Hydrogen Embrittlement Testing Can Prevent Big Losses

About the Author

JOE GREENSLADE

Joe Greenslade is president of Fastener Inspection Products, Greenslade and Company and Tarrant Machinery Exchange, Inc. All three firms sell exclusively to fastener manufacturers and distributors throughout North America. Greenslade has held positions in major fastener forms in sales, applications engineering, research and development, sales management and general management. He has authored several articles and a book on fastener-related topics. Greenslade feels strongly that greater emphasis on quality assurance on the part of fastener manufactuers, importers, distributors and users is a must in the future for the survival of American industry.

Hydrogen embrittlement is one of the worst problems that can occur in fasteners. Its appearance is frequently devastating since it only becomes evident after screws are put under stress by being assembled into a product. Hydrogen embrittlement failure in screws therefore generally causes additional losses in terms of rework or scrapped products.

The typical failure is a part which breaks where the head meets the shank or where the thread runs out on the part. This occurs within 24 hours after assembly, but *not* at the exact time of assembly. *Hydrogen embrittlement is a delayed failure.* The material will have a crystalline appearance at the break.

Commercial categories of fasteners susceptible to hydrogen embrittlement failure are electroplated parts which are Rockwell C 32 or greater in hardness. This category includes all tapping screws, spring lock washers, Grade 8 bolts, and all socket cap screw products.

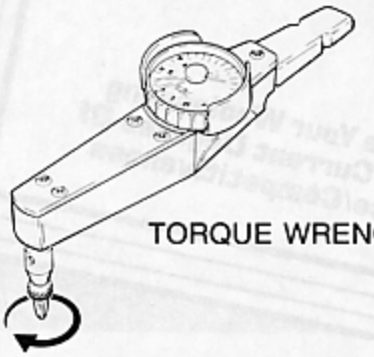
All of these types of products should be baked within one hour after electroplating to help eliminate hydrogen embrittlement. Your specification should read, "Bake at 400 degrees F. for 4 hours *at temperature*." It is important that the parts be *at* temperature a full 4 hours and not just in the oven for 4 hours.

This procedure still does not insure that the hydrogen has been eliminated. This author knows of an instance in which the parts had to be baked 12 hours to eliminate failures in a particular lot of threadrolling screws.

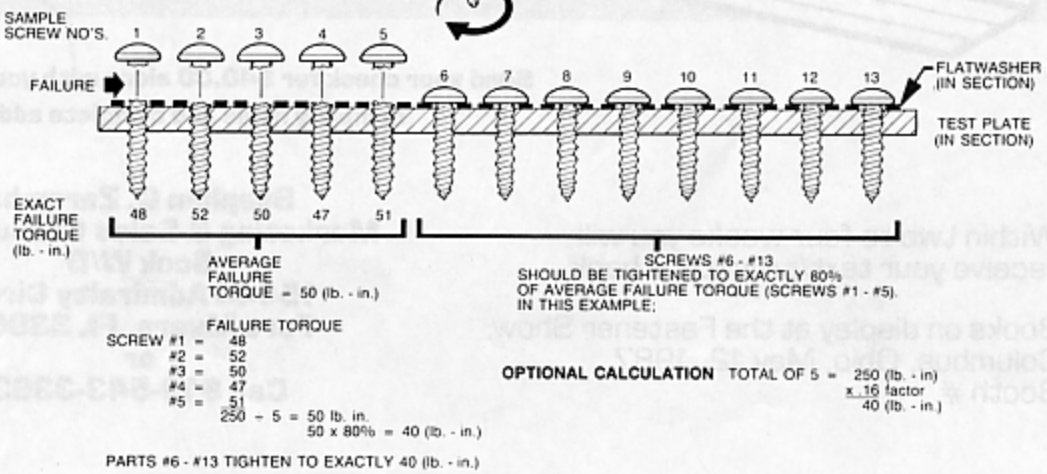
All hardened-electroplated parts, even those which have been baked, should be tested. There is no known test which will indicate that parts have hydrogen embrittlement prior to use except for the "simulated application" test described in the following paragraphs. The test concept is the same for all types of parts.

