "dew" on surfaces.

Whenever insulation thickness is increased, the facility needs to carefully calculate where the dew point will be in the finished wall or roof. What happens when the insulation is increased and vapor retarders are added is that condensation of moisture occurs within the facility wall or ceiling. The moisture will negate much of the energy savings initially estimated, but it can also cause the walls to "drip." Also, moisture in the wall can corrode the fasteners which will stain the wall or ceiling.

Figure 6-1 shows the indoor relative humidity in winter above which a roofing or cladding system would need a vapor retarder. To use the chart a facility manager needs to know the approximate inside temperature and expected indoor relative humidity. The latter can be estimated or a humidistat can be used to measure the indoor humidity.

Calculating Dew Point Inside a Roofing Membrane

Regions with cold winter temperatures and high indoor humidity should install a vapor retarder to prevent saturating the building insulation. However, the vapor retarder must be located within the roofing membrane correctly, otherwise the vapor retarding membrane can become the place where moisture condenses.

Calculations are performed to estimate temperatures inside a roofing or a cladding membrane. Then the temperature at the vapor barrier is compared to the dew point temperature for that particular facility. If the vapor retarding barrier temperature is below the dew point temperature, it is fairly certain that moisture will condense into the membrane.

The temperature at the vapor retarder is proportionate to the thermal resistance between the inside and outside. Therefore if the thermal resistance Rt for the whole roof is 15.66 and the thermal resistance between the inside and the vapor retarder Rx is 6.07, then the vapor barrier temperature is estimated by taking Rx for the insulation to the barrier, dividing by Rt through the whole membrane and multiplying by the difference between the inside and outside temperature.

T (at barrier) = T inside minus Rx/Rt*(Temp Difference)

T = 75 F - 6.07/15.66*(75-0)

T = 46 F

If the dew point is 55 degrees for the inside air, moisture will condense on the inside of the vapor retarder. For a wall or roof membrane with this problem either insulation has to be removed outside the barrier or additional insulation added between the barrier and the inside ceiling or wall. The calculations are repeated and the temperature at the barrier is compared to the dew point.

The other thing a facility could do is lower the humidity inside by increasing air flows or removing the source of moisture. Sometimes this second option isn't practical.

Calculation of Thermal Expansion in a Roofing Material

The building frame and deck explained in the previous chapter and the roofing membranes and insulating materials explained in this chapter are all subject to changes in size when outside temperatures increase or decrease. This process is known as thermal expansion. Thermal expansion is the lengthening and shortening of all the elements of the roof system with changes in temperature. The frame members, the deck planks or slabs, the insulating boards, and finally the moisture barrier will be longer and shorter during temperature changes. This expansion and contraction leads to forces on the waterproofing membrane that can eventually break it, allowing water to penetrate and causing leaks. Expansion and contraction of the roofing materials must be accommodated for in the design without tearing the membranes for the roof to be successful.

Calculations of expansion and contraction are performed using thermal expansion coefficients applied to mathematical formulas. Typical expansion coefficients are given in inches per inch per degree of Fahrenheit. Usually the change in lengths are small; on a long sheet, only a fraction of an inch, but it can be enough to crack concrete or tear membranes. Wood, felts, and fibers will stretch before breaking. Some typical coefficients are shown in Table 6-5.

Table 6-5: Thermal Expansion Coefficients for roofing and cladding materials. Change in Length for a 50-foot-long bar with a 100 degrees F temperature change.

Coefficient		delta L for L = 600 inches
i	inches/inch/F	inches in 50 feet per Degree F
Aluminum	.000013	0.0078
Copper	0.0000092	0.0052
Structural Steel	0.0000067	0.0042
Stainless Steel	0.0000078	0.0047
Concrete Structural	0.000006	0.0036
Concrete Lightweight	0.0000045	0.00027
Wood		
Fir	0.0000021	0.0013
Pine	0.0000030	0.0018
Stone		
Granite	0.0000044	0.0026
Limestone	.0000042	0.0025
Brick	.000036	0.022
Polyvinyl Chloride Sheet	.000033	0.020

Thermal expansion is estimated by taking the length of the sheet, board, batt, beam or slab, in inches, estimating the change in temperature in degrees and multiplying the three together.

delta L = A × L (T1-T2)

where: delta L = change in length (inches)

A = coefficient from table

L = original length

T1 = initial temperature

T2 = final temperature

Example:

A the thermal expansion of a structural steel beam 40 feet long when the beams temperature changes from 30 degrees F to 80 degrees F.

$$\text{delta L} = \frac{40 \text{ feet} \times 12(\text{in/ft})}{50 \text{ feet} \times 12(\text{in/ft})} * 0.0042(T1 - T2)$$

$$= .00336(T1 - T2)$$

$$= .00336(80 - 30)$$

$$= .168 \text{ inches longer (approximate)}$$

Chapter 7— Fasteners and Flashings: Holding the Roof on the Roof

Introduction to Fasteners and Flashings

After becoming familiar with the components of roof decking, insulation and waterproofing membranes; there is one more element to be examined before the facility manager is ready to begin a roofing project. Flashings and fasteners provide the roofing or cladding system's attachment to the decking and/or walls. If incorrectly installed or used, fasteners or flashing errors can cause the entire roofing system to fail. While the costs of flashings and fasteners are small compared to other roofing elements, their proper application and use is critical to the roofing system.

Flashing

Flashing is that part of a roofing system that provides transition between a horizontal and a vertical surface. It is common at the edge of the roof, at projections, along parapet walls, and in other areas were a roof and a wall intersect. Flashing is also used on the roof at mechanical equipment openings and at structural expansion joints. See Figure 7-1.

Flashing is comprised of several parts, each of which must work with the others to prevent leaks. Base flashing is a flexible material similar to the waterproofing membrane and can be bituminous, rubber or plastic. The base flashing must be compatible with the insulation and with whatever waterproofing membrane has been selected. In addition to base flashing, another element,

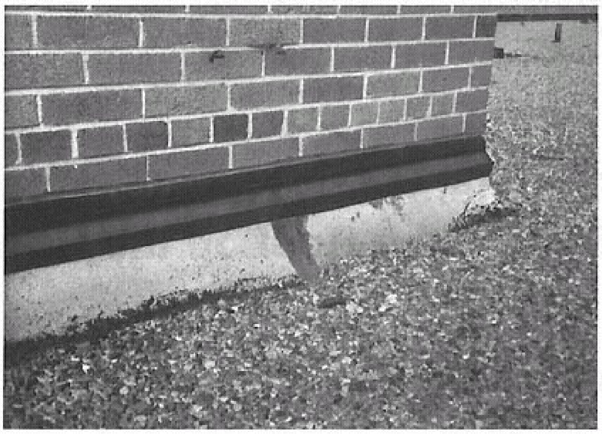

Figure 7-1
Photo of edge flashing. Flashing is needed to protect the roof in an area where the roofing membrane cannot be used.
Photograph by author.

called the counterflashing, covers the vertical part of the base flashing. The two types of flashings are not attached to each other. This way the base flashing can expand and contract without tearing as it would if it were firmly attached to the counterflashing.

Cant Strips

The National Roofing Contractor's Association recommends the use of a cant strip for bituminous roofing systems to prevent the change in angle of the base flashing from being too abrupt. See Figure 7-2. Instead, a small wedge shaped block of wood called a cant strip is used to support the flexible roofing membrane as the angle changes from horizontal to vertical. The cant strip supports the base flashing and prevents the material from puncturing.

Figure 7-2 is a side view of the base flashing, counterflashing, wood block and wood cant strips in a typical parapet installation. By using wood blocking and a cant strip, base flashing can flex with the roofing membrane as it expands and contracts. In many installations counterflashing is metal, either galvanized steel, aluminum, or even copper. Strips installed within a masonry wall hold the counterflashing although some metal counterflashing is attached to the wall with toggle bolts or screws.

The base flashing must be a material that is compatible with the insulation below it and with the waterproofing membrane. Usually base flashing is a heavier version of the main waterproof-

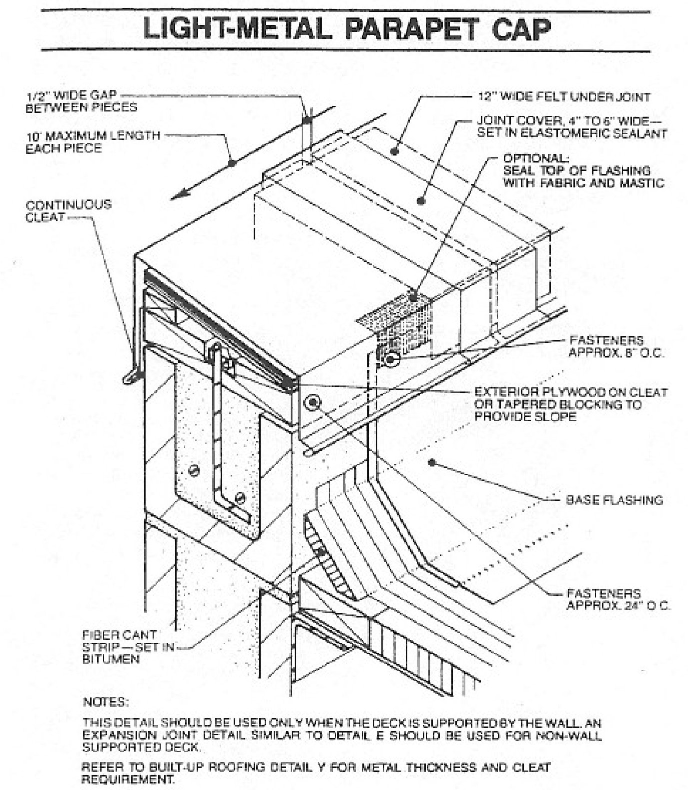

Figure 7-2
Cant strips are used to hold the roofing membrane at corners.
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ing membrane. Because the base flashing is at the edge of the sheet, it must hold greater stresses than the main membrane. In addition, base flashing can be stepped on by maintenance personnel during roofing access and the extra thickness helps to prevent it from tearing.

Metal edging is used on roofs without a parapet wall as shown in figure 7-3. This metal facing protects the top of the masonry wall as well as incorporating the base flashing material.

For sloped roofs, metal flashings are used around chimneys, in valleys, and at openings such as skylights and pipe penetrations. Recently manufacturers have begun marketing plastic flashing that can be used in some of these locations as well.

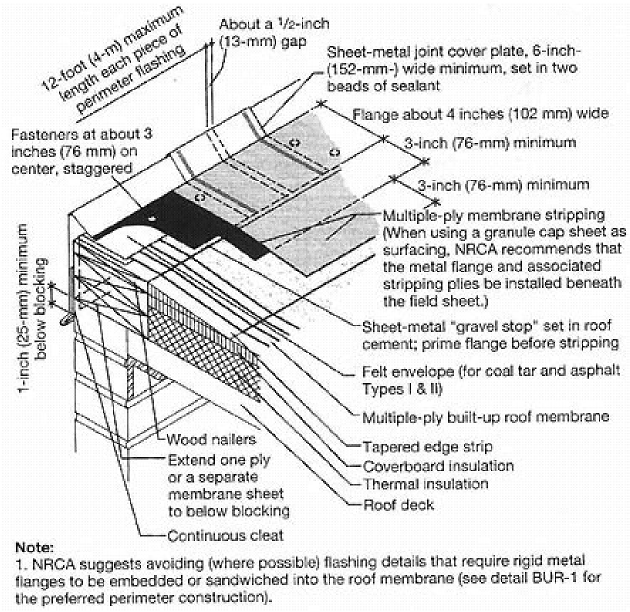

Figure 7-3
Flashing a roof without a parapet wall.
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Crickets. For a sloped roof, a cricket is used to prevent water from being trapped by an curb or projection due to an opening in the roof. The cricket can be made as part of the main structure or it can be metal or plastic placed on the roof and flashed into the roofing membrane. See Figure 7-4.

Fasteners

Fasteners are the nails, bolts, or screws used to hold the roofing materials and flashings on the roof. The most common fastener for steep roofing is the galvanized roofing nail. Roofing nails are selected based upon the thickness of the material the nail is attaching to the roof and on the decking material to which it is being attached. The design of roofing fasteners for thermal insulation and membrane roofing has become quite sophisticated and

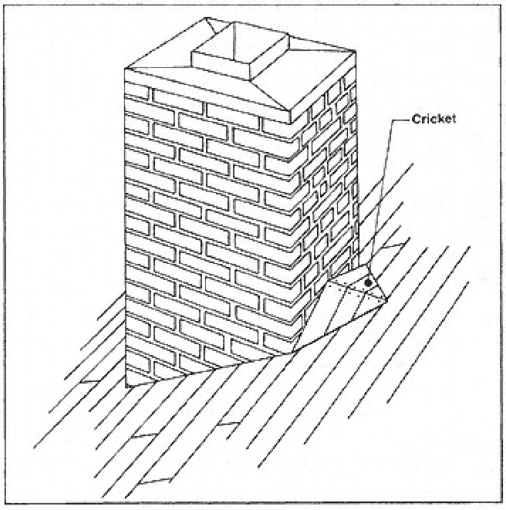


Figure 7-4
A roofing cricket is used to drain water away from a hatch or other projection. The cricket channels water to the roofing drains.
Reprinted from: "The NRCA Steep Slope Roofing Manual" with permission from the National Roofing Contractor's Association; Rosemount, IL. Copyright 1990.

now fasteners are made from plastics, coated with various inert materials and metals. Figure 7-5 shows some of the more typical roofing fasteners.

One of the most classic roofing repair mistakes is to use a standard metal nail because the craftsman is out of galvanized roofing nails. The problem with this solution is that the regular nail will eventually rust away leaving a hole in the roofing material.

Metal and plastic fasteners are also used to hold insulation boards discussed in Chapter 5. Usually the nail or screw has large head or even a small metal or plastic plate that provides a large

	Base Material						Insulation Thickness																Coating / Plating or Material				
Section/ Fastener Type	Steel Deck	Wood Deck	Concrete Deck	Insulating Concrete	Cement Wood Fiber	Gypsum	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"	16"	Plated Steel	Coated Steel	410 Stainless Steel	Zamac Alloy	Engineered Plastic
39.0 No. 12 Deck Screw	●	●					●	●	●	●	●	●	●											●			
39.0 No. 12 Deck Screw Stainless Steel	●	●					●	●	●	●	●	●	●	●	●	●	●								●		
39.0 No. 14 Deck Screw	●	●	○				●	●	●	●	●	●	●											●			
39.0 No. 15 Deck Screw	●	●	○	○			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●			
39.0 No. 12 Hex Head Deck Screw	●	●					●	●	●	●	●	●	●											●			
41.0 Woodie™		●					●																			●	
42.0 SPIKE®			●				●	●	●	●	●	●	●	●	●	●	●	●						●			
43.0 Rawlite™				○	●	●	●	●	●	●	●	●	●	●	●	●											●
44.0 Speed-Lock® Toggle	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			

● Suitable ○ May be Suitable Depending upon Application

Figure 7-5
Fasteners are an important part of any roofing system. Fasteners hold the insulation and some types of membranes to the roofing system.
Courtesy of The Drilling and Anchoring Systems Design Manual,
The Rawlplug Company Inc., New Rochelle, NY.

head or even a small metal or plastic plate that provides a large area to hold the insulation down.

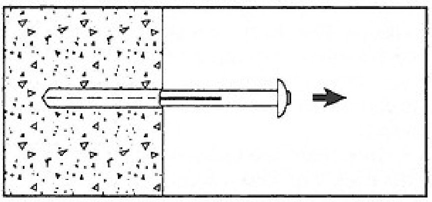
As was discussed in Chapter 1, winds are one of the elements resisted by the roofing system and it is necessary that mechanical fasteners hold the insulation to the deck under wind uplift conditions. In addition single-ply roofing systems that use polyisocyanurate insulating boards are very light and can be caught up during windy, gusty conditions while being constructed. On windy days it can be dangerous to have the membrane and or decking only partially attached. Winds can catch under the flashing and peel the roofing system back from the deck. Therefore it is important to fasten the boards and insulation as soon after installation as possible.

Mechanical Fastening. To protect the roof from uplift mechanical fasteners are used to attach the flashings and insulation to the structure. The fasteners must be placed often enough that they hold the system to the deck and they must be sized correctly to prevent being pulled out or breaking.

Fasteners can fail in one of three ways. Figure 7-6 shows anchor pullout. In this case the fastener simply fails to hold and pulls out from the decking where it is has been driven.

Figure 7-7 shows how a base failure occurs. In a base material failure forces are simply too strong for the construction material and it breaks allowing the fastener to pull out along with a part of the deck material.

Figure 7-8 shows what happens in an anchor failure. In this case the material of the fastener itself pulls apart allowing the roofing material to separate.



This type of failure occurs when the applied load is greater than the friction or compressive force developed between the anchor body and the base material. The anchor is unable to fully transfer the load to develop the strength of the base material. For adhesive anchors, this can occur with products which have a low bond strength.

Figure 7-6
Anchor Pullout.
Courtesy of The Drilling and Anchoring Systems Design Manual The Rawlplug Company Inc. New Rochelle, NY.

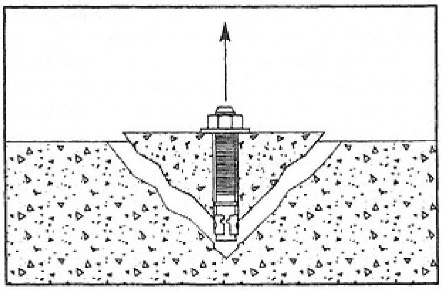


Figure 7-7
Anchor Base Failure.
Courtesy of The Drilling and Anchoring Systems Design Manual The Rawlplug Company Inc. New Rochelle, NY.

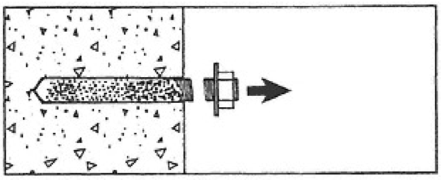


Figure 7-8
Anchor Material Failure.
Courtesy of The Drilling and Anchoring Systems Design Manual The Rawlplug Company Inc. New Rochelle, NY.

Lastly, a roofing system can fail when the material being fastened pulls over the fastener. Use of large washers or plates will prevent this type of failure.

Obviously, the facility manager doesn't want to have to deal with any of these failures and if his system is properly designed none of these will occur. Most flashing problems occur with the light roofing systems such as single ply systems or light metal roofs in high wind conditions. This is the greatest advantage of the built-up or modified bitumen systems as their weight and adhesion tend to limit this type of problem.

A few fastener manufacturers include Rawlplug, Deckfast, Hilti, Olympic and Truefast.

To prevent fastener failure there are three methods of attachment of the fastener to the deck. The first, common with nails and several types of bolts is a friction anchor. The pullout strength is a function of the friction of the shaft of metal against the base material. Wood and nails are a very effective fastening attachment because the wood swells against the fastener, holding it. Often, wood/fastener failures are the result of the wood itself tearing, rather than a pullout of the nail.

Figure 7-9 shows a toggle bolt designed to penetrate clear through the deck. Toggle bolts are designed to hold because the wings of a toggle bolt open after being pushed through the hole driven for the bolt. The fine wire shown in the drawing is provided to hold the wings of the toggle bolt while it is being tightened.

For fastening in a cement or gypsum deck a spring bolt is used. A hole is drilled and a metal rod with a small bend on the end is pounded into the hole. The bent tip acts as a spring and flattens in the hole causing the bolt to resist pullout. Figure 7-10 shows this type of anchor attachment. The disadvantage of the toggle and spring bolts is that they cannot be removed. The toggle

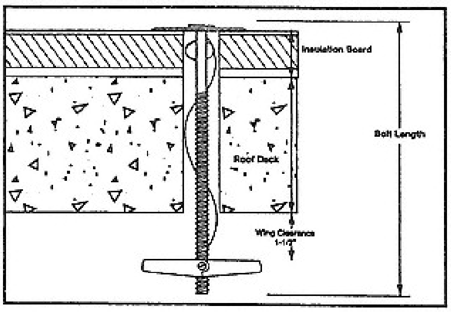


Figure 7-9
Toggle Bolt.
Courtesy of The Drilling and Anchoring Systems Design Manual The Rawlplug Company Inc. New Rochelle, NY.

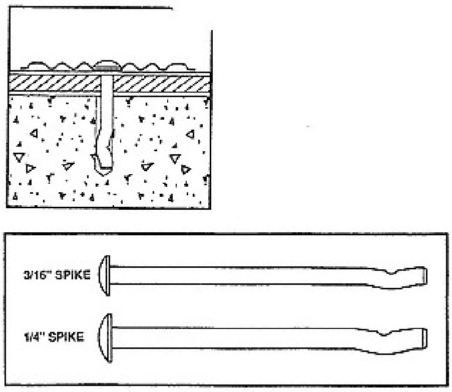


Figure 7-10
Spring Bolt.
Courtesy of The Drilling and Anchoring Systems Design Manual The Rawlplug Company Inc. New Rochelle, NY.

bolt can be unscrewed but the fluted end will drop inside. The spring tip type can be pulled but reinstallation in the same hole would not be recommended since either the spring tension in the bolt or the hole will have been compromised.

Just by way of information, friction type anchors in cement and concrete decks require that the hole that has been drilled be flushed of flour, the result of drilling the hole. This is usually accomplished with a can or hose of compressed air and a straw or probe inserted into the hole. A blast of air blows the hole clean.

Because a large number of these fasteners are used on a roofing system their cost adds up on a roofing job, although their cost is minimal compared to the costs of the waterproofing membrane and the insulation boards.

Placement of Roofing and Cladding Fasteners. Roofing and cladding systems should be attached to the deck with the right number of fasteners installed at the correct locations. Fasteners must be made of the right materials and the correct size and length. The roofing industry is careful to assure that each roofing system gets the right fasteners.

To not use enough fasteners increases the risk of a pullout, while using too many fasteners is a waste of money. The roofing contractor wants to use the minimum number and still have a reasonable margin of safety against a fastener failure. Fastener spacing and pullout strength are usually recommended by the roofing manufacturer of the particular system being installed and are tested and approved by the Factory Mutual Research Corporation. The FMRC Approval Guide Pages 18-1 to 18-249 indicates fasteners placement and spacing for each type of approved roofing systems. Fastener placement is also a function of the wind pressures and directions discussed in Chapter 1.

There are other types of anchors such as chemical anchors or grouted anchors but these aren't usually used for roofing installation as their cost prohibit use. They are more often used for structural attachments than for roofing materials attachment.

