Standards Topics

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Controversy Concerning ASTM B 849 & B 850

Some of you may be unaware that a controversy has arisen concerning the ASTM specification for reducing the risk of hydrogen embrittlement in metallic-coated articles, ASTM B 849 and B 850. In my September column, I alluded to the controversy and stated that I had been made a party to the controversy and, therefore, would not discuss it in this column.

Opponents of the ASTM standards, rather than allowing any perceived problems with the specifications to be corrected using the ASTM process, are trying to rally support by misquoting the specifications and citing outrageous consequences if they are used. To counter this program of disinformation, I am forced to address it here. ASTM has given me permission to reproduce portions of the standards to show what the specifications really require, and the benefits that come from their use.

The Origins

Before discussing the documents themselves, let me review the origins of the documents and the problems they were intended to address.

At the Spring 1979 meeting of ASTM Committee B08, the representative of the National Association of Metal Finishers, Francis O'Dell, reported to the Executive Committee the problems being encountered by plating shops with treatments for hydrogen embrittlement relief.

O'Dell pointed out that ASTM B 242, Practice for Preparation of High Carbon Steel for Electroplating, in clause 6.3, recommended that all hardened high-carbon steel parts receive a low-temperature heat treatment for 30 min at a temperature of 205 °C. There was no temperature tolerance to take into account for the approximately 15 °C (25 °F) variation that occurs in most commercial ovens, nor was there any provision to start the timing of the treatment from the time at which the part reaches temperature.

It should be noted that this Practice, B 242, was first issued in 1949. It was amended with additional information in 1953 and revised in 1954. Since that time, it has been reapproved without change.

O'Dell also pointed out that B 242, in clause 9.2, stated that "The hydrogen may be largely removed and the physical properties of the steel substantially restored by heating, for example, 1 to 5 hours at temperature in an oven maintained at a temperature of 150 to 260 °C." (303 to 500 °F) The quote goes on to say, "the temperature and length of treatment depends on the severity of embrittlement, the cross section of the article, the requirements of the steel, and the kind and thickness of the electrodeposited coatings. The baking should be done as soon as possible after electroplating, and before any supplementary chemical treatment of the electroplated surfaces. The best time and temperature in some cases must be established experimentally."

O'Dell went on to point out that many manufacturers had, as ASTM B 242 advises, experimentally determined

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Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement[1]

This standard is issued under the fixed designation B 849; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers procedures for reducing the susceptibility or degree of susceptibility to hydrogen embrittlement or degradation that may arise in electroplating, autocatalytic plating, porcelain enameling, chemical conversion coating, and phosphating and the associated pretreatment processes. This specification is applicable to those steels whose properties are not affected adversely by baking at 190 to 230°C or higher (see 6.1.1).

1.2 The heat treatment procedures established herein have been shown to be effective for reducing the susceptibility of steel parts of tensile strength 1000 MPa or greater that have been machined, ground, cold-formed, or cold-straightened subsequent to heat treatment. This heat-treatment procedure is used prior to any operation capable of hydrogen charging the parts, such as the cleaning procedures prior to electroplating, autocatalytic plating, porcelain enameling, and other chemical coating operations.

NOTE 1—1 MPa = 145.1 psi.

1.3 This specification has been coordinated with ISO/DIS 9587 and is technically equivalent.

[1] This specification is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.02 on Substrate Preparation.
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Fig. 1—Title and scope of B 849-94. Reprinted with permission of ASTM.

the best time and temperature for their parts. Temperature adjustments to the oven, therefore, became impossible to keep up with because of the wide variety of times and temperatures being specified on part drawings.

After considerable discussion, the executive committee agreed that this subject should be studied by B08 with a view to producing a suitable document to cover the baking treatments. Chairman Joffe assigned the project to Subcommittee 2 on Substrate Preparation, which I was then chairing. In turn, I set up Section 14 of Subcommittee 2 to address hydrogen embrittlement baking.

Discussions continued between O'Dell and me. The result was he supplied me with a very large volume of drawings to illustrate the varieties of drawing call-outs. A number of members supplied the call-outs that their companies were using. I began a literature search for further information concerning baking treatments to avoid hydrogen embrittlement.

The literature search, the contributions from O'Dell and from the other members resulted in a list of 34 stress relief baking treatments and 61 hydrogen embrittlement relief treatments. As an example, the following call-outs (in °F) were cited for stress relief of steels of tensile strength greater than 260, 000 psi (1800 MPa): 415 ± 25, 415 +30 -25, 400 +30 -25, 410 +30 -25, 375 to 425, 380 to 430, and 420 ± 25. These were rationalized to the metric value of 200 to 230 °C.

