

## About the Author/JOE GREENSLADE

Joe Greenslade is President of Greenslade & Company, Inc. in Fort Worth, Texas, a supplier of fastener inspection products, inspection software, and ISO 17025 (A2LA) accredited calibration services. He also provides a variety of consulting services including serving as Expert Witness in fastener related litigations.

Joe has been in the fastener industry in a variety of capacities since 1970. He has written over 220 fastener technology related articles and has spoken to many fastener industry organizations throughout the United States. Joe has been awarded 12 U.S. Patents for fastener inspection devices.

Joe is an active member of the American Society of Mechanical Engineers (ASME), the American Society for Testing and Materials (ASTM), the National Fastener Distributor's Association (NFDA), and a member of the Board of Directors of the American Association for Laboratory Accreditation (A2LA). He is a former member of the Industrial Fasteners Institute (IFI). He was a member of the Fastener Quality Act Task Force representing the fastener industry. Joe also serves on the Screw Thread Improvement Task Force working with government and industry to improve aerospace related thread specifications, and thread gaging and calibration procedures.



# Here Is What a Hydrogen Embrittlement Failure Really Looks Like

**T**he picture of the broken zinc plated socket head cap screw in this article is a great example of what a typical hydrogen embrittlement failure looks like. I thought this would be a good example to share with readers because the discussion of hydrogen embrittlement comes up so often, but most people in industry do not know what a real hydrogen embrittlement failure looks like.



There are several classic indicators of a real hydrogen embrittlement failure. If any of these factors are missing, then the failure must be attributable to something other than hydrogen embrittlement. These five characteristics are:



1. The failure must be a DELAYED failure. The delay is generally from one to 24 hours after installation. If the failure occurs during installation, it is definitely NOT caused by hydrogen embrittlement.

If the delay is a week or later after installation, the cause is probably stress corrosion and not hydrogen embrittlement. The failure modes and metallurgical appearances are identical in stress corrosion failures and hydrogen embrittlement failures. The primary indication of stress corrosion is that the delay is longer than 24 to 48 hours after installation. More details on stress corrosion will be dealt with in a later article.

2. The fasteners must be hardened to at least Rockwell C37. Unhardened fasteners never suffer from hydrogen embrittlement. Fasteners that have a hardness of Rockwell C36 or less are extremely unlikely to ever suffer from hydrogen embrittlement.

The greater the fastener's hardness above Rockwell

C36, the greater the chance that the part will experience a failure attributable to hydrogen embrittlement. Inch socket head cap screws, L-9 bolts, metric property class 12.9 screws and bolts, and spring steel washers and roll pins are the common fasteners which are most susceptible to hydrogen embrittlement failures because of their high hardness.

3. The failed parts must be electro-plated. The creation of the hydrogen in the metal fastener is caused by the cleaning processes where acids are used and not by the actual application of the plating. I have heard of many cases where non-electroplated parts were suspected of hydrogen embrittlement, but I am not aware of any that were confirmed to have failed from hydrogen embrittlement.

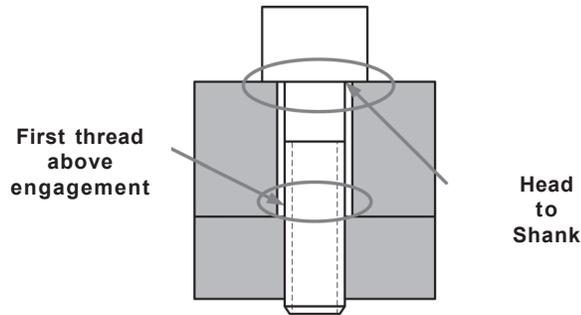
4. The appearance must be that of an "intergranular" failure. Look closely at the surface of the broken areas in the photograph in this article. The surface of the failure looks relatively smooth with a texture that looks like the surface of emery cloth. If you look at it under magnification, you see that the surface has a crystalline appearance with many sharp faces or facets. Some describe the appearance as being similar to broken rock candy.

A bolt or screw failure caused by excessive torque or tensile stresses produces a failure surface that has peaks and valleys in it which is referred to as "dimpling." This is also technically referred to as a "ductile" failure as opposed to a "brittle" failure which is characteristic of a hydrogen embrittlement failure. If you look at the failure surface of a bolt or screw failure surface that has peaks and valleys and/or a swirling appearance. The failure is highly unlikely to be attributable to hydrogen embrittlement.

5. The failure location is either where the fastener's head connects to the body or in the threads within two thread pitches above where the bolt's thread engages the mating thread.

In the case of head to shank failures, it frequently looks like someone used an ice cream scooper to scoop the shank out of the underside of the heads, as is the case in the pictured part.

If the hydrogen location is somewhere other than one of these two locations, then hydrogen embrittlement is probably not the culprit. Hydrogen embrittlement



failure always occurs where the stress concentrations are the greatest. If the bolt is absolutely straight when tightened, the failures will generally be where the fastener head joins the body. If there is any lack of straightness or bending action in the application, the failure will most likely fail in the thread just above the thread engagement.

When investigating reported fastener failures, keep in mind that for the failure to be attributable to hydrogen embrittlement, ALL FIVE of the characteristics listed above must be present. If any one of the above are not associated with the failure, it is extremely unlikely that hydrogen embrittlement is the culprit.

The best insurance against ever experiencing a hy-

drogen embrittlement failure is to avoid the factors that make hydrogen embrittlement failures possible by doing the following:

1. Do not electro-plate inch socket head cap screws, L-9 bolts, or metric property class 12.9 bolts or screws.

2. If customers insist on using electro-plated bolts and screws, suggest they consider using a Grade 8 or property class 10.9 part of a slightly larger diameter instead of using the socket head cap screw or property class 12.9 part.

3. If the customer insists on using an electro-plated socket head cap screw or property class 12.9 part, specify that the parts must be baked at 375-400 degrees F within one hour after plating for at least four hours "at temperature."

Also, conduct one of the recognized hydrogen embrittlement tests on every lot of parts to provide you the opportunity to catch hydrogen embrittlement before it is exhibited in the user's application.

4. If you must electro-plate any type of tapping screw, specify to the heat treater that the core hardness of the screws must not exceed Rockwell C36.

If you will adhere to the preceding suggestions, you will greatly improve your odds of never having to refer to this article to see if your customer's failure looks like the picture in this article.

For more information on the subject or any other fastener quality assurance, gaging, or calibration matter, contact the author at 800-435-2647 by phone or by email at [greensladeandcompany@sbcglobal.net](mailto:greensladeandcompany@sbcglobal.net). ☐