With the proper fasteners and flashings, the roofing membrane will be adequately attached to the deck and remain throughout the roof life. There are usually a number of penetrations through the roofing membrane deliberately installed to accommodate mechanical, plumbing or electrical systems. Openings in the roof deck and membranes are discussed in the next chapter.

Chapter 8— Penetrations through the Roofing System Membrane

Sooner or later, nearly every facility manager is given the opportunity to capitalize on all that extra space up above. All sorts of opportunities exist for a facility to profit from information or systems that can be located on the seemingly cost free space overhead. This is especially true if the facility has an easily accessible low slope roof design.

Roofs can be utilized for communication antennas, satellite dishes, solar panels, and even landing pads for helicopters. If the structure will withstand it, cars can be parked on the roof. All this space utilization can be potentially profitable, or it can be a disaster depending upon how well the facility manager understands the roofing system.

Roof Loads

The facility manager wants to make sure that a roofing system isn't overloaded when considering a new element to be placed upon the decking. First, the design considerations discussed in Chapter 3 need to be addressed. When items are added to an existing roof, an evaluation of the added weight to the structure needs to be made. The stresses and forces of the new loads are combined with the old ones. "Will the roof hold it?" is a critical question.

If there is a significant structure change, the facility may be required by code officials to update the building to meet current structural codes. This, by itself, can eliminate modification of many roofs or decks because an older structure may not be designed to the same strength as a newer one. If a building is being modified and it has to meet new codes, the cost of upgrading the structure: the beams, columns and deck can be prohibitively expensive.

While roofing loads are being checked the wind and water forces need to be reviewed as well. A satellite dish may be light enough to sit on the existing deck but the wind catches that big dish. Forces from winds on a dish are carried into the roof deck so the structure may have to be modified to carry the additional loads.

Penthouse Enclosures

Often, a designer can save costs by locating mechanical equipment for a building; air handlers or fans, pumps, and coolers; within a separate small enclosure on the roof called a penthouse. This "room on the roof" then provides an enclosure for the necessary equipment. Since the penthouse wall itself projects up through the roof decking, the interface between the penthouse wall and the roofing insulation and waterproofing membranes is critical.

Rooftop-mounted Equipment

Mechanical equipment designed for outside service can be placed on the roof without a penthouse but the deck must have enough strength to carry the weight. Roof mounted equipment does not sit directly on the roofing deck but is placed either on an elevated pad or mounted on a stand. If placed on a stand, the waterproofing membrane runs under the equipment while the legs of the stand extend down through the membrane and directly to the deck.

The equipment pad or stand must hold the equipment high enough above the deck to keep it out of any ponded water during storms or runoff. Rooftop equipment is not placed directly upon the membrane because the weight of the equipment will cause it to settle into the membrane and either cut or damage it.

Roofing Penetrations

Another category of roofing penetrations include ducts, plumbing, and electrical service lines. All require a hole through the deck to allow the pipe or wires to pass through. Penetrations for utility service can be the source of troublesome maintenance for a facility since separation of the waterproofing membrane often occurs at such a penetration. This allows water to migrate in and can result in a leak.

For some medical or industrial type buildings, fume hoods in the rooms exhaust air out onto the roof through a duct or opening that penetrates the deck. Figure 8-1 is of roof mounted exhaust fans used for laboratory hoods in the rooms on the floor below. These types of installations can be difficult to roof without the use of pitch pockets or other special applications to hold the waterproofing membrane in place and prevent leakage through the deck into the rooms below.

Vibration Noise

Another problem with roof mounted equipment is vibration or noise when the equipment is running. Whenever any piece of mechanical equipment is being planned for addition to a roofing system, the facility wants to make sure that noise and vibration from rotating equipment are taken into consideration as well as any structural loads. Placing a pump directly upon a concrete deck can cause some interesting vibration noises within the building and these noises can carry down into interior floors as well.

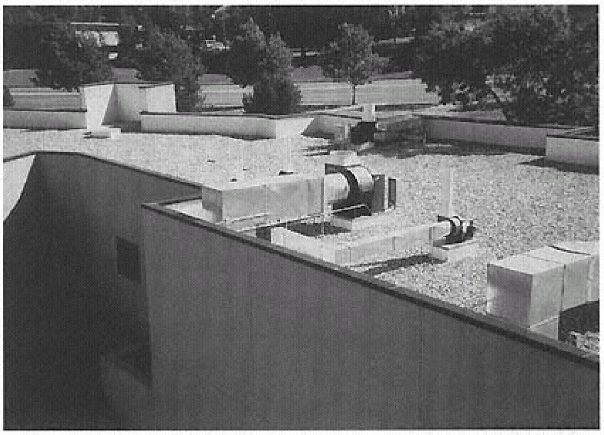


Figure 8-1
Photo of roof mounted exhaust vents. These roof deck and membrane penetrations have to be flashed and sealed, otherwise they will leak and allow moisture to ruin the roof.
Photograph by author.

The occupants of the top floor of an apartment don't want to be awakened in the middle of the night when the air handler fans start and vibration rumbles through the entire building. To alleviate this problem equipment is placed on isolation dampening rubber pads or springs. This keeps vibration from being transferred to the building deck or frame.

Plumbing/Piping Projections. In addition to holes cut into the roof for air ducts and utility service lines, building codes require that plumbing vent lines from drains be carried to clear air above the roof of the finished building. These vent lines are designed to release the various sewer gasses and prevent noxious odors from backing up into the building. Pipes have to project up through the roof to comply with the plumbing code.

Figure 8-2 shows flashing of a plumbing pipe from one of the floors below. Usually, however, the designer usually tries to tie all of the plumbing vent lines together into just a few penetrations to reduce the number of holes through the roof and to make the roofing job easier. The more penetrations through the roof the greater the possibility of a roofing leak problem later on.

Vents. On many roofs the area between the finished ceiling of the structure below and the roofing deck requires an opening to

Figure 8-2
Plumbing vent. Note that flashing is carried up and over the pipe.
Photograph by author.

allow any moisture or heat out. This opening is called the roof vent. On some buildings ventilation of this space is provided by exhaust fans while on others, natural ventilation occurs as the result of differential temperatures and wind pressures on the structure. Ideally the vent keeps heat inside during winter while letting moisture out. Unfortunately, when exhausting moisture heat is carried out with it. In many cases this heat loss cannot be avoided.

On a sloped roof with insulation at the ceiling and a dead air space between the insulation and the deck, a vent allows heat absorbed by the waterproofing membrane to escape. The vent will cool the building significantly in the summer. During winter, the vent allows moisture that creeps into the insulation from the living spaces to exhaust and prevents it from becoming trapped in the insulation.

In some cases vents project horizontally out through the cladding system instead of vertically up through the roof. This is often seen at restaurants where the exhausts from cooking grills is drawn out through the back of the structure.

Wire Penetrations. Sometimes a designer places a piece of equipment on the roof and decides to cut a hole in the roofing membrane and send the wires to power it up through the deck. Codes require that the electricians put the wires in a pipe, called a conduit. The conduit then must be made leak proof, just the way a plumbing pipe is. Electrical power supply wires are not be allowed on any roof since there is a chance for the wires to short out and ignite the roofing materials. If wires are required on the roof, then they can be enclosed in conduit which protects the wire from the elements.

Signal and cable wires, like coaxial cables and telephone wires, have such low voltage that their presence on a roof does not pose a problem.

Occasionally bare copper conductors from medium voltage lines run over a roof.

Case Study

"Youth sues city after being disabled by city power lines." In a court case in Utah in the Late 1980s a youth who had been playing on a roof grabbed onto bare utility conductors overhead. The 12.5 Kilovolt Power burned the young man's hands severely. His family sued the city, claiming the power lines should have been turned off if the city officials knew of anyone accessing the roof. The city lost the lawsuit and had to pay the young man's family several million dollars.

General Problem of Roofing Projections. All of the ducts and vents pose potential problems for the roofing system. Most of the problem comes because the membrane expands and contracts with varying temperature differentials throughout the year. The expansion and contraction is okay if the roofing system has been designed for it. However where penetrations exist, the expansion and contraction no longer has any room to swell and shrink. The roofing material can pull away from the opening, tearing the felt or the membrane or even in some cases the metal flashing.

Skylights. Another roofing element that cuts the waterproofing membrane is a skylight. Usually installed for increased task lighting within, a skylight or series of skylights allows sunlight to pass directly into the room below. As with all roofing penetrations the opening where the skylight is placed should be raised to prevent water running into the building. Usually a curb is installed either on the roof deck or the decking is cut and the curb attached to the underlying structural members. A curb is recommended to be at least 8 inches high and it is flashed (base flashing and counter flashing) to protect the edge of the roofing membrane. Skylight material will shrink and expand at a different rate than the roofing materials. Therefore when temperatures change one will change shape more quickly than the other resulting is a stress buildup between the two types of materials. A good base flashing prevents the roof membrane from separation at the opening.

A few building areas have large skylights or even rollback transparent flexible roofing systems. This type of roof is occasionally seen over swimming pools in some of the more exclusive hotels.

Skylights are also used in malls or large shopping areas where many people gather.

Chimney. Many resort facilities have a large chimney to impress guests. The stone hearth and blazing fire conjure up images of warmth and security. If a facility has a chimney then the roof to stone interface is a region where leaks are likely. Like any stone/masonry projection through a roofing membrane, clips should be provided within the masonry or stone to hold the counterflashing and the base flashing should roll up vertically on the chimney for at least 8 inches.

On the roof stone chimneys are usually flashed with metal flashing. The stone gets warm when there is a fire in the fireplace. This expands the stone, although the chimney is designed to keep the heat inside the flue. The problem of differential temperature between the stone, the flashing and the roof is typical of what is encountered in roofing installations.

Parapets. As discussed in Chapter 4, a parapet wall is constructed around the perimeter of low sloped roofs to protect the edges of the roofing membranes from wind. The roofing membrane is then flashed up the vertical parapet and then counterflashing extends down from the masonry wall to cover the base flashing. For built-up and modified bitumen roofing a cant strip is required to ease the sharp transition from the horizontal to the vertical and to prevent creating a weak spot in the membrane. Photograph in Chapter 7 (Figure 7-1) shows how the cant strip works to protect the edge of a roofing membrane. Figure 8-3 shows a typical flashed parapet wall.

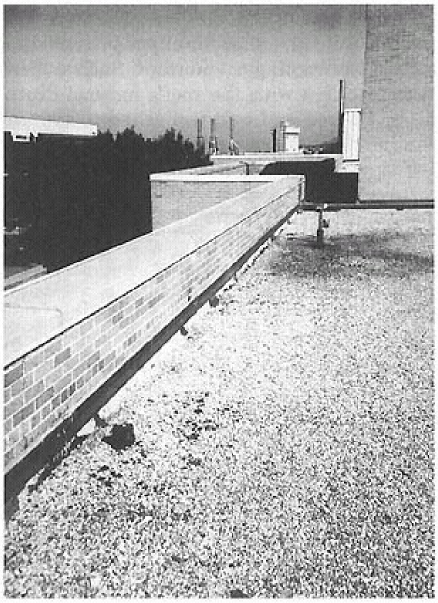


Figure 8-3
A roof parapet wall.
Photograph by author.

Building Extensions. In some cases a gable, penthouse, or additional floor extends up from the roofing membrane. These are flashed in the same way as other projections to prevent separation of the roof membrane from the vertical wall.

Roofing Extras/Additions

In addition to building elements that are required to project up through the roofing membrane, the facility manager will often have to decide on the advantages or disadvantages of installing "extras" on the roof to satisfy the needs of building clientele. These extras take many forms and provide functions necessary and unique.

Antennas. Communications equipment plays an important role in any building and communications antennas are usually located on the roof in order to elevate them to provide broader coverage. The higher the antenna the better the communication.

Winds and weather affect the attachment between the communication equipment and the roofing membrane. The base and attachment, whether bolted, welded, nailed, or clipped to the deck will have to accommodate the roofing membrane. Such a base should not be allowed to interfere with the roof's natural drainage and it will have to be flashed and counterflashed to prevent leaks in the membrane. In addition, provision should be made to prevent thermal bridges that were discussed in Chapter 5.

Lighting Protection. Depending upon the building's location and height, and to a lesser extent upon the functions performed in the building, facilities may have a lightning protection system installed to protect equipment inside from electrical impulses should a bolt of lightning strike the facility. A lightning system is a series of rods or masts on the roof, wired to electrical cable that extends down the building walls and into a specially constructed grounding grid in the ground. The grounding grid is a series of wires spaced around the perimeter of the building with copper rods pounded into the ground at regular intervals. The intent is to provide a easy electrical path from the roof into the ground. The electrical path is to prevent electrical voltage from a lightning strike from jumping from structural beams or electrical wiring inside the building into equipment or products. Lightning protection is extremely critical in facilities where explosives or flammable materials are processed or stored. In addition, as the data stored in computers becomes more and more valuable, the risk of a lightning strike to the computer or communications systems becomes more critical.

The lightning system starts on the top of the building, above the roof and the author has seen many cases where building parapet wall flashing has been punctured with bolts or screws to attach the lightning rod masts. Of course these penetrations fail, as all roofing penetrations ultimately do and allow the flashing to leak. Figure 8-4 shows lightning lines and masts on a protected industrial building.

The design of a lightning protection system is usually performed by electrical engineers who need to be informed about building function in order to design lightning protection systems adequately. The important thing to remember is the lightning system has to be mounted on top of the roof and that the masts and wires have fasteners that penetrate the roof deck. Usually the penetrations are coated with roofing mastic, an asphalt product that covers the fastener holes and protects them. Routine maintenance inspections and reapplication of the mastic every two or three years goes a long way to protecting the roofing system integrity and adding to roof life.

Satellite Dish. As communication continues to become more

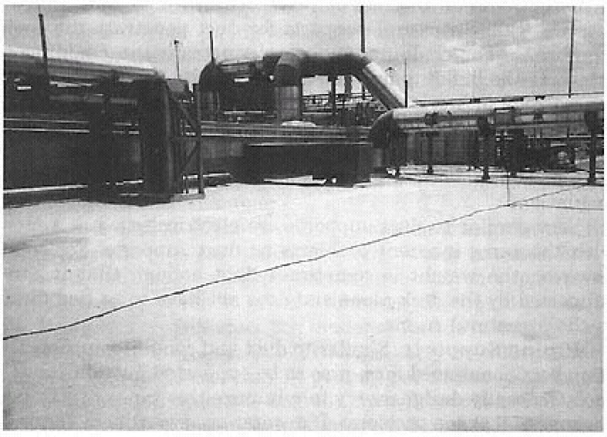


Figure 8-4
Lightning protection on a PVC roof.
Photograph by author.

and more critical in the business world the use of satellite dish antennas becomes more prevalent. Right now, most satellite antennas are used for receiving television signals but a few corporations and many apartment type complexes are using satellite antennas to access more and more information. The military also uses these types of communications devices and is seeking to provide more reception for their bases throughout the world.

The roof structure has to hold up the dish, of course, but the dish is also subject to wind and snow loads. If these put excessive stress on the roofing structure where they are mounted, the bolts or fasteners holding the base of the antenna can pull or work loose and allow a water path down into the insulation.

A satellite antenna's base should be mounted firmly to the structural beams, or the roof deck should be modified reinforced to provide substantial structure to hold the dish. The calculations of stresses should be checked by a competent professional, usually a licensed engineer. The roof membrane should be flashed as discussed in Chapter 7.

Duct or Conduit Support. Another element that often projects through the roofing membrane are duct and electrical conduit supports. Figure 8-5 shows typical installations of both.

Occasionally the designer places ventilation duct work outside of the building on the roof or vertically on the outside along the exterior wall. Structural supports for duct penetrate the roofing membrane. For cladding, supports penetrate the cladding and attach to the building frame. Fasteners; bolts, studs, rivets, nails, can corrode or work their way through the waterproofing membrane. Supports can become a thermal bridge that allows heat to escape and can cause condensation from within the building to collect inside. Thermal bridging is discussed in Chapter 5 under insulation.

Very similar to duct supports are electrical conduit supports with the same inherent problems as duct supports. For conduit however, the weight is sometimes light enough that it can be supported by the deck alone and does not have to be tied directly to the structural frame.

Piping Supports. Similar to duct and conduit supports there is an occasional need for a pipe to be supported outside above the roof. Generally designers try to minimize this type of installation because of leakage problems. If a water or sewer line is located on a roof, there is always a potential the line could become plugged and require draining. If the line is on the roof, then it has to be

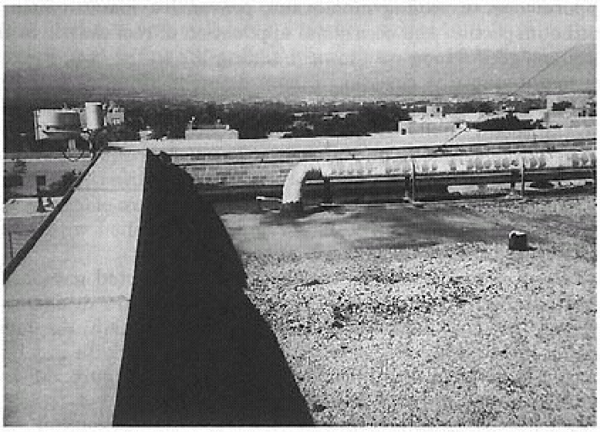


Figure 8-5
Duct Roofing Supports.

drained onto the roof deck. However, piping is sometimes routed outside simply because it is easier to run. Occasionally special facility needs require the piping be run outside over the roof instead of inside. When piping is run outside, it should, of course be heat traced to prevent the freezing of liquid inside the pipe during cold weather. Piping supports are similar to the duct and conduit supports.

Probably more than duct or conduit, piping that carries a liquid like water or another liquid chemical is subject to movement both from thermal expansion and contraction and from a phenomena known as water hammer.

Water hammer is the result of a sudden change in the flow that causes the pipe to shudder or bang. Water hammer can be prevented but almost all pipe that is mounted on supports will move slightly as a result of flow forces of the liquid inside the pipe. Designers try to reduce the tendency for movement by keeping the velocity down but a 4-inch pipe carrying 100 gallons of water per minute is carrying 14 pounds per second. This is a lot of momentum and when the angle is changed at a bend or corner the pipe is prone to move slightly or even vibrate. The movement is carried down into the supports where it works against the waterproofing membrane and the fasteners. When pipe is run on supports over a roofing membrane, preventive maintenance or routine inspection and occasional application of roof mastic to the fasteners, goes a long way toward adding life to the roof. Preventive maintenance is covered in more detail in Chapter 11.

Hatches. Occasionally the roof will have an hatch that opens onto the roof. Usually the hatch will be accessed by a ladder but a large hatch can accommodate stairs. A hatch opening is framed with studs or purlins that extend 6 or 8 inches above the deck and are flashed. The hatch is then simply a framed box placed upside down over the opening. The hatch is usually flashed with metal over felt and mastic to make it waterproof.

Some vendors manufacture specially constructed galvanized metal hatches. These come already flashed and are designed to drop into the roof deck wherever a hole is cut. Again, the hatch opening has to be flashed, otherwise, water will work its way back along the metal edging and the roof will leak. Figure 8-6 is a vendor's catalog drawing of a skylight and hatch.

Helicopter Landing Pad. Where space is at a premium such as a large downtown metropolis, a building may have a helicopter landing pad on the roof. Figure 8-7 shows some typical marking details for helicopter landing pad on a roof. This type of application requires special engineering calculations not just for the roof deck but for the pilot and helicopters also. There are several major details to be resolved with such a pad, which include approach, winds, clearances to other buildings, antennas for commu-

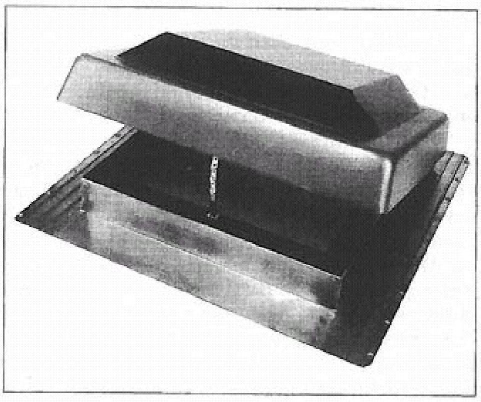


Figure 8-6
Roof hatch for access. Note how the hatch is designed to be flashed up several inches from the roof plane.
Courtesy of Fox Lite Inc. Fairborn, OH.

nication for the pilot, etc. The pad has lights to accommodate night landings and will have a design painted on it to make it easy to identify from the air. Both of these are to aid the pilot in depth perception as he is landing.

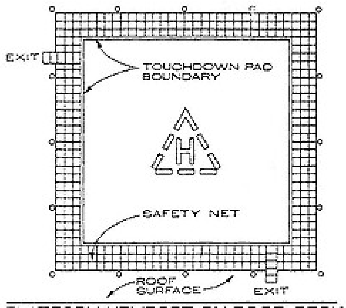


Figure 8-7
Roof-Deck Heliport boundary and markings.
Courtesy: Architectural Graphic Standards, 8th Edition Copyright 1990 John Wiley & Sons, Somerset, NJ

Helicopter pads are elevated above the deck and above the waterproofing membrane since the skids of the helicopter's landing gear can tear a membrane if the helicopter slides when landing or taking off.

Solar Panels. Figure 8-8 is a photograph of a solar array placed on the roof of a hospital/medical building. There are two basic types of panels. The first is the direct heated panel which has liquid inside the cell. The liquid is heated by the sun's rays and then pumped into the building to where the heat is needed. The other type of solar array is the solar electrical cell. This type of cell converts sunlight directly into electricity. The inability to store electrical energy generated by solar panels is the main problem with solar applications. Solar panels or cells can be placed on the roof of most buildings but the problems with thermal bridging, supports, and fasteners is encountered as with other roof structures. Support legs should be touched up with roofing mastic on a annual or bi-annual basis.

Dr. Heshmat Laaly, one of the technical reviewers of this handbook, invented and patented a solar waterproofing membrane. The intent is to roll the material out onto the roofing deck or insulation and hook up the wires. Mr. Laaly is still test marketing this system which has great potential in the years to come.

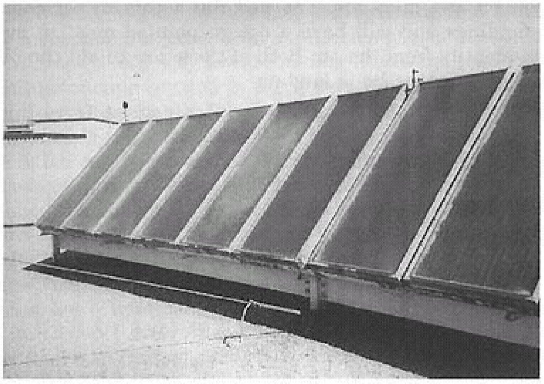


Figure 8-8
A roof mounted solar collecting array.
Photograph by author.

Drainage. The supports for these systems can affect the roof drainage. If a large weight changes the amount of deflection in the roof decking, ponding can become a problem. In addition, the supports themselves and the associated flashing can act as a dam or dike to cause more ponding.

General Rules for all Roofing Projections

For roofs that have large numbers of penetrations in the roof membrane for supports and equipment, a preventive maintenance program goes a long way toward extending the life of these roofs. In general a facility with a large number of roofing projections can expect the roofing system to require more maintenance and will not last as long as a roofing system with few projections. Maintenance is discussed further in Chapter 11.

Cladding Penetrations

While the roof has penetrations to serve the buildings inner systems like power, communications and ventilation, cladding systems have penetrations designed more for aesthetic reasons and for the direct benefit of occupants.

Cladding penetrations include access for doorways and windows, along with penetrations for drainage. Cladding also has penetrations for duct supports, conduits, and piping although cladding penetrations are not seen as often as roof penetrations because ducts, conduit and piping detract from the aesthetic aspects of the building's appearance from the ground.

How a cladding system looks is a significant aspect of building design that is not as much of a concern in low sloped roofing systems. As discussed in Chapter 4, cladding systems consist of stone, glass, metal, exterior insulating finish systems, vinyl and tile.

Windows. Basically there are two types of windows, with the most common being a plate of glass enclosed in an aluminum frame. The aluminum frame is then mounted into the cladding or attached to the structural frame with clips. Figure 8-9 shows a

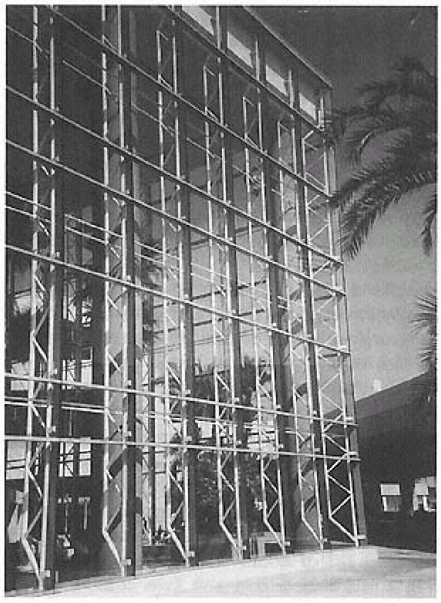


Figure 8-9
Glass cladding wall attached inside aluminum frames.
Photograph by author.

glass cladding system connected to a structural frame. Designers can specify a glass that allows visibility one way allowing those inside to see out while those outside cannot see in.

For tall buildings, combined glass/cladding systems are common. Older structures of stone, concrete, or masonry have windows of glass set in a frame attached to the building frame. Frames for windows can be metal, including aluminum and steel or the frame can be made from wood. However, today's construction techniques have almost eliminated wood window framing from all except residential applications.

Windows in commercial facilities don't open directly to the outside because open windows make it difficult to control indoor temperatures. Windows that open to the outside have also been eliminated for safety and security reasons as well.

Doors. By far the most common cladding system penetration is the exterior door. Doors penetrate cladding for access including access to a patio or deck, from penthouses onto roofs, and other locations. Exterior doors are significantly different from interior doors in that they are designed to interface between the harsh outside elements and moderate indoor temperatures. Doors for commercial businesses are usually automatic glass sliding doors.

In addition to sliding glass there are hinged doors, revolving doors that consist of a panel of four that turns on a vertical axis, and roll up doors that wind up on a roller. Each type of door serves a unique purpose for allowing either people or vehicle access to a building.

The facility manager will profit from knowledge about the interface between a door and a cladding system and from knowing fundamental door design principles.

Since a door represents a direct opening to the outside, any differential temperature between the inside and outside of building will cause a loss of energy when the door is opened. For some buildings the inside of the building is at a lower pressure than the outside. Cold air is drawn into a building when the door is opened.

Almost without exception, a facility with significant door traffic during business hours will profit from the energy savings of constructing a tandem set of doors to provide a buffering airlock between the outside and inside. Tandem doors reduces migration of air between the inside and outside. Airlock type assemblies are designed such that the first set of doors close before the second set opens. By buffering the air between the two sets of doors, energy loss is significantly reduced, especially in buildings constructed in colder climates.

The interface between doors and exterior cladding is unique. Figure 8-10 is a cutaway view of a manufacturer's hollow metal exterior door. The cladding system attaches to the frame of the door and the door itself then moves within the door's frame. For a facility manager concerned with cladding systems, the frame is the element that must be coordinated with the cladding.

Door frames are designed to attach to the main structure. That is, the frame drops into place between structural members designed to hold the frame of the door in place without movement. The action of doors opening and closing causes vibrations which can crack a cladding system if the movement has not been taken into account. Hence, many doors have a flexible membrane between the frame and the cladding. A flexible sealant like caulk or putty is common. The material is especially designed for flexibility and it allows expansion of the door frame at a different rate than the exterior cladding. Some doors use a rubber or plastic gasket for the same purpose.

Depending upon the width of the door, a beam is required above the door frame to hold building cladding between the top of the door and the roof. Some old masonry structures did not have a strong enough beam and consequently, old automobile garages and parking buildings sometimes have a crack in the masonry above the center of garage doors. The crack results from the door frame beams deflecting and allowing the masonry to settle.

Many entry doors have a protective canopy over the area immediately outside the opening. This prevents weather such as rain or snow from blowing in through the door when it is opened and prevents water from dripping onto the area immediately in front of the door. The roofing membranes and drainage from this covered projection are the same as those used on the main roof.

Drainage. Exterior finish systems have openings for drainage in the form of gutters and scuppers. Usually a scupper is made from bronze or clay and projects through the masonry parapet wall. The scupper's lip extends out away from the wall to prevent water from running down the masonry and staining it.

Gutters and down spouts are also attached to a cladding exterior. Again the support members should be designed to limit thermal bridging. Fasteners and membranes should be compatible with the support and with the cladding. Preventive maintenance goes a long way to protect the cladding system from the

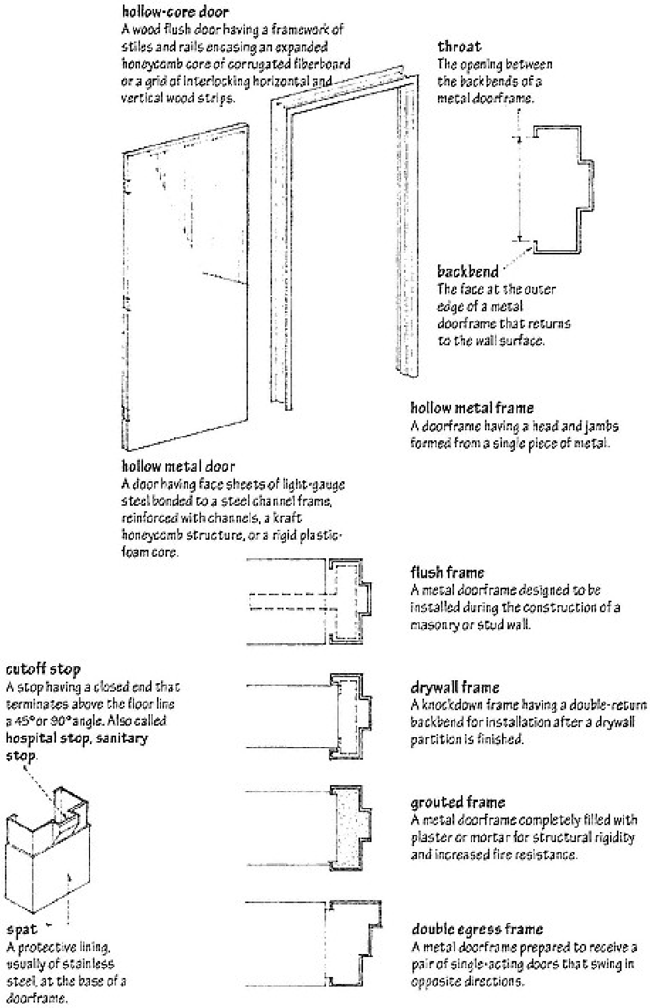


Figure 8-10
Cutaway view of a hollow metal door.
Reprinted from: *A Visual Dictionary of Architecture* by Francis D.K. Ching.

start of any corrosion.

Final Word about Cladding System Projections. Similar to roofing, cladding systems are subject to damage from expansion and contraction, from fastener corrosion, and from water intrusion. In addition, cladding systems can be corroded by environmental conditions such as smog, soot and dust. Masonry and stone cladding can be sand blasted to remove corrosion and give the building a cleaner look.

Cladding system projections for drainage, windows, doors, and other elements can become a haven for birds, especially rock pigeons and insects like hornets or bees. Removal requires constant maintenance. Insect nest removal can be accomplished with chemicals such as insecticides or sprays. Birds can be discouraged with ultrasonic sound, symbols of the birds' natural enemies, or physical removal, although this last can be difficult if the bird nesting area is difficult to reach.

Bird droppings stain many cladding systems and require recovering or sand blasting to remove. Again, no insect or bird removal system is going to be totally effective hence, routine preventive maintenance is necessary to remove the nests, droppings and sometimes even the birds themselves.

Conclusion

Roofing and cladding systems have to be able to accommodate the many systems that penetrate through the membranes. The details of the penetration is critical to the roofing or cladding system as these are prime places for weathering and leakage. Cladding systems can also stain from drainage or bird or insect infestation. Supports have to be checked for thermal bridging and doors, windows, and skylights can affect the building energy balance.

Now that the facility manager has reviewed the individual components of roofing and cladding systems the next step is: Roofing Project Management.

Chapter 9—
Roofing Project Management

Sooner or later every facility manager runs a roofing project. Sometimes these projects are small like a roof maintenance or repair while, on other occasions, the roof of the facility must be replaced. The facility manager wants to make sure the new roof lasts for as long as possible and perhaps even the balance of the facility life. By following a series of steps the facility manager can make the best use of the facility resources and solve the roofing problem in the shortest time and for the most efficient use of facility dollars.

Emergency Leak Repair. Too often a facility waits until the roofing project is critical before gathering the information needed for good roofing decisions. If the roof is leaking and the clients are angry, it is hard to exercise the cold discipline necessary for making roofing decisions that need to be made.

Temporary patching by using plastic sheeting or by troweling mastic sometimes stops leaks in the short run but it is not a permanent fix. Fortunately, a temporary patch or fix may give the facility time to perform a logical, rational study to solve a long term roofing problem.

If winter conditions exist, snow or ice removal may be required before patching can begin. Since snow shovels, scrapers, and other implements used to remove snow or ice can penetrate the waterproofing membrane, care must be exercised during removal. Sometimes an awning or tent can be erected over the area of the leak. Heat, using electric or portable propane heaters can be applied to warm the area, dry the insulation and soften the membranes.

Once the roof is exposed, the leak may be immediately apparent. Asphalt cement or mastic can be applied to provide temporary solution until more permanent measures can be taken.

Temporary patching details are discussed more thoroughly in Chapter 11.

The ideal initial step in roofing project management is to conduct a roofing survey to determine the exact roofing condition. This survey can be taken at a time of the year when the roof is easily accessible. Most roofing assessments are conducted twice each year, once in the spring after the cold winter, and again in the autumn, after the hot summer.

Earthquake Evaluation.

After earthquakes in California in 1990, geologic studies led to revision of structural codes in many western states. Schools and other public buildings had to be retrofitted. Some were simply abandoned after the new seismic calculations revealed the structure would be unsafe in an earthquake. Reroofing such a structure would not be wise, given that its useful life is terminated. Such structures may be converted to a different use, like offices, but most facilities soon discover the floor plan doesn't adequately meet their needs. In addition, depreciation and associated tax structure gives an added advantage to con structing a new facility over leasing and retrofitting an existing one.

Conducting a Roofing Survey

If a leaking roof has been temporarily patched, the facility manager should conduct a roofing survey to determine what the next step will be. A worn or leaking roof can be either patched or repaired. It can be recovered with similar or a new type of material, or the entire roof can be removed and a new roof placed over the deck instead. This decision is a matter of: condition of the existing roof, anticipated remaining life of the structure, and cost of installing alternative roofing including removal of any existing roofing.

Most roof decks will allow the existing material to be re-covered with a new material at least once since an inherent factor of safety in the design of the roofing system is not affected by the additional loads. This type of project is called a re-cover project.

However, if the building has already been re-roofed several times without removal of the old membranes it will be wise to check the initial design assumptions and re-estimate the roofing loads.

Next, the facility determines the expected remaining life of the facility. For institutional structures, the life can be assumed to be 100 years. For others a life of 50 years is used. See Table 9-1. Other types of structures may simply be considered temporary and the reroofing project becomes a matter of providing roofing that will only last the balance of the structure's life.

Table 9-1. Approximate Useful Economic Life of Structures

Facility Type	*Approximate Economic Life (Years)*
Public School	50
Public Hall	100
Theater	20-40
Hospital	50
Skyscraper (Office)	100
Public Mall	20-40
Airport Buildings	25-40
Parking Garage	50
Convenience Store	20
Department Store	20
Manufacturing Plant	20-40
Residence	200
Historic Building	200

The attached Figure 9-1 is a sample of a roofing inspection form used for built-up roofing but the information gathered will serve other types of roofing as well. A facility manager may want to utilize the services of a qualified roofing consultant to conduct this assessment. However, if he decides to allow visitors onto the roof he or she should consider using a roof access policy shown in Chapter 13.

Once the roof has been inspected, or when the roofing consultant's report is in hand the next step toward the reroofing project decision can be initiated. Most roofing consultants can accurately estimate the remaining life of any roof.

Examining Alternatives

After the existing roof data has been collected, the next step,

BUILDING ID: ____________ INSPECTION DATE: ____________

HISTORICAL RECORD NUMBER: ____________

ROOF DECK UNDERSIDE:
Record locations of signs of water leakage/damage: ____________

Record locations and extent of deck deterioration: ____________

Record locations of bitumen drippage: ____________

PARAPET/WALL EXTERIOR:

Deteriorated Mortar Joints ____________ Settlement Cracks ____________
Open Coping Joints ____________ Cracked/Broken Coping Cap ____________
Efflorescence ____________ Damaged Facia/Overhang ____________
Deteriorated Gutters, etc. ____________ Other ____________
Record locations of signs of water infiltration: ____________

FIELD OF ROOF:
General Condition: Good ______ Fair ______ Poor ______

Watertightness:
No leaks ____________ Leaks during continued rain ____________
Leaks every rain ____________ Leaks during high wind ____________
Leaks continuously ____________

Check for evidence of: (indicate level of damage as L=light, M=moderate, S=severe. Record location on roof plan.)

Wind Damage ______ Hail Damage ______ Heavy Roof Traffic ______
Vandalism ______ Debris ______ Mechanical Damage ______
Cracks ______ Punctures ______ Deteriorated Felts ______
Fishmouths ______ Blisters ______ Alligatored Coating ______
Splits ______ Buckles ______ Standing Water ______
Exposed Felt ______ Low Spots ______ Other ______

FLASHINGS:
General Condition: Good ______ Fair ______ Poor ______
Watertightness: No leaks ____________ Leaks during continued rain ____________
Leaks every rain ____________ Leaks during high wind ____________
Leaks continuously ____________

Check for evidence of: (indicate level of damage as L=light, M=moderate, S=severe. Record location on roof plan.)

Base Flashings:
Deteriorated Base Flashing ____________ Open Vertical Joints ____________
Flashing Separated from Wall ____________ Sagging Base Flashing ____________
Deteriorated Surface Coating ____________ Missing Counterflashing ____________
Punctured Base Flashing ____________ Cracked Felts ____________
Insufficient Flashing Height ____________ Movement ____________

Gravel Stop:
Deteriorated Stripping Felts ____________ Deteriorated Metal ____________
Flashing Separated from Wall ____________ Loose Flashing Flange ____________

Drains:
Standing Water around Drain ____________ Clogged Drain ____________
Deteriorated Stripping Felts ____________ Deteriorated Metal ____________

PHOTOGRAPHIC RECORD:
Prints ______ Slides ______ Video ______ Other ______ None ______

Attached ______ Other Location ____________
(NOTE: Each photo/tape should be identified with Building ID, inspection date, inspection form number and a description of what is being shown.)

ROOF PLAN: Draw a roof plan on the next page showing the location of all problem areas found. Also note any changes or additions to the roof since the roof was first completed.

Form filled out by: ____________ Date: ____________

INSPECTION RECORD: (File this inspection form with the historical record.)

Figure 9-1
Sample roof inspection form. These forms help to protect the facility's investment. Reprinted with permission from: "The NRCA/ARMA Manual of Roof Maintenance and Repair," Copyright 1988 by the National Roofing Contractor's Association, Rosemount, IL.

of deciding which reroofing options are the most economical, can begin.

If the roof is large and has a low slope, then the facility manager will consider removal of the old roof and replacing it with one of the inexpensive single ply roofs. If there are a lot of roofing projections then a built up roofing system that can be hot mopped should be considered. Energy calculations need to be evaluated based upon the calculations shown in Chapter 6.

The facility manager or consultant should utilize a spreadsheet to analyze the long term effects of the roofing project. If the building is going to last for 20-30 years, then an economic analysis of the roofing alternatives indicates the most economical long term choice. The term for this type of analysis is a Life Cycle Cost Analysis.

Life Cycle Cost Analysis of Roofing Systems

Life-cycle cost means evaluating the total cost of the roofing system not simply the first cost. The first cost could be thought of as the cost after getting an estimate from one or two roofing contractors. After the project to re-roof has been estimated, there are still other costs to be considered. For example, one type of roof may require more maintenance than another. The trade-off of a lower first cost might be less attractive when maintenance costs every year have been factored in.

Many roofing suppliers and vendors may quote on systems with different lives in the warranty. If one roof is supposed to last 15 years and another lasts 20 years which roofing system is the better deal? Another factor in the life cycle analysis can be energy consumption. Especially if the existing roofing insulation has been ruined or is saturated in some way.

The bottom line is that a properly conducted life cycle cost analysis can show the facility manager the true annual costs, or the present value. This can be important in facility budgeting and decision making. And it can prevent the facility having to replace the roof sooner than expected or having to refinance or relocate just to keep the contents dry.

Life Cycle Cost Analysis Terminology

In order to understand life cycle costing, a minimum amount of information is needed to understand the analysis. Life-cycle analysis predicts the most attractive alternative based upon life, value, and expected monetary growth.

Models. Mathematical models are used to predict the expenses required in the future and to transfer those estimated costs to today's dollars. Each roofing system can be analyzed with a single model and each model compared to the others at the end of the analysis. The most common method is called the *annualized* cost method but *present value* method is also often used.

The annualized cost method spreads all of the dollar costs out into even annual payments. The present value method converts all of the costs into one value at the beginning.

Project Life. When any life cycle cost analysis is done, the assumed project life is important. As stated earlier, if the building isn't going to last for another 20 years, why should the facility purchase a roof that will last that long? On the positive side, if the building is a historic structure and is expected to last for the next hundred years or so, doesn't it make sense to decide which roofing system will last that long? Finally, with the state of the art of the roofing industry changing as rapidly as it has, the facility may decide to estimate roof life based upon a short span of 10 years, recognizing that a new roofing project will be required 10 years from when the current planned project is completed.

Some manufacturer's guarantee their roofing systems will last 50 years. However, not many low slope roofing systems last that long and roofing consultants are currently recommending that any low slope roofing system that states it will last longer than 20 years is suspect. Steep slope roofing systems on the other hand, especially tile, slate, or metal can be expected to last up to 100 years.

Case Study

When the library at Oxford University had to be re-roofed after serving for over 400 years, the people who were tasked with estimating the project noted that replacement of the oak beams that held up the roofing deck would be extremely expensive. However, it was pointed out that when the library was built, the builders had the foresight to replant young oak trees where the original oaks had been felled. The young trees had grown to maturity and were ready to be hewn down for the new roof. Since the trees were on the university property their cost was next to nothing. Such foresight is commendable today, the result of a very long range and profitable life cycle decision.

Discount Rate (also called interest rate). For any life- cycle study the interest rate or discount rate is the number used to estimate the growth of value. At the present time, a single rate is used for the duration of the study although accountants and specialists who analyze life-cycle costs routinely can use a variable rate. The problem with discount rates is that they are subject to fluctuation and ten year averages or even 20 year averages should be used. For a life cycle study, it is important that the same rate be used for all the models.

An important thing to note about discount rates is that the higher the interest rate the more attractive short term options are. This means that if interest rates are above 10 percent, a 10 to 15 year life roof may be more attractive than a 30 year roof. Another item about interest rates is that after about 100 years the options at the end of the project vastly outweigh any decisions made now. Hence, many life-cycle cost studies are based on 20 to 25 year life.

Present Value. Present value is the dollar amount of money at the present time. If one hundred dollars is needed ten years from now, it is possible to put a lower amount in the bank today that will appreciate in value until the time it is needed.

Annual Cost. Annual cost is essentially the opposite of present value. In order to have one hundred dollars ten years from now, it is possible to put an amount in the bank each year so that in ten years the total value will equal the needed one hundred dollars.

Annual cost, present value and discount rate are terms are common to all life cycle cost studies, not just roofing system studies. However for a roofing analysis there are a couple of other factors that must be considered.

In a low slope roof, if the manufacturer warranties the roof for 20 years, there is an assumption that some maintenance will be done on the roof throughout its life. These costs are estimated and incorporated into the model. In addition, a life cycle study that compares a 20 year roof with a 10 year roof must include replacement of the 10 year roof after the first 10 years in order to make the two alternatives compare. Therefore to analyze the true life-cycle cost comparison of roofs with a different life cycle, the maintenance and replacement costs should be added to the costs at the appropriate time.

What the life cycle cost study does then is to take all of the associated estimates of alternate roofing system choices and compare them against each other. The one with the lowest Present Value would also be the one with the lowest annual cost. This roof would be the most attractive alternate. It isn't always obvious from an initial estimate of the numbers to determine which roofing system is the best choice.