At the 1979 meeting of ISO/TC 107 in May in Camogli, Italy, I reported to the member countries that we at ASTM B08 were working on a new document for stress relief and hydrogen embrittlement relief, and agreed to keep the ISO committee informed.

At the Spring 1980 meeting of ASTM B08, I advised the executive committee that the hydrogen embrittlement project involved so much time that I needed to have someone else chair Subcommittee 2, so that I could do the embrittlement project. George DiBari agreed to take on that job.

Section 14 of SC 2 met for the second time in April of 1980 with the following members present: Joe Andrus, Allan Brooks, Stanley Brown, George DiBari, Jack Horner, Irv Ireland, Ed Jankowski, Boris Joffe, Abner Kayser, Francis O'Dell, Konrad Parker, Charlie Sanborn, Ed Seyb, and Joe Zehnder. The objective was to produce a Practice for Stress Relief and Embrittlement Relief Baking. Allen Brooks proposed that two documents be prepared—one for stress relief baking and one for embrittlement relief baking to avoid any confusion between the two operations. The members agreed. Our task was then to take this enormous number of call-outs actually used on drawings—34 for stress relief and 61 for embrittlement relief—and reduce them to a manageable group, free of any redundancy.

4. Requirements

4.1 Heat treatment shall be performed on basis metals to reduce the risk of hydrogen embrittlement in accordance with Table 1. The duration of heat treatment shall commence in all cases from the time at which the whole of each part attains the specified temperature.

4.2 Parts made from steel with actual tensile strengths ≥ 1000 MPa (with corresponding hardness values of 300 HV_{10kgf}, 303 HB, or 31 HR_c) and surface-hardened parts shall require heat treatment unless Class SR-0 is specified. Preparation involving cathodic treatments in alkaline or acid solutions shall be avoided.

4.3 Table 1 lists the stress-relief heat-treatment classes to be specified by the purchaser to the electroplater, supplier, or processor on the part drawing or purchase order. When no stress relief treatment class is specified by the purchaser, Class SR-1 shall be applied (see Note 4).

NOTE 2—The treatment class selected is based on experience with the part, or similar parts, and the specific alloy used or with empirical test data. Because of factors such as alloy composition and structure, size, mass, or design parameters, some parts may perform satisfactorily with no stress relief treatment. Class SR-0 treatment is therefore provided for parts that the purchaser wishes to exempt from treatment.

NOTE 3—The use of inhibitors in acid pickling baths is not necessarily guaranteed to minimize hydrogen embrittlement.

NOTE 4—Class SR-1, the longest treatment, is the default when the purchaser does not specify a class. The electroplater, supplier, or processor is not normally in possession of the necessary information, such as design considerations, induced stresses from manufacturing operations, etc., that must be considered when selecting the correct stress relief treatment. It is in the purchasers' interest that their part designer, manufacturing engineer, or other technically qualified individual specify the treatment class on the part drawing or purchaser order in order to avoid the extra cost of the default treatment.

TABLE 1 Classes of Stress Relief Requirements for High-Strength Steels (See Sections 4 through 6 for Details on the Use of Table 1)

Class	Stress-Relief Heat-Treatment Classes for High-Strength Steels		
	Steels of Tensile Strength (R_m), MPa	Temperature, °C	Time, h
SR-0	not applicable		
SR-1	over 1800	200–230	min 24
SR-2[A]	over 1800	190–220	min 24
SR-3	1401 to 1800	200–230	min 18
SR-4[A]	1450 to 1800	190–220	min 18
SR-5[A]	1034 or greater	177–205	min 3
SR-6	1000 to 1400	200–230	min 3
SR-7[A]	1050 to 1450	190–220	min 1
SR-8	surface-hardened parts ≤ 1400	130–160	min 8

[A] Classes SR-2, SR-4, SR-5, and SR-7 are traditional treatments used in Federal Standard QQ-C-320. They do not apply to any other standard.

Fig. 2—The requirements for B 849-94. Reprinted with permission.

ASTM-ISO Cooperation

Two weeks later the ISO/TC 107 Committee met in Philadelphia. The U.K. Secretariat of TC 107/SC 3 proposed that an ISO Working Group be formed to prepare guides to stress relief baking and hydrogen embrittlement relief baking. This proposal was acceptable to all the delegates and I was selected as the Convenor of the ISO Working Group.

The U.K. submitted an initial proposal for consideration, written by Dr. G. Paul Ray of the British Ministry of Defence. The proposal was shared with our B08.02.14 Section. It was immediately recognized by the B08 Section that the U.K. draft proposal, besides providing an excellent start, also provided a means of rationalizing the large number of treatment varieties into a smaller, more manageable set, and that a joint effort between ASTM B08 and ISO/TC 107 would be the fastest way to achieve documents that would be satisfactory to all.

