# Failure analysis 101

**When the irrigation system blows, a little detective work helps determine the cause.**

Early in the first summer following the complete reconstruction of the Lawrence (Kan.) CC course, then-superintendent Brad Minnick came to work and was confronted by this scene on No. 6. The diagnosis: Heavy rain combined with settling caused a thrust block at the irrigation run's end to give way. **Photo courtesy of Lawrence CC**

Larry Workman

**An entire industry and scientific** community supports the fine art of forensic, or failure, analysis. But using just a few basic principles, you can discover where and how your irrigation system and its parts are likely to fail.

The primary purpose of finding the source of failure is, of course, to prevent continuing or future problems. It's important to enter into a failure analysis with an open mind, one not biased with a preconceived conclusion. As the often-repeated saying on the popular TV crime investigation shows puts it, "See where the evidence leads!"

Though all the examples and principles I write about in this article focus on PVC (polyvinyl chloride) piping systems, most apply to other materials as well.

## Look for the pattern

Your first and most important step in finding out what caused your irrigation system to fail is to understand the circumstances that affected the broken part and possibly led to its failure. Important information that leads to the root of the failure often comes from answering a few simple questions:

- What is the part's position and role within the system?
- What time was it and which cycle was running when the break occurred?
- What was the system pressure?
- What was the ambient temperature or other weather factors?

These questions are even more important when you're looking into a series of similar failures. Even with a single or isolated incident, assume it may be the first of more to come, and the information collected can help pinpoint the cause. When you gather information from multiple failures, obvious randomness disappears and a pattern develops.

The more extensive the collection of exemplars (fragments), the easier it is to pinpoint the source of the failure. Once you have gathered this collection in a central location, clean off any residual mud or dirt. Work carefully, so you don't destroy any telltale signs of the failure's origins. For plastics, use a gentle stream of water to wash the parts; don't use brushes, scrub pads or anything that will destroy the surfaces or indicators.

**The orientation of the crack, or tears, will tell you the direction from which the damaging loads were applied.**

### Damage direction and shape

The first thing to understand is that the orientation of fractures, cracks and breaks is perpendicular to the direction of the causing forces. I often use a paper strip to show the mechanics principle of a failure. When you pull a long rectangular strip of paper at both ends, it will tear in a direction that is perpendicular (or at a right angle) to the direction of your hands.

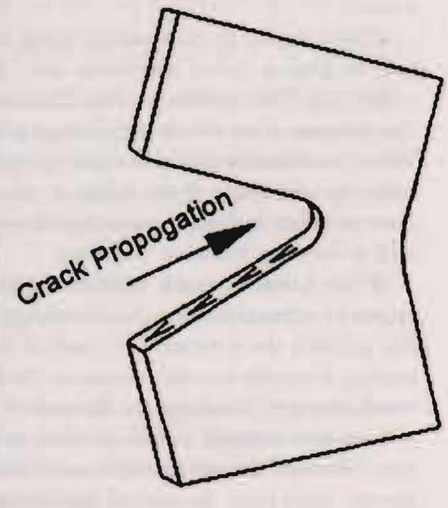
This is similar to the standard tensile test, where a sample held by grips is pulled lengthwise until it breaks across the midsection. The orientation of the crack, or tears, will tell you the direction from which the damaging loads were applied. When you examine your damaged piping components, determine the orientation of the failure so you can categorize the cause as either hydraulic internal pressure or external loads, such as bending, vibration or impact.

If the failure or crack encircles a pipe or fitting, it was caused by external forces such as bending or vibration. A crack that parallels the waterway is a result of internal or hydraulic loading. Excessive internal pressure in the form of hoop stress, which attempts to enlarge the diameter of the pipe or fitting, will produce a tensile failure or crack parallel to the waterway. Threaded fittings that split are evidence of exposure to internal loads from the tapered pipe threads and not usually from system pressure. When the male and female components wedge together during tightening, the taper of the male component attempts to stretch the female part to a larger diameter. As the diameter increases, the wall is stretched and a longitudinal crack will form.