Other costs to consider in making the life cycle study are the costs to remove the old roofing materials and the costs for their disposal, independent consultant costs, installation of a new vapor retarder, repair of the old roof deck (if necessary), installing new tapered insulation, changing roof slope (if necessary), raising Air Conditioning Equipment Curbs, repairs to any parapet wall or masonry, and replacing any sheet metal flashing or coping.

For the life-cycle study, the facility may want to ask for rough estimates from the various types of roofing vendors and see what their recommendations are. For a low slope roof without many roofing projections a single ply, modified bitumen, or built up roof may be estimated.

The facility manager needs to be cautious however, about committing to any one roofing contractor at the early stage of the game. If the facility has a policy of bidding all jobs on a fixed price basis then it should be clear that the job will be competitively bid and that after the bidding documents are in place each of the vendors will be allowed to provide their own estimate.

Figure 9-2 shows how a typical roofing project was estimated. A spreadsheet program was used to calculate the numbers.

Planning and Executing a Roofing Project

After the life cycle-study has been completed and a decision reached on which roofing system will be used to replace the old one, the next step is to hire a contractor to do the reroofing job.

The facility may decide to write a contract for a two stage development. The first part will be the life-cycle cost study and the second will be the installation of the new roofing. The idea is to provide enough information to all of the bidders that the project is fairly and accurately bid.

There is still a lot that can go wrong however, so the facility should not commit to spending more of its resources than it has to at any point in the project.

A decision should be made about installing a temporary roof while the work is underway. Again, this is a function of what is happening in the building over the time it is being re-roofed. For schools as an example, reroofing may done in the summer when the building is not occupied. For another type of facility, it may be

Life-Cycle Cost

System	Bid price	Warranty
Liquid	$4750	5
Thermo	$9000	10
Metal	$13,500	20
Size in ft^2	5000	
Discount rate	8%	

Table 1. Computations for the present-value life-cycle cost of liquid applied system

Year Discount Value	1 1	2 0.86	3 0.79	4 0.74	5 0.68	6 0.63	7 0.58	Total for Installations	
Bid Price	$4750					$4750		PV Capital	
PV Installed	$4750	$0	$0	$0	$0	$2993	$0		$7743
Leak Cost				$500	$750			PV Leaks	
PV of Leak Cost				$368	$510				$878
Maintenance	$200	$250	$275	$250	$325	$200	$200	PV Maint.	
PV of Maintenance	$200	$214	$218	$184	$221	$126	$117		$1280
Depreciation	$122	$122	$122	$122	$122	$122	$122		$9902
PV of Depreciation	$122	$104	$97	$90	$83	$77	$71		
Tax Benefit 40% rate	($49)	($42)	($39)	($36)	($33)	($31)	($28)		($257)
Unrealized Depreciation					$4141				
Tax Loss Consequences					($1127)				($1127)
Salvage Value							$1848		($1848)
								PV Depreciation & Salvage	($3232)
								Net PV for roof	$6669

Table 2. Computations for the present-value life-cycle cost of sheet system

Year Discount value	1 1	2 0.86	3 0.79	4 0.74	5 0.68	6 0.63	7 0.58	Total for installations	
Bid Price	$9000							PV Capital	
PV Installed	$9000	$0	$0	$0	$0	$0	$0		$9000
Leak Cost								PV Leaks	
PV of Leak Cost				$0	$0				$0
Maintenance	$150	$150	$150	$150	$150	$150	$150	PV Maint.	
PV of Maintenance	$150	$129	$119	$110	$102	$95	$88		$792
Depreciation	$231	$231	$231	$231	$231	$231	$231		$9792
Tax Benefit 40% rate	($92)	($79)	($73)	($68)	($63)	($58)	($54)		($487)
Unrealized Depreciation									
Tax Loss Consequences									$0
Salvage Value							$2188		($2188)
								PV Depreciation and Salvage	($2676)
								Net PV for roof	$7117

Table 3. Computations for the present-value life-cycle cost of metal system

Year Discount Value	1 1	2 0.86	3 0.79	4 0.74	5 0.68	6 0.63	7 0.58	Total for installations	
Bid Price	$13,500							PV Capital	
PV Installed	$13,500								$13,500
Leak Cost								PV Leaks	
PV of Leak Cost									$0
Maintenance	$75	$75	$75	$75	$75	$75	$75	PV Maint.	
PV of Maintenance	$75	$64	$60	$55	$51	$47	$44		$396
Depreciation	$346	$346	$346	$346	$346	$346	$346		$13,896
PV of Depreciation	$346	$297	$275	$254	$236	$218	$202		
Tax Benefit 40% rate	($138)	($119)	($110)	($102)	($94)	($87)	($81)		($731)
Unrealized Depreciation									
Tax Loss Consequences									$0
Salvage Value							$5120		($5120)
								PV Depreciation & Salvage	($5851)
								Net PV for roof	$8045

Figure 9-2.
Estimates from a life cycle roof estimate.
Reprinted courtesy of the Proceedings of the Low-Slope Reroofing Workshop, United States Department of Energy, Oak Ridge, Tennessee.

advantageous to schedule the project at a different time of the year.

The facility manager should be aware that roofing is one of the most weather dependent of all the building trades. If it rains or is cold or windy, a roofing project may have to be placed on hold. Winds can blow the insulation off the roof and many types of sprayed asphalt or sprayed polyurethane foam can blow off the roof and onto cars in the parking lot. Finally, if hot coal tar or hot asphalt is used, the facility wants to take steps to see that the vapors aren't drawn into the buildings ventilation system during the project.

Contract Plans and Specifications

Successful completion of a life cycle study yields the following results. First it tells the general cost of what a new roofing system is going to be. This allows budgeting to get started to raise the needed funds since it is doubtful any facility is going to have the money up front for this type of work. Second, the life cycle study reveals the best type of roofing system for that particular building. The results are then used to prepare the detailed specifications for the project.

Specifications. Specifications or specs. are the written description of the work to be done and on some jobs specifications are lengthy documents. Legally, text specifications take precedence over drawings so if notes on the drawings conflict with words written in the specifications the specifications govern. This is where a good designer comes in. His job is to make sure that there aren't any conflicts between the documents.

Specifications also take into account general items like payment terms, warranty, bonds, hours of work, etc. On Government projects there are many other attachments like Affirmative Action Plans, Buy American Act, Davis-Bacon Wage Agreements and other non-technical clauses.

Whichever roofing system is chosen, specifications should make it clear that the roof must be inspected either by the manufacturer of that particular roofing system or his representative and they must approve the final installation. In addition, it is a good idea to have a pre-job site conference where all these matters can be discussed. Usually, the roofing contractor and the manufacturer want to get onto the roof and make sure they have a clear understanding of the work.

If other work is going on at the same time, the contract should specify who has final say. Many roofing projects include work on the air conditioning equipment and what happens is that the air conditioning mechanics walk about on the unfinished or partially finished roof and tear the felt or the single ply membrane. If this happens then there is no choice but to replace the material, or patch it. If the air conditioning people work for the facility, the roofing contractor is going claim extra work, and he probably is entitled to it.

Roofing specifications should state that the system installed must meet the requirements of the local codes and it is recommended that all roofing specifications require the installation be approved and accepted by the Factory Mutual Research Association. The Factory Mutual Organization tests the various vendor designs in laboratories and approves that type of system. For many buildings, the insurance company wants to see the acceptance certificate from the FM organization before they will insure the materials inside. This can be a costly mistake if the roofing system isn't installed correctly or it isn't an FMRC approved system.

Clear specification language helps to prevent this type of dispute.

Drawings. In addition to the specifications, usually there are drawings. Drawings make the job easier for the contractors and bidders but drawings aren't actually necessary for a contract. With drawings however, the chances for disputes are reduced. The language of the specifications can state that the roofing contractors prepare their own drawings, but when this happens many good roofing contractors will drop out of the bidding process because they realize the odds of getting the job are slim and there is a lot of work they have to do on their own without any guarantee they will get any work.

Drawings should show the essential portions of the work. The location of the job, and details. One of the really good resources for construction roofing drawings is the National Roofing Contractor's Construction Manual which details some of the finer points of flashing, insulation, drains, coping, metal edges, and curbing. However, the facility manager should allow flexibility with the manufacturer to use his own details since the manufacturer will have studied his system and will be recommending installation techniques that were used when he obtained the roofing system certification from the Factory Mutual Research Association.

Allowing substitutions approved by the manufacturer that were the results of FM research is the preferred practice.

Bids. After the drawings and specifications are ready, bids are solicited for the project. Bids can be advertised in any big city's Associated General Contractor's organization, or simply a letter can be written to all of the roofing contractors asking if they are interested in bidding on the project. These letters are usually issued as a "call for bids." Some public facilities like state organizations require the project be advertised in the local paper. Bids should state the exact time when the bids will be opened and read. Smaller jobs can just be bid by letter quote. Most contractors will work with the facility and provide a bid in the format requested.

Bonds. For all construction projects there is usually some discussion about bonds and this material is presented here because it applies to roofing equally as it does to other remodeling projects. A bond is essentially an agreement that a certain amount of money has been set aside to assure the contractor will do what he says. The contractor pays for these bonds, usually to a large bank or bonding company. The money is held in escrow as surety against the contractor's commitment to perform the work.

There are three types of bonds, bid bond, performance bond and payment bond.

A **bid bond** is usually posted with the bid. This bond is requested to prevent the contractor's from submitting frivolous bids. For projects where the bids are open to all bidders this may be a good idea, while on a project where only qualified bidders are asked to submit a bid, a bid bond might not be necessary. There have been jobs where the contractor submitted a frivolously low bid and because he doesn't want to lose the bid bond, he tries to go ahead and do the work anyway. This is unfortunate but it happens more than most contractors want to admit. If such a thing happens, the facility manager should commit to taking the inspector out to dinner when the job is over because it is often going to be a tough project.

On a lot of projects the bid bond is eliminated. To encourage the submission of a bid the plan holder has the bidder pay for the plans with the understanding that the money paid for the plans will be refunded when the bid is received. Plan sets can range from $100 to $350 Dollars.

After the bid bond, a **payment bond** is sometimes required. This bond, which is probably the one most beneficial to the facility is a guarantee that the main contractor will be sure to pay all of his subcontractors. If, for example, the contractor bills the facility for a portion of the work but does not pay the subcontractor, the subcontractor can sue the facility. It doesn't happen often, but it has happened. Some states have laws that require the main contractor to immediately pay the subcontractor any money obtained for that subcontractor from the owner. If a contractor does not pay the subcontractor the payment bond is used to protect the facility.

Finally, some jobs require a **performance bond**. A performance bond is posted to guarantee that the contract will be performed as agreed in the contract. Basically it acts as insurance that the contractor will finish the work. Since this type of bond is expensive, many facilities have been foregoing this bond in lieu of limiting the bidding to only preselected or prequalified bidders. In some states, the United States Small Business Administration acts as the bondsman for a performance bond and, in effect, guarantees the performance of a small contractor. However, if the contractor gets into trouble under this arrangement, the facility manager now gets to deal with a poor contractor and a government bureaucracy. And this can be a real nightmare, especially when the project is a roofing project.

Unique to roofing is a **bond on roofing performance**. This bond is posted by the roofing contractor as an assurance that the roof will perform. However, this kind of bond was more popular in the 1940s and 1950s than it is today.

Construction Progress

After the bidding is completed and a contractor is selected, work can commence. The National Roofing Contractor's Association recommends a pre-job conference and a pre-work inspection before work actually starts. The inspection is for all parties to agree on the status of the roof before actual roof work begins. The pre-job conference usually includes the manufacturer of the roofing system that is to be installed. This conference is designed to resolve any minor differences between the specifications and the manufacturer's roofing system. Example: The contract documents call for 7/8" nails but the roofing manufacturer wants to use 1-1/2" screws. This kind of discrepancy is common and it is best to have it addressed before the roofers have placed several hundred nails and the inspector decides to reject the roof because of them.

After the conferences the contractor will schedule the work. He may not have all of the materials needed to start the job and so he will order them. In addition, equipment has to be scheduled and workmen either hired or scheduled from other jobs. Depending upon the size of the contract or job, it may be necessary to schedule waste trucks to haul any removed debris away.

At the same time the facility manager can be passing the word among the building clients that the roofing project is getting underway. Depending upon the roofing method and materials chosen, the contractor will need a staging area on the ground for parking his equipment. This area is usually roped off with tape or barricaded. It is important to keep building users separate from the contractor's equipment since they could impact with each other.

Access Control. The ideal roofing location allows only limited access to the work. This could be from within the building through a secured penthouse or hatchway. However, during a roofing or reroofing project access can be provided by ladders or through the use of a temporary stairway erected solely for the purpose of the roofing workmen. The facility manager should make sure the contractor secures any exterior access ladders or stairways after hours to reduce the threat of vandalism. In addition, if the contractor leaves ladders or scaffolds in place and a child or teenager uses this equipment to get onto the roof and subsequently falls, there is a high probability of a lawsuit of the building owner by the child's parents. Therefore to minimize any liability to the facility, a facility manager wants to clearly spell out in the contract a requirement for securing the facility at the end of each business day.

Work progresses steadily, one step at a time until the roof is complete. There will be halts in various stages as the phases of the work change. In addition, if there is any rain or other bad weather this will halt the work until the conditions clear enough to allow the work to resume.

The roofing contractor should be careful not to place all the roofing material in one place on the roof, unless the weights have been checked against the loads. Also, while the roofing is stacked in one area, the roof deflection there may be more than usual and cause ponding of water at that spot.

At the end of the project the completed roofing system is usually inspected by the manufacturer's representative. Sometimes this may the contractor himself, or the manufacturer may send in a consultant. In any case after the roofing system has been inspected and the work is complete, the concluding paperwork is turned over to the facility. This would include the roofing guarantee, the manufacturers recommended maintenance, any leftover materials that might be used for patching, the final release of the bonds, a release of claims, etc. Final payments are made to the contractor and a release form is signed stating the work is complete and the contractor has been paid in full for the work.

The facility should ask for a statement that all of the subcontractors have been paid or examine documentation that they have been paid since a failure by the main contractor to pay the subcontractors can result in a mechanic's lien being placed on the property.

Payment. A few short words about payment of contractors for facility managers. Most contractors borrow the money to buy the materials for any job they are working on. They may have their own funds but they will try not to tie these up on the job. Once they have a contract, they find it fairly easy to go to the bank and borrow the money they need to get started. In addition, the suppliers are usually on a 30 to 60 day billing cycle. That is the material going onto the roof isn't paid for until billed which could be several weeks later. Other materials, tools, equipment, and labor require immediate payment. Some contractors may want to get some funds from the facility up front, or make another arrangements, since payments go out of the contractor's bank accounts before they go in. Usually, if the material is on the job site, the facility can pay for them based upon invoices from the manufacturer. Labor, of course, is another matter since the value of the labor isn't seen until later in the job. A lot of workmen who aren't very efficient can add up quickly. This is the contractor's problem of course but the facility doesn't want to let too much of the money go out until the value is on the roof.

For a facility, the safest course is to pay for the job when it is finished but this policy can be more expensive than allowing the contractor to draw funds against the contract amount as he goes along.

The whole point is to make sure that the contractor isn't being paid more than the actual value on the roof. If the facility gives all of the funds to the contractor up front, the incentive to get the job finished is gone. Almost all facilities hold back at least some funds to make sure the contractor finishes all the paperwork and closes out the bonds and warranty matters. Contracts written with a maintenance agreement in the first year of roof life should hold those funds back as well.

Inspection of the Work

Probably nowhere in construction is inspection as critical as it is during roofing installation. Since the roof is one of the most important aspects of the structure and since modern methods and materials have made the roofing system so light relative to the rest of the components, inspection is necessary to assure the value of the work. In addition, the roofing system won't be looked at by the clients or building occupants and hence roofing inspection does not usually get the attention it deserves.

Inspection should be performed by an agent that represents the facility and this person or persons should have access to the designer and to the roofing system manufacturer. This way if there are discrepancies, the inspector can find out what needs to be done and explain what is necessary to the contractor's foremen.

One element common to all construction is that contractor's generally don't like inspectors. Such is the nature of the beast. Sometimes the inspector isn't all that qualified and this is where a camera comes in. A camera can record all of the activities that take place on the roof and an inspector can photograph as much of what needs to be inspected at any time. Many a job has been performed where the contractor changed what he was doing just because someone showed up with a camera and started taking pictures. Even through the photographer didn't know what he was taking pictures of, the contractor did, and he knew that if someone competent was to look carefully at the photos the work would be challenged. Hence, a camera is one of the most important inspection tools on the job site.

The inspector should also look at job site safety and make sure the contractor complies with construction safety regulations. The facility manager needs to keep safety liability in the contractor's court by specifying in the construction documents that the contractor will comply with all construction safety regulations. Roofing and job site safety are presented in Chapter 13.

Inspectors should look at the deck as it is completed and before the placing of roofing insulation begins. The deck should comply with the specifications, of course, and the workmanship should meet accepted construction standards for that type of deck. This is where experience pays off. The deck should be clean, free of holes, and stable enough for the workmen and any additional construction materials. The slopes of the decking should be checked at this time to make sure the roof will drain properly. If the building has a parapet wall, then the wood blocking should be inspected to make sure it is correctly attached.

After the deck is ready, assuming a low slope roof is being constructed, the insulation is laid along with the necessary tapered pieces to assure drainage. If a vapor barrier is called out, it should be installed. If the design called for mechanical fasteners to attach the insulation to the deck, then the inspector should check to assure that the correct size and number of fasteners is being placed. The fasteners themselves should be inspected along with the correct insulation materials to assure the specified products are being used.

After the insulation has been placed, the waterproofing membranes are placed, (provided this is the design, of course) The waterproofing membranes should be checked against the specified materials. If it is a built up roof, the felts, mopping boards, and application temperatures are verified. The contractor should be using a thermometer that is calibrated. That is, the thermometer has been checked to assure that it registers the correct temperatures. The felts and mats should be laid out according to the manufacturer's guidelines.

The number of moppings or broomings should be checked and the thicknesses measured. Cant strips and blocking should be free of knot holes and protruding nails.

Final flood coats are applied along with the spreading of any aggregate.

For a single ply, materials should be placed and spread on the roof according to the manufacturer's guidelines. Depending upon the materials, either thermoplastic or elastomeric, the seams will either be adhered or welded using the manufacturer's specified procedure. If the system is ballasted, the rock ballast should be inspected before lifting it onto the roof. If there are sharp edges in the aggregate it should be rejected before it is spread on the single ply membrane.

Flashing and drainage installations should be inspected. Drains should be at low points on the deck and both flashing and drains installed with the correct number, size and material fasteners.

Finally, the contractor's tools and materials should be removed. Many roofing system has leaked because the contractor forgot and left a box of nails on the roof which, over time eventually settled into the roofing membrane and punctured it.

Openings should be flashed and curbed. Fasteners installed correctly and flashed or covered with roofing mastic per the manufacturer's recommendations.

All ladders, materials, equipment, tools and scraps are removed and the area around the perimeter of the building picked up. Nails that have blown off with pieces of insulation or shingles have caused many flat tires on cars in the parking lot.

Finally the warranty papers and the inspection certificates are turned over to the owner. The roofing project is complete and the warranty period begins.

Other Project Management Considerations

The following list identifies some of the smaller items that will be encountered during a roofing project. The facility manager does not have to take care of each of these other details as the contractor's, roofing consultants, and designers will have addressed these in the course of assisting the facility manager with the project.

One of the most classic construction accidents, which happens more times than one cares to admit, is when a hole is cut into a roof deck for installing equipment. To prevent a fall through the hole, a workman places a sheet of plywood over the hole to prevent someone from falling through. Unfortunately, this looks just like a piece of plywood laying on the deck. Another workman comes along who needs a piece and picks up the plywood. Because the sheet is large, he cannot see where he is going and walks forward, falling through the hole. To prevent this from happening, a hole should be roped off with warning tape. If this cannot be done, the opening should be guarded by a workman until some rope or flagging can be obtained. One fall can halt a project and cost the contractors and the facility a lot of money in legal bills. Especially if the injury is severe.

Roof Access. Briefly mentioned earlier in this chapter is the problem of roofing system access. For steep sloped roofs, everyone has to get onto the roof at one time or another. Since the roofing industry is plagued with falls, it needs to be discussed here what the facility manager can do to protect himself and the facility from any liability.

Usually the roofing subcontractor is not responsible for the roofing deck. The assumption is that this work will be performed by others. However, on some projects the deck needs to be reworked because it is faulty. This is one of the reasons for the preroofing conference discussed earlier in this chapter.

Safety during the actual construction should be outlined in the specifications. In addition, the Occupational Safety and Health Act (OSHA) has some relatively strict rules for worker fall protection. Chapter 13, Roofing Safety and Liability, discusses fall protection. Chapter 13 addresses roofing safety and liability.

Discarding Roofing Materials. When a roofing project includes tearing off and disposing of the old roof, some additional considerations will assist the facility manager and reduce his costs. Recent laws regarding disposal of hazardous waste have seriously affected the roofing industry. There is a definite process for determining if disposal of roofing products is classified as a hazardous waste. One of the most significant problems is in disposal of asbestos, an insulating material used extensively from the early 1930s until the early 1970s.

Specifically asbestos and more generally, hazardous waste must be disposed of properly with special steps taken to keep the material from casually entering the environment. Asbestos waste handlers must be specially trained and certified to perform their tasks. Roofing systems considered for replacement should be assessed early in the project for a determination of whether the materials will have to be disposed of as hazardous waste. If so, then the cost of the project is increased considerably. In addition, disposal of hazardous wastes involve additional requirements for record keeping.

Cradle to Grave Material Accountability. Hazardous waste disposal has a requirement for cradle to grave accountability. This means the generator of the waste must prepare a shipping manifest that will accompany the material to its ultimate destination, usually a hazardous waste landfill or disposal area. The manifest must be correctly prepared because if there is anything wrong with this paperwork, the receiver won't accept it. There are tales of trucks loaded with Hazardous Waste driving endlessly around looking for a place to leave the materials and even the press has reported drivers finally abandoning the trailer in some residential area because he couldn't get rid of it. The facility manager wants to make sure this kind of thing doesn't happen to the facility, because the penalty is severe. The cradle to grave rule means that if the material can be tracked back to the facility, the facility could be held responsible for it.

If the material isn't hazardous waste, it still has to be disposed of properly. One of the tools used by roofing contractors is a discardchute such as the one shown in Figure 9- 3. These chutes are attached to the side of the building and control the fall of the material. Usually a bin or dumpster type waste receptacle is placed at the bottom of the chute to collect the debris and make it easy to haul away.

Material Safety Data Sheets. New roofing materials, and materials to be discarded will affect the employees who do the work. Since chemicals and hazardous materials may be a concern, it is important that the workers know what the materials are and what necessary protection they can take to protect themselves from any hazard from the material. The primary means to notify

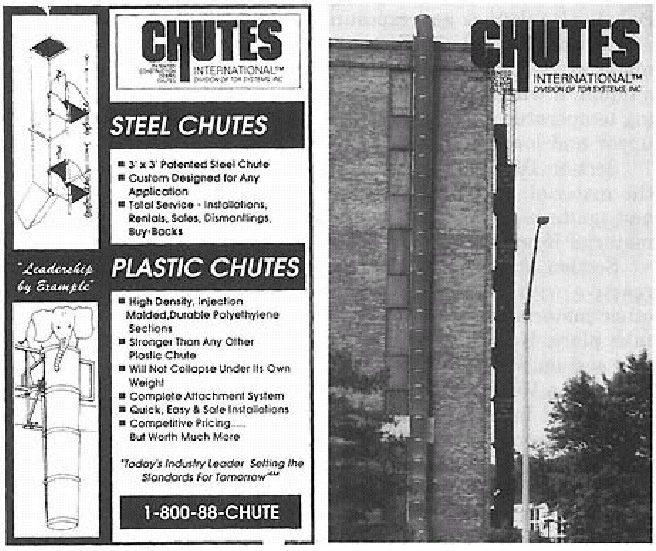


Figure 9-3
A reroofing discard chute. Chutes such as these keep the debris that is removed from spreading when dropped off the roof.
The chute channels the material into a waste bin below.
Courtesy: Chutes International, Waldorf, MD.

workers of possible hazards is with a Material Safety Data Sheet. This sheet is prepared by the manufacturer of the material. The roofing contractor is required to have one on the site for any of the materials that he uses. The material safety data sheet is sometimes a complex document and an example of one for Gibson-Homans Company Self-Leveling Neoprene Sealant is shown in Figure 9-4.

A careful examination of the MSDS shows there are several categories which include:

Section I: This section includes the name of the material, who the manufacturer is, how to contact him, and some of the trade names or other names by which the material is known. The general section also includes the relative hazards associated with the material. Generally the higher the numbers the more hazardous the material is.

Section II: Identifies any hazardous ingredients in the material. It also defines any exposure limits to the material.

Section III: This section gives any physical data about the material. Section III will give the weight of the material. If it is a liquid, it will provide the boiling point, melting point, and freezing temperatures. If it is a gas, it will give the flash point and the upper and lower explosion limits.

Section IV: Section IV provides any fire or explosion data on the material. The temperatures at which the material will burn and ignite is included. It also tells how to put a fire out in the material if one is started.

Section V: Provides reactive data, that is, if the material is reactive with another material this section will tell what the other materials are and under what conditions a reaction could take place. If there is any material released during the reaction this section will address that as well.

Section VI: Provides the health hazard data for the material. This would include the amounts of safe levels for exposure, any hazards associated with handling the material or breathing the fumes. It will give any cancer or lung disease risks.

Section VII: This section provides any spill, release or disposal procedures including containment and clothing to be worn while handling it.

Section VIII: Section 8 provides special protection information to protect the worker from the material. This includes ventilation, clothing, face shields, eye protection, gloves, etc.

Section IX: This section provides any special precautions to be

MATERIAL SAFETY DATA SHEET THE GIBSON-HOMANS COMPANY 1020.1 PAGE 1

ABBREVIATIONS: NA = NOT APPLICABLE
ND = NOT DETERMINED
NE = NOT ESTABLISHED

HEALTH = 2
FLAMMABILITY = 3
REACTIVITY = 0
PERSONAL PROTECTION = +
+ SEE SECTION VIII

SECTION I-MATERIAL IDENTIFICATION AND USE

MATERIAL NAME/IDENTIFIER: PC502 SELF-LEVELING NEOP. SLNT
MANUFACTURERS NAME AND ADDRESS: GIBSON-HOMANS COMPANY
1755 ENTERPRISE PARKWAY
TWINSBURG, OHIO 44087
EMERGENCY TELEPHONE NO.: (DAY) 216/425-3255 (24 HOUR) 216/843-2982
DATE PREPARED: OCTOBER 5, 1995 REVISED: APRIL 11, 1996
CHEMICAL FAMILY: MIXTURE
CHEMICAL FORMULA/MOLECULAR WT: NA
TRADE NAME AND SYNONYMS: NA
MATERIAL USE: ROOFING, FLASHING CEMENT

SECTION II-HAZARDOUS INGREDIENTS

CHEMICAL NAME	OSHA-PEL	ACGIH-TLV	LD50/LC50	% WT
XYLOL CAS #1330-20-7 CARCINOGEN: NO Sara Title III, Sect. 313 reportable: YES	100 PPM 150 PPM STEL	100 PPM 435 MG/M3	4300 MG/KG ORAL RAT	30-35
MICA CAS #12001-26-2 CARCINOGEN: NO Sara Title III, Sect. 313 reportable: NO	3 MG/M3 -	10 MG/M3 RESP. DUST	ND -	18-23
ETHYLBENZENE CAS #100-41-4 CARCINOGEN: NO Sara Title III, Sect. 313 reportable: YES	100 PPM -	100 PPM 125 PPM STEL	3500 MG/KG (ORAL-RAT)	3-7
CARBON BLACK CAS #1333-86-4 CARCINOGEN: NO Sara Title III, Sect. 313 reportable: NO	3.5 MG/M3 -	3.5 MG/M3 -	ND -	8-13
CHLORINATED PARAFFIN CAS #63449-39-8 CARCINOGEN: NO Sara Title III, Sect. 313 reportable: YES	- -	- -	- -	1-5

SECTION III-PHYSICAL/CHEMICAL CHARACTERISTICS

BOILING POINT: 275-285 DEG.F
VAPOR PRESSURE(MM): 25 DEG.C 9 MM
VAPOR DENSITY(AIR=1): >1
SPECIFIC GRAVITY/DENSITY(G/ML): 1.1-1.2
MELTING/FREEZING POINT: NA
EVAPORATION RATE(BUAC=1): <1
SOLUBILITY IN WATER: INSOLUBLE
%VOLATILE BY VOLUME: 35-45
PH: NA
COEFFICIENT OF WATER/OIL DISTRIBUTION: ND
ODOR THRESHOLD(PPM): ND
APPEARANCE, PHYSICAL STATE AND ODOR: BLACK PASTE, XYLOL ODOR.

SECTION IV-FIRE AND EXPLOSION DATA

FLASH POINT: 80 DEG. F. MIN. PMCC
UPPER EXPLOSION LIMIT: 6.6
AUTO IGNITION TEMPERATURE: 465 DEG. C.
LOWER EXPLOSION LIMIT: 1.1
SENSITIVITY TO CHEMICAL IMPACT: ND
RATE OF BURNING: ND
EXPLOSIVE POWER: ND
SENSITIVITY TO STATIC DISCHARGE: ND
EXTINGUISHING MEDIA: FOAM, CARBON DIOXIDE, DRY CHEMICAL.
SPECIAL FIRE FIGHTING PROCEDURES: THE USE OF A SELF-CONTAINED BREATHING APPARATUS IS RECOMMENDED FOR FIREFIGHTERS. WATER MAY CAUSE FROTHING, APPLY CAUTIOUSLY.
UNUSUAL FIRE AND EXPLOSION HAZARDS: VAPORS MAY TRAVEL AT GROUND LEVEL TO SOURCES OF IGNITION DISTANT FROM POINT OF APPLICATION.
FLAMMABILITY: YES
UNDER WHAT CONDITIONS: FLAMMABLE LIQUID - NFPA CLASS III B

(Continued)

Figure 9-4
A typical material safety data sheet.
Courtesy: Gibson-Homans, Twinsburg, OH, 1-800-433-7293.

taken when handling the materials.

Section X: Section 10 gives the workers information on any transportation of the material. What packing is required and what labels to place on the Department of Transportation (DOT) Shipping labels.

MATERIAL SAFETY DATA SHEET   THE GIBSON-HOMANS COMPANY   1020.1   PAGE 2

SECTION V-REACTIVITY DATA

STABILITY-MATERIAL IS: STABLE
CONDITIONS TO AVOID: SOURCES OF IGNITION.
INCOMPATIBILITY(MATERIALS TO AVOID): STRONG OXIDIZERS.
HAZARDOUS DECOMPOSITION/COMBUSTION PRODUCTS: CARBON DIOXIDE, CARBON MONOIDE, OXIDES OF NITROGEN.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR
CONDITIONS TO AVOID: NA

SECTION VI-HEALTH HAZARD DATA

PRIMARY ROUTES OF ENTRY: INHALATION - SKIN - INGESTION
EFFECTS OF OVEREXPOSURE, CHRONIC: OVEREXPOSURE TO XYLENE HAS BEEN SUGGESTED AS A CAUSE OF THE FOLLOWING EFFECTS IN HUMANS: CARDIAC ABNORMALITY, LIVER, AND KIDNEY DAMAGE.
EFFECTS OF OVEREXPOSURE, ACUTE: SKIN: PROLONGED/REPEATED CONTACT MAY CAUSE IRRITATION. EYES: MAY CAUSE SLIGHT IRRITATION. INHALATION: EXCESSIVE BREATHING OF HIGH VAPOR CONCENTRATION MAY CAUSE HEADACHE, DIZZINESS, NAUSEA. INGESTION: MAY CAUSE NAUSEA, VOMITING, HEADACHE, DIZZINESS.
EMERGENCY AND FIRST AID PROCEDURES: SKIN: WASH WITH SOAP AND WATER. EYES: FLUSH WITH LARGE AMOUNT OF WATER. INHALATION: REMOVE PERSON FROM AFFECTED AREA TO FRESH AIR. INGESTION: DO NOT INDUCE VOMITING. CONTACT A PHYSICIAN IMMEDIATELY.
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE: OVEREXPOSURE TO XYLENE HAS BEEN SUGGESTED TO AGGRAVATE PRE-EXISTING LIVER, SKIN, KIDNEY, PULMONARY DISORDERSC&CARCINOGENICITY: NO
LD50 OF PRODUCT: ND   LC50 OF PRODUCT: ND
IRRITANT?: NO   SENSITIZER?: NO
SYNERGISTIC MATERIALS: NA
REPRODUCTIVE EFFECTS: NO   TERATOGENIC: NO   MUTAGENIC: NO

SECTION VII-PREVENTIVE MEASURES, SAFE HANDLING AND USE

LEAK AND SPILL PROCEDURES: DIKE SPILL AREA. REMOVE SOURCES OF IGNITION. VENTILATE AREA IF NECESSARY. RECOVER FREE MATERIAL. ADD ABSORBENT TO SPILL AREA.
WASTE DISPOSAL METHOD: DISPOSE OF ACCORDING TO FEDERAL, STATE AND LOCAL REGULATIONS.
PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: KEEP AWAY FROM SOURCES OF IGNITION. AVOID PROLONGED/REPEATED CONTACT WITH SKIN.
OTHER: KEEP OUT OF THE REACH OF CHILDREN!

SECTION VIII-CONTROL MEASURES/PROTECTION INFORMATION

VENTILATION: AS NECESSARY TO MAINTAIN EXPOSURE BELOW TLV LEVEL.
RESPIRATORY PROTECTION: NOT NORMALLY REQUIRED IN WELL VENTILATED AREA. IF TLV IS EXCEEDED, A NIOSH/MSHA APPROVED BREATHING APPARATUS IS RECOMMENDED.
PROTECTIVE GLOVES: SOLVENT RESISTANT.
EYE PROTECTION: NOT NORMALLY REQUIRED.
OTHER PROTECTIVE EQUIPMENT: SOLVENT RESISTANT APRON AND BOOTS.
WORK/HYGENIC PRACTICES: REMOVE CONTAMINATED CLOTHING, LAUNDER BEFORE REUSE.

SECTION IX-REGULATORY INFORMATION

REPORTABLE QUANTITY (MIN. UNDER ANY ACT): 330 LBS. (DOT = 3,400 LBS.)
RCRA HAZARDOUS WASTE NO: (FED) D001, D006
PROPER SHIPPING NAME: ADHESIVES *
DOT HAZARD CLASS: FLAMMABLE LIQUID, 3, UN 1133, PACKING GROUP III
IDENTIFICATION NO: NMFC ITEM NO. 170060 NMFC CLASS 055
VOLATILE ORGANIC COMPOUNDS(VOC): 420 G/L MAX.
EXPORT CLASSIFICATION: MARINE POLLUTANT (CHLORINATED PARAFFIN), IMDG CLASS 3.3

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* MAY BE CLASSIFIED AS "CONSUMER COMMODITY" IF APPLICABLE.

THE INFORMATION ACCUMULATED HEREIN IS BELIEVED TO BE ACCURATE BUT IS NOT WARRANTED TO BE, WHETHER ORIGINATING WITH THE COMPANY OR NOT. RECIPIENTS ARE ADVISED TO CONFIRM IN ADVANCE OF NEED THAT THE INFORMATION IS CURRENT, APPLICABLE AND SUITABLE TO THEIR CIRCUMSTANCES.

Figure 9-4
(Continued)

Personal Protective Equipment. Once any health hazards are known the workers protect themselves with the necessary personal protective equipment or PPE. Personal protective equipment can include dust masks, gloves, cotton clothes, rubber boots, face shields, or goggles. Workers handing roofing materials that pose a risk should wear the proper personal protective equipment. Every employer is obligated to provide training in reading Material Safety Data Sheets and personal protective equipment is usually provided by the employer.

Case Study

On a small single ply project the contractor bid with the supplier for delivery. The roofing material was to be delivered in rolls to the rooftop. The contractor was not available when the product was delivered however the instructions and the agreement were clear, the materials were to be delivered and placed on the roof deck. The supplier used a large crane to hoist the material into place but it was necessary to put the crane near the building. An existing parking structure prevented supplier's crane from parking on the pavement. The supplier decided to locate the crane on the lawn immediately adjacent to the building.

However, when the crane operator put the feet down on the crane, these left large "footprints" in the lawn, a condition that was unacceptable to the building tenants. The large divots left from the crane activity had to be repaired by removal of the sod, fill in the form of extra earth, and replacement with new sod. It wasn't expensive, nor did it take a long time, but it was a problem for the contractor who was continually called back by the tenant. To prevent this from occurring on later contracts the crane only accessed the roof by a driveway or paved road. If pavement wasn't available, blocks were used underneath the crane's feed to spread out the load and prevent the feet from pushing down into the wet sod.

While all of the roofs fall into the categories mentioned in this chapter, the facility manager may encounter some unusual or offbeat roofs. These unconventional roofs are discussed in the next chapter.

Chapter 10— Conventional and Unconventional Roofing Structures

While every facility manager eventually becomes involved in a roofing or reroofing project, some facility managers have the opportunity to work with more unconventional roofing structures. By their shape, materials, size and what the roof covers, unconventional roofing poses unique problems for facility managers. By studying the usual and some unusual roofs, the facility manager can benefit from the lessons learned and profit by the experience of others.

Denver Municipal Airport - The city of Denver, Colorado wanted to embellish their new airport with a monument representative of the Colorado skyline, something that people would remember and that would call people's images to Colorado and to Denver whenever they saw it. The idea was somewhat akin to the Golden Gate Bridge in San Francisco or the St. Louis Arch: both "Gateways to the West."

Accordingly, a structure was envisioned of the snow capped Rockies and the design was for peaks and valleys similar to those found in nature.

Figure 10-1 is photo of the new Denver Airport Facility. Note the series of high points and low ridges. The roofing system is fabric: fiberglass sheets coated with Teflon. Each sheet was manufactured under close quality control techniques and hoisted into place. The fabric is erected on masts and held in place with cables uniquely attached to the fabric. The fabric roof encloses a great hall where passengers move to catch their flights.

The roofing material was chosen for its ability to allow light into the building and it was erected early in the construction process to allow many of the other construction activities to work inside in dry conditions.

While such a unique structure may not be encountered by many facility managers, the important characteristics like maintenance, energy, and replacement were considered in design of this system. (Source: July 1993 Issue of Buildings)

Metal Roof Retrofit. In 1996 a metal warehouse at Palo Verde, Arizona, Nuclear Generating Station was replaced with a single-ply system designed specifically for retrofit of metal roofs. The original warehouse, built in 1977, was becoming expensive to maintain and concern existed because the warehouse were used to store spares for the power station. Facility managers selected a single-ply membrane over polyisocyanurate boards for the retrofit.

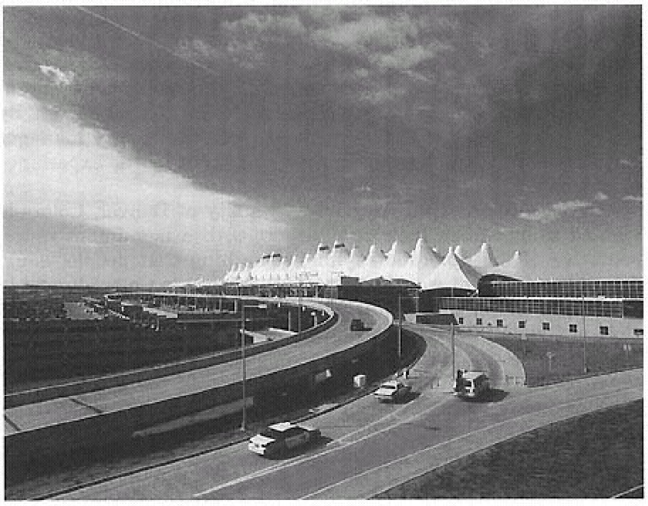

Figure 10-1
Denver's New International Airport with fabric roof
to remind visitors of the Rocky Mountain Skyline.
Courtesy: Denver International Airport.

Severely corroded metal panels were replaced, new insulation boards placed over the existing metal panels and a new membrane rolled out over the new insulation and mechanically fastened to the deck with stainless steel metal rails.

This system was chosen because it utilized most of the existing roof structure, could be erected in a short time, it increased the building insulation to R-19, and it met the wind and load requirements. Since little roof traffic was anticipated, the single-ply membrane was appropriate for this application. (Source: September 1996 *Buildings Design and Construction Magazine*.)

Modified Bitumen Hospital Reroof - Converse with the single-ply example above, a hospital in San Antonio was reroofed with modified bitumen built up system because of a high degree of foot traffic. Officials thought modified bitumen would stand up better than a single ply on this low sloped application. (Source: September 1996 *Buildings Design and Construction Magazine*.)

Church Retrofit in Washington State - A church building needing a roofing retrofit was subject to project requirements limited by weather. Bellevue, Washington, has rain many days of the year and a church's flat roof retrofit needed to be completed quickly as rain was expected during construction. In addition, with the old roof removed, there wasn't time to dry any wet insulation if discovered. The old membrane was removed from the 26,000-square-foot concrete deck, a one-inch-thick water resistant insulation was placed over the old deck and a new 0.060-inch-thick EPDM membrane was installed and ballasted with stone. The seams were reinforced with a 12-inch overlay to provide additional protection. There were minor difficulties flashing around the church steeple but the speed of installation out-weighed the disadvantage of the extra work. Finally, EPDM was chosen over built up materials because of the difficulty of applying built up membranes in occasional cool and rainy weather. Officials felt that quality control of hot asphalt would be difficult. (Source: April 1995 *Buildings Magazine*.)

Domed Roof Research Building Recovered with PVC Single Ply. This instance was one of bird infestation. Facility manager's at Northern Arizona University were plagued with birds who pecked at a sprayed polyurethane foam on a domed research facility on campus. Maintenance was high and required touch up of the foam every three or four years. The facility recovered the foam roof with a single ply PVC membrane. The membrane would require less maintenance, was capable of being fitted over the existing foam roof and was tough enough that the problem birds could not peck through the new membrane. (September 96 *BD&C Magazine*.)

Sprayed Foam Is Used to Recover a Metal Roof. In Vermont an office manufacturing facility with a standing seam metal roof had leaks at the panel laps (where panels overlay one another) and through eroded fastener holes. Facility manager's decided to use a sprayed polyurethane foam application because the foam could be applied without the use of fasteners to puncture the deck. The new foam layer also increased building insulation. Finally, a waterproofing membrane was sprayed on over the foam to prevent the insulation from getting wet. (Source: Sept 96 *BD&C Magazine*.)

Plum Colored Metal - A Playworks recreation facility in Shakopee, Minnesota, wanted the have the right colored roof for its facility. Building owners had selected a purple color, (Atomic Plum) from a wide array based upon their experience with the architect and the contractor. The decision was for aluminum metal roofing coated with the correctly colored paint (kynar.) The designers had to try the paint on all of the various substrate materials with consideration that UV rays would make similar paints appear different under different applications.

For each piece of the roof a full scale model was made of cardboard and plywood to assure the correct fit. No field fitting would be allowed since the metal roof components were fabricated and painted in the shop. (Source: *Roofer Magazine*, February 1996.)

Recovering BUR with Standing Seam Metal. In 1993, two dock warehouses enclosing cocoa beans, timber and rubber products were recovered with standing seam metal roofing. Constructed in the 1940s, the existing built up roofing membranes had passed the end of their economic useful life. Facility managers felt that reroofing with metal would give the buildings another 75 years of economic useful life. Since the warehouses were located in a coastal area, the metal was one of the few systems that exceeded the UL-90 wind criteria required because of high coastal winds. The roof had to meet wind uplift pressures of 30 pounds per square foot. The contractor reported he was able to recover the warehouses with metal roofing, light enough to install over the built up membranes without changes to the main building frame, for approximately $5.00 per square foot.

Conclusion - From the above examples, facility manager's can see how other managers were able to determine the important characteristics for roofing or reroofing their facility. In some cases, aesthetics played an important factor. In others, energy or weather at their site overrode other concerns. These examples show how other facility managers used the important characteristics to retrofit their facility. Once the roofing system is established the facility needs to maintain the systems and any warranties.

Chapter 11— Warranty and Maintenance of Roofing Systems

Probably one of the most significant questions in roofing system management is the status of a roof's warranty. If a roof is purchased to last for 20 years and after 10 years the roof begins to leak what can the facility do? If the facility finds that replacement is necessary and expensive, the next step is to check the status of the roofing system warranty. If the warranty is still in effect the facility wants to try to recover some of the costs. How is this done?