Dr. Ray was invited to join ASTM B08, after which he and I crafted the documents in both ASTM and ISO formats, based upon input from members of both groups. It should be noted that many experts in hydrogen embrittlement from around the world provided valuable input and review.

The ISO Working Group on hydrogen embrittlement held its first meeting in May of 1982 in Berlin, West

Germany. First draft documents were prepared in both formats and balloted for comments in 1983. Based on the comments received, second draft documents were prepared and discussed at a joint ASTM and ISO Working Group meeting held in conjunction with the Second National Symposium on Test Methods for Hydrogen Embrittlement, Prevention and Control in Los Angeles, May 24-26, 1985.

At the meeting, the concept of treatment classes was endorsed. The major discussion centered on how much time could elapse between the final plating rinse and initiation of baking. It was agreed that most small parts could easily be treated within two hr (often within one hr); large parts, however, such as 16-in. naval guns, needed at least three hr to move to the ovens. It was determined that there was no conclusive evidence that shorter times should be required.

Mr. Kayser and Mr. Clegg, who both represented the U.S. military at B08, stated that the documents could not be used by the military if they remained practices. If the documents were written in specification format, however, the military could cite the document and class as a requirement, as they do in QQ-C-320, QQ-N-290 and QQ-P-416. Other commenters said that the mandatory language “shall” should be changed to “should” if the documents are to be a Practice, or to retitle the documents as Specifications. The second draft documents were published in 1988 in ASTM STP 962, Hydrogen Embrittlement: Prevention and Control, in order to provide a wider distribution of the drafts for comments.

At the next ASTM B08.02.14 meeting, it was agreed to recommend to our ISO counterpart that we put the documents in specification format. I personally supported that move based on my then-recent experience of being subpoenaed on two occasions to testify for platers regarding ASTM B 242 and hydrogen embrittlement failures.

In each of those cases, the parts had been made from high carbon steel that had also been cold-straightened. The plater had not been informed of these facts and consequently had not provided any stress relief baking or hydrogen embrittlement relief baking as advised by B 242. This made me realize that only the purchaser is in full possession of all the information concerning the tensile strength of the steel employed, the stresses imparted during fabrication and stresses the parts will be subjected to in their operating environment, as well as any materials changes that might occur. It is therefore absolutely necessary for the purchaser to specify any stress relief or embrittlement relief treatments the parts require. When this treatment is not specified by the purchaser, then the liability for any part breakage resulting from non-treatment or incorrect treatment selection falls on the plater.

At the next ISO/TC 107 meeting held in 1985 in Washington, DC, the ISO Working Group also agreed to revise the documents as specifications. Dr. Ray and I set about to the task. A class “0” was added so that the purchaser could specify that no treatments were to be performed. The addition of the Class 0 was brought about by a manufacturer of heavy chain. Its product, although surface-hardened to RC 45 and plated, was not detrimentally affected by the hydrogen embrittlement cracking of the surface, principally because of the massive size of the individual links. Classes were also introduced so that the major “traditional” treatments from MIL-C-320 could be included.

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Standard Specification for Post-Coating Treatments of Iron or Steel for Reducing the Risk of Hydrogen Embrittlement[1]

1. Scope

1.1 This specification covers procedures for reducing the susceptibility or degree of susceptibility to hydrogen embrittlement or degradation that may arise in the finishing processes.

1.2 The heat treatment procedures established herein have been shown to be effective for reducing susceptibility to hydrogen embrittlement. This heat-treatment procedure is used after plating operations but prior to any secondary conversion coating operation.

1.3 This specification has been coordinated with ISO/DIS 9588 and is technically equivalent.

NOTE 1—The heat treatment does not guarantee complete freedom from the adverse effects of hydrogen degradation.

Fig. 3—Title and scope of B 850-94. Reprinted with permission.

The last addition to the specifications was that of a default clause. A default was necessary so that when the purchaser specified the treatment by its specification number but failed to call-out the treatment class, the plater was not put in the position of choosing a class for the purchaser and thereby assuming the liability.

The ASTM versions of the specifications were completed and balloted. Advisory ballots were also sent to ASTM Committees A05, F07.04 and F16.03. The only comments received from the advisory ballot were from an individual in F07.04, which were accepted. In the ASTM B08 Committee, a negative vote was cast by the chairman of the chromium plating section who did not believe that the purchaser had the right to specify Class 0 with chromium plating. The specifications were delayed for two years while a suitable wording was worked out.