The test concept is to place parts under the most stress practical for the design in a simulated application. This stress is generally achieved by tightening a fastener to a particular or calculated torque value. Allow the parts to sit 24 hours under stress and then retighten. If any parts break prior to or when retightening hydrogen embrittlement is present and the parts should be rebaked and retested until the test is passed before use. In no case should parts exhibiting this kind of failure in this kind of test be used in actual application because of the potential problems which may occur.

please turn to page **138**



TORQUE WRENCH



HYDROGEN, *from page* **36**

The specific test procedures are as follows:

TAPPING SCREWS

1. Place flat washers on 13 parts and start them into the test plates as specified in I.F.I., S.A.E., A.N.S.I., F.I.P., etc, but do not seat.
2. Tighten the first 5 screws to their failure torque and record the values. Calculate the average failure value and multiply that by .80 (80%) to establish the "Test Tightening Torque." NOTE: A shorter method is to multiply the sum of the five failure values by .16 (16%).
3. Tighten the remaining 8 parts to the "Test Tightening Torque" and allow to sit for 24 hours.
4. At the end of 24 hours retighten to the same value as used in step #3. If any parts break before or during retightening, hydrogen embrittlement is present. Parts should be rebaked and retested until this test is passed.

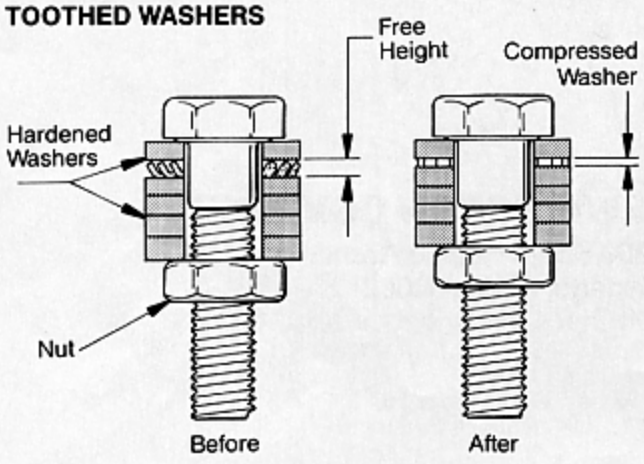
NOTE: This is the test described in GM6110, 6170, 6171, and 6172. The reason for breaking 5 parts by seating them is to simulate an application failure by determining the maximum stresses in the torque-tension relationship for a particular lot. The torque-tension relationship in each application varies depending upon the finishes of the mating parts, the condition of the bearing surfaces and, in the case of tapping screws, the hole size, thickness of material, and thread configuration.

Because there are so many variables involved in tapping screws it is more practical to derive the optimum seating torque for each lot of fasteners as described above instead of using predetermined values based on one particular set of variables. To over-simplify the test by the use of a single set of values would mean that many parts would be under too much stress, indicating false rejects, or that not enough stress would be created, allowing bad parts to pass.

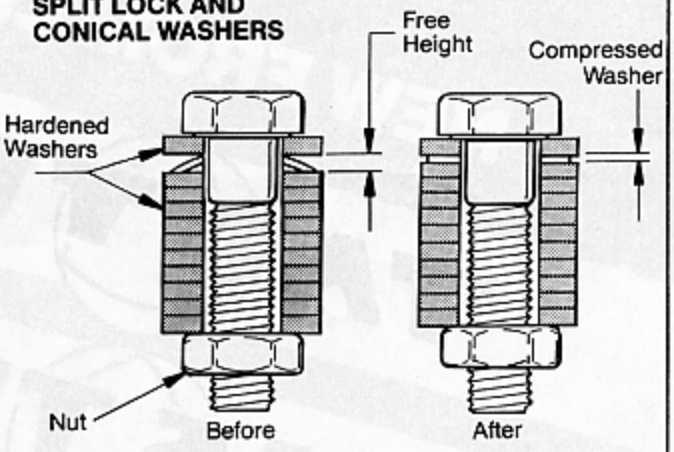
LOCK WASHERS

1. A washer should be placed between 2 hardened flat washers with a bolt passing through all three. Assemble a nut on the bolt or thread the bolt into a test plate. A minimum sample size of 8 is recommended.
2. Tighten the nut as stated below and allow to sit 24 hours.
   A. Toothed washers are to be clamped to a height of material thickness plus .005 inch.
   B. Split lock and Conical washers are to be compressed flat.
3. Loosen the nut after 24 hours. If the washer is fractured hydrogen embrittlement is present and parts should be baked and retested until the test is passed.

