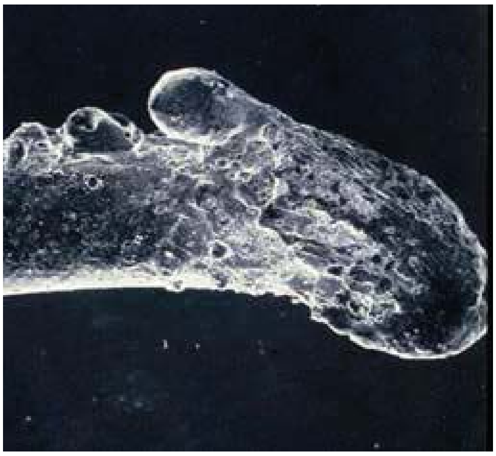
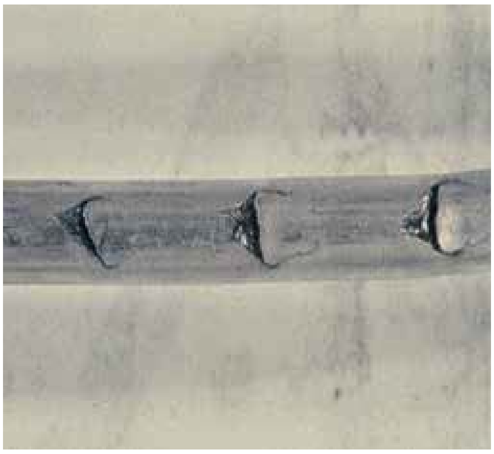
SOME TIPS ABOUT THE CLASSIFICATION OF WIRE BREAKAGES

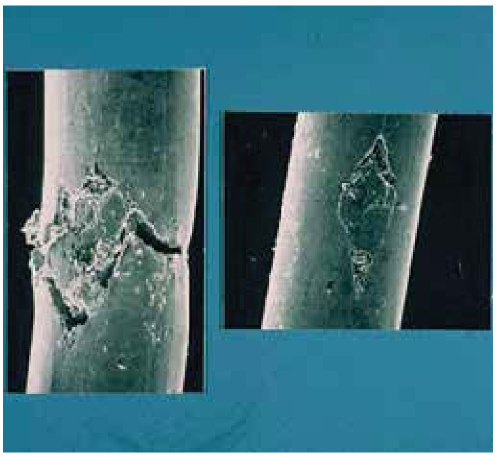
Part A



Molten End



Crows-Feet



Steel Inclusions

With the exception of ultra-fine wires, most wire breaks can be adequately examined using either a high-power magnifying glass or a low power stereomicroscope. In order to reduce costs through improved productivity, it is important to collect, examine, and categorize all wire breaks that occur during drawing or annealing, with the sole exception being those occurring during machine stringing-up. Breaks should be collected from each shift and drawing machine and placed in specially marked envelopes. In addition to relevant production data, the wire size and rod lot number should be recorded to enable traceability back to the original rod source. Arguably the most important aspect of any analysis is to distinguish between breaks caused by rod related problems with issues that arise during wire drawing. It makes very little sense to spend time analyzing and altering dies, lubricants, and drawing practices when the actual problem is attributed to incoming rod issues. Under these circumstances the rod producer should be notified immediately. Likewise, it is unproductive to lay blame on rod quality when drawing related issues are at fault. Each plant must decide for themselves whether it is better to have wire drawing operators analyze their own breaks or assign one person from quality control to perform this task. In any case, it is useful to place photographs of the most common wire break types within the plant so that all operators can immediately assess problems occurring on their shift.