To summarize, two specifications have been produced. The first is a document that, when invoked by the purchaser, requires that the purchaser select a treatment class to be carried out by the plater. When the purchaser fails to select a treatment class, a default class is invoked. Nine stress relief baking treatments are listed, one of which could be used to specify that no treatment be applied.

The second is a document that, when invoked by the purchaser, requires that the purchaser select a treatment class to be carried out by the plater. When the purchaser fails to select a treatment class, a default class is invoked. Seventeen hydrogen embrittlement relief baking treatments are listed, one of which could be used to specify that no treatment be applied.

ASTM B 849

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4. Requirements

4.1 Heat treatment shall be performed on coated metals to reduce the risk of hydrogen embrittlement. The duration of heat treatment in all cases shall commence from the time at which the whole of each part attains the specified temperature.

4.2 Parts made from steel with actual tensile strengths ≥1000 MPa (with corresponding hardness values of 300 HV_{10kgf}, 303 HB, or 31 HR_C) and surface-hardened parts shall require heat treatment unless Class ER-0 is specified. Preparation involving cathodic treatments in alkaline or acid solutions shall be avoided. Additionally, the selection of electroplating solutions with high cathodic efficiencies is recommended for steel components with tensile strengths above 1400 MPa (with corresponding hardness values of 425 HV_{10kgf}, 401 HB, or 43 HR_C).

4.3 Table 1 provides a list of embrittlement-relief heat-treatment classes from which the purchaser may specify the treatment required to the electroplater, supplier, or processor on the part drawing or purchase order. When no embrittlement-relief treatment class is specified by the purchaser, Class ER-1 shall be applied (see Note 4).

NOTE 2—The treatment class selected is based on experience with the part, or similar parts, and the specific alloy used or with empirical test data. Because of factors such as alloy composition and structure, trap population density, size, mass, or design parameters, some parts may perform satisfactorily with no embrittlement-relief treatment. Class ER-0 treatment is therefore provided for parts that the purchaser wishes to exempt from treatment.

NOTE 3—The use of inhibitors in acid pickling baths is not necessarily guaranteed to minimize hydrogen embrittlement.

NOTE 4—Class ER-1, the longest treatment, is the default when the purchaser does not specify a class. The electroplater, supplier, or processor is not normally in possession of the necessary information, such as design considerations, operating stresses, etc., that must be considered when selecting the correct embrittlement relief treatment. It is in the purchaser's interest that his or her part designer, manufacturing engineer, or other technically qualified individual specify the treatment class on the part drawing or purchase order in order to avoid the extra cost of the default treatment.

TABLE 1 Classes of Embrittlement-Relief Heat Treatment (See Sections 4 through 6 for details on the Use of Table 1)

Hydrogen Embrittlement-Relief Treatment Classes for High-Strength Steels			
Class	Steels of Tensile Strength (R_m), MPa	Temperature, °C	Time, h
ER-0	not applicable		
ER-1	1701 to 1800	190–220	min 22
ER-2	1601 to 1700	190–220	min 20
ER-3	1501 to 1600	190–220	min 18
ER-4	1401 to 1500	190–220	min 16
ER-5	1301 to 1400	190–220	min 14
ER-6	1201 to 1300	190–220	min 12
ER-7[A]	1525 or greater	177–205	min 12
ER-8	1101 to 1200	190–220	min 10
ER-9	1000 to 1100	190–220	min 8
ER-10[A]	1250 to 1525	177–205	min 8
ER-11[A]	1450 to 1800	190–220	min 6
ER-12[A]	1000 to 1500	177–205	min 4
ER-13	1000 to 1800 unpeened items and for engineering chromium plated items	440–480	min 1
ER-14[A]	surface-hardened parts <1401	130–160	min 8
ER-15[A]	surface-hardened parts 1401 to 1800 plated with cadmium, tin, zinc, or their alloys	130–160	min 8
ER-16	surface-hardened parts <1401 plated with cadmium, tin, zinc, or their alloys	130–160	min 16
ER-17	parts >25-mm thickness and parts with threads or sharp notches	190–220	min 24

[A] Classes ER-7, ER-10, ER-11, ER-12, ER-14, and ER-15 are traditional treatments used in Federal Standard QQ-C-320. They do not apply to any other standard.

NOTE 6—The time period referred to is the length of time between the end of the plating operation and loading of the item concerned into the heat treatment processor.

Fig. 4—Requirements for B 850-94. Reprinted with permission.