TOOTHED WASHERS

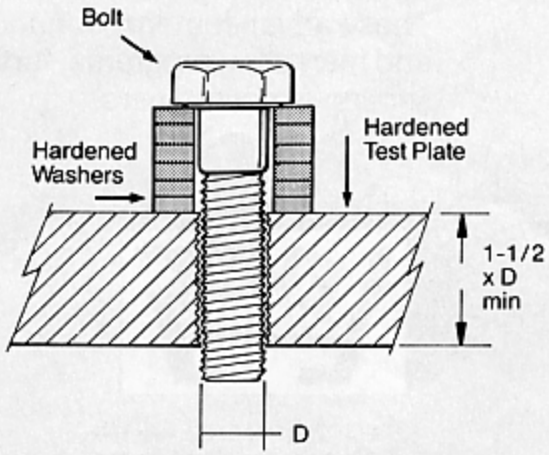


SPLIT LOCK AND CONICAL WASHERS



GRADE 8 BOLTS AND SOCKET CAP SCREW PRODUCTS

1. Hardened washers and/or spacers should be placed on a minimum of 8 pieces and they should be driven into a 2B tapped and hardened test plate having a minimum thickness of 1-1/2 times the screw or bolt diameter. The washers or spacers should be of a sufficient combined thickness so the stress on the bolt is concentrated on the underside of the head and not a shoulder or radius.
2. Tighten the parts to the values in the chart below with a laboratory grade torque wrench being accurate within +/-2%. These values are recommended assembly tightening values to achieve a stress in the bolt equal to 75% of its proof load. When testing parts not on this chart, tighten 5 pieces with hardened washers under their heads in 2B nuts and tighten to screw or bolt failure. Calculate the average failure torque and multiply that figure by .80 to determine the "test tightening torque." Conduct the test in the hardened plates. Allow to sit 24 hours.
3. Retighten to the charted values after 24 hours. If any part breaks before or while retightening, hydrogen embrittlement is present and the part must be rebaked and retested until this test is passed.



please turn to page **140**

HYDROGEN, *from page* 138

RECOMMENDED HYDROGEN EMBRITTLEMENT TEST TIGHTENING TORQUE GRADED BOLTS AND SOCKET HEAD CAP SCREWS

SIZE	Gd 8		S.H.C.S.	
	in. lb.	ft. lb.	in. lb.	ft. lb.
1/4-20	160	13	175	14
1/4-28	200	16		
5/16-18	330	27	220	27
5/16-24	440	33		
3/8-16	660	55	600	50
3/8-24		66		
7/16-14		94		88
7/16-20		105		
1/2-13		135		125
1/2-20		155		
9/16-12		190		
9/16-18		220		
5/8-11		270		250
5/8-18		300		
3/4-10		460		440
3/4-16		500		

A single hydrogen embrittlement failure can be disastrous to a user and in turn to his supplier. Settlements as high as $50,000 have been awarded to users against suppliers whose screws had hydrogen embrittlement failure resulting in the reworking of thousands of major assemblies.

These tests are simple to perform and easy to interpret. The detection of hydrogen embrittlement failure prior to actual assembly can save end users and suppliers big losses in terms of rework, scrap, downtime and possible litigation.

It is the author's opinion that thousands of cases of hydrogen embrittlement failure occur each year but the true cause is unknown because the end user and in many cases his supplier do not recognize the problem. Most users want to investigate strength and hardness when a failure of this kind occurs. Both will usually be article to see for themselves. Believe it. It is real. Beware!

