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Roofing Solutions (Part One)

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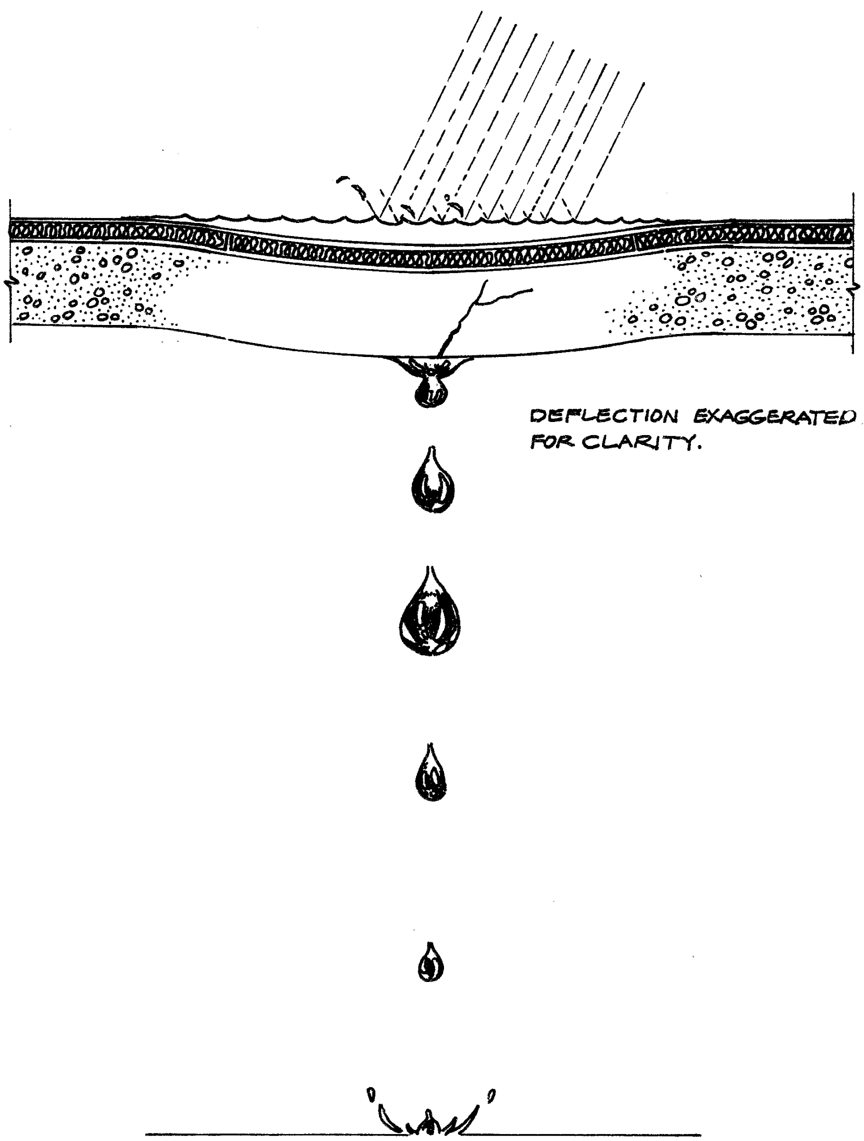

THE ACHILLES' HEEL OF ALL FLAT ROOFS

ROOFING SOLUTIONS (PART ONE)

Ruben A. Gomez, P.E.

PROLOGUE

While in average just only 10% of a new building construction budget is spent on the roof coverage (roofing materials and installation), on the other hand, roofing problems such as repairs, damage to appurtenances, as well as, the resulting lawsuits, litigation and settlements, account for an additional dollar amount in excess of 60% of the cost of such roofs.

The causes of roofing inadequacy, underperformance and ultimate failure have their roots in many areas of the process, such as: material quality, design & detailing, adequacy of drainage, installation experience and building codes. Below you will find our take on those areas:

MATERIAL QUALITY

The old cliché saying that *you get what you've paid for* seems to have a particular meaning in the roofing practice. The incidence of the materials' quality seems to become more important as the age of the roof increases and the effects of ultraviolet rays, temperature changes, heat load, ozone attack, variable humidity, algae growth, precipitation and wind take a terrible toll on the roof surface.

In most cases, the warranty terms, description and conditions offered voluntarily by the manufacturer, is a clear indication of the expected product quality, performance and durability.

COMPETENT DESIGN & DETAILING

In residential design, the roof dominates the appearance of a house or building and may well be either the enhancer or killer of a particular design configuration. Consequently, practicing architects are usually asked to design a roof, amongst other things, and put together a set of working drawings and specifications showing how it is to be built in a way that does not crack, peel off, move or leak, and further, a roof that is resistant to the wind forces generated by snow blizzards and hurricanes.

Yet, a large number of architects do not have the foolproof experience to perform the task in a way that is efficient, comprehensive enough and with sufficient and clear details for the contractor to execute the work in a way that keeps the judicial system and litigation out of the equation.

The best method for an architect to keep himself away from litigation is by keeping in mind the old adage that predicates the principle of: *an ounce of prevention is worth a pound of cure,* and to pay the greatest attention to the fact that, more often than not, roof leaks tend to occur at valleys, ridges, parapets, penetrations, expansion joints and edges rather than in the middle of the slopes. Therefore, the architect's roofing team should make sure to develop exceedingly abilities in dealing with flashings, counter-flashings, mechanical fasteners, jointery, insulation materials, vents and air circulation methods and components.

A roof detail may look pretty and adequate in general appearance; however, that does not necessarily mean adequacy and correctness. Therefore, careful thought should be devoted to the end conditions and intersections where the probabilities of primary or secondary leaks may take place and ruin an otherwise splendid design.

ROOF DRAINAGE

Historically and up until the Second World War, all roofs were sloped and designed with adequate pitch to drain down rapidly, therefore, the roofing materials needed for such purpose were very basic. However after that war, roof designers entered into a mood of a *low slope* mode and even dead level roof decks.

A dead level roof entirely depending on *hydraulic gradient* to dispose of rain water is a grave and unforgivable mistake that guaranties serious problems down the road. Even a roof designed for a slope of say ¼ in. per foot slope will generate some undesirable problems. During the period from 1970 through the early 1990's, the author observed a myriad of condominium roofs built in the South Florida area following that trend. Fifteen years down the road, they all showed the natural *pay-back:* standing water, rot, leaks, mold, property damage, as well as the resulting allergies and litigation.

Since roof construction is not an exact science, even those flat deck roofs which are carefully planned and executed seldom get built with a rigorously uniform slope, there will always be pockets and larger areas holding standing water. Let along the fact that the roof structure will naturally sag in short and long term basis, thus creating those undesirable pockets for stagnant water to gather with absolutely no escape, other than by evaporation.

Standing water on a roof is hazardous in many different ways, give water some time and it eventually find its way through the roofing membrane, not to mention the fact that constant humidity will accelerate degrading of the roofing material and insulation underneath through repetitive cycles of evaporation, condensation and freezing which may cause the felt layers to separate and break away.

Stagnant rain water when accumulated in larger amounts may also increase the load burden on the supporting structure underneath, thus reducing the residual service load capacity of such structure.