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Figure 1 shows the title and the scope of the specification. In particular, the first sentence of clause 1.2 states that the heat treatment procedures have been shown to be effective for reducing the susceptibility of steels of 1000 MPa or greater that have been machined, ground, cold-formed, cold-straightened subsequent (after) heat treatment (tempering to hardness). What this tells us is that parts that have been hardened and then had stresses imparted to them by bending or straightening or grinding, etc., can have some or all of the stress removed by baking according to one of the treatment classes listed. Indeed, that *does not* automatically add 24 hr of treatment to every part. It may do so to a few parts, such as aircraft landing gear or other parts made from very high-strength steel. The purchaser will determine what is needed. As to those parts that invoke the default treatment of 24 hr; that is the lesser of two evils. The purchaser cannot use the ploy of not calling out the treatment class to place the product liability responsibility on the plater. Enough platers have been sued over treatment issues to recognize that they are not responsible for selecting the treatment, nor do they have sufficient information or data to make the choices.

Figure 2 shows Clause 4, the requirements of the specification. In particular, clause 4.3 states that Table 1 lists the stress-relief heat-treatment classes to be specified by the purchaser to the electroplater, supplier or processor on the part drawing or purchase order. It states that when no treatment class is specified by the purchaser, Class SR-1 shall be applied. Note 4 explains that Class SR-1 is the longest treatment (24 hr) and that the electroplater, supplier or processor is not normally in possession of the necessary information that must be considered in selecting the correct treatment. The note further states that it is in the purchaser's best interest to have one of their technically qualified individuals specify the treatment to avoid the extra cost of the default treatment. Note 2 informs the reader that selection can be based on experience with the part or empirical test data, and that some parts may perform satisfactorily without any treatment.

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Figure 3 shows the title and the scope of the specification. In particular, the first sentence of clause 1.2 states that the heat treatment procedures established herein have been shown to be effective for reducing susceptibility to hydrogen embrittlement. It should be noted that there is really nothing new about the procedures. The basic baking temperatures have been in continuous use since the late 1930s, and were employed by government arsenals during World War II. They were later codified as requirements in the Federal specification system at the end of the war.

What we have done here is taken the 61 varieties of temperature range and rationalized them into a single metric value of 190–220 °C (374–420 °F). The initial use of this treatment in the 1930s was for four hr. As higher strength steels came into use, baking times were extended. MIL-C-320 has three-, eight- and 12-hr embrittlement relief baking requirements, and MIL-STD 1501 has 23-hr baking requirements. What was done in this specification was to gather all of the treatments actually used in the industry and codify them for the purpose of call-out on drawings and purchase orders.

Figure 4 shows Clause 4, the requirements of the specification. In particular, clause 4.3 states that Table 1 lists the embrittlement relief heat-treatment classes from which the purchaser may specify the treatment required to the electroplater, supplier or processor on the part drawing or purchase order. When no embrittlement relief treatment class is specified by the purchaser, Class ER-1 shall be applied. Note 4 explains that Class ER-1 is the longest treatment (22 hr) and that the electroplater, supplier or processor is not normally in possession of the necessary information that must be considered in selecting the correct treatment. The note further states that it is in the purchaser's best interest to have one of their technically qualified individuals specify the treatment to avoid the extra cost of the default treatment. Note 2 informs the reader that selection can be based on experience with the part or empirical test data, and that some parts may perform satisfactorily without any treatment.

The opposition to these specifications—those asking that they be withdrawn—is led by a representative of a fastener manufacturer with support coming from some platers who do plating for them. This is particularly curious because the specifications do not address threaded fasteners. We had considered adding treatment classes for threaded fasteners and had asked the ASTM F16.03 Subcommittee on Coated Fasteners to supply us with treatments actually used. None was forthcoming over the five-year period that we pressed for them, so they were not addressed in the specifications.

My own experience at IBM Corporation has been that there are a few fastener manufacturers who do not use stress or embrittlement relief treatments as part of their process and yet have supplied fasteners seemingly free of any embrittlement. There are some fastener manufacturers that regularly use these treatments as part of their process, and have supplied IBM with fasteners seemingly free of any embrittlement. Fastener manufacturers who were unwilling or unable to control their processes to eliminate embrittled fasteners were dropped in favor of those who could meet the requirements.

These specifications, which only come into force when invoked by the purchaser or some other document, will help both the purchaser and the plater, particularly in meeting ISO 9000 certification requirements. The purchasers need to control their processes so that parts susceptible to hydrogen embrittlement can be successfully treated by the plater, who will also use a controlled process that may or may not include stress and embrittlement relief treatments. Purchasers need to determine that, when required, baking treatments specified to the plater will consistently restore the parts to the specified quality level. Any questions as to the invocation of these specifications should be addressed to the party or document concerned. ***P&SF***