Warranty is an offer provided by the manufacturers of roofing and cladding products to encourage potential buyers to purchase a product. Warranty is a way to assure the buyer the product will meet the needs of the user for the estimated life of the product. However for a warranty to be valid it must meet specific criteria.

In general, a roofing contract has a warranty clause. That is, upon completion of the roofing installation, the warranty requires the roofer come back for the first year or two and correct any deficiencies that result from his workmanship. For a roof that is guaranteed for 20 years, the warranty is assumed by the manufacturer after the initial year or two year period covered by the construction contract. Usually the manufacturer's warranty requires leaks to be repaired throughout the life of the roof, however, no roofing contractor is going to get into an unlimited warranty.

Many times, the contractor is called in to perform warranty work and finds that the facility has done something that invalidated the warranty. Even in attempting to repair the leak, if the wrong materials are used in the immediate repair, the warranty can be compromised.

The entire legal profession has made the business of warranty and guarantee so vague and qualified that many facility managers don't believe that a warranty exists. They have come to the conclusion that warranty is "just talk."

It does take a stream of evidence to establish a warranty claim and even then it may take legal counsel to enforce it. Many times a warranty issue is abandoned because it isn't worth the effort and in most cases maintaining a roofing warranty requires a great deal of effort. Records of inspections, the warranty statement, eyewitness records and photographic evidence are all used to establish a warranty claim.

Most manufacturers, however, want to have success with their product and all manufacturers are insured against claims by their clients. The intent of warranty is to protect the client, to assure them that the product meets or exceeds client expectations. Therefore a warranty is a written document where the roofing supplier or roofing contractor agree to repair or replace portions of the roofing system if it leaks or fails to last the expected time.

However, enforcement of warranty terms is another matter and a facility manager who has a leaking roof may find it simpler to abandon the warranty than to try to fight for one while the tenants are upset over the roof's problems.

In general a warranty claim must be made quickly, in fact at the first sign of a roofing problem the roofing contractor or manufacturer should be notified. If the facility is in a hurry a limited amount of time is required for notice to the contractor. It is usually best if the facility takes the approach that a limited time will be given to the manufacturer, say 24 or 36 hours. After that the costs of the repair will be billed to whoever is providing the warranty. This approach works best but it still has to be documented. Many reputable contractors will respond as soon as they can. Others won't show up no matter how long the facility waits. Therefore, notice should be given and if the contractor does not respond within the time requested, the facility should take immediate action to fix the leak.

Photographic evidence is essential. Also, it is important to keep a written record of all communications. If the matter ends up in court, and there is a good probability it will, the written records and photographs will help document the case. Also, it is important to ask the facility be notified of any visit by the contractor. Sometimes the contractor comes after business hours and gets up on the roof by himself. If he claims that he got up there and fixed the facilities leak after business hours, who could prove him wrong?

So, for warranty service remember to notify as soon as possible, give a fixed time for response. If no action is taken, hire the repair and notify the contractor of the action taken. Take pictures and record telephone and face to face communication.

Maintenance of Roofing Systems

For the facility to obtain the maximum life from the roofing materials and to make sure the full warranty life is reached the facility should establish a roofing maintenance program. The program should be one that closely follows any manufacturer's recommendations that came with the original roof.

The Value of a Routine Inspection Program

Roofing designers and the National Roofing Contractor's Association recommend that a low sloped roofing system be inspected twice a year, preferably in the spring and again in the fall. The temperature extremes of winter and summer cause lots of expansion and contraction of the waterproofing membrane and temperature extremes flex the insulation. In addition, spring rains and late summer thunderstorms tax the roof's drainage system.

In order to establish a record of roofing inspections, a typical inspection form like the one shown in Figure 9-1 can be used. The facility may use the form in this book or establish their own form. It is important that the results of the inspections be kept on file as the record will grow as the life of the roofing system grows.

When combined with the roofing assessment as explained in Chapter 2 the records will go a long way toward maintaining the roofing system in good condition and will prove valuable in substantiating any warranty claims.

Spring Inspection. In the spring roofing should be checked for cracks or tears in the roofing membranes. Openings could have been caused by moisture penetrating the membrane and freezing and thawing over winter. In addition it is a good idea to check any membrane or insulation fasteners to make sure they are still holding after the winter storms. It is also a good idea to verify there are no cracks or splits in the flashing systems.

Sometimes winter temperatures create ice dams that cause water to pond on the roof which damages the waterproofing membrane.

If the membrane is a single-ply roofing system check to see that the material is still fastened or ballasted correctly. Verify that the drainage is working correctly and hasn't become plugged by the movement of gravel or debris. It also helps to make sure high winds haven't moved a single-ply system's stone ballast.

Fall Inspection. In the fall the roof needs to be checked to make sure there is no flashing or membrane damage left over from the hot summer. For asphalt systems the roof should be checked to make sure there is little blistering or alligatoring of the bitumen and verify the aggregate is still in place.

For single-ply systems that are ballasted with stone, check to make sure the stone is still spread evenly. Any ruffling of the membrane in high winds could have moved some of the stones. If so, then the stones should be carefully replaced. If there is a pattern of stone movement additional ballast should be added. Some aggregates don't weather as well as others and in some instances the stones will fracture in the extremes of winter/summer temperatures.

Both Seasons. In both the summer and winter inspection, a roof should be checked for evidence of ponding by looking for stains or evidence of puddles. Large dust or dirt accumulations should be rinsed or washed down since these can become areas for vegetative growth whose roots can penetrate membranes and roofing insulation.

The drainage system should be checked to make sure it is ready for the coming season. In the fall, if the gutters and roof eaves are going to be heat traced, the heat tracing should be checked to make sure it is working properly. All these checks should be accomplished before any major snowfalls or ice storms, because some roofs can be dangerous to access after the weather has deposited a large amount of snow or ice.

Special Surveys

Often for the unprepared facility manager, the first inkling he has of a roofing problem is when the roof leaks. This style of reactive management is one of the most unfortunate methods of facility management. Several studies and scientific methods are available that allow a facility to be proactive in roofing and cladding system maintenance. Since energy is one of the highest expenses of an operating facility, the manager may decide to have an energy survey performed.

For roofs that are near the end of their economic life, or which have had punctures to the roofing membranes, moisture may have penetrated the deck. The reroofing verses repair decision may be aided with performance of a moisture survey. A moisture survey will determine the extent of moisture damage to underlying insulation and to some extent, to the waterproofing membrane as well. Finally, a facility may have to have a fire insurance survey to verify the roofing system meets a certain fire resistive criteria.

Energy Survey. The specific details of how to calculate energy losses are shown in Chapter Six. However, for many facilities, the ability to perform these calculations may be beyond the facilities' expertise. In this case a consultant may be hired to perform the necessary calculations. An energy survey may also be beneficial since the value of increased insulation, varying fuel rates and installation of airlock or double doors may be readily apparent after such a study.

A roofing consultant can conduct the study for a roof, but energy studies need to consider the heat lost through the cladding and exterior walls as well. In addition, energy studies often consider alternate methods of heating and cooling the building in addition to an evaluation of the building's thermal insulation adequacy.

Depending upon the size of the facility and its age, the costs for these studies can vary from a few hundred to several thousand dollars. The surveys are typically performed by mechanical or energy engineering firms who can be located through a local telephone directory.

One of the more interesting opportunities for a facility manager is the energy retrofit. Some engineering firms design and aid a facility in adding roofing and wall insulation. When the estimates are completed, the energy consultant, working closely with a local utility and the facility, may be able to provide information that allows a facility to increase energy insulation at nominal cost. With energy tax credits and reduced energy costs, the consultant may be willing to perform the study at no cost to the facility. What happens here is that the consultant takes his fee out of the energy costs saved by the facility.

For example, if a facility spends $400,000 per year on fuel and electricity and an energy retrofit can reduce this cost to $320,000 per year, the $80,000 can be used to offset the cost of the retrofit. In addition, by adding energy saving materials like insulation and low energy furnaces, the costs of installation can be offset with tax credits. If a facility is over 25 years old and has not been retrofitted in the past, this may be an attractive option. For more information about these options contact the author or the American Association of Energy Engineers listed in the directory in Chapter 14.

Moisture Surveys. For roofs that are suspected to have problems because of excessive heating costs, or which have had problems with membranes tearing or splitting, a moisture survey can be conducted to determine if the insulation has been damaged. In addition, moisture can be present in the structure if it is gypsum or wood. The presence of moisture in the decking and insulation can place significant loads on the building frame and water can weaken some of the members. Moisture absorbed into insulation and decking can become infected with microbial or fungi growth, some of which will give foul odors in warmer weather.

Water corrodes fasteners and rust can corrode structural members and metal decking. Moisture can get into the roofing membrane as well as the insulation, causing it to swell and become brittle when freezing in winter. This embrittlement can crack or split the membranes.

For these reasons a facility manager may decide to conduct a moisture survey. Engineering and roofing consultants will conduct such a survey for a nominal fee.

There are three types of non-destructive moisture surveys: infrared imaging, nuclear backscatter, and electrical capacitance. Each method has advantages and disadvantages over the others and costs vary according to the sophistication of the instruments. Each type of survey should be performed by personnel trained to use the equipment, otherwise the results can be meaningless.

Infrared Imaging. The most effective of the tools for the roofing moisture survey is the use of infrared cameras or optics to determine differential temperatures. The advantages of IR Imaging are that the same instruments can be used for an energy survey. Infrared image scanners reveal warm spots showing energy leakage and will also reveal cool spots which can be checked to confirm the presence of moisture. The cost of an IR camera or optical device ranges from $2000 to $50,000 dollars and the use of such equipment usually requires surveys to be conducted in the evening.

Since the infrared camera can provide a photo image that is turned over with the results, it is one of the most impressive and popular methods for detecting energy losses and moisture. A thermal survey can cost from as little as $100 for a small residence to several hundred or even one to two thousand dollars for a complete thermal scan of a large building. In some large metropolitan cities, aerial photography firms will fly over a facility and photograph it, providing a "birds eye" view.

However, the IR survey measures difference in temperatures and does not actually detect moisture. Hence, if moisture is suspected, other steps have to be taken to confirm water. The IR camera can be fooled by light fixtures in the ceiling below, along with heat from vents or other sources.

Electrical Capacitance. After infrared imagery, another test for the presence of moisture is an electrical capacitance test. This type of test equipment uses electrical resistance or capacitance to indicate the presence of moisture. Since water is an excellent conductor of electricity, a low resistance can indicate the presence of moisture in the insulation or waterproofing membrane.

There are several types of instruments used for an electrical capacitance survey. Some use electrical clips tied to the structural frame and then a rolling charge is passed back and forth over the roof with a recording instrument logging the data. The results are not as impressive to look at as the IR imagery but this method can more accurately detect moisture than the IR system. The electrical capacitance method can be 'fooled' by metal foils, metal decking, and metal structures. Again the electrical capacitance survey requires trained technicians to collect the data and the results need to be analyzed by a trained professional.

Nuclear. In addition to the electrical and infrared methods of moisture detection, a third method using nuclear backscatter can be used. While the other methods are continuous, reading the entire roof, the nuclear backscatter method is capable of sampling only points on a grid. Therefore, the nuclear method is often used to confirm moisture detected by one of the other two methods. The nuclear instrument uses a radioactive source housed in a lead lined box called a camera. The source is opened and neutrons are allowed to fire down into the material being tested. Some of the neutrons strike hydrogen particles in water, and bounce back into a neutron detector also located in the camera. Nuclear moisture testing is more accurate than IR or Capacitance and this instrument is capable of reaching further down into the roofing materials than the other methods.

The main disadvantage of a nuclear imaging instrument is that it is only capable of detecting moisture at a point, usually located on a grid. Another disadvantage is that asphalts and bitumens, being organic compounds have a lot of hydrogen in their makeup as well as water. Therefore a nuclear survey is one that compares a known dry area against a suspected moist area. The instrument has to be calibrated over a dry area for that type of roof. If the roof has different types of roofing materials, say over adjacent wings, or different plies, or different types of insulation, the nuclear moisture test can be "fooled" by the variations in the materials. For each type of area being tested the meter must be set up on a dry patch of exactly that type of material.

A nuclear moisture survey can detect varying types of roofing systems and show where a boundary between two types of systems or plies might be. The instrument cannot determine if this is simply a variation in construction methods or if moisture is present.

Roof Cuts. As a result of the varieties in moisture sampling of the infrared, capacitance, and nuclear backscatter methods, most roofing surveys are confirmed by making test cuts into the material to confirm suspected moisture. Roof cuts are made through the membranes and removed, along with a sample of the insulation. The roof cuts must be patched immediately, of course after they are taken. Roof cuts are almost exclusively used on low sloped roofing installations. Prior to performing any roofing cuts, the method of patching should be established and the materials in place before the roofing cuts are made.

Roofing cuts remove physical samples of the waterproofing membrane and the insulation. The samples are taken to a laboratory where the moisture from the samples are analyzed. Of course the lab samples must be handled in such a way to prevent any moisture from leaving the samples prior to their arrival at the lab. If the sample allows the moisture to escape then the data resulting from the roofing cuts is meaningless. While roof cuts are made through the waterproofing membrane and insulation, the cuts do not extend into the deck.

Often, after cutting, the degree of moisture saturation of insulation is immediately apparent. Therefore it is usually a good idea to have a camera present to record the condition of the roofing insulation as it is removed.

Roofing cuts, infrared imagery, electrical capacitance, and nuclear moisture analysis all serve to determine the exact dimensions of the moisture present below the waterproofing membrane. This information is then used to determine if the entire roof needs to be removed and replaced, or if only a portion needs to be repaired.

Leak Repair

The repair of roofing cuts is similar to repairs of splits or tears in the roofing membrane and leaking roofs should be repaired as soon as it is practical. Often a leak is discovered and roof inspection reveals that the roofing drains have plugged. Of course it won't be possible to repair the roofing materials until the roof has been properly drained so the drains must be unclogged first, allowing any water that has ponded to drain. If the roof has deflected, such that the drains are at high points, the roof has to be drained by squeegeeing or brooming water to the drains, or by pumping or channeling the water. In the latter case, it may be more simple to allow the roof ponds to evaporate rather than try to modify the roofing system to remove the water.

On large ponding problems, sometimes the best solution is to punch a hole through the deck from below, allowing water to drain into buckets or building drains. This option should not be chosen without checking the roof first since there may be more water than is initially suspected.

Emergency Repair. When a roof is leaking, stopping the leak is top priority. Sometimes, the area under the leak must be evacuated and materials and equipment removed. This type of emergency response is frustrating to everyone, especially to the tenants or occupants because leaking water will damage and ruin work that is underway, i.e. paperwork. The water can also damage electrical equipment, i.e. appliances and especially computers.

Leaking water also gets into light fixtures, requiring they be shut off, leaving the occupants in the dark. Water can also get into furniture, wood flooring, and carpeting staining it and/or warping wood.

Temporary repair of roofing leaks includes placing buckets on the floor where water runs in, this is the most common emergency action. Depending upon the severity, installation of drip or drop cloths and even removal of furniture, and equipment are necessary.

One vendor offers an emergency temporary roof which is erected inside the building in the vicinity of the leak. The tent like structure channels the water to a funnel connected to a hose which is then carried either to a nearby window or to a building drain. Figure 11-1 is a copy of the drawing contained in the vendor's promotional data.

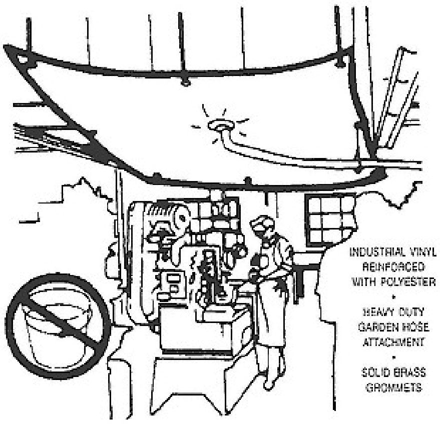

Figure 11-1
Roofing Leak Channeling Equipment.
Courtesy: Sulmac Inc., Holyoke, Mass.

Once the leak and weather conditions have stabilized roofing repairs can begin.

Roofing Repairs

If a roofing system is near the end of its useful life, a decision may be made to go ahead and replace the roof rather than to try to repair and patch leaks. Several factors weigh in the decision to effect permanent patching. These are:

The age of the existing roof.

The size and seriousness of leaks.

The condition of the area requiring patching. (Patch possible?)

Condition of the underlying insulation. If it has been ruined, patching may not be effective.

The status of the structural material or decking. If this is poor, then the structure may have to be replaced.

Nothing is more frustrating to tenants and staff than a roof leak. Water drips through onto desks, file cabinets, book cases and computer equipment. Water saturates ceiling tiles which fall onto desks and computer equipment leaving a globby, soggy mess. For these reasons many facilities require that materials be put away at the close of each work day and that computer and electrical appliances be turned off.

Water and electricity don't mix! So if water had dripped onto energized electrical equipment the safest course is to shut off electrical equipment at the electrical circuit breakers. In a worst case disaster, power to the entire building can be disconnected.

Many types of computer equipment can be salvaged and restored. Some systems will recover if allowed to dry thoroughly before being re-energized.

Patching. Quite often, especially on low sloped roofs, a decision is made to replace the entire roof, when patching of portions of the decking would be adequate. In addition, because of cumbersome organizational behaviors, a roof could be patched if action was taken rapidly, where hesitation because of replace vs. repair or warranty determination takes too long, the roof is further damaged by water action. Facility managers should be aware that inaction favors the replacement decision.

If the decision is made to patch the roofing the details of a repair method have to be determined. Patching is more profitable in a facility where regular roofing inspections take place since an undetected tear in the membrane can ruin the underlying insulation before a patch can be placed.

Problems that can be repaired include: tears in the materials or in flashing, punctures, splits, blisters, buckles, punctures, ridging and lifting (sometimes called fish mouths because the result looks like an open fish mouth.)

General deterioration, such as alligatoring of asphalt, loss of or destruction of felt, aggregate deterioration, and severe aging cannot be permanently repaired and require replacement.

Fortunately this is where the value of a good roofing consultant comes in. A consultant can determine the exact conditions under which repairs can be made, and the life of the resulting repairs. For facility manager's that have not even done preventive maintenance or routine inspections however, the roofing consultant cannot come up with a magic fix that saves the facility big money in a short time.

Repair of each problem depends upon the roofing material since it is important to patch with a compatible material to prevent further problems. Use of asphalt materials on single plies won't hold, neither will the reverse by using single plies to try to patch built up or modified bitumens. Fortunately, the close relationship between a modified bitumen and a built up roofing system (both contain asphaltic or coal tar elements) allows them to be patched with the alternate element. Unfortunately coal tar materials will not mix with asphaltic materials. A fast temporary patch can be made with the alternate material but it will have to be removed along with part of the original deck when the permanent repair is made.

Patch and Repairs of Asphaltic, Coal Tar and Modified Bitumens

Splits, tears, punctures and blisters can all be repaired. Splits need to be checked to determine the reason for the split which is either the result of moisture in the material and its drying out and cracking, or of shrinkage of the material and its tearing. For these types of repairs, a comparable repair material of felts and bitumens is used or a comparable modified bitumen can also be used. Before attempting a repair the roofing and surrounding areas must be dry.

First the area around the problem is swept free of gravel, dirt, dust, and debris. Then cuts are made in to the membrane to reduce the tendency to continue to tear or split. The insulation is checked under the tear and allowed to dry. For a split, a slip sheet is placed over the tear to provide for additional expansion. A patch of felts or modified bitumen is cut that extends beyond the hole 6 inches in each direction and the area is primed with asphalt cement, either hot or cold, or coal tar. The new felt is pressed down into the primed asphalt or tar. For most roofs a second ply is added over the first and the area is then replaced with aggregate to protect the patch.

Coal tar and asphalts are incompatible. The coal tar tends to make asphalt brittle while asphalt tends to liquefy coal tar. Unfortunately it isn't possible to determine by looking which material is used on the roof. Some roofing consultants can make an educated guess but the best thing to do unless it can be assured which material was used is to have a lab test the material. In many areas of the country either one or the other material is used because one type of material has an economic advantage over the other. Where coal and coke are mined and used extensively, coal tar is probably the material of choice. Where petroleum products are economical, most of the roofing materials will be derived from asphalt.

Patch and Repairs of Single-ply Membranes

On single-ply applications the patch repair is much the same as for built-up membranes. The area is swept clean of debris and rocks, the tear is cut to prevent further tearing. Insulation below is allowed to dry. Compatible patch material is cut to cover the area with at least six inches overlap on each side. The new patch is adhered to the old material using the appropriate cement for elastomeric materials, (EPDM etc.) or welding or solvent sealer for the thermoplastic single plies. (Chapter 5 discusses these materials in detail.) The patched materials are then either ballasted or re-adhered with the designed roofing system fastening method.

For blisters, an X is cut into the membranes to allow the material to lay back down and the area is patched as discussed above after the insulation has been allowed to dry.

Ridging. The repair of ridging problems can be more difficult because ridging is often the result of insulation expansion or another structural defect that is not directly related to problems in the roofing membrane. Ridging caused by expansion of the insulation from moisture saturation generally requires the roof be torn off and completely recovered. A moisture survey is especially valuable in this instance.

Repair of ridging can be accomplished in a manner similar to repair of blisters after the details of the cause of ridging is known.

Shingle Repairs. Asphalt shingles are often used for some commercial buildings although their most common application is for residences. Asphalt shingles will break and tear which can be repaired. For asphalt shingles that have lost bitumen and granule outer layer, only a temporary repair will be possible. Again, the remaining life of the asphalt roofing shingles is important when deciding whether to repair or replace.

A broken or torn asphalt shingle, or series of shingles, can be removed by lifting up the upper courses and prying the nails out with a flat bar. The new shingle is slipped into place and while the shingles above are held out of the way, new nails are driven to hold the new shingle in place. A dab of roofing cement is recommended to cover the new nail. Asphalt shingle work is best accomplished when it is warm as this will make the shingles more pliable and easy to work. Repair when cold, below 65 Degrees F, can break the existing shingles.

Flashing Repair. In addition to rips, tears, and punctures in the main membrane, there is often a problem with roofing flashings. For base flashing repair, which is an organic material, flashing repairs are similar to repairs discussed above for main membranes. The material is swept, cleaned, and patched with a compatible material exceeding the flashing tear by six inches in each direction. Some flashings, however, have a vertical tear on that portion that extends up a parapet wall. Again, these are patched with a compatible material, although the six inch rule is reduced to three inches in all directions. In some cases the entire base flashing has to be replaced which is more economical than replacing an entire roof membrane. If the base flashing is separated from the parapet or from the membrane, then flashing should be replaced with more compatible material.