The sharp, jagged edges of this PVC piping indicate a failure from extreme pressure and probably were found after a burst-pressure test. **Photos courtesy of Larry Workman**

The texture of the failure surface shows a lot about its progression. Sharp, jagged edges are a strong sign of rapid failure. Brittle material or failures from extreme pressure result in almost razor-sharp fragments.

You'll usually find damage of this type after a burst-pressure test. When a water-filled system is pressure-tested, the sharp and dangerous fragments will be contained within a few yards. But when the system has been leak-tested with air or has an air pocket, a failure can propel these shrapnel-like pieces hundreds of feet, creating the potential for serious injury.




**(Top)** The straight, Y-shaped fracture lines on this fitting probably resulted from water freezing inside the PVC piping. The pieces typically remain close to the source of the failure.

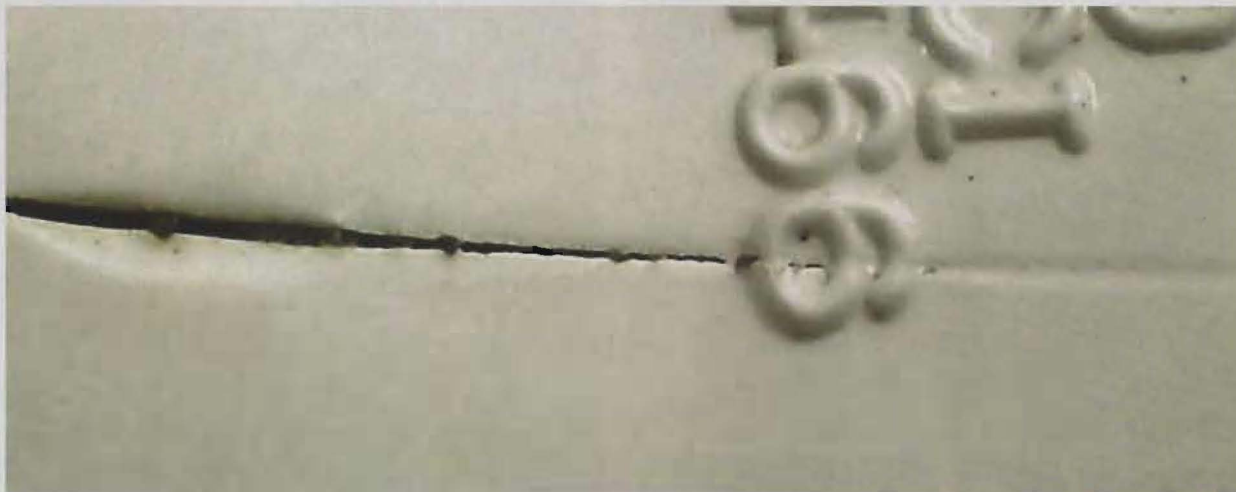
**(Bottom)** Tell-tale signs of failures that result from a slow progression include "beach marks" (left) and a deformity known as "creep" (center). Creep failure most commonly occurs near the interior of a direction change often called the crotch (right).

No one needs to tell superintendents about the damage that can come from an irrigation system blowout, like the one shown in these photos from Lawrence CC. However, a little forensic analysis on a leak can keep you from suffering through potentially bigger leaks in the future. **Photos courtesy of Lawrence CC**

## Long-term stress failures

When water freezes inside PVC piping, the material may fail because of the natural phenomenon of cold "embrittlement." Breaks caused by frozen water have sharp edges, similar to those previously described.

In this type of failure, fracture lines are straight and take




Failure from multiple surge cycles will have "stretch marks" at the end of any surface crack.

a V- or Y-shaped form. Pieces are not scattered but rest close to the source.