When a wire break occurs, it is common practice to collect only the end of the break remaining in the drawing machine, because the other end oftentimes becomes badly damaged as it exits the drawing die. In spite of this mechanical damage, both ends should be collected, particularly if they are different in appearance. This difference can be a very important clue as to the true cause of the break. In addition, a training program on wire breaks can serve as a useful tool for operators, supervisors, engineers, and quality control staff. Most wire drawing plants do not have the necessary test equipment, such as metallographic preparation equipment, a scanning electron microscope, or even the wherewithal to conduct a thorough analysis of inclusions and cross-sectional micro-sections. Under these shortcomings the wire breaks should be returned to the rod producer since they ought to have such facilities and know-how. When inclusions are retained in the wires after breaking they should be covered with transparent tape because inclusions tend to fall out of the wire very easily after the break occurs. A small hand magnet should be placed near all retained inclusions to make a distinction between ferrous versus non ferrous contaminants. Most steel inclusions are picked up from mill rolls that are used for hot-rolling at the concast plant. Non ferrous inclusions can be picked up anywhere, including wire drawing, casting of molten metal, hot-rolling, annealing, handling, and transportation.

There is no reliable rule of thumb for predicting the number and percentages of both rod and drawing related wire breaks that might occur at any plant and wire size. It is also possible to have more than one cause of a wire break, which sometimes makes it difficult for correct categorization. A general discussion of the most common types of breaks is presented in this article.

Inclusions are one of the most common yet detrimental causes of rod related wire breaks. Since these contaminants usually fall out of the wire more than half of the time, they are classified as "**inclusion absent**", and therefore have an unknown origin. Inclusions are frequently brittle metal oxides that get transferred as slag from the molten copper into the cast bar. Most of the **magnetic inclusions** are small pieces of steel that are picked up from heat-checked mill rolls, and are almost always embedded in the surface of the drawn wire. A surface tear is oftentimes present in the copper wire near the steel inclusion or resulting void because steels do not deform easily in the draw die. When particles of frozen copper splatters or drippings fall into the casting ring mold they are known as **icicles**, and most have a layer of copper oxide on the surface. In general, icicles are found near the center of the wire since they tend to move to the center of the cast bar during solidification. Although very **high equilibrium oxygen** contents are not the norm (much greater than 600 ppm), they inevitably cause a brittle type of fracture. **Macroporosity**, which can form during solidification as internal voids within the as-cast bar, usually occurs near the center of the rod and drawn wire. If the voids are very large they cannot be closed completely by hot-rolling, and ductile wire breaks may occur with considerable necking at both ends of the break. Rod related breaks that occur because of hot-cracks, **surface slivers**, or **internal seams** are associated with subsurface copper oxides. Unfortunately, the only way to properly distinguish rod related slivers or seams from drawing related slivers is to metallographically examine the cross-sections of wires near the breaks. It is not necessary to etch the samples since oxides are much harder than the copper matrix and show up in the metallograph by relief polishing.

In comparison with rod related defects, there are a larger number of wire break classifications that are associated with wire drawing and other processes. Theses breaks can be caused by issues with handling, transportation, annealing, dies, lubricants, speed control, fines, inclusions, shaving, and alignment. **Tensile breaks** are probably the most common, and for copper are always ductile in nature. During necking of the conductor, small shallow voids form in the center of the wire. Since there are a myriad of reasons why the drawing force exceeds the tensile fracture strength, such as wire cross-overs, misalignment between the wire and the draw die, poor lubrication, dies packed with fines, worn or broken dies, etc., a thorough discussion of tensile type breaks is beyond the scope of this article. When a break occurs during resistance annealing, **molten ends** form that wipe out the original cause of the defect. Faulty **hot-welds** that occur when two different rod coils are butt welded together frequently do not break until numerous die passes have been made. The breaks have either flat ends perpendicular to the drawing direction or a V-shaped morphology. A duplex grain structure is always present in the immediate vicinity of the break. Sharp notches that are formed on the surface of the rod or wire by **mechanical damage** are extremely harmful, and more likely to cause a break than damage caused by scraping or abrasion. Galling or slip- stick conditions may arise when poor lubrication is coupled with misalignment and may lead to surface defects known as "**crows-feet**". If severe, wire breaks may also occur with the V-shaped ends pointing in the direction of wire drawing. **Torsion breaks** can occur in both single and multi-wire drawing machines when there is contact between moving wires. **Cuppy wire** breaks occur because of central bursting, but because there are so many different factors involved it will be discussed in the next Properzi Tech News. *by Horace Pops*

Tensile Break

Macroporosity

Inclusion Absent