Often a flashing problem is the result of improper or unsatisfactory cant strips (see chapter 5.) If this has happened or is happening, the old flashing should be removed, the cant strips replaced and new flashing placed that is compatible with the roofing membrane. Any other type of patch will only be temporary.

If metal flashing or counterflashing has been used and it has been punctured or torn it should be replaced. A temporary patch can be made with roofing cement but this too will eventually leak. Metal flashing that is degraded because of weather can be cleaned and repainted to protect it. Application of paint should be with a material compatible with the metal.

Repair of Metal Roofing Systems. Metal panel roofing systems can be repaired provided the existing metal has the necessary strength. Many metal panel roofing problems are related to fastener corrosion or to corrosion between the metal panels and the fastener. On relatively few roofs the problem is corrosion of the main panels themselves.

Severe corrosion of the main panels require replacement, usually of that entire section of roof. Small tears or punctures from dropped tools or objects can be patched with a plate of similar material. The plate extends beyond the hole size at least three inches in each direction. The area where the plate is to be attached is coated with roofing cement then the underside of the plate to be attached is also coated with cement and the plate is fastened to the metal panel with sheet metal screws or fasteners that have been specially designed for patching metal roofing panels. The fasteners are then dabbed with roofing cement to protect them from the elements.

Small holes in metal panels can be dabbed with roofing cement.

Some metal roofing systems with myriad problems are repaired by covering with sprayed polyurethane foam. This type of repair has been attractive and cost effective for many failed metal roofing systems.

Fastener Corrosion. As was touched on briefly in Chapter 7 fastener corrosion can become a serious problem if not addressed properly. For example, moisture that has penetrated the roofing insulation, can affect the performance of the fasteners, causing the fasteners to fail. Usually roofing fasteners are designed for wet service. That is, roofing nails are always galvanized or otherwise coated to protect them. Roofing screws and sheet metal nails and screws are coated with plastic, or are made from stainless steels to enhance their water resisting capability.

Problems with corroded fasteners is one that cannot be easily repaired. Usually the fasteners are removed, the hole plugged with roofing cement, coal tar or asphalt, and a new fastener placed adjacent to where the old one was removed. It is not recommended to place a new fastener in the hole left by the old one as the holding power is greatly reduced.

Repair of Wind Damaged Roofs. When the wind gets up under a roofing system and lifts it, separating the fasteners from the decking, it usually requires this portion of the roof to be replaced. On a few occasions the membrane can be folded back down satisfactorily. Sometimes new, longer fasteners are placed to prevent this from occurring.

In conclusion, roofing repair can be effective and can save a facility a great deal of funds. The key to a roofing repair is quick action since the longer a damaged roof remains damaged the worse any underlying damage will be. The most effective thing a facility manager can do is establish a routine inspection program at least annually. Inspections can warn the facility of impending problems and give a facility manager some time to prepare contingency plans.

Many roofing contractors and consultants conduct a roofing survey for a nominal fee. Roofing people include many types and the next chapter tells the facility manager something about the roofing people he may encounter.

Chapter 12— Roofing People

Facility managers accomplish most of their tasks through others and this chapter provides the facility manager with some insights to make this part of the job successful. By considering the people with which the facility manager is working, his role in roofing and cladding systems management can be easier and more satisfying.

The quality of any facility is the result of the success of the performance of the building envelope of which the roofing and cladding systems are key components. If these systems fail, the facility will be faced with expenses from loss of materials and equipment, downtime and more importantly a loss of faith in the building envelope to successfully restrain the elements.

The facility manager will profit from utilizing a number of resources and contacts who can advise the facility on the more economical methods of building envelope management. The two individuals who provided technical advice to this volume specialize in consulting with facility managers about what to do with their roofing and cladding system problems. By networking with professionals familiar with similar problems faced by facility managers, their job will be an easier one.

A tremendous amount of research and engineering has gone into roofing and cladding systems designs in the past 50 years and the facility might as well profit from it.

The most important thing a facility manager can do is establish a routine inspection program of facility roofs and claddings. Inspection enables the facility manager to identify potential problems before they elevate into more serious ones. Just by cleaning roofing drains on a routine basis and checking them every three to six months can add a tremendous amount of life to a low sloped roofing system.

Roofing consultants are available through associations mentioned in Chapter 14. A roofing consultant has spent many, many years in roofing system design and is knowledgeable and familiar with the many types and designs of roofs in use. The Roofing Educational Institute routinely offers classes in roofing system design and management for professionals and facility managers who have the time to attend their courses.

If, however, the facility manager has waited until the roof has started leaking and he is faced with angry tenants or customers, the roofing consultant may be reluctant to allow himself to be called in, if the purpose is just to shift the blame from one face to another. It will also affect the consultant's fees and the facility manager may not be pleased with the result.

Roofing inspections are best accomplished with in house staff if it is available. This staff is probably not as highly trained as a roofing contractor or consultants but they are the facility manager's first line of defense against roofing problems. A roofing problem can often be spotted and corrected early with minimal resources. In house staff can also initiate temporary or even permanent repairs provided they are given the proper instructions and tools with which to perform the work.

Again, consideration should be given to the limit of the in house staff expertise in roofing technology and safety. Low sloped roofs with parapet walls pose little risk, however, steep sloped roofs with tile, metal, or slate are potentially dangerous and more proficient and trained help should be utilized inspecting this type of system.

Roofing Contractors. The National Roofing Contractor's Association represents about 60% of the vast numbers of roofing contractors. Some of these firms are small businesses utilizing a few workers and hiring local labor for many jobs. These entrepreneurs work hard to provide excellent service. Many are in business simply to support new construction of one building type such as residential roofing. Other roofing contractors are in business to support remodeling or various commercial or industrial facilities.

Unique roofing system types, like sprayed polyurethane foam systems may be performed by out of state companies that perform this unique application nationwide. Roofing contractors often have many jobs at once and it is seasonal work. Not much is happening with roofing projects in many areas of the country during winter.

Many roofing contractors specialize in one or two types of roofing systems and dedicate their firm to installing this type. In the low sloped industry; however, the built-up roofing system has been steadily losing customers to the single ply roofing systems. As a result many contractors have switched to installing single ply as well as built up roofing systems.

Small roofing contractors purchase materials from supply houses while the large contractors are able to deal directly with the manufacturers. The manufacturers work closely with the roofing contractors and with architects and engineers in order to have their systems specified for many jobs.

Roofing workmen are subject to the problems of seasonal work. The craft is often called out for a few jobs and then has to wait until the next big project before work is found. Because of this, most craft try to locate and stay with one local contractor. However, on many jobs the craft is called out to work from a union hall. When the job is completed they go back to the hall to wait until called out on another job, perhaps in another city or state.

Roofing work is hot and hard. Especially the work of applying hot applied built up roofing materials. In summer and in warmer climates the work is performed from early morning while it is still fairly cool until early afternoon when workmen will stop for the day. The roofers can come back in the late afternoon after temperatures have cooled and work until dark. Since the roofing materials will ruin most clothing types, roofers' clothes are stained with tar and asphalt. Long hair and a ball cap generally protects the head and back of the neck from summer sun.

Manufacturers are usually represented in the community by salesmen. The sales representatives call on facility managers, engineers, architects and roofing contractors keeping them abreast of new roofing materials and technologies.

Insurance Assessors. A facility often has to be inspected by an insurance adjuster who will inspect the roof to make sure the roofing system is intact. In addition, many banks require a facility be inspected by an independent insurance agent if they are considering loaning money to cover the cost of a facility upgrade or new materials. The insurance professional looks at the integrity, age, and fire resistance of the roof because its performance is essential to protecting the investment of whatever is inside the building.

All these people work together to protect the buildings' occupants from the harsh effects of the environment. The facility manager will encounter each one of them at some time during their tenure as a facility manager.

Case Study: Roofing Personnel Interface

In a job at major hospital, one of the buildings was undergoing renovation and the job included a separate contract for reroofing. The old roof was removed and a new ballasted single ply system was being installed. During the course of the project the roofing superintendent decided to request clarification of the specifications. He came directly from the roof into the director's office looking for the facility manager. He was covered with sweat, dust and soot and his clothes were nearly rags. He was recognized by the inspector, of course, but the rest of the office staff, especially the secretaries were shocked because they weren't sure if the individual was a contractor or a homeless person who wandered in off the street. The foreman didn't provide his company much credit. Any gain from clarifying the specifications was lost because of the rough manner in his dress. Next time, he called and asked for the inspector to come meet him on the job.

Chapter 13— Roofing Safety and Liability

Roofing work, by its nature poses some inherent risks, both to the workmen and to the facility. Many an unfortunate project starts with removal of the old roof and when this phase of the work is complete, a sudden rainstorm halts all work for several days. Unfortunately this scenario is a potential problem on any roofing project.

Safety and liability go hand in hand. If the facility, workmen, tools, contents, or structures are unsafe, then the facility is potentially liable. To minimize liability, insurance and warranties are purchased to protect the assets of the facility and the finances of its management.

Facility Safety. For the facility to minimize its liability it must adequately provide for protection of the structure and its contents. The value of the facility itself and the value of its contents are the responsibility of facility managers. If the envelope should fail, either in a roofing leak or structural damage, then the contents of the building are at risk.

Structurally, buildings are designed to resist extreme weather and environmental conditions through the application of building codes discussed in Chapter 2. If the building is constructed in compliance with the codes then the risk to the facility is minimized by the technical competency of those who have written those codes. Since the codes are legal requirements, violation of the building codes can have legal repercussions.

During a construction project at the facility, the risk increases slightly because of the additional workmen and the ever changing nature of a project. Construction has its own safety rules and requirements, primarily in federal law under the Occupational Safety and Health Act. OSHA law outlines requirements for worker protection and safety which is the responsibility of the individuals and the contractors.

If a contractor is adequately bonded and insured, the risks to the facility from a safety accident or incident is minimized. In addition, it is often a good idea to have only one or two persons authorized to negotiate with the contractor. In many cases the contractor can misunderstand guidance from the facility staff leading to increased costs for which the contractor will want to invoice the facility.

The facility manager should control the work such that the contractor's personnel and only those authorized have access to the roof. This will aid in reducing the potential risks to a facility from falls by the facility staff. When old roofing is being removed, the area around the building should be roped off to prevent someone from being struck by falling debris. The area should also be picked up at the end of each work day or more often to prevent people from stepping on any nails or broken glass.

Roof access should be secured at the end of each work day. Young people are tempted to climb ladders left about and one of the most serious problems with roofing systems is falls.

Worker Safety. Of course a roofing project requires fall protection to prevent people from falling off the roof or from falling down through the roof deck. OSHA laws are specific about what type of protection is required depending upon how high off the ground the workers are. Fall protection during certain portions of the work is more extensive than during other portions. Once the decking is complete and secured on a low sloped roof with parapet walls, fall protection would only be necessary near any openings. For a low sloped roof without parapet walls, fall protection is only needed near the edge and this can be accomplished with a temporary railing.

For fall protection of workers installing decking, fall protection includes a harness and/or ropes to prevent the person from falling to the deck below. This fall protection requires the worker to be tied off while working, but when moving from one point to another, being roped off may not be required. If no fall protection is being used, then the facility manager should ask the contractor what the policy is and have the contractor show him the specific rule allowing his workers to go without fall protection in the OSHA regulations. It is highly recommended that the facility manager not take the contractor's word for this but to actually look at the regulation. If the contractor does not have a copy of these regulations, make him get one. The facility could be liable for the death of a worker who falls if the contractor cannot pay or goes broke as the result of a lawsuit.

Workers are also responsible for safety from chemicals and materials in the work place. Material Safety Data Sheets were discussed thoroughly in chapter 9 under project management. The workers have the right, and the obligation, to know and understand what chemicals they work with and what the health hazards are from working with those chemicals. The workers are also required to wear the proper personal protective equipment while working with chemicals and solvents. Personal protective equipment or PPE varies with the job being performed. If it is the right equipment it will adequately protect the workers from the hazards involved with that task. Some types of personal protective equipment include: hard toed boots, hard hats, safety glasses or goggles, gloves, safety harness (fall protection), dust mask, rubber gloves, respirator with the correct cartridges.

Safe Work Practice. The facility manager wants to make sure that his employees and all of those at his facility follow safe work practices. The best way to accomplish this is to reward safe work and to penalize unsafe work. Safe work practices are most effective when workers are trained and know what they need to do. When they aren't sure, they should stop what they are doing analyze what they are about to do, get the right equipment or materials and then go ahead and get the job done. No one is to take any chances, it simply isn't worth the risk.

To protect a facility from roofing liability it may help to utilize a controlled access policy such as the one shown in the Figure 13-1. This also provides a facility with information as to who had access to a roof at what times which serves to document any events that adversely affect the roof.

Fire Safety. Fire safety for a facility is potentially complex. However, for roofing projects the fire risk occurs when the roof is being built, especially if coal tar or asphalt is being heated with torches. Therefore this type of operation requires oversight and some codes specifically require a fire watch on a roof for a period of time at the close of the work day. Other systems, like single-ply and foam aren't as combustible and hence fire risk during roofing work is less. The other problem with fire safety is with the completed structure. To minimize risk to the facility, the insurance industry approves roofing systems. A facility manager should

Sample Roof Access Policy

It is imperative that *everyone* who goes onto the facility's roof understands the critical and sensitive nature of this roof system. Please read and sign the following form.

1. Stay on walk treads where provided.
2. Exercise caution when working with chemicals to prevent spillage.
3. When walking on the roof, avoid stepping on roof blisters or other roof deficiencies.
4. When working with tools, put down a protective layer of plywood.
5. When crossing firewalls, parapets, or expansion joints, exercise caution to prevent "kick holes" in base flashings, movement of metal caps, or tearing of expansion joints.
6. Remove all debris, obsolete material, containers, etc., when completing work.
7. When using a wheeled cart, make sure the tires are of sufficient size so as to prevent overstressing the roof.
8. Avoid pushing, pulling, or dragging equipment or tools across the roof.
9. If any disturbance to the roof system or adjacent components should occur, please notify the person indicated below as quickly as possible.
10. If any portion of the roof or roof details are to be altered during your work, please get authorization from the person indicated below so as not to void any roof warranties.

Please notify ______________________________
in the event of possible damage.

Signature ______________________________

Time in ______________ Time out ______________

Reason for requiring access:

____

____

____

____

Sample provided by RTD Associates

Figure 13-1
Roofing Access Policy helps to protect the roof and the facility liability.
Courtesy: *Buildings Magazine*, reprinted with permission. Copyright 1994.

verify that any modification to the roofing system will meet the requirements of his or her insurance provider.

Fire safety includes small things like housekeeping. Fuel cans, paper, and other combustibles should be kept to a minimum. Fuel should always be kept in the proper container.

An occasional visit by the city fire department isn't a bad idea, however, make it understood that the inspection is a courtesy visit. If there is imminent risk, the fire officials can issue citations to have situations corrected.

Ladders. Almost every roofing project requires the use of ladders. Most ladder safety is pretty simple, but it requires discipline to make it safe. Not having a ladder seated correctly on the ground is obviously a problem. Reaching too far off of a ladder is another. Many ladders are required to be tied off. That means that the ladder is tied at the top so that it can't slide or move. Shingles, tar buckets, roofing cements are heavy and hauling them to the roof while navigating the rungs of a ladder require caution. Many contractors use a device called a man lift instead. A man lift is a hydraulic truck with a bucket or platform. The platform is raised to the roof and the workmen can step off onto the roof deck.

Stairs. On large roofing and decking projects, it is more economical to erect temporary stairs to the roof. This allows workmen to safely get up to the roof and get down again while hauling materials. Stairs should have the necessary hand rails and toe boards to prevent falls.

Weather report. Finally, one of the roofing contractor's best items of information is the weather report. These reports are much more sophisticated than they were just a few years ago and the national weather service provides updates to the media on a regular basis. If the weather is going to be poor, wait for a better day.

Chapter 14— Industry Trade Associations

American Institute of Architects
1735 New York Avenue NW
Washington, DC 20006
Phone (202) 626-7526
Toll Free (800) 365-2724

American Concrete Institute
P.O. Box 19150
Detroit, MI 48219
Phone: 313-532-2600
Fax: 313-538-0655

American Institute of Steel Construction
3030 Malmo Drive
Arlington Heights, IL 60005
Phone 1-800-644-2400
Fax 1-847-364-1268

American Iron and Steel Institute (AISI)
1101 17th St, N.W., Suite 1300
Washington, DC 20036-4700
Phone: 202-452-7100

American Society for Testing and Materials,
100 Barr Harbor Drive
West Conshohocken, PA 19428
Phone: (610) 832-9500
Fax: (610) 832-9555
email: infoctr@local.astm.org

The Asphalt Institute
Asphalt Institute Building
College Park, Maryland 20740-1802
Phone: 301-Asphalt 301-277-4258
Fax: 301-927-5226

Asphalt Roofing Manufacturers Association (ARMA)
6000 Executive Blvd., Suite 201
Rockville, MD 20852-3803
Phone: 301-231-9050

Building Officials and Code Administrators International
4051 W. Flossmoor Rd
Country Club Hills, IL 60478
Phone (708) 799-2300
Fax (708) 799-4891

Construction Specifications Institute
601 Madison Street
Alexandria, VA 22314-1791
Phone (703) 684-0300
Fax (703) 684-0465

EIFS Industry Members Association (EIMA)
EIFS=Exterior Insulation and Finish Systems
2759 State Road 580, Suite 112
Clearwater, FL 34621-3350
Phone: 813-726-6477
Fax: 813-726-8180

Factory Mutual Research Corporation
1151 Boston-Providence Turnpike,
P.O. Box 9102
Norwood, MA 02062
Phone: 617-255-4681

International Conference of Building Officials
5360 South Workman Mill Road
Whittier, California 90601
Phone 310-699-0541

National Concrete Masonry Association
2302 Horse Pen Road
Herndon, VA 22071-3499
Telephone: 1-703-713-1900
Fax: 1-703-713-1910

National Fire Protection Association
1 Batterymarch Park, P.O. Box 9101
Quincy, MA 02269-9101
Phone (617) 770-3000
Toll Free (800) 344-3555

National Insulation Association
99 Canal Center Plaza Suite 222
Alexandria, VA 22314-1538
Phone: 703-683-6480
Fax: 703 549-4838

National Roofing Contractor's Association (NRCA)
O'Hare International Center
10225 W. Higgins Road, Suite 600;
Rosemount, Ill 60018-5607
Phone: 847-299-9070 Fax: 847-299-1183

Roof Coatings Manufacturer's Association (RCMA)
6000 Executive Blvd, Ste 201
Rockville, MD 20852
Phone: 301-230-2051
Fax: 301-881-6572

Roofing Consultants Institute (RCI)
7424 Chapel Hill Road
Raleigh, NC 27607
Phone: 800-828-1902

Roofing Industry Educational Institute (RIEI)
14 Inverness Drive
East Englewood, CO 80112
Phone: 303-790-7200
Fax: 303-790-9006
email: richroof@aol.com

Single Ply Roofing Institute
20 Walnut Street, #8
Wellesley Hills, MA 02181
Tele: 1-617-237-7879

The Society of the Plastics Industry, Inc.
The Spray Polyurethane Foam Division
1801 K Street, NW, Suite 600K
Washington, DC 20006-1301
Phone: 800-523-6154
Fax: 202-296-7005
email: mknowles@socplas.org

Southern Building Code Congress International, Inc.
900 Montclair Road
Birmingham, AL 35123
Phone 205-591-1853
Fax 205-591-0775

The Rawlplug Company, Inc.
New Rochelle, NY 10803
Phone: 914-235-6300
Fax 914-633-1981

Sheet Metal Contractor's Association (SMACNA)
4201 Lafayette Center Dr.
Chantilly, VA 22021
Phone: 703-803-2980
Fax: 703-803-3732

Western Wood Products Institute
APA The Engineered Wood Association, 7011 S. 19th St.
PO Box 11700 Tacoma, Washington 98411-0700
Telephone: (206) 565-6600

Federal Agencies

Occupations Safety and Health Administration-Washington, DC
United States Department of Energy-Washington, DC

Appendix I— Glossary of Roofing Terminology

A

Abrasion resistance—the ability of a stone, tile or material to resist being worn away by friction.

Adhesion—the state in which two surfaces are held together by interfacial forces, which may consist of molecular forces or interlocking actions or both.

Aggregate—crushed stone, crushed slag, or water worn gravel used for surfacing.

Anchor stresses—the mechanical pressure or force present at a point of support or attachment.

Asbestos—a group of natural fibrous impure silicate materials Asbestos handling and removal is regulated for health reasons

Asphalt—a dark brown to black sticky material in which the predominating constituents are bitumens, which occur in nature or are obtained in petroleum processing. ASTM D312 defines 4 types of roofing asphalts.

B

Backer framing—a skeletal structure used to support a thin facing material.

Back-up wall—a vertical plane of masonry, concrete, or framing used to support a thin facing such as a single wythe of brickwork.

Base flashing—see FLASHING

Batten—a thin strip of wood or metal used to cover the crack between two adjoining panels.

Bed—the bead of compound applied between sight bar glass or panel and the stationary stop or the sight bar of the sash or frames, and usually the first bead of compound when setting glass panels.

Bitumen—(1) A class of amorphous, black or dark colored, (solid, semi-solid or viscous) cement-like substances, natural or manufactured, composed principally of high molecular weight hydrocarbons, soluble in carbon disulfide, and found in asphalts, tars, pitches and asphaltites; (2) a generic term used to denote any material composed principally of bitumen.

Blisters—an enclosed pocket of air, water or solvent vapor, trapped between impermeable layers of membrane or between membrane and substrate, felt, or between the felt and substrate. Blisters should be left alone during wet periods and when dry, if present, should be punched or perforated to allow the gas out and then patched under the roofing manufacturer's standard patching procedure.

Block—a small piece of wood, lead, neoprene, or other suitable material used to position a panel in its frame.

British Thermal Unit (Btu)—a unit measure of heat energy defined as the amount required to raise one pound of water 1 degree F.

Brooming—embedding a ply by using a broom to smooth it out and ensure contact with the adhesive under the ply.

Building code—Published regulations and ordinances established by a recognized agency describing design loads, procedures, and construction details for structures. Usually applies to a designated political jurisdiction (city, county, state, etc.). Building codes control design, construction, quality of materials, use and occupancy, location, and maintenance of buildings and structures within the area for which the code was adopted.