The fracture surface that results from a slow progression has a defined pattern often labeled as "beach marks." The ridges and valleys of the fracture surface also point toward the failure's origin. This mode is generally the consequence of a failure that progresses over a "long term" and multiple incidents of the cause. Still, in the vernacular of failure analysis, "long term" can be short in the span of time — maybe even a fraction of a second. Besides, many times the failure timeline will consist of beach marks at the beginning, and end with a catastrophic result.

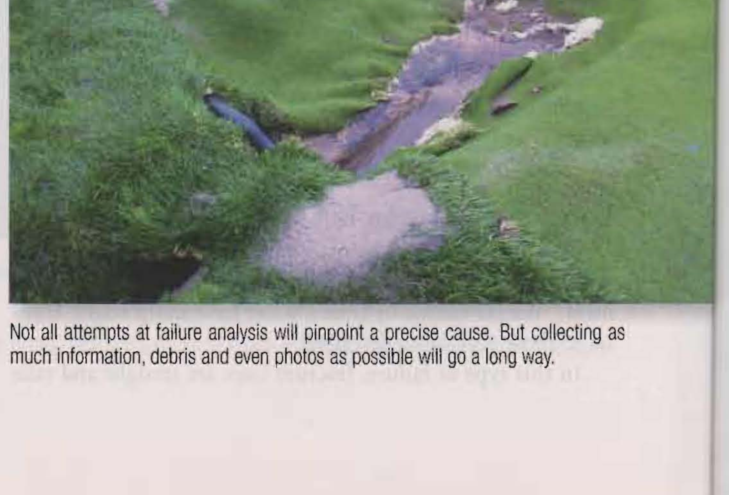
Because plastics — and specifically PVC — are pliable, a failure that is a result of long-term stress shows various amounts of creep. Creep is the tendency of a solid material to deform permanently under the persuasion of loads. It occurs because of continuing exposure to levels of stress that are below the failure strength of the material. The appearance of a failure that is the result of many pressure cycles over a long time will have beach marks on the fracture surface.

Creep failure most commonly occurs at directional fittings, near the interior of a "direction change" often called the crotch. PVC is a visco-elastic material and reacts more like taffy than glass to tensile loads. Slow, medium loads will cause the material to stretch. But a sharply applied load will cause the material to snap. A failure from multiple surge cycles will have "stretch marks" at the end of any surface crack. Many times these indicators can foretell system leaks.

### The weak link

There are two types of threaded connection failures: male or female. A joint is sealed by tightening the tapered threads, wedging the male into the female part. This compresses the diameter of the male part and stretches the female part's diameter. Compressive loads are not harmful, but stretching loads quickly cause a crack. The crack begins along the thread engagement diameter and progresses outward. Once the crack starts, the thickness of the female part's wall offers little resistance or added protection.

Once started, a crack will progress through the double wall where a coupling has been solvent-welded. The extra materials of the two walls afford little, if any, added protection. A



Not all attempts at failure analysis will pinpoint a precise cause. But collecting as much information, debris and even photos as possible will go a long way.

The failure pictured here is at the structurally weakest link of a joint: the first exposed thread of the male part.

common misconception is that using Schedule 80 threaded fittings will prevent this failure. The only solution is to use proper installation procedures and not to over-tighten the joint.

The taper of a male thread removes some pipe wall in the threaded segment. This and the inherent stress riser at the root, or bottom, of the thread create a weakness in the joint. This drop in structural strength becomes the potential for failure at the point of the first exposed male thread, outside of the female.

Any external bending or vibration on this connection will soon end with the male threaded part failing at the root of its first exposed thread. Structurally, this is the weakest link of the joint.

## Share your findings

Not all attempts at failure analysis will pinpoint a precise cause. But collecting as much information, debris and even photos as possible will go a long way. A comprehensive investigation can remove many alleged or suspected causes and help you focus on the true origin of your irrigation system's failure.

It's also important to share your findings with the manufacturer of the products involved. The more information everybody has about irrigation products — strengths, limitations, uses and history — the faster you can solve mysteries about their failure in the future.

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