INSTALLATION EXPERIENCE

When a roofing contractor is hired by the general contractor, it is mostly assumed that there is a minimum level of competency amongst his employees. Unfortunately and in larger cities particularly, there is an abundant under-trained and transient labor pool whose members seem to be expected to learn the trade in a hands-on fashion and as they go. Many of those laborers are more often than not working on their very first job and have no certain idea of what is expected of them.

If that would not be bad enough, the nature of the construction business is such that mistakes can be accidentally buried or intentionally covered up and not be discovered until a later date when the problems have already caused thousands of dollars in damage. Consequently, it is not only important to examine the roofing contractor's own abilities and experience, but also those of his employees and the sub-subcontractors that he intends to use in the particular project.

BUILDING CODES

Another cause is rooted on the fact that too much credence is placed on building codes. It is common to hear building officials and contractors talk about the buildings and their respective roofs being "built to code", as if that should be construed as a guaranty to quality or as an assurance to adequate performance, when in reality codes only provide a set of *minimum standards to safeguard property and public welfare.* That is all, and which really and truly basically means "just enough to get by".

The so called "minimum standards" are nothing more than the very minimum that a building or house needs to comply for a bare-bones condition of safe habitation, instead of a high standard of adequacy necessary to provide a reasonable number of years of problem free performance with a comfortably embedded safety factor.

Consequently, the next time you hear of a building roof that has been "built to code" and so approved, although it may give you –as an architect, engineer or builder- a certain level of assurance that in a civil court you may be able to make such an assertion and satisfy a judge or a prosecutor for that matter. However, it does not necessarily mean that your resulting building product could be regarded as one of high quality and proven good standard.

TWO LAST COMMENTS TO CLOSE THIS INTRODUCTION

The word "roof" as a generic term, is commonly and loosely used by almost everyone in the construction and roofing business in a way that one is left to reach one's own interpretation and conclusions. However, that word may mean many things to different people and if it is not properly qualified may lead to the wrong perception. Firstly, it could refer to the roof structure; secondly and on the other hand, it could mean the roof coverage and thirdly, a combination of those two as an overall division of the building trade. Therefore, to facilitate clear understanding it is advisable that when we refer to the "roof", we make an effort to clarify which one of those three distinct aspects we are referring to. In this course when we are referring to the roof, we will be making a specific allusion, no more and no less, than that of the roof coverage of a building or house.

Lastly, the topic covering roof design, detailing, erection, treatment and maintenance is a lengthy one due to the large accumulated experience to this date. That is why, in this course we have broken the studying material in three parts; and in such a way that the readers can pick and choose what they want to study in accordance to their own wants, preferences and needs.

Nevertheless, this Part One also covers general classifications, recommendations, rules and references that in many instances are common to all roof kinds, therefore, we suggest for it to be read in conjunction with any one of the other two selected parts.

Happy trails!

1.0 CLASSIFICATION OF ROOFS

Since the roof substrate could be built out of many different materials, such as, wood planks, plywood sheets, fiberboard, aluminum, sheet metal, steel, gypsum or concrete. Furthermore, since the roof covering systems available in the market today may easily cross over those boundaries of applicability, roofs could not be clearly classified by only the substrate material.

In the past, efforts were made to classify roofs by some of their leading characteristics. For instance, the traditional *built-up roof* manufacturers first came up with their version of *nailable* and *non-nailable* decks. As their name implies, nailable decks (such as in the case of wood, fiberboard or gypsum) were those where the roofing material was fastened to the deck by means of nails, screws or staples; while non-nailable decks (such as aluminum, steel or concrete) had the roofing materials attached to the substrate by using either a cementitious slurry, an adhesive, an asphalt compound or other form of bituminous mix.

Later on, the architects came up with a classification of their own, but this time it was not determined by the method of attachment, but by the roof configuration or by the finishing material. The first class was based on the idea of attaining rapid drainage inherent to the pitched roofs, *the watershed approach.* The second class was applicable to the flat leveled or nearly flat roofs; this type was quite often observed in commercial buildings where drainage was slow and often prone to rain water stagnation, therefore, requiring an effective water tight barrier or membrane, which was the reason why they have been designated as *the waterproof approach.*

In order to arrange this course in a more comprehensive way, we have sided with the architects' way of thinking, not just as a matter of organizational convenience but also obliging by the power of their logic. Again, when Nature happens to dump a given amount of rain water on a man-made roof, and whether you are a design engineer, an architect, the builder in question, or the property owner for that matter, you want every drop of that rain water to be disposed off that roof immediately! And admittedly, we cannot overemphasize enough on the urgency of such need. That in itself, and although not always possible, points out directly to the "watershed roof" as the most desirable roofing approach. Consequently, we will begin our narrative with that type of roof for a good start.

2.0 GENERAL WATERSHED ROOFS

Although not necessarily and absolutely so, most of the watershed roofs belong in the residential construction. Albeit most codes would allow a minimum slope of 2½ in. in 12, the desirable minimum should be 3 in. in 12 so to prevent rainwater back-up in the event of a high wind occurrence.

When it comes to the roof sheathing, through the years codes have allowed a series of solutions which have ultimately proven to be inadequate at best and regrettable at worst. We are referring here to the old codes having allowed the use of assemblies such as 5/8" x 3-½" slats at 12 in. on centers, with the resulting open spaces in between; water sensitive materials such as OSB (Oriented Strand Board), which corners also behave poorly to handling; a whole family of chip and fiberboards; and finally, the half inch (½") plywood which generally feels unsafe when walked over and is prone to develop buckles, rises and dips, both in short and long term performance. Instead of all those, we recommend a standard sheathing adequately supported and nail-fastened to either manufactured trusses or rafters spaced at 24 in. on centers and consisting of a sturdier 5/8" water resistant plywood with staggered joints.

Figure 2.1 illustrates a commonly found condition of a watershed roof consisting of two contiguous slopes separated by a valley. On said figure we have marked with letters the different components that are customarily part of this type of roof. Although we do encourage the provisions of any jurisdictional code to be met as a set of minimum requirements, it does not mean that such provisions could not be improved upon or made better to the judgment of the design professional, who is indeed the one person who happens to know best the characteristics of the project and the particulars of the geographic location where the material is being used.

After the plywood deck (A) is completed and swept clean free of erection debris, a single ply of *underlayment* (B) or *anchor sheet* is fastened in place. *Tin caps,* a short term for "tin-capped nails" consisting of 12 gage (1½ in. long) galvanized or zinc coated nails (C) driven through a 26 ga. metal disk, with a recommended 12 in. spacing in both directions and following a pattern as indicated in the figure. It needs to be said that some municipal codes do not even require anchor sheets while some other ones are met with just a 15 pound felt. Unfortunately, that type of lightweight felt when attached with regular roofing nails, would not last in place more two hours in a windy day before it would be flown away or turned into pity rags. Therefore, for a quality, dependable and long lasting roofing job we recommend the use of a single ply 30# anchor sheet fastened with tin caps.

All free edges of the anchor sheet must be finished around with rust resistant *drip edges* (D) lapped not less than 3 inches and nailed in a staggered pattern every 4 inches on centers.

Roof valleys should be covered entirely, first with an 18 in. wide felt (E) fully set in plastic cement and crowned by a 12 in. wide flashing (F) centered at the valley and set in bituminous mastic. Temporarily pin or tack the edges to keep said flashing set in position and until the shingles get installed in place.

ROOF PENETRATIONS

When it comes to vent pipes, exhaust ducts and other penetrations, there are some rubber boots or plastic collars with an adjustable flange, which provide a seal by exerting pressure on the pipe shaft (see arrow) as depicted in Figure 2.2(a). Although such contraption works well at first, unfortunately, in four or five years of merciless attack from heat, ultraviolet rays, humidity and dryness, the tight collar will get distended and thus allowing water penetration and the resultant side effects we have already mentioned elsewhere. In such case instead, we recommend a lead boot as it has been illustrated in Figure 2.2(b). In spite of the lead pollution concerns raised by the "save the planet" advocates, they will perform efficiently, dependably and almost forever, well exceeding the life of the house or building were installed. As an alternative to the lead boot, there are available vinyl preformed boots made to fit at least three of the most popular pipe diameters.

One more source of troublesome water penetration is found around chimneys and dormers, particularly on the upstream side. Cants will not work well in such instance, therefore we recommend the installation of *saddles* (aka. Crickets) which is an idea that speaks by itself, as it is shown in Figure 2.2(c). Use regular straight flashings on the downstream end and 6 in. step flashings on the sides. Apply a 4 in. strip of plastic cement around the collar and under the shingles.

TYPICAL SHINGLES

We have also shown in Figure 2.1 the common configuration of a three-tab fiberglass or asphalt shingle. Also shown is the manufacturer's recommended location of fasteners. Since we do not recommend use of staples, that leaves as the only practical solution the use of galvanized or zinc coated roofing nails, which in no case should be driven any closer than one inch away from the edges of the shingles.

Nails must be driven <u>straight</u> until their heads come to rest <u>flush</u> with the shingle surface. Crooked nails, under penetrated or over penetrated nails should be removed and deemed unacceptable to the roof inspector.

It is a well known fact that during high wind conditions, shingles start to fail by peeling off at the roof slope edges. Therefore, in order to improve their performance in such conditions, it is recommended that all free edges be installed with a continuous 8 in. strip of bituminous mastic all around, as marked (G) in Figure 2.1.

CROSS VENTILATION

It is important to consider the fact that inadequate cross ventilation of the attic space under the watershed roofs can cause undue accumulation of moisture and build up of heat. They are both undesirable conditions that can lead to a myriad of conditions, such as, buckling and blistering of the shingles, delamination of roof components, early deterioration of the structural members and insect infestation. Any of such conditions may also lead to invalidation of warranties and premature failure of the roof.

To insure adequate cross ventilation and air circulation in the attic space, it is commonly recommended the installation of louvers* at the gable ends (if any), roof vents, vented ridge caps and vented eaves and soffits.

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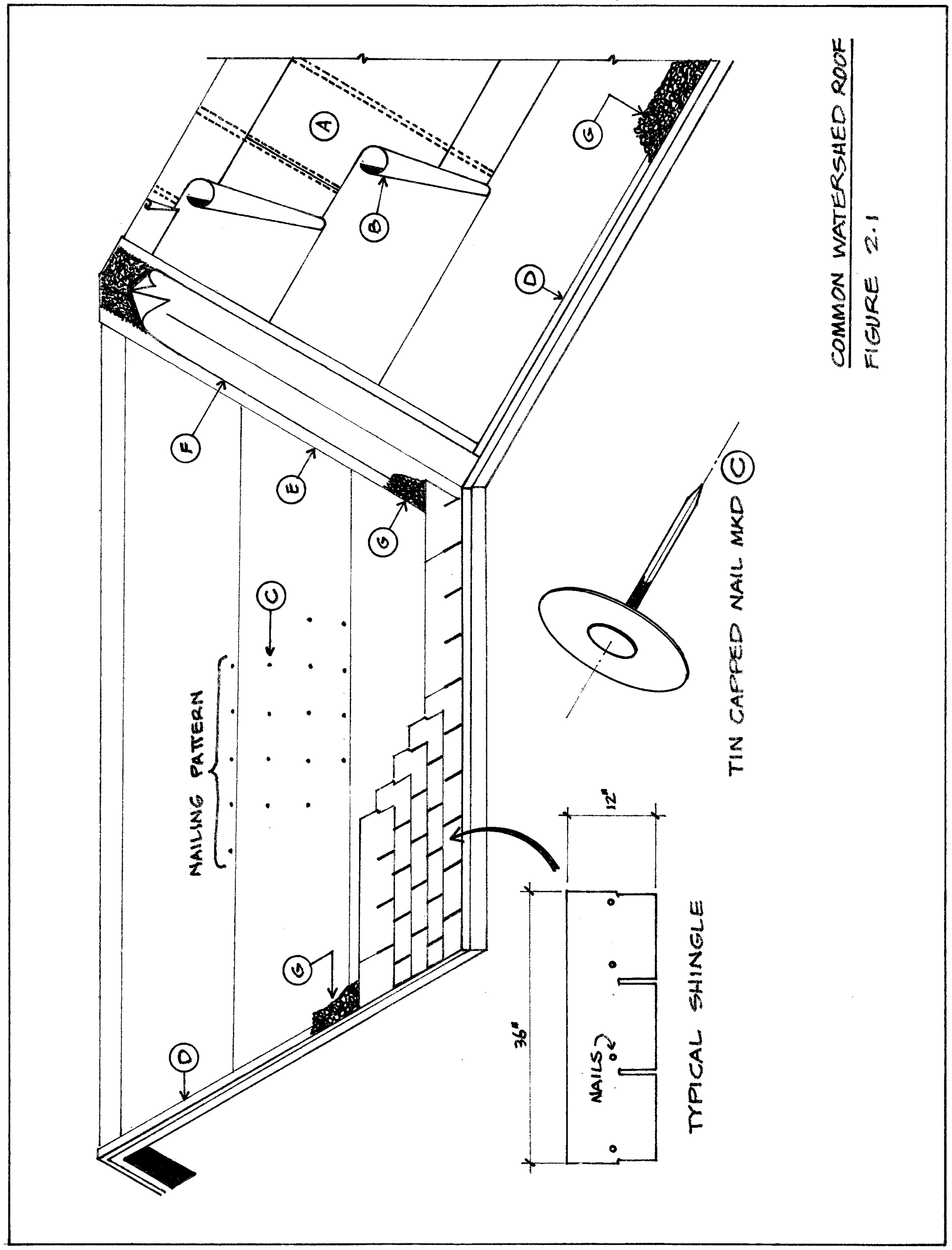
*Available in the market there is an ingenious louver that comes with a small exhaust fan wired to a solar panel. For as long as there is sunlight, the exhaust fan will be at work removing the overheated air from the attic space.

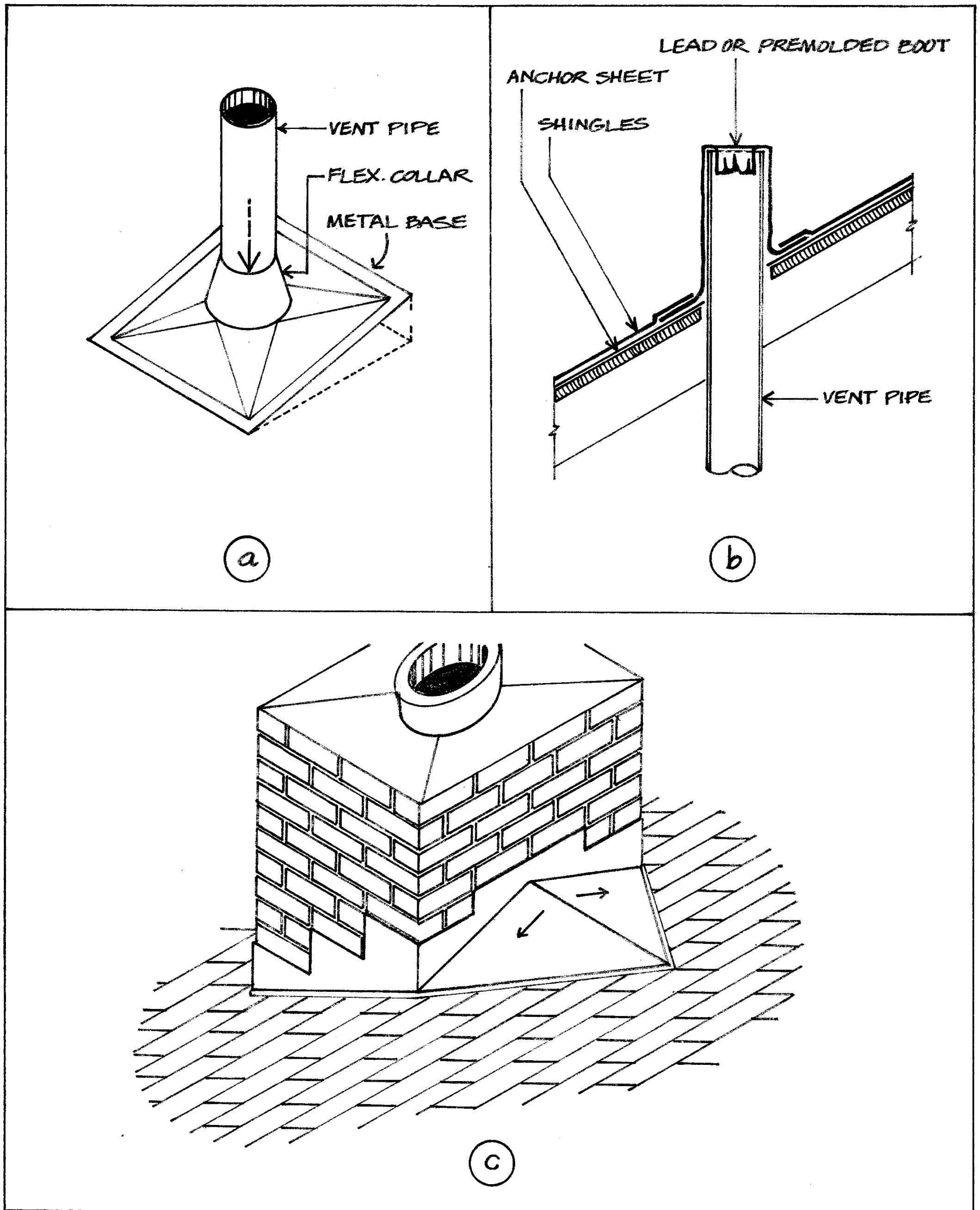
Those ventilation methods mentioned above must be proportioned to certain minimum established standards by either FHA or the jurisdictional building codes and they may vary from one square foot (1 sq. ft.) of net ventilation area for every 150 to 300 square feet of attic space, depending on certain conditions that the roof designer must carefully evaluate.

One important aspect that needs to be considered: while attic cross ventilation is an utmost consideration, there is a downside to it, which is the dreaded *wind uplift.* The more efficient the provided cross ventilation mechanism would be, the more would be the induced increase in the up-lift forces, especially considering the fact that a 125 MPH hurricane wind velocity can produce an equivalent upwards pressure of about -62 PSF. As usual there is a price to pay for everything, as he (or she) introduces the highly desirable benefits of cross ventilation, the roof design engineer or architect should give serious consideration to the pros and cons, and make sure that in doing so, *the benefits outweigh the consequences.*

Because of the importance of cross ventilation, we will see more about this topic as we move along, as well as the benefits and shortcomings on the roof details, as they are used in the roofing practice.



COMMON WATERSHED ROOF
FIGURE 2.1



ROOF PENETRATIONS
FIGURE 2.2

3.0 WATERSHED TILED ROOFS

Still within the confines of the watershed roofs, what we have said above would not be complete if we did not consider the finishing of a roof by an application of tiles rather than asphalt or fiberglass shingles.

Sun-baked mud tiles were first found about 4,000 years ago in the island of Crete where they were used to adorn the palatial roof of the local ruler. The idea was taken from there to the mainland Greece where the Greeks learned how to perfect them and fire-bake them, the very same clay tiles which they eventually used on the roofs of their renowned temples. To this day, clay tiles still remain as one of the most popular roof materials in the Mediterranean area where homes are built to last for twelve or more generations, in contrast with the American generalized idea of homes intended to last for just two mortgage terms.

While finishing of a roof with barrel tiles could be a more expensive proposition than that of a fiberglass shingle roof, it is also of much higher quality, of better appearance and of a much longer durability. On the fall side, we should not go without saying; however, that tile finishing also imposes a larger load burden on the supporting roof structure underneath. The dead load difference between fiberglass shingles and barrel tiles may well be around 10 to 12 pounds per square foot (PSF) depending on the tile material used, whether it is clay, fibro-cement, terracotta or steel. Therefore, when a barrel tile application is considered by the design architect, he should make his structural engineer aware of such fact early on, since his load analysis will be done in a descending order from the roof down to the foundation, the roof finishing being the first item on the load summation list.

We will start by using the same two-slope roof intersection shown in the chapter before and reproduced as part of Figure 3.1. However, you may notice that we have reduced the scale without altering the outline actual dimensions, that way we had room to add extra features, such as the chimney, a vent pipe penetration, as well as the ridge and the rake nailers.

As shown in Figure 3.1, in this case water tightness has been attained by applying to the wood deck a single layer of 30# anchor sheet (meeting ASTM Specification D-226) tin capped every 12 inches in both directions. On top of the anchor sheet, a 90# mineral felt was mopped and set in hot asphalt maintaining the usual 2 inch overlaps, making sure in the process that there were no air pockets, bulges, buckles, wrinkles or fish mouths left behind.

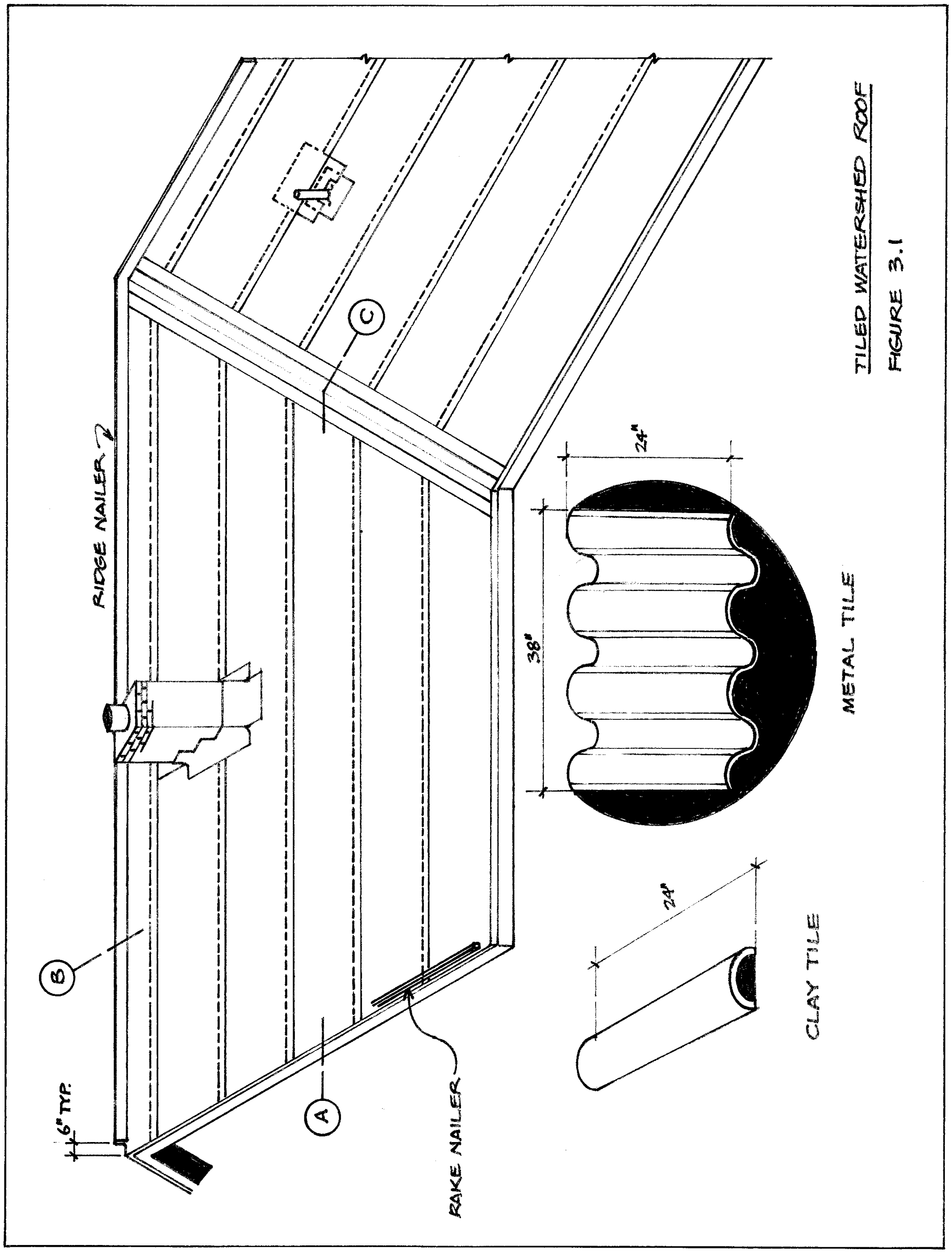
Once the waterproofing membrane had been completed, the flashing works around vent pipes, chimney, valleys and other penetrations were done, as well as the nailers got installed in place and once that part of the work had been properly inspected, then the barrel tiling process of installation began. On the same figure we have added, as a matter of example, two of the common tiles found in this type of roofing, clay and steel.

In Figure 3.2 we have shown three typical conditions, which sections have been selected as a matter of general illustration: the roof gable, the ridge and the valley conditions. Figure 3.2 (A) depicts the gable end with its tile configuration. While the middle tiles in the fields are set in either cement mortar or an especially formulated tile adhesive, the end tiles need to be nailed secured in place. The upper tile is commonly fastened to a suitable nailer provided for such a purpose; while the "wrap-around" tile is nailed to the fascia board.

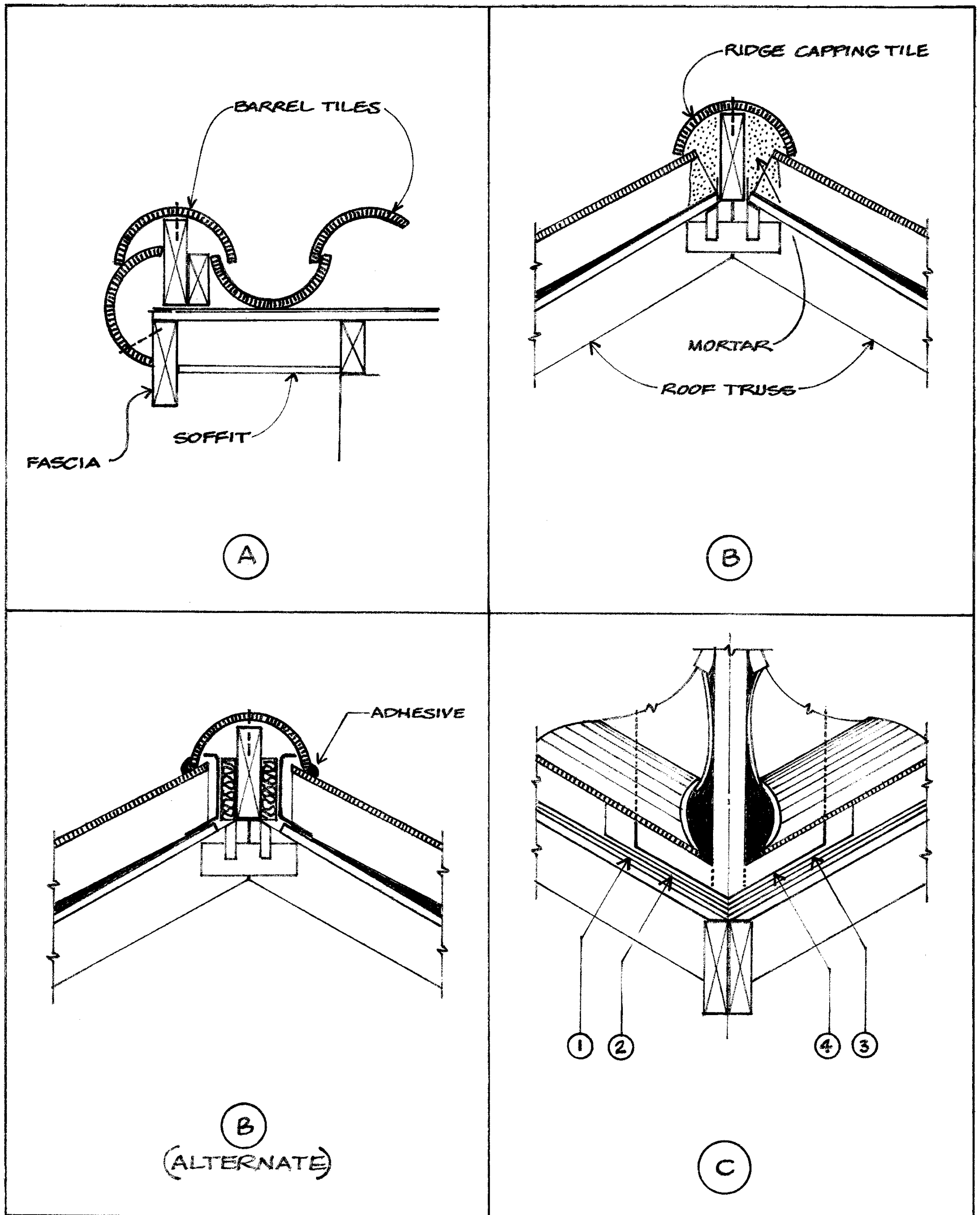
Figure 3.2 (B) illustrates the ridge capped by a tile that has been fastened to the ridge pressure-treated nailer in addition of being set in cement mortar. It should be noticed in this case, that this kind of detail does not allow for attic's hot air exhaust.

Consistent with our statement where emphasis was made on the importance of adequate attic ventilation, we have also included an alternate detail (B) which permits such ventilation. In order to achieve that goal, four fundamental changes were introduced. Firstly, the roof plywood sheathing was cut back 4 inches (2 in. on each side of the ridge) so to allow for air circulation. Secondly, a *breathing joint filler* was added on both sides of the ridge nailer. Thirdly, metal stops were added on both sides to keep the filler sandwiched in place, and fourthly, the ridge mortar was eliminated to allow free hot air flow to the outside. In order to stabilize the ridge cap, in addition to the nail in the middle we suggest that such cap should be either glued with RT-600 Roof Tile Adhesive or mortared to the crowns of the roof tiles in the perpendicular direction.

Figure 3.2 (C) shows a projected cross section of the roof valley. It should be noticed that in order to provide a water tight and trouble free valley with a good life expectancy, we recommend the use of a tin-capped 30# anchor sheet (1), plus a mopped 90# mineral sheet (2), plus a mopped 20 in. wide band of 90# felt (3), plus a 26 ga. 12 in. wide rust resistant flashing (4) set in a thick coat of bituminous compound.



TILED WATERSHED ROOF
FIGURE 3.1



GENERAL DETAILS ON BARREL TILE ROOFS
FIGURE 3.2

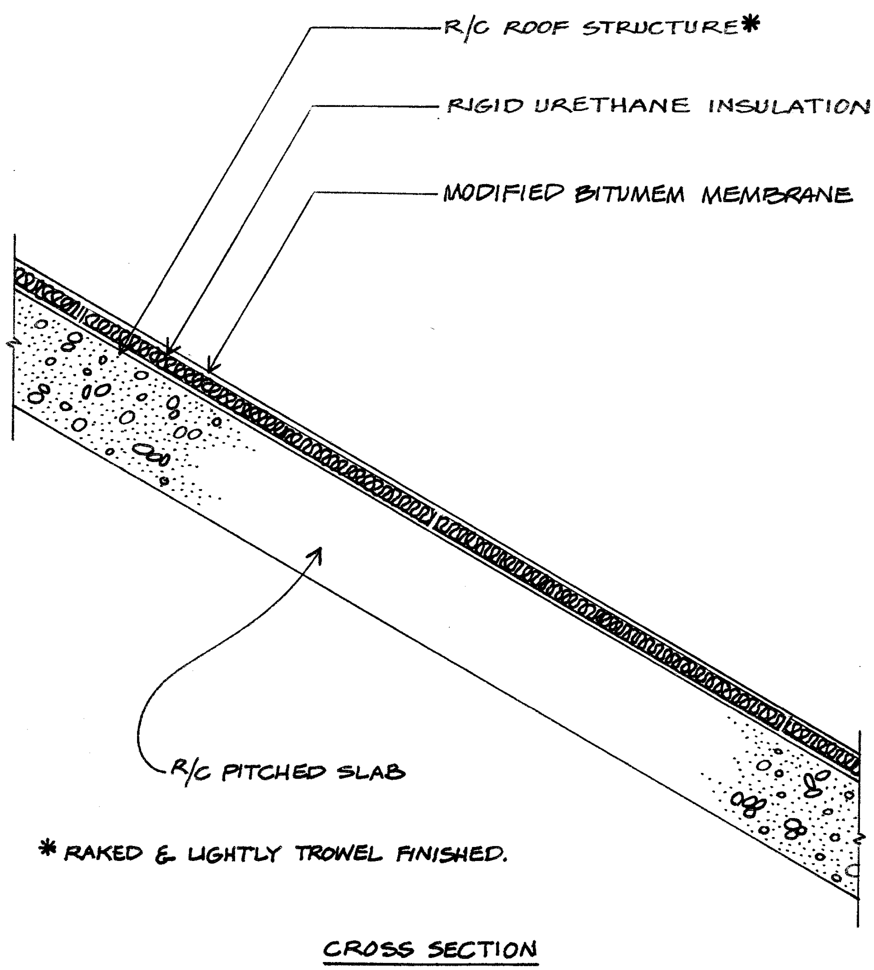
4.0 WATERSHED CONCRETE ROOFS

Although pitched concrete roofs are not exactly of common occurrence in the United States, nevertheless, we have seen quite a few concrete roofs in Ft. Lauderdale and Boca Raton, Florida; some of those have been designed and built by this author himself. In spite of their uncommon occurrence in the U.S., they are quite common in areas within the path of hurricanes, such as: Cuba, Puerto Rico, the Dominican Republic and the other lesser islands in the Caribbean basin.

Considering the property damage and loss of life that could be averted by using more concrete roofs along the eastern seaboard of Florida, Georgia and the Carolinas, as well as along the so-called "tornado alley" in the states of Texas, Oklahoma, Kansas, Missouri and Iowa. We have strongly advocated for such kind of roof construction in our course titled "Tornado Resistant Homes".

Since concrete roofs fall within the old classification of the *non-nailable* category, water-tightness would have to be achieved by using hot mopped and/or torched membranes which could withstand the expected wind pressure and uplift forces generated by the hurricanes. To that respect we have included an example of roofing treatment in the enclosed Figure 4.1 that is self-explanatory.

Naturally, nothing would stop the design engineer or architect to adding on top of the treatment shown on that figure, a barrel tile finishing as he/she would see fit.



WATERSHED CONCRETE ROOF
FIGURE 4.1

5.0 CONCLUSION

The roof cover (or roofing) of a building or house is subject and mercilessly castigated by all the worse that Nature has to offer, such as sunlight, baking heat, rain, hail, sleet, snow and high winds. Yet, we expect it to take the punishment day after day, season after season and year after year without giving or taking any quarters and until it reaches the end of its service life, dries up and then develops leaks for our dismay and disappointment.

The user needs to realize that the same way when a faucet leaks, he needs to change the seating gasket or when an interior door squeaks it needs a few drops of oil in the hinges. The same level of maintenance should be devoted to that forgotten cover that protects him/her from the elements. After everything gets said and done, the secret of roof longevity hinges on solely two factors: first, the right choice of covering system for the application, and second, the proper maintenance program to follow-up.

In this first Part One of the roof series, we have mainly covered the watershed roofs as the centerpiece of the roof technology, with the added bonus that if properly managed, they would become an architectural and *curb appeal* enhancer.

In the coming Part Two, we will cover the dreaded flat roofs and the necessary details and safeguards that need to be instituted in order to preclude inconvenience and losses due to leaks and their accompanying consequences and grief.

APPENDIX

1- BASIC ROOFING RULES

A common problem with roofs as an integral part of a given building or house is that, as the saying goes "everybody knows the roof is up there and nobody gives an old caboose about it" and further, nobody takes the effort nor the time to look at it, let alone to inspect it on a regular basis or to provide whatever is the needed maintenance.