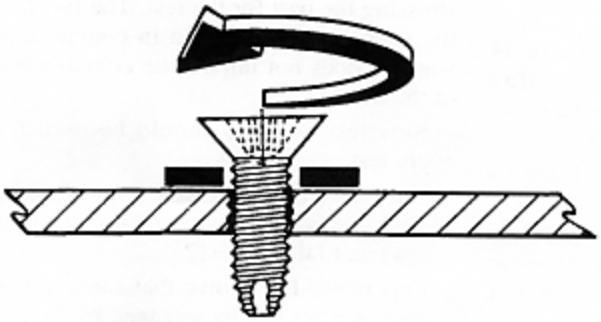
More Suggestions On Hydrogen Embrittlement Testing of Tapping Screws

By Joe Greenslade

All electroplated tapping screws should be tested for hydrogen embrittlement. Hydrogen embrittlement failures are costly yet preventable phenomenon that sometimes occur in screws, such as tapping screws, that are hardened to Rockwell C 36 or greater and then electroplated. These failures are characterized by the screw heads breaking from their shanks an hour or more after they have been driven into a product assembly. It is important to understand that hydrogen embrittlement failures are "delayed" failures. When screws break during assembly, the problem is always something other than hydrogen embrittlement.

Failures are characterized by the screw heads breaking from their shanks an hour or more after they have been driven into a product assembly.

The best way to avoid hydrogen embrittlement failures is to always specify that all electroplating tapping screws must be baked within one hour after plating at 400 degrees Fahrenheit for a minimum of four hours. This stipulation should be a part of all purchase orders for finished parts and a part of all orders to platers when tapping screws are sent out for electroplating. Screw suppliers must realize that the additional few cents per pound added to plating costs for baking is cheap insurance against a hydrogen embrittlement failure that can create a liability claim costing many thousand of dollars.



The only effective way to test for hydrogen embrittlement is to simulate a severe application and inspect the parts 24 hours after installation. There is no known short cut to testing for hydrogen embrittlement.

Past articles have explained the recommended hydrogen embrittlement test procedure, but because of the many frequently received questions the procedure will be reviewed again here. It addition to the past explanations of this procedure, suggestions on how to test countersunk head screws and how to try to salvage embrittled lots is covered.

Tapping Screw Hydrogen Embrittlement Test Procedure

1. Place one or more washers on the test screws.
2. Using a torque wrench, drive five screws into a certified tapping screw test plate until the screws break in two

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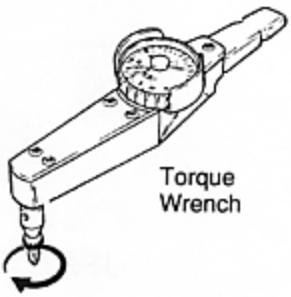
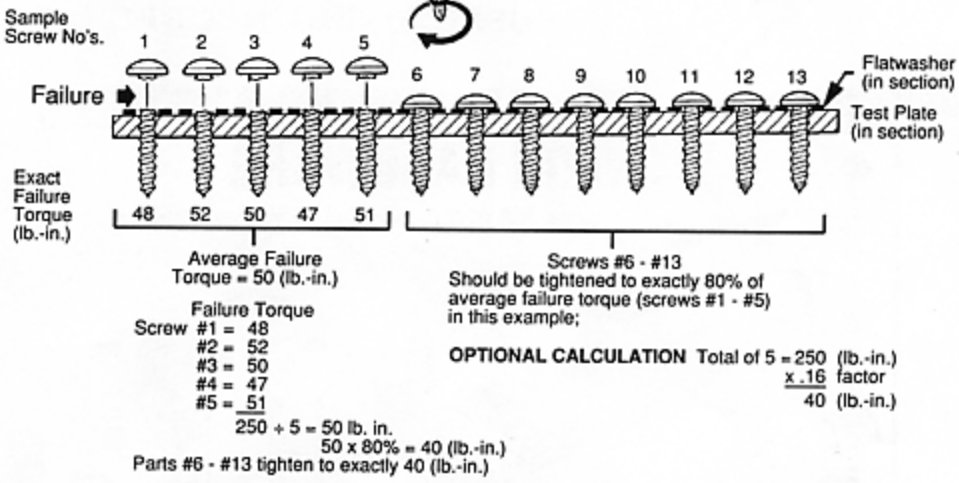




Joe Greenslade is President of Greenslade and Company, Inc. located in Rockford, Illinois. His firm specializes in providing manufacturing tooling and inspection equipment to suppliers of screws, bolts, rivets, and nuts throughout the world,

Joe is an inventor, author, and lecturer. He holds eleven U.S. Patents, has written over 80 technical articles for industrial trade journals, and has spoken frequently at trade association meetings and technical conferences on issues related to industrial quality for the past ten years.

He is an Associate Member of the Industrial Fastener Institute and a member of the American Society of Mechanical Engineers B1 Thread Specification Committee. In 1992, Joe was recognized for his technical and innovative contributions to the fastener industry when, at age 44, he became the youngest person to be inducted into the National Industrial Fastener Show "Hall of Fame."

Hydrogen Embrittlement

(Continued from page 59)

or the plate strips. Record all five failure values.

3. Calculate the average of the five values; multiply that average by 80%.
4. Seat a minimum of eight more screws with washers on them in the same plate at the 80% calculated value.
5. After the screws sit in the plate for 24 hours, apply the calculated seating torque to the screws again in the tightening direction.
6. If the any of the heads twist off, the lot should be rejected.

The question of what type of washers should be used is a common one. On non-countersunk heads (pan, truss, round, hex washer, etc.) split lockwashers make a good test washer because they are hard and they are readily available.

When testing countersunk head screws (flat and oval), it is not necessary to use countersunk washers. Use hardened flat washers if they are available. If not, soft flat washers are acceptable. What is important, is that enough washers are used to insure that the head-to-shank radius is not contacting the test plate when the screw is fully seated. By using this test procedure, the initial five piece test and calculation establishes the desired 80% torque-tension relationship for properly stressing the part for the test. The fact that the screws are not seated in countersunk washers does not impact the effectiveness of the test.

New test washers should be used for every test.

Another frequently asked question is, "What can be done with a lot of tapping screws that fail this test?"

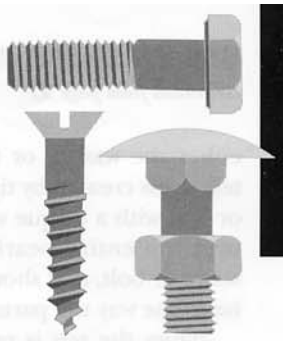
Experience has shown that some lots of tapping screws can be salvaged by the following procedure:

1. Strip the plating using as short a stripping cycle as possible.
2. Bake the stripped parts for a minimum of 4 hours at 400 degrees Fahrenheit.
3. Replate the screws.
4. Bake the lot for 24 hours at 400 degrees Fahrenheit.
5. Retest as described earlier, increasing the test sample size to a minimum of 250 pieces for lots up to 250,000.

If any part fail this test, the lot is probably not salvageable and should be scrapped.

Hydrogen embrittlement is a real potential problem for those supplying electroplated tapping screws. The procedures recommended above should be followed by fastener suppliers to help avoid the catastrophic failures which occur when customers find hydrogen embrittled screws in their completed assemblies. ❑

Use Washers When Testing Screws and Bolts For Hydrogen Embrittlement



by Joe Greenslade

Recently, more fastener suppliers have become convinced of the importance of testing electroplated, hardened screws and bolts for hydrogen embrittlement. The reason is simple: a single occurrence of a verified hydrogen embrittlement failure can result in damage claims as high as several million dollars.

Whether either the customer or the applicable specifications call for hydrogen embrittlement testing or not, I recommend suppliers either do the testing themselves or have the plater certify that hydrogen embrittlement testing has been performed. All electroplated tapping screws, electroplated socket products, electroplated metric property class 12.9 parts, or any fasteners having a core hardness over Rockwell C 36 should be tested.

Several past articles have described the recommended tests for hydrogen embrittlement. But, small over looked details can have a significant impact on the test results. One such small detail is the use of hardened washers under the heads of bolts and screws when performing hydrogen embrittlement tests.

The hydrogen embrittlement test can be performed using standard SAE hardened washers or split lockwashers. The thickness of the washer should be equal to or greater than two times the thread's pitch length. As an example, the thread pitch length of a 1/4-20 is .050 inches (1.000 inch divided by 20). Therefore, a 1/4-20 screw should be tested using a washer or stack of washers that are .100 inches thick or thicker. When washers are not used on the test parts the bearing surface of the parts will not properly seat on the top surface of the test plate. This happens because the head-to-shank radius interferes with the top thread in the test plate, thus keeping the parts from fully seating.

When the test is performed without using a hardened washer, the test torque might be reached without apparent failure, but all of the stress on the part will be concentrated on the radius. In many cases, the test part's radius will be cut or broken by this interference. This can result in erroneous delayed failures causing disputes between suppliers and purchasers.

Those interested in seeing the effects of the damage done to the parts tested without washers only have to drive a screw or bolt into a hardened test plate and seat them one time. Remove the parts and look at the head-to-shank radius under a 10X magnification; the damage to the radius will be obvious. The observed marks or cuts in the radius are referred to as "stress risers." These cuts or marks are where part failures are most likely to occur during testing because ultimate failure fractures will emanate from those small marks.

When the parts are seated on the hardened washers having a thickness two times the thread's pitch length the head-to-shank radius is not in contact with

continued on page 34

All electroplated tapping screws, electroplated socket products, electroplated metric property class 12.9 parts, or any fasteners having a core hardness over Rockwell C 36 should be tested.

Joe Greenslade has been active in the fastener industry since 1970. He has held positions with major fastener producers in sales engineering, marketing, product design, manufacturing management, and research and development management.

Mr. Greenslade holds twelve U.S. patents on various fastener related products. He has authored over 136 trade journal articles on fastener applications, manufacturing and quality issues. He is one of the fastener industry's most frequent speakers at trade association meetings and conferences. He is the youngest person ever inducted to the Fastener Industry Hall of Fame.

Mr. Greenslade is active in numerous fastener industry associations and societies holding office in several of them.

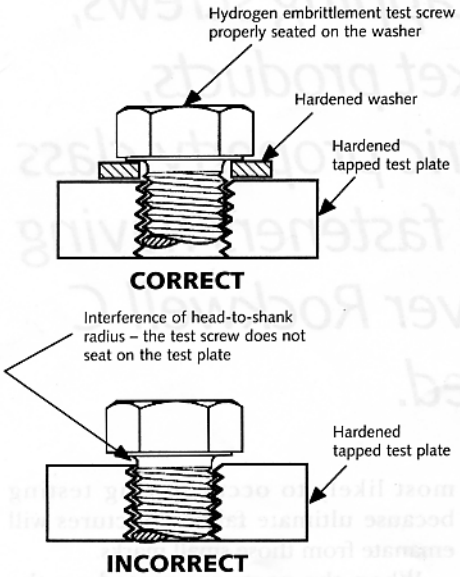
In addition to guiding the activities of Greenslade & Company, Mr. Greenslade works as a consultant with fastener suppliers and end users on product design, applications engineering, and quality issues. In this capacity he works to resolve fastener applications problems, to help select the best fastening approaches in new product designs, to assist in the standardization of fasteners used within an organization, and to provide training on various aspects of fastening technology and fastener quality assurance. He also serves as Expert Witness in litigation involving fastener related issues.

USE WASHERS WHEN TESTING

continued from page 33

either the washer or the test plate. The test stress created by tightening the screw or bolt with a torque wrench is dispersed over the entire bearing surface of the screw or bolt, as it should be. This is similar to the way the parts are actually used.

When the test is properly performed the parts are seated on hardened washers having the proper thickness to a torque equal to approximately 80 percent of the value required to break the parts when twisting them into two pieces. The parts should be left to sit for 24 to 48 hours and then a torque equal to that initially applied to the parts should again be applied in the tightening direction. If the parts break at the head-to-shank radius or where the thread engages the test plate, the parts are probably embrittled and should be rejected. If the torque can be re-applied without failure the parts are probably free of hydrogen and should be accepted.



Hydrogen embrittlement testing is an area where suppliers should not cut corners. One relatively small hydrogen embrittlement failure in the field can result in huge damage claims. When doing the test, use the correct equipment and follow every small procedural detail, including always using washers on the screws or bolts, to assure the validity of the test results. ■