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*Inquiries about the Manufacture and Use
of High Performance Steel,
Grades HPS 70W and HPS 50W for Bridges,
Plus Other Steel Related Topics*

Responses to Inquiries by
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Inquiry 1

December 1999

INQUIRY: Can HPS 70W be heat curved?

RESPONSE: Tests were conducted as part of a Federal Highway Administration demonstration project to determine the effects of localized, short term applications of heat up to 1250⁰F on HPS 70W steel using routine shop practice defined by the *Standard Specifications for Highway Bridges*, Sixteenth Edition. These tests indicated that localized, short term, applications of heat for purposes of heat curving, camber correction or sweep correction had no apparent effect on ultimate strength, yield strength, elongation or Charpy V-notch toughness of HPS 70W steel. Currently, the *Guide for Highway Bridge Fabrication with HPS 70W Steel*, a supplement to ANSI/AASHTO/AWS D1.5-95, recommends limiting application of heat to 1100⁰F.

Be aware that one fabricator's experience suggests that some additional heats may be necessary to obtain a given camber/sweep, when compared to conventional Grade 50W steel. However, please keep in mind that individual fabrication techniques may have a direct bearing on this experience.

Inquiry 2

January 2000

INQUIRY: What base metal should be used when conducting welding procedure qualification tests using undermatched consumables.

RESPONSE: The *Guide for Highway Bridge Fabrication With HPS 70W Steel*, a supplement to the ANSI/AASHTO/AWS D1.5-95, *Bridge Welding Code*, recommends that filler metals for all full penetration groove welds joining Grade HPS 70W base metal to Grade 50W base metal, and filler metals for all fillet welds conform to the requirements of AWS D1.5, Table 4.1 for ASTM A709, Grade 50W base metal.

Since the acceptance criteria for undermatched weld metal is based on the requirements for welding Grade 50W base metal, it is my opinion that the base metal for the welding procedure qualification tests could be either Grade HPS 70W, Grade 50W or a combination of both base metals, at the contractor's option, providing the tests conform to all other provisions of the governing specifications, to the satisfaction of the owner or his authorized representative.

Inquiry 3

January 2000

INQUIRY: What tests are required to qualify tack welding HPS 70W steels using the Gas Metal Arc Welding process?

RESPONSE: It is my opinion that the GMAW process can be allowed for remelted tacks based on satisfactory performance of a series of fillet weld soundness tests as described in Figure 5.8 of AWS D1.5, exactly duplicating the work to be done. This includes the following:

- Weld a minimum of two specimens using the proposed GMAW consumables, i.e., one each at high and low heat input parameters to establish GMAW process tolerances and tack weld size restrictions.
- The base metal must be Grade HPS 70W with thicknesses as described in AWS D1.5-95.
- Demonstrate that the GMAW tack weld will be remelted by the submerged arc welding process by welding over the tack welds using the approved consumables for making fillet welds, with the welding equipment adjusted to the parameters for minimum heat input.
- Test as required by AWS D1.5-95, including macroetched specimens.
- All welders or tack welders must be certified in accordance with AWS D1.5 for the type of weld and position to be used in the work.

It is understood that this response applies only to tack welds to be remelted by the submerged arc welding process. Other tack welds not remelted by the SAW process must be done by procedures qualified in accordance with the contract documents. Further, I suggest that you propose these recommendations to the bridge owner, or his authorized representative, for consideration.

Inquiry 4

February 2000

INQUIRY: Can we use GMAW tacks that are remelted into the [tandem] SAW welds [for flange to web fillet welds joining Grade 50 to HPS 70W steel]?

RESPONSE: AWS D1.5, Article 3.3.7.2 states, “Tack welds which are incorporated into the final weld shall be made with electrodes meeting the requirements of the final welds....”. Further, AWS D1.5, Article 4.1.5.3, Gas Metal Arc Welding, states, “Single pass fillet welds up to 5/16” maximum ... may be made using an E70S-X electrode conforming to ... Table 4.2”. It is my understanding that you intend to tack weld combinations of Grade HPS 70W and Grade 50W flanges and webs in preparation for making final tandem SAW flange to web fillet welds. Your proposal to use the GMAW process, and specifically, ER70S-6 classification consumables, appears to conform to these specification requirements. AWS D1.5, Article 5.11.1, Prequalified Tack Weld WPS states, “WPS’s for tack welds which are completely remelted by subsequent SAW shall be exempt from WPS qualification as otherwise required by this code.” Further, AWS D1.5, Section 12, AASHTO/AWS Fracture Control Plan for Nonredundant Members, Table 12.2, provides that the GMAW process may be used for tack welding without the Engineer’s approval. When the tack welds are remelted by the SAW process, a WPS is not required, and there are no leg size, length or preheat requirements. I recognize that the work that you are doing does not require conformance with the referenced Fracture Control Plan, but nonetheless meets the referenced requirements.

As further evidence that the SAW process completely remelted the GMAW tack welds, a fillet weld macroetch test plate and fillet weld break test was welded using mean parameters for both the GMAW process and the SAW process to be used in the work. The test plate consisted of a 1” thick HPS 70W TMCP flange plate, with a ½” thick Grade 50W web, both 12’ long and configured similar to that shown in AWS D1.5, Figure 5.21-Option 1. The simulated GMAW tack welds were intermittent, each about 3” long. A tandem SAW process was used to make the final SAW single pass fillet weld. A specimen was then taken thru the final weld and tack weld. Macroetched test results indicated that the tack weld was completely remelted, with acceptable weld profile and good fusion to the base metal. Further, the fillet weld break test provided a fractured surface along the weld throat, with uniform appearance and no tears.

Based on the [witnessing of testing as described previously, and satisfactory test results as described] above, I recommend that the proposed GMAW process be allowed for tack welding combinations of HPS 70W webs and flanges in preparation for final tandem SAW flange to web fillet welds. Please keep in mind that final approval must be obtained from the Bridge Engineer for this project, in accordance with the provisions of AWS D1.5, Table 4.2, when using the GMAW process on Grade 70W steel.

Inquiry 5

February 2000

INQUIRY: [The] flange to web welds are tandem-arc fillets with undermatched [SAW process, Lincoln L61/Lincoln 960 consumables] weld metal on a HPS 70W flange to a HPS 70W web. A PQR has been run on this weld metal on Gr. 50W steel. Is it necessary to run a PQR on HPS 70W steel and test to Gr. 50W properties?

RESPONSE: AWS D1.5 specifications do not specifically address the base metal to be used when performing WPS qualification tests for undermