Does the roof leak?—Part 1

Here is what you need to know on why roofs fail, and how to go about finding the failures and deciding what to do.

Roger V. Morrison,
Plastic Coatings Corp.

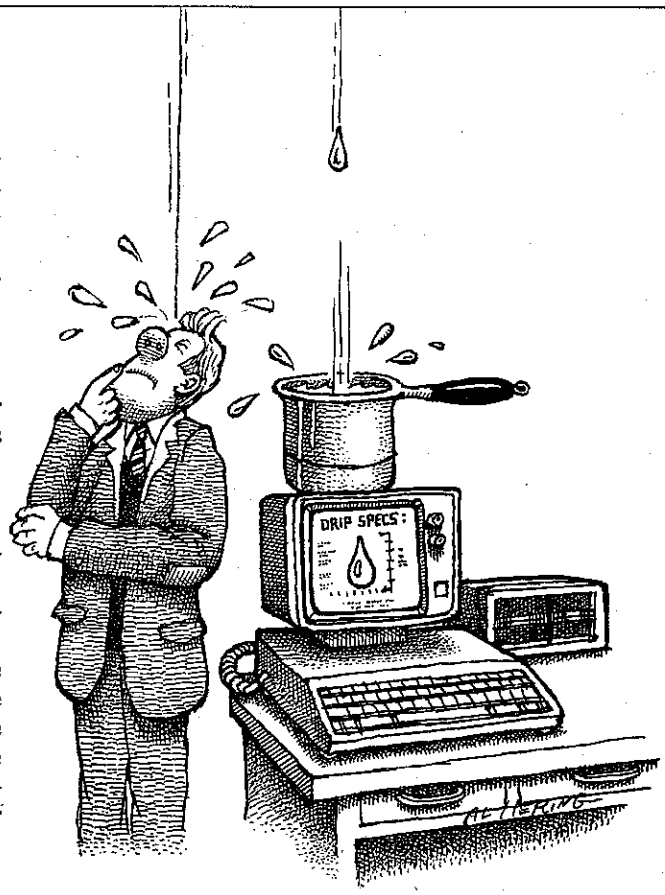
Typically, a roof is noticed only when it leaks. Although preventive maintenance will prolong the life of a roofing system, a roof rarely gets the attention it needs.

Types of roofing systems

The more common roofs for chemical process industries plants are:

- Built-up roof (BUR).
- Single-ply.
- Spray-applied polyurethane foam (SPUF).
- Insulated roof membrane (IRMA).

This article, and the one following, will concentrate on the built-up roof (the most common type) because its problems, and their repair, apply to many other systems too.



Why early roof failure?

The "20 year" bonded BUR was introduced early in this century to reduce weight and construction costs (as an alternative to heavy slate, tile or metal). It consisted of four or five plies, alternating layers of jute felt and Trinidad asphalt. Today, however, a BUR seldom lasts 20 years. These failures stem from changes that have come about since the system was introduced.

Insulation—The original BURs were designed without insulation, typically over a vented loft. The air in the loft absorbed heat during the day, and warmed the roof at night, thus minimizing temperature extremes.

Insulation under a roof changed this, so that the roof became hotter during the day and colder at night; on a fair day, the day-night temperature difference may be 50°F greater if insulation is used. Maximum membrane temperatures of 180°F are common (the design temperature for uninsulated BURs was 120–130°F).

Structure—Roofs have become larger, particularly for single-level plants. Drainage has become more complex, and there are greater stresses due to expansion and edge effects. Long roofs require expansion joints, with added chance of leakage.

Materials—Costs of the original jute felt and asphalt have increased faster than the inflation rate. Wood pulp has been substituted for the felt, and weights have been reduced; petroleum byproducts and residues are used in place of the asphalt. Manufacturers have been only partially successful in reproducing the properties of the original materials.

The net effect has been to reduce BUR life from 20 to about 10 years. The margin for error has been reduced; mistakes in construction, workmanship, design and materials are magnified and less readily forgiven.

Why do roofs fail?

A roof "fails" when it no longer satisfies the building occupants. Usually this means that water has penetrated the roof in some manner that results in inconvenience, discomfort, hazard or economic loss.

But moisture penetration, which usually occurs long before it becomes obvious, is a leading cause of damage that leads to failure. Moisture between the plies, or within the insulation, will result in delamination owing to expansion-contraction or vaporization-condensation effects caused by daily and long-term temperature cycles. The resulting blisters, ridges and splits will allow further moisture penetration, and membrane damage.

Moisture can enter the roof system because of:

Construction practices—Improper storage or excessively long storage of roofing materials, roofing in poor weather, or roofing over an uncured concrete deck are some ways moisture may enter during construction.

Flashing leaks—Splits at flashing joints, dried and cracked caulking, damaged parapet caps, cracks in exte-

rior masonry walls, improperly installed penetration flashing and missing counter-flashing, all lead to introduction of moisture.

Condensation—When the dewpoint of a building's interior exceeds the outside ambient temperature, condensation will occur in the insulation layer unless the roofing and insulation system is properly protected by a vapor retarder and vents. A wet insulation layer will substantially reduce the insulation's efficiency, reduce the strength and load-bearing properties of the roof system and cause blister formation at the membrane. If the interior humidity is high enough (as with many enclosed chemical processes), condensed vapor will drip back inside the building and be perceived as a roof failure.

Roofing damage and defects—Splits and holes in the roof membrane itself will admit moisture. These defects may have been the result of poor original workmanship, or subsequent damage due to traffic, or maintenance of roof-mounted equipment.

Roof inspection

Whether you are looking for a leak, or planning roof maintenance, the first step is an inspection. This should begin in the files. First, try to determine (from drawings, plans, purchase orders, etc.), the roof's age, type and size, the contractor who installed it, applicable warranties or bonds, and any other pertinent information. If a drawing is available, copy it, or make a sketch of the roof to use during the on-site inspection.

The ideal time to perform the physical inspection is one or two days after a hard rain. Leaks will still be visible and fresh in the occupants' minds, and ponding on the roof will be evident. (An extensively ponded roof should be reinspected when dry, to check the areas previously under water.)

Walk around—Walk around the exterior of the building. Note any cracking or deteriorated mortar, damaged downspouts and gutters, or efflorescence (indicating moisture seeping through masonry).

Interior checks—Talk to the occupants; if there are leaks, they will probably know about them. Examine interior walls for signs of moisture such as peeling paint or efflorescence. Look in loft areas, if present.

Safety—Before going up onto the roof, consider your safety. Inspect any ladders, and use them properly. If the roof is steep or slippery, use a safety harness. Wear rubber-soled shoes to minimize slipping and damage to the roof membrane. Follow the plant's safety rules.

Roof overview

Once on the roof, make a quick overview, noting:

Roof type—Note the type of roof (BUR, SPUF, single-ply, IRMA), and verify if the file information (if any) is correct.

Ponding—Are any areas under water? How extensive? How deep?

Drainage—Where are the drains? Are they functional? Is the roof pitched?

Debris—Is there any trash or leaf accumulation?

Chemical attack—Are there major areas of discoloration, corrosive deterioration, or other evidence of general chemical attack?

Roof membrane—Overall, does the roof membrane appear smooth or blistered? Does the surface have a washboard appearance?

Roofing details

Carefully check the following roofing details:

- Flashing at parapets and firewalls.
- Flashing at roof penetrations (vents, stacks, etc.).
- Fascias and gravel stops.
- Gutters.
- Drains.
- Skylights.
- Roof-mounted equipment (process equipment, air-conditioning units).
- Expansion joints.
- Walkways.
- Hatchways.

All joints between details and the roof membrane must be sealed tight. Note for repair: cracks in caulking, loose overlaps of sheet metal flashing, gravel stops, expansion-joint covers, or fascias.

Check roof-mounted equipment for proper flashing on supports, and for spillage and vibration damage. Carefully examine any protrusions through the roof of piping related to the equipment. Inspect the roof membrane in the vicinity for possible damage caused by equipment maintenance.

Roof system

Inspect the roof surface for blisters, cracks, splits, and areas that do not appear to be tightly sealed. Gravel or

A glossary of roofing terms

The varieties of roofing systems available may confound the specifier who deals with roofs only occasionally. Most roofing systems are arrangements of several common elements; variety occurs in the arrangement of these elements, and the materials of construction employed. Most systems employ the following components:

Deck—The deck provides the primary structural support for the roof. Usually, it is made of steel, concrete or wood.

Membrane—The membrane is the main barrier for moisture protection. For BUR and single-ply systems, the membrane may be at the surface, or covered with gravel ballast. IRMA systems protect the membrane by installing insulation above it. SPUF systems utilize closed-cell foam, and coatings, as the membrane.

Insulation—Polystyrene, polyurethane, and fiberglass are common insulating materials used in roofing. The insulation may be applied below the deck (common in retrofit situations), above the membrane (IRMA), or between the membrane and deck (BUR and single-ply).

Vapor retarder—A layer installed between a building's interior and the insulation, to reduce moisture migration into the insulation.

Anchorage—Roof systems may blow off unless secured to the deck and building. Anchorage may be achieved by mechanical fasteners (nails, clips, screws), adhesives (cements or self-adhesive materials), or ballast (gravel or cinders).

When evaluating alternative systems, look for the presence, arrangement, and materials of construction of these elements.

cinder ballast may hide these problems; take the time to clear off areas that may be suspect.

Blisters (raised bumps on the surface) are indications of delamination and may contain air or vapor, or water. Examine the area around the blister for possible associated splits.

Splits and cracks may appear without blisters. There may be no apparent water associated with the split, but the weight of your foot beside the split may squeeze hidden water from beneath the plies.

Examine the plies themselves; look for deterioration of the felt backing. Cut out a sample core to the depth of the plies (repair the cut with roofing cement). The depth of ply deterioration will be a key factor in determining the stage in the life cycle of the roof, and what repair or replacement options are available.

Check the condition of the insulation, if any. If areas feel soft or mushy beneath your feet, it is likely that the insulation is saturated in these areas. A more definitive evaluation of the insulation and underlying roof condition may be had by employing a nondestructive testing service. Techniques for indicating the presence of gross moisture within a roof system include thermal scanning, nuclear magnetic resonance techniques, and capacitance or conductance measurements. The cost of the testing depends on the technique used and the detail of the report provided.

If the results of the "foot feel" test indicate extensive areas of saturated insulation, then nondestructive testing, core sampling, or both, probably are warranted.

Finding a leak

If you are trying to pinpoint the source of a leak, here are a few hints that may help.

First, determine when the leak appears. If it begins with the onset of rain, and stops when the rain does (or soon after), it is probably a true external leak, and should be located on the roof close to where the water appears inside (sometimes, channeling within the roof may cause the leak to show up at some distance from its original penetration).

If the leak appears on cold days, especially following a hot humid period, the "leak" may be the result of condensation. Check the relative humidity of the building. If the vapor retarder is breached and the dewpoint is reached within the insulation, condensation will occur. This condensed water will accumulate above the vapor retarder until it finds a channel through which it can flow back into the building.

If the leak appears during rain, but only when the wind is strong, or blowing in a certain direction, the source is likely to be a flashing or wall leak.

If the leak persists long after the rain has stopped, it is likely to be coming from a ponded area on the roof, or from saturated insulation.

The design of the roof deck will influence where a leak occurs. For example, a corrugated metal deck will allow the water to channel for several feet before finding a seam to leak through. Knowing the roof structure will help you to visualize where the leak originated.

The location of the leak may provide some clues as to possible sources. A leak that appears only on a wall suggests a source in the flashing, wall or parapet. A leak in proximity to an internal drainpipe suggests a poor seal between the drain and the roof, or a break in the drainpipe itself.

A true external leak often can be confirmed by using a hose or bucket of water to simulate rain. (This technique will not confirm condensation "leaks" or those due to wet insulation.)

Roof repair or replacement?

The roof inspection will provide data on its overall condition. Analysis of the data will help to determine the viability of the existing roof, and suggest strategies for maintaining it or replacing it.

Although no two roofing situations are alike, the following guidelines can be used to determine whether a roof can be maintained and saved, or if replacement should be considered.

Repair the roof if:

- Leaks are confined to flashing, parapet, wall, or detail areas, and are easily repaired.
- Ply deterioration and embrittlement are limited to the top two plies.
- Blisters are limited in number and size—a maximum of three blisters per 100 squares (10,000 ft^2) of roof surface.
- Insulation is dry, stable and strong.
- The roof deck is sound.

Replace the roof if:

- Leaks are extensive, cannot easily be repaired, or both.
- All plies are deteriorated and embrittled.
- Splits and blisters are extensive.
- The roof deck has deteriorated.
- Flashings are no longer functional, and are beyond repair.

Other considerations that can influence the decision to repair or replace:

- Changes in the building's function, such as the installation of electronic equipment, increased internal relative humidity, or creation of office space.
- Adequacy of insulation.
- Recent or planned installation of roof-mounted equipment.

The second installment of this two-part article will appear in the Feb. 18 issue, and will cover the repair of existing roofs and the various options available if the roof is to be replaced, including the advantages and disadvantages of a number of common roofing systems.

Roy V. Hughson, Editor

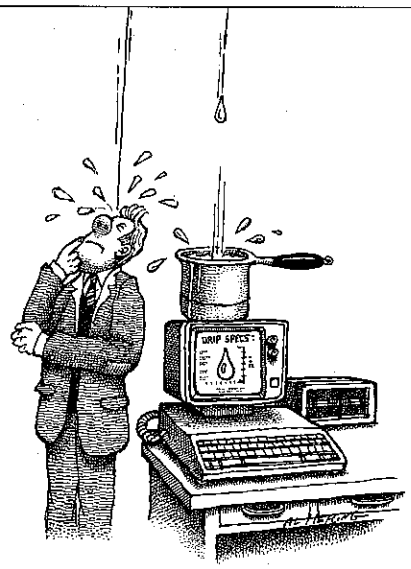
The author

Roger V. Morrison is Northeast marketing manager of Plastic Coatings Corp., 2 Belle Glades Lane, Belle Mead, NJ 08582; tel: (201) 359-4308, a company that manufactures coatings for the roofing and insulation industries. He holds a B.S. in chemical engineering from West Virginia University and M.B.A. from West Virginia College of Graduate Studies, and is a registered professional engineer in New Jersey and West Virginia.

Does the roof leak? — PART 2

The previous article* explained how to find leaks and how to decide whether to repair or reroof. Here is the way to go about doing either one.

Roger V. Morrison
Plastic Coatings Corp.



Roof repairs should be planned with the objectives of sealing existing and potential leak sources and extending the useful life of the existing roof. Leak sources associated with roof details normally require recaulking or masonry repair. Splits and tears of the roof membrane will require patching using multilayers of roof patching cement and woven fabric. Blisters should be opened, dried out, and patched as a split.

Flashing and masonry repairs may require special tools and materials depending on the condition and type of the existing system. Recaulking alone may suffice where flashings and masonry are in good condition.

The roof membrane itself may require servicing. If the top one or two plies have become embrittled, consideration should be given to coating the membrane surface with a resaturant or an elastomeric coating. A resaturant is an asphalt or coal-tar material formulated with solvents to encourage penetration of the oils into the top roofing plies. Its purpose is to restore lost flexibility and water repellency to the surface. An elastomeric coating, usually a polymeric material, is applied as a weather barrier and is not expected to penetrate the roof membrane. Its purpose is to protect the damaged surface plies from further degradation by excluding moisture and ultraviolet light.

The value of using resaturants or elastomeric coatings is the subject of current debate within the roofing industry. Evidence suggests that resaturants have little or no effect on the strength of plies. However, they may improve water repellency, thereby adding life to the existing roof system.

Elastomeric coatings, like resaturants, will add no additional strength to a roof but will provide a new first barrier to water penetration. This new membrane will often extend the life of a roof five years or more.

The resaturants and elastomeric coatings are liquids that may be applied by troweling, brushing, rolling, or spraying. The act of removing gravel or cinder ballast will often result in more damage than can be corrected by the application of these coatings; hence these materials should be considered only for use on unballasted roofs.

These aforementioned roof repairs are routine and can be completed by any competent roofing crew or contractor. Further details on roof repairs can be found in the references.

Roof replacement

There are many options available. New systems have been designed to deal with unique roofing problems and to take advantage of new materials. The engineer evaluating alternative systems will first need to study the existing building and roof. If it has failed prematurely, one must determine why. The new roof should compensate for the deficiencies in the old system. Factors to evaluate are:

Deck condition—Before a new roof can be applied, the roof deck must be examined for evidence of deterioration. Core samples will be necessary if the deck cannot be visually inspected from underneath. A new roof should not be installed over a weak or corroded deck.

Nature and use of building—The building must be examined to determine whether there are any special conditions for roof design. These could include high relative humidity, cold storage rooms, heating or air conditioning, fire-hazard rating, and the presence of corrosive chemicals or fumes.

Nature and use of roof—Determine whether the roof will be exposed to unusual materials: roofing systems are usually designed for suburban and city environments; chemical-plant roofs may require materials of construction designed to withstand unique circumstances. If there is, or will be, roof-mounted equipment, the roof system will need to accommodate maintenance traffic. Equipment vibration and potential spillage must also be considered.

Insulation—The amount and condition of existing insulation must be determined. Roof replacement is an ideal time to add insulation, which frequently provides a payback, making the entire roof replacement economically justifiable. (Wet insulation generally cannot be salvaged.)

Drainage—If drainage on the existing roof has been poor, the new design should include improvements. The design slope should be ¼ in./ft, minimum.

Tear-off or reroof

Tearing off the existing roof allows for the inspection and repair of the roof deck, and installation of tapered insulation

*Part 1 of this article appeared in the Jan. 21, 1985 issue, p. 131. To meet the author, see the last page of that article.

for drainage improvement. However, a tear-off will add substantially to the cost of roof replacement and may disrupt the normal activities in the building. Reroofing over the existing system can be accomplished if: the deck is sound; the existing roof system is well adhered; existing insulation is strong and essentially dry; the existing membrane is reasonably smooth or can be made so; and the load bearing capacity of the deck can support the added load.

Prior to reroofing over an existing system, the old roof needs proper preparation. All blisters must be opened, dried out and repaired. Limited areas of wet insulation must be opened and dried or replaced. Most existing flashing should be replaced. The surface must be relatively smooth and free of dirt, dust or other loose material. Priming of the membrane surface may be required. Tear-off should be favored if there is: extensive ponding; a deteriorated deck; saturated or deteriorated insulation; poor anchorage between the deck and insulation; or an irreparable membrane surface.

Built-up roof (BUR)

The uniqueness of BUR lies in its dependence on alternating layers of bituminous material and supporting felts. Improved asphalt and coal-tar specifications, uniform flashing and detail standards, and the growing use of fiberglass felts promise to renew BUR's popularity.

Advantages:

Long history of use.
Good resistance to foot traffic.
Repair techniques widely understood.
Excellent adhesion between system components.
Many experienced roofing contractors.

Disadvantages:

Comparatively heavy, especially if ballasted.
Difficult to apply to unusual surfaces.
Requires expensive flashing at details.
Membrane susceptible to thermal shock.

Single-ply

Single-ply-membrane roofing is a fairly recent entrant to the roofing market. In this system, a single-ply membrane is generally applied directly over insulation board and held in place by adhering, fastening or ballasting. The membrane may be made from modified bitumens, polyvinyl chloride (PVC), chlorinated polyethylenes (CPE), chlorosulfonated polyethylenes (Hypalon), neoprene, ethylene-propylene-diene monomer (EPDM), or polyisobutylene (PIB). The specific requirements of the roof would dictate the type of membrane and method of attachment. The membrane is applied in sheets from rolls; the seams are lapped and joined by using adhesives, solvents or heat sealing.

Advantages

Light weight (unballasted).
Adaptable to irregular surfaces.
Superior appearance.
Good heat reflectivity (white).
Good elongation.
Easy application.
Installation less weather-dependent.
Easy repair of punctures and splits.
Substantial choice of membrane materials.

Disadvantages

Seam security a problem.
Leak detection may be difficult, owing to channeling.
Substrate must be smooth.
Subject to wind lifting.

Spray-applied polyurethane foam (SPUF)

SPUF roofs were introduced in the late 1960s and have had a slow, steady growth since then. The system consists of polyurethane foam sprayed directly on the roof surface to a depth of 1–3 in. The roof surface, in this case, could be the roof deck or an existing BUR membrane. The foam is then coated with an elastomeric coating, usually spray applied, to a cured coating thickness of 20–40 mils. Several generic types of coatings are available: acrylics, urethanes, silicones, butyl, and Hypalon. The coating used is an integral part of the SPUF system and must be carefully selected in order to meet individual coating/performance requirements.

Advantages

Extremely light weight.
Can be installed quickly.
Can be applied directly over many BUR surfaces, avoiding tear-off.
High insulation value.
Very adaptable to irregular surfaces.
Self-flashing.
Slope can easily be added to a dead-level roof.
Excellent adhesion of all components.

Disadvantages

Foam requires recoating periodically.
Highly dependent on the applicator's skill.
Dependent on good substrate.
Less impact and traffic resistance.

Insulated roof membrane (IRMA)

The IRMA roof was developed in an attempt to isolate the roof membrane from the effects of thermal shock and ultraviolet light degradation. The system consists of a membrane applied directly to the roof deck or on roofing board directly above the deck. The insulation, usually expanded polystyrene, is placed above the membrane. The system is topped off with a layer of woven fabric that supports gravel ballast.

Advantage

Membrane is protected.

Disadvantages

Leaks are difficult to find and repair.
Retrofitting is difficult because the membrane is lower than the previous membrane.
Membrane is not visible for inspection; ponding or chemical attack will not be observable.
Insulation is exposed to rain and chemical attack.

The choice

The choice of roofing system must be made on a case-by-case basis. Every building and roof has its own history, characteristics and functions. Costs will also vary case-by-case.

***Roy V. Hughson**, Editor*

References

1. RIEI Maintenance Manual, Roofing Industry Educational Institute, 6851 S. Holly Circle, Englewood, CO 80112.
2. NRCA Manual of Roof Maintenance and Roof Repair, National Roofing Contractors Assn., 8600 Bryn Mawr, Chicago, IL 60631.
3. SMACNA's Architectural Sheet Metal Manual, Sheet Metal and Air Conditioning Contractor's National Assn., P.O. Box 70, Merrifield, VA 22116.