Building facade—the face of a building.

C

Camber—a predetermined curvature designed into a structural member to offset the anticipated deflection under design load.

Canopy—any overhanging or projecting roof structure with the extreme end usually unsupported.

Cant strip—a beveled strip used under flashing to modify the angle at the point where the roofing or waterproofing membrane meets any vertical element.

Caulking—the process of making a joint watertight.

Centipoise—unit measurement of viscosity equal to centistokes multiplied by the specific gravity.

Centistoke—a unit expression for the "runniness" of a roofing liquid asphalt. It is a unit term for viscosity in the same way that miles-per-hour is a term for speed. The higher the centistokes the thicker the material. The viscosity of water is 1 centistoke and honey is about 1000 centistokes.

Cladding—the exterior covering of the structural components of a building.

Clip Angles—miscellaneous sizes and shapes of metal used to attach cladding materials to subframes.

Coal tar—A dark brown to black, semi-solid hydrocarbon material produced by the destructive distillation of coal.

Coated fabric—a fabric impregnated and/or coated with a plastic material in the form of a solution, dispersion hot melt, or powder. (The term also applies to materials resulting from the application of a preformed film to a fabric by means of calendering.)

Coefficient of contraction (or expansion)—different materials increase or decrease in size with changes in temperatures. The amount of increase per unit of length sometimes called the coefficient of contraction or expansion. Proper understanding of expansion and contraction coefficients leads to proper placement of joints in roof decks and slabs and helps to prevent cracking in inappropriate locations.

Composite structural decks—a type of roof decking made up of different materials and combined for decking. Composite structural decks include combined metal and wood, metal and insulation, wood and insulation. A complete definition of a composite structural deck defines the exact thicknesses and layers of the composite deck.

Concentrated load—A concentrated load is a structural design term used to express a weight on a roof deck at a specific location. This type of load is common when referring to air handling units or building equipment. In contrast to the concentrated load is a design term called a uniform load. See uniform load.

Control joint—usually used in concrete deck terminology but equally applicable to any type of poured decking or material. A control joint is placed to make a slab crack at a certain location rather than randomly. Hence the name-control joint. A control joint is created by troweling a groove into a wet concrete slab. Later when the slab shrinks under cooler weather temperatures, the slab will crack at the joint where it has already been grooved. Reinforcing bars are allowed to run through a control joint. See expansion joint.

Coping—the covering plate, tile, brick or metal that is placed over the top of a wall to prevent water from running down into the wall.

Counterflashing—usually plastic or metal, counterflashing is applied above base flashing to protect the top edge. Counterflashing is placed in the vertical portion of a parapet wall and extends down over the outside of the base flashing. See Figure 7-1.

Creep—the permanent deformation of a roofing material or roof system caused by the movement of the roof membrane that results from continuous thermal stress or loading.

Crickets—a relatively small, elevated area of a roof constructed to divert water around a chimney, curb or other projection. Figure 7-4.

Curtain wall—a building exterior wall, of any material, which carries no superimposed vertical loads.

D

Davit—a small crane that projects over the side of a building, usually used to support equipment and personnel responsible for cleaning the building exterior.

Dam—a roof dam is a raised portion designed to channel water to roof drains. Usually a roof dam is placed in a valley while a curb is placed on a flat roof.

Dead load—Dead load is the weight of the members, decking and roofing materials. Different roofing membranes have different weights and this weight is used to calculate the sizes of the building's columns and beams. Various roofing systems have different weights. When a re-roofing project is contemplated the dead load of the new roofing system is checked against the dead load of the old system. If the new system is significantly heavier than the old one, then an analysis of the building frame may be required. Dead load also includes any fixed, mounted roof equipment such as air conditioning units.

Deck—the structural surface to which the roofing or waterproofing system (including insulation) is applied.

Deflection—deflection is another structural term for the sagging of beams and decking after placement on the roof. For most common roof designs the codes require the deflection to be limited to 1/360 of the span or less. This means that a roof that has a 360 inch span (30 feet) the deflection is less than one inch. Deflection can be checked with chalk line or string. Stretching string between two points the deflection of a beam will be the distance at mid-span between the string and the beam. For very long spans even a string is not accurate since it will also deflect between two points. A laser can also be used to measure deflection of spans up to about 300 feet.

Dew-point—the temperature at which water vapor starts to condense in cooling air at the existing atmospheric pressure and vapor content.

Dike—temporary dams.

Drainage cricket—see cricket.

Drywall— an interior facing panel consisting of a gypsum core sandwiched between paper faces. Also called gypsum board, plasterboard.

E

EIFS—see Exterior Insulation and Finish Systems.

Embedment—(1) the process of pressing a felt, aggregate, fabric, mat, or panel uniformly and completely into hot bitumen or adhesive; (2) the process of pressing into coating in the manufacture of factory-prepared roofing.

End joints—the notch or grove at the end of a long board. Sometimes these are tapered so that one fits snugly into the other. End joints have to be carefully prepared or covered or coated to prevent leaks.

End lap—the overlap where one panel or felt nests on top of the underlying panel or felt.

EPDM—a synthetic elastomer based on ethylene, proplylene, and a small amount of a nonconjugated diene to provide sites for vulcanization. EPDM features excellent heat, ozone, and weathering resistance and low-temperature flexibility. EPDM stands for ethylene propylene diene monomer.

Equiviscous temperature—a term used with roofing asphalts and coal tar applications. The equiviscous temperature is the temperature at which the viscosity is 75 centipoise for asphalt and 25 for coal tar products; the equiviscous temperature is the recommended temperature for application plus or minus 25 degrees F.

EVT—a short form of Equiviscous Temperature

Expansion joint—a structural separation between two building elements that allows free movement between the elements without damage to the roofing or waterproofing system. Expansion joints can usually be recognized because they are covered with a long metal or rubber plate. Construction of expansion joints is one of the more critical operations in construction of a roofing deck.

Exterior Insulation and Finish Systems (EIFS)—A non-load bearing exterior wall cladding system consisting of an insulation board which is attached to a substrate, a reinforced base coat, coated fiberglass mesh, and a finish coat. See Figure 2-15.

F

Facing brick—a brick selected on the basis or appearance and durability for use in the exposed surface of a wall.

Factory Mutual (FM)—a organization that classifies roofing and cladding assemblies and materials for wind and fire resistance for insurance companies in the United States.

Feathering—the art of tapering a material in thickness usually down to nothing. Feathering is tapering a material from a lip or curb to a deck so that the result is a smooth incline.

Felt—an flexible sheet manufactured by the interlocking of fibers through a combination of mechanical work, moisture and heat. Felts are manufactured principally from vegetable fibers (organic felts), asbestos fibers (asbestos felts) or glass fibers (glass fiber felts); other fibers may be present in each types.

Fenestration—the design and position of windows in a building.

Filler material—any loose material used to fill up the space between two layers. Filler can be asphalts between felt layers or insulation between decks.

Fire rating—an evaluation of the top side fire resistance of a roofing assembly when tested according to the standards of the American Society for Testing and Materials E-108 Fire Test of Roof Coverings. Fire ratings fall into one of four classes A, B, C or "unrated." Class rating of A is the most fire resistive and C is the least fire resistive. Roofs are also rated for resistance to internal fires in other tests by FM and UL.

Fishmouths—a half cylindrical or half conical opening formed by an edge wrinkle, so named because the opening resembles the open mouth of a fish.

Flash Point—the temperature at which a test flame will ignite a vapor above a liquid surface.

Flashing—the system used to seal membrane edges at walls, expansion joints, drains, gravel stops, and other places where the membrane is interrupted or terminated. Base flashing covers the edge of the membrane. Counterflashing covers the edges of the base flashing.

Flexural strength—the ability of a material, membrane or member to resist bending.

Foam—a polyisocyanurate, polyurethane or other solid plastic material used for insulating material.

Formboard—large flat sheets made from a combination of wood and foam used as a deck insulation.

G

Gable—a sloped roof structure formed as an inverted V shape. Gables most often house a window but also include a porch or parapet.

Galvanized—Treated with zinc coating as a means of preventing corrosion.

Gauge—the thickness of thin metal sheets. Gauge definitions vary with manufacturer. As gauges increase the thickness decreases. 18 gauge (0.048 in.) is thicker and heavier than 24 gauge (0.025 in.) See Table 4-1, page 69.

Gravel—stone used as ballast and as a protective layer in roofing systems. Gravel is evenly mixed with the maximum size about 3/4 inch and the minimum size is limited to 1/4 inch. Gravel should be free of sand (smaller than 1/4 inch) and dust, dirt or organic materials like sticks, leaves etc. Gravel can be graded using special screens to separate the larger and smaller particles.

Grout—a thin, watery, cement-like material similar to concrete but without the stones. Grout is used to fill in cracks and voids.

Grout is also used on concrete decks for machine base and is usually poured after the machine has been set and leveled.

I

Impact resistance—a term used to describe the resistance of a material to puncture. A standard test is used where a precise weight is dropped or swings into a material and the dent or hole is measured. Impact resistance is important for roofing membranes, metal sheeting, and cladding systems. The higher the impact resistance the more resistive to penetration from impact the material will be.

Incline—the slope of a roof expressed either in percent or in the number of vertical units of rise per horizontal unit of run. Three inches per foot (3/12) means three inches vertical per 12 inches of horizontal.

Incombustible—the property of a construction material that will not sustain a flame. Incombustible materials include steel, concrete, and gypsum.

Insulation or Thermal Insulation—a material that is applied to reduce the flow of heat.

K

k-value—the heat energy that will be transmitted by conduction through 1 square foot of 1 inch thick homogeneous material in one hour when there is a difference of 1 degree of Fahrenheit perpendicular across the to surfaces of the material. The formula for thermal conductivity is: k=Btu/Square Foot/inch/hour/degree F.

kerf—a groove or notch made by a cutting tool.

Kettle—a special item of roofing equipment designed for heating hot applied roof asphalt to its equiviscous temperature prior to application.

Kiln-dried materials—usually lumber, that has had some of the moisture removed by drying in a controlled environment.

Knot—an imperfection or non-homogeneity in materials used in fabric construction, the presence of which causes surface irregularities.

L

Lap—the dimension by which a felt covers an underlying felt in BUR membrane. Edge lap indicates the transverse cover; end lap indicates the cover at the end of the roll. The terms also apply to single-ply membranes.

Lightweight insulating concrete—special concrete used on roofs for insulating and sloping. Lightweight concrete does not have the same strength as structural concrete.

Live Loads—moving or movable roof installation equipment, wind, snow, ice or rain.

Low slope—roofs with a slope of less than 1 inch per foot

M

Masonry veneer—a single wythe of masonry used as a facing over a frame of wood or metal.

Membrane—a flexible or semi-flexible roof covering or waterproofing layer, whose primary function is the exclusion of water.

Metal flashing—(see flashing) Metal flashing is frequently used as through-wall flashing, cap flashing, counterflashing or gravel stops.

Mineral Granules—opaque, natural, or synthetically colored aggregate commonly used to surface cap sheets, granule-surfaced sheets, and roofing shingles.

Mineral Stabilizer—a fine, water-insoluble inorganic material, used in a mixture with solid or semi-solid bituminous materials.

Mineral-Surfaced Roofing—built-up roofing materials whose top ply consists of a granule surfaced sheet.

Modified Bitumen—composite sheets consisting of a copolymer modified bitumen often reinforced and sometimes surfaced with various types of films, foils and mats.

Mopping or moppings—the application of hot bitumen with a mop or mechanical applicator to the substrate or to the felts of a built up roof membrane.

Mullions—vertical or horizontal bars between adjacent window or door units.

N

Neoprene—a synthetic rubber (polychloroprene) used in liquid-applied and sheet-applied elastomeric roof membranes or flashings.

Nailer—a wood member bolted or otherwise anchored to a non-nailable deck or wall to provide nailing anchorage of membrane or flashing.

Ninety-pound—a prepared organic felt roll roofing with a granule surfaced exposure that has a mass of approximately 90 pounds per 100 square feet.

P

Parapet wall—that part of any wall entirely above the roof.

Penetration—the consistency of a bituminous material expressed as the distance in tenths of a millimeter (0.1 mm) that a standard needle or cone vertically penetrates a sample of material under specified conditions of loading, time and temperature.

Perimeter—the outside edge of a roofing of cladding system.

Perlite—an aggregate used in lightweight insulating concrete and in preformed perlite insulation boards, formed by heating and expanding siliceous volcanic glass.

Permeability—(1) The capacity of a porous medium to conduct or transmit fluids. (2) The amount of liquid moving through a barrier in a unit time, unit area, and unit pressure gradient not normalized for but directly related to thickness. (3) The product of vapor permeance and thickness (for thin films, ASTM E96; for those over 1/8 in., ASTM C355). Usually reported in perm inches or; grains/(hr*ft2*in Hg) per inch of thickness.

Perm—a unit of water vapor transmission defined as 1 grain of water vapor per square foot per hour per inch of mercury pressure difference (1 inch of mercury (Hg) = 0.49 pounds per square inch) The formula for perm is:

P=grains of water vapor/square foot * hour * inch Hg

Phenolic plastic—Plastics based on resins made by the condensation of phenols, such as phenol and cresol, with aldehydes.

Pitch—see coal tar and incline.

Pitch pockets—a flanged open bottomed container placed around a column or other roof penetration and filled with hot bitumen, flashing cement, or pourable sealer.

Plies—A layer of felt in a roofing membrane; a four-ply membrane should have at least four plies of felt at any vertical cross section cut through the membrane. Usually a roof with more plies will have a longer life than a roof with fewer plies.

Plywood—a flat panel built-up of sheets of wood veneer called plies, united under pressure by a bonding agent to create a panel with an adhesive bond between plies as strong as or stronger than the wood. Plywood is constructed of an odd number of layers with the grain of adjacent layers perpendicular. Layers may consist of a single ply or of two or more plies laminated with parallel grain direction. Outer layers and all odd-numbered layers generally have the grain direction oriented parallel to the long dimension of the panel.

Pointing—(1) Troweling mortar into a joint after masonry units are laid. (2) Final treatment of joints in cut stonework. Mortar or a putty like filler is forced into the joint after the stone is set.

Polyethylene—a thermoplastic widely used in sheet form for vapor retarders, moisture barriers, and temporary construction coverings.

Polyurethane—Any of a large group of resins and synthetic rubber compounds used in sealants, varnishes, insulating foams and roof membranes.

Polypropylene—a synthetic thermoplastic polymer with a molecular weight of 40,000 or more.

Polyvinyl chloride (PVC)—a synthetic thermoplastic polymer prepared from vinyl chloride. PVC can be compounded into flexible and rigid forms through the use of plasticizer, stabilizer, filler, and other modifiers; rigid forms used in pipes; flexible forms used in the manufacture of sheeting.

Precast concrete—concrete that has been placed in special forms, allowed to cure and then erected in place after it has set.

Primed—an initial coat of painting or material designed to make the material to be painted or coated ready for receiving additional coats of paint or material.

Primer (bitumen)—a thin, liquid bitumen applied to a surface to improve the adhesion of subsequent applications of bitumen.

Purlin—a timber or piece laid horizontally on the principal rafters of a roof to support the common rafters.

R

R-value—thermal resistance. An index of a material's resistance to heat flow; it is the reciprocal of thermal conductivity (k) or thermal conductance (C) The formula for thermal resistance is: R=1/C or R=1/K or R=Thickness in inches/k

Re-covering—the process of covering an existing roofing system with a new roofing system.

Reglets—a groove in a wall or other surface, adjoining a roof surface for use in the attachment of counterflashing.

Relative humidity—the ratio of the weight of moisture in a given volume of air-vapor mixture to the saturated (maximum) weight of water vapor at the same temperature, expressed as a percentage. For example, if the weight of the moist air is 1 pound and if the air could hold 2 pounds of water at that temperature, the relative humidity (RH) is 50 percent.

Replacement—the practice of removing an existing roof system and replacing it with a new roofing system.

Re-roofing—the process of re-covering or replacing an existing roofing system. (See Re-covering and Replacement.)

Ridge—the highest point on the roof of the building, a horizontal line running the entire length of the building.

Ridging—an upward, tenting displacement of a roof membrane frequently occurring over insulation joints, deck joints and base sheet edges.

Roof Assembly—an assembly of interacting roof components (including the roof deck) designed to weatherproof and, normally, insulate a building's top surface.

Roof System—a system of interacting roof components (not including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Roof deck—the solid structure upon which a roofing system of insulation and waterproofing membranes is placed. In most construction projects the deck is placed by carpenters or framers while the insulation, felts, adhesives, and ballast are placed by the roofing contractor.

S

Safing—fire resistant material inserted into a space between a curtain wall and a spandrel beam or column, to retard the passage of fire through the space.

Saddle—a small structure that helps channel surface water to drains, frequently located in a valley, and often constructed like a small hip roof or like a pyramid with a diamond shape base. (See Cricket.)

Sandwich panels—a panel consisting of two outer faces of wood, metal, gypsum, or concrete bonded to a core of insulating foam or other dissimilar material.

Sash—framework holding the glass and glazing system

Scrim—a woven, open-mesh reinforcing fabric made from continuous filament yarn. Used in the reinforcement of polymeric sheeting.

Scupper—a channel through a parapet, designed for peripheral drainage of the roof, usually a safety overflow to limit accumulation of ponded rain water caused by clogged drains. Figure 3-5.

Scuttle—a hatch that provides access to the roof from the interior of the building.

Self-drilling screw—A fastener that drills and threads its own hole.

Shark fin—curled felt projecting upward through the flood coat and aggregate of a BUR membrane.

Shear, horizontal and vertical—the force tending to make two contacting parts slide upon each other in opposite directions parallel to their plane of contact.

Sheeting—a form of plastic or rubber in which the thickness is very small in proportion to the length and width and in which the polymer compound is present as a continuous phase throughout, with or without fabric.

Shingle—(1) A small unit of prepared roofing designed for installation with similar units in overlapping rows on inclines normally exceeding 25 percent. (2) To cover with shingles. (3) To apply any sheet material in overlapping rows like shingles.

Sill—the horizontal bottom portion of a window or door.

Slag—a hard, air-cooled aggregate that is left as a residue from blast furnaces, used as a surfacing aggregate.

Span—the clear distance between supports such as the distance between columns or beams on roofing or between columns or girts on siding.

Spandrel—the wall area between the head of a window on one story and the sill of a window on the floor above.

Split—a membrane tear resulting from exceeding the material's tensile strength.

Spudding—the process of removing the roofing aggregate and most of the bituminous top coating by scraping and chipping.

Square—the term used to describe 100 square feet of roof area.

Stack vent—a vertical outlet in a built-up roof system designed to relieve the pressure exerted by moisture vapor between the roof membrane and the vapor retarder or deck.

Steep slope—roofing that depends primarily upon water shedding rather than waterproofing. Usually steep slope roofing is roofing that has a slope greater than 3 inches in 12.

Stucco—Portland cement plaster used as an exterior cladding or siding material.

Substrate—the surface upon which the roofing or waterproofing membrane is applied (i.e. the structural deck or insulation)

Sump—the intentional depression around a roof drain.

T

Tanker—a special tank truck used on large built-up roofing jobs to carry and heat the bitumen.

Temporary roof—the erection of a false roof or tenting material to protect the structure and workers. Not permanent.

Tensile strength—the unit strength of a material in tension usually given in pounds per square inch units.

Test cuts— a sample of the roof membrane that is cut from a membrane to (a) determine the weight of the average interply bitumen moppings; (b) diagnose the condition of the existing membrane to detect leaks or blisters.

THERM—a unit measure of heat energy equal to 100,000 Btus.

Thermal Conductance (C)—a unit of heat flow that is used for specific thicknesses of material or for materials of combination construction, such as laminated insulation. The formula for thermal conductance is:
C= k/thickness in inches.

Thermal Conductivity (k-factor)—see k-value.

Thermal expansion—the elongation of a material as a result of increases or decreases in internal temperature.

Thermal insulation—a material applied to reduce the flow of heat.

Thermal resistance (R-factor)—see R-value.

Thermal shock—the stress-producing phenomenon resulting from sudden temperature changes in a roof membrane when, for example, a rain shower follows brilliant sunshine.

Thermoplastic—capable of being repeatedly softened by increase in temperature and hardened by decrease in temperature. The thermoplastic form of material allows for easier seaming, both in the factory and in the field.

Thermosetting—A material that has undergone a chemical reaction by the action of heat, catalysts, ultraviolet light, etc., leading to a relatively unfusible state.

Through-wall flashing—a water resistant membrane or material assembly extending totally through a wall and its cavities, positioned to direct any water within the wall to the exterior.

Toggle-bolt—a two piece assembly consisting of a threaded bolt and an expanding clip than can fit through a drilled bolt hole, then spring outward to provide anchorage from the blind side.

Tongue and groove construction—a method of laying pieces together where one is notched and fits into a slot on the other side giving the joint resistance to movement along the entire area of contact. Most commonly seen in decking.

Tuck pointing—(1) troweling mortar into a joint after masonry units are laid; (2) final treatment of joints in cut stonework. Mortar or a putty-like filler is forced into the joint after the stone is set.

U

Underwriters Laboratories (UL)—an organization that classifies roof assemblies for their fire characteristics and wind uplift resistance.

Uniform Load— a design term used to express a load that is spread out over a large area or even over the entire deck. A weight on a roof deck from a blanket of snow is an example of a uniform load. In contrast to a uniform load is a concentrated load. See concentrated load.

V

Valley—the low area between two separate sloped roof sections.

Vapor retarder—a material designed and installed to restrict the passage of water vapor through a roof or wall.

Veneer—a thin layer of material placed to overlay or cover.

Vent—an opening designed to convey water vapor or other gas from inside a building or a building component to the atmosphere,

Vermiculite—an aggregate used in lightweight insulating concrete, formed by the heating and consequent expansion of a micaceous mineral.

Viscosity—index of a fluid's internal resistance to flow, measured in centistokes for bitumens. Centipoise is the viscosity in centistokes multiplied by the specific gravity of the material.

Vulcanization—an irreversible process during which a rubber compound, through a change in its chemical structure, e.g., cross-linking, becomes less plastic and more resistant to swelling by organic liquids; and elastic properties are conferred, improved, or extended over a greater range of temperature.

W

Weep hole—a small hole or opening whose purpose is to permit drainage of water that accumulates inside a building component.

Wicking—the process of moisture movement by capillary action.

Wind uplift—upward acting pressure resulting from air motion across a roof.

Wythe—a masonry wall, one masonry unit wide, a minimum of two inches thick.

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