On the other hand, after a roof has been neglected for years and suddenly it starts to leak and those dreaded water stains appear on the ceiling and drops of water drip on the floor, then, everyone gets alarmed and the repair of the roof condition suddenly takes a first priority in their lives. In some instances, it is just too late to do small repairs or simple patch-up jobs, but rather it is time to incur in the large expenditure of a roof replacement, when that could have been avoided with a well planned and executed maintenance program.

Any building owner can save himself (or herself) a lot of expenses and aggravation by keeping in mind that the life of any given roof could had been substantially lengthened if it had been kept clean and all the dried up joints, caps, flashings, counter-flashings and/or anchorages had been regularly brought up to par by just applying a new coat of roofing cement where it was needed.

Here are some rules that should be kept in mind during the design, erection or maintenance of a roof in order to save money, inconvenience or business interruption:

Rule #1
A successfully installed roof should be characterized by having an efficient positive drainage by which the rain water is disposed off and out of the roof surface, as rapidly as possible.

Rule #2
Keep roof drains away from column grid lines and never ever place rain leaders inside of columns. In most cases high roof points happen to occur on top of columns rather than the opposite; therefore, having drains over columns would work against the most basic common sense. Furthermore, if you place a rain leader inside of a hollow steel column, the pipe will have to come out at the base of the column, so displacing valuable column material. If the case happens to be applicable to a concrete column, the damage is even more devastating to the supporting member.

Rule #3
Remember that all roofs will eventually have to be either repaired or replaced, therefore, the roof designer should prepare all of his detail solutions in such a way that he gives

outmost consideration to make it easier for those who come after him to do the repairs or to maintain the roof operational.

Rule #4
There is a lot of movement that takes place at roof joints, ridges, valleys and step-downs. Use all your wisdom to select the correct flashing sheets, not only in what refers to the kind of material to be used, but also the gage to employ. While it is true that most codes will allow a 26 gage, there are cases where a bit thicker flashing would do a much better and reliable job.

Rule #5
As it is true that PVC drains are substantially cheaper, they will not last as long as cast iron, as the latter type of roof drain assembly will last all through the building's lifetime and then some.

Rule #6
We encourage the use of counter flashings "to save the day", nevertheless, the flashing underneath by itself, must be water tight enough to handle the job adequately.

Rule #7
Design your roof in such a way to avoid the use of pitch pockets as much as possible, for they dry out and eventually become a maintenance headache.

Rule #8
Just because you followed the manufacturer's general recommendations, it does not mean that your design is good and complete. Do not just rely on "one size fits all" type of general instructions. You are the one who knows best of all the particulars of the job at hand, challenge your own solutions and details to see if they would stand to tough criticism. Pride aside, have someone in your office to play the Devil's advocate to help find your own pitfalls.

Rule #9
When in service, keep a roof clean from leaves, limbs, debris and other deleterious materials, for they will help to retain humidity and encourage mold and algae growth.

Rule #10
Other than roofers (who are supposed to know how), keep people from walking on your roof. Walking on a roof may start leaks where there were no leaks before. Walking over roof nails left behind or random pebbles and gravel, may drive them into the roof layers and create an easy access for rain water, thus inducing undesirable and costly leaks. Even those so called and designed walkable roofs should have designated catwalks especially built and treated for foot traffic.

Rule #11
A roof will last twice as long if the property owner (with the help of his maintenance engineer, if any) carefully and attentively designs, institutes and executes a complete, adequate and regular maintenance program.

2- MOISTURE CONTENT TEST SURVEY

Any roof, especially if it has been neglected for a period of time, is prone to develop leaks. Watershed roofs develop leaks because of faulty installation, aging, accumulation of leaves and debris, or because of wind and hail damage. Flat roofs, on the other hand and in addition of all above, may develop water ponding due to either or both, the short and long term deflections of the supporting structure. Very particularly, that sagging may become a vicious cycle, as the structural deflection (or sagging) grows larger, the accumulated amount of water may increase thus triggering even larger sagging, larger sagging allows more water and so on until it may become a structural stability problem for the engineer to ponder on, or solve as part of his entrusted assignment. Water ponding is indeed the *Achilles' heel* of all flat roofs.

Stagnant water on the roofing membrane may find its way down to the lower layers of the roof and its insulation. The constant humidity will lead to delaminating, rotting and eventual disintegration of the roof. Once humidity is detected within the thickness of a given roof coverage, by itself, that is an indication of a problem that must be paid attention to and the sooner the better, or pay for the consequences.

Water seepage into a roof is a pervasive problem that can lead not only to roof failure, but also to loss of insulation properties. Further, it may become an electrical hazard and eventually lead to significant structural deterioration. The repair of such problems may represent out of pocket expenses of many thousands of dollars for the property owner. Naturally, such expenses could be averted by regular inspections and early detection.

While the visual inspection phase is an important part of a roof survey since it helps to detect signs of roof degradation such as cracks, blisters, alligatoring*, blocked drains, flashing failure, water ponding* and settlements, however, there are other signs of trouble and aging that lay well beyond the reach of the human eye to detect.

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*While *alligatoring* and *ponding* may not exactly be accepted dictionary terms, they are commonly used and accepted roofing industry terminology which happens to be quite descriptive in their common use.

We all know that water has two main constituents: hydrogen and oxygen. Therefore, the presence of hydrogen is an indication of the existence of humidity. If we can measure the hydrogen content in a roof, that will lead us to assess its humidity content. A certain instrument called the *Isotopic Moisture Gauge* is capable to perform a non-destructive reading of humidity content by being able to penetrate thicknesses of up to 10 inches of material in a few seconds and to provide a comprehensive assessment condition.

The common procedure starts with marking a preferred but not necessarily 10 x 10 ft. alphanumeric grid system on the flat roof under analysis, naturally, the smaller the grid module, the more accurate the procedure would be. Readings are taken at the grid points, recorded and formulated into a computerized *histogram* where they are categorized by levels of severity and then evaluated by the roofing consultant, who then writes a comprehensive report furnished with the proper graphs, details, conclusions and recommendations.

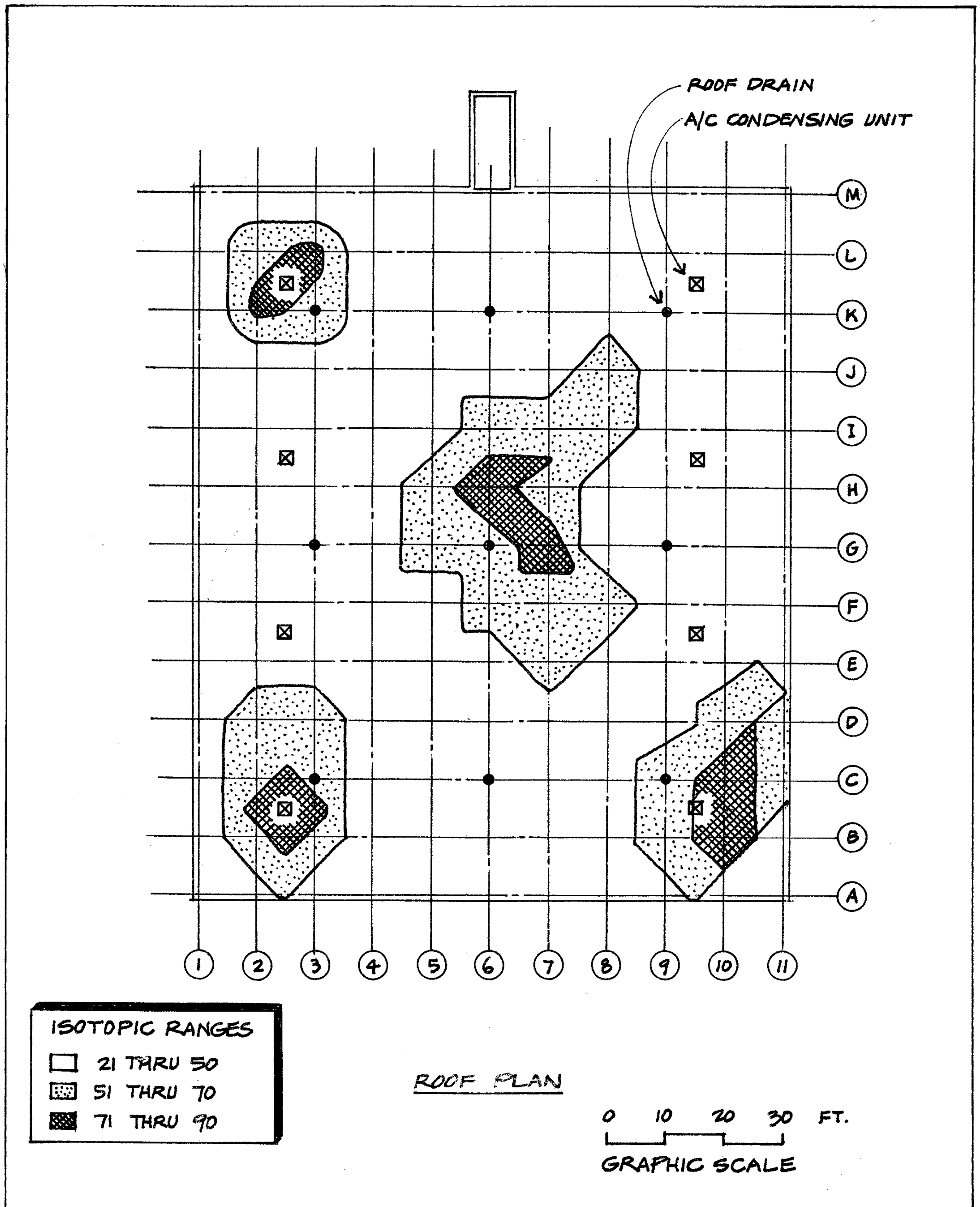
We have herein reproduced an abbreviated version of a roof examination prepared for a condominium association in West Boca Raton, Florida. Their building had a long history of roofing problems since its construction in the early 1970's as part of the flat roof wave that became the modality of the times. We have also included herein the graphs (see the enclosed "roof plan" and "hydrogen relative readings") as well as the recommendations which were originally part of the submitted report.

The readings were grouped in three levels of concentration. It is important to interject here that since all roof materials intrinsically have a certain degree of humidity in them, there will always be a hydrogen reading other than zero (0). The first level adopted was for hydrogen concentrations varying from 21 through 50. The second level was for concentrations of 51 to 70 and the third level for concentrations of 71 through 90.

All those readings taken as result of the hydrogen concentration survey were indeed relative values indicating variations from high to low moisture content, but they did not indicate points of saturation. In order to convert them to absolute values, if so necessary, some core samples could have been taken, especially from the areas of high humidity concentration. Those samples could then have been evaluated and assigned absolute values, and from there deducted the proportional indices applicable to all other grid points.

The importance of maintaining a "dry" roof with the proper and desirable drainage cannot be overemphasized. Standing water is a constant source of moisture that would eventually saturate the roof membrane and the deck underneath. Wet insulation will lead to the rotting of its organic fibers, thus drastically reducing its thermal resistance.

Perennial cycles of water saturation from rain and induced evaporation from sunshine will accelerate the aging and degradation of the waterproofing membrane. Further, standing water will promote vegetation growth, a place for breeding insects and the production of objectionable odors.



APPENDIX, EXHIBIT #2
MOISTURE CONTENT SURVEY

The following table summarizes the readings taken at the Sol-i-mar Condominium at the end of year 1990:

HYDROGEN ISOTOPIC READINGS

Grid Point	Reading	Grid Point	Reading	Grid Point	Reading
A-1	31	C-1	50	E-1	42
A-2	47	C-2	62	E-2	48
A-3	48	C-3	69	E-3	49
A-4	31	C-4	50	E-4	36
A-5	19	C-5	46	E-5	39
A-6	18	C-6	49	E-6	49
A-7	19	C-7	50	E-7	58
A-8	36	C-8	50	E-8	50
A-9	48	C-9	68	E-9	31
A-10	50	C-10	80	E-10	50
A-11	24	C-11	67	E-11	49
B-1	48	D-1	48	F-1	28
B-2	69	D-2	52	F-2	32
B-3	70	D-3	51	F-3	40
B-4	47	D-4	49	F-4	48
B-5	32	D-5	32	F-5	49
B-6	31	D-6	39	F-6	52
B-7	34	D-7	49	F-7	68
B-8	48	D-8	48	F-8	53
B-9	63	D-9	49	F-9	48
B-10	81	D-10	52	F-10	31
B-11	48	D-11	54	F-11	26

G-1	19	I-1	21	K-1	48
G-2	28	I-2	32	K-2	73
G-3	50	I-3	39	K-3	70
G-4	50	I-4	46	K-4	49
G-5	61	I-5	50	K-5	47
G-6	70	I-6	61	K-6	46
G-7	78	I-7	68	K-7	41
G-8	50	I-8	51	K-8	46
G-9	49	I-9	49	K-9	50
G-10	39	I-10	32	K-10	41

G-11	20	I-11	20	K-11	26
H-1	20	J-1	32	L-1	46
H-2	29	J-2	46	L-2	68
H-3	37	J-3	49	L-3	74
H-4	48	J-4	46	L-4	48
H-5	61	J-5	48	L-5	36
H-6	81	J-6	49	L-6	31
H-7	63	J-7	50	L-7	38
H-8	49	J-8	51	L-8	31
H-9	36	J-9	49	L-9	39
H-10	24	J-10	39	L-10	28
H-11	19	J-11	21	L-11	19

M-1	31	M-5	24	M-9	21
M-2	47	M-6	21	M-10	19
M-3	48	M-7	23	M-11	18
M-4	32	M-8	24		

3- STANDARD ROOF SLOPES & PITCHES

The building codes as well as the roofers in their jargon, refer to a particular roof slope by the rise in inches (or fractional inch) as it takes place in the horizontal projection of one foot (12 inches), as in the commonly designated case of *two and a half inches in twelve (2½" in 12"),* which case is well defined and understood by everyone in the business.

However, there are cases where the design engineer or architect must refer to that same roof by the actual angle or the rise percentage. To assist them in such pursuit, we have enclosed the table with the most common cases found in roof construction:

ROOF SLOPES & PITCHES

Pitch (inches)	Rise (%)	Angle (degrees)
1/16	0.52	0.3
1/8	1.04	0.6
1/4	2.08	1.2
3/8	3.12	1.8
1/2	4.17	2.4
3/4	6.25	3.6
1	8.33	4.8
1-1/2	12.50	7.1
2	16.67	9.5
2-1/2	20.83	11.8
3	25.0	14.0
4	33.33	19.0
5	41.66	23.6
6	50.0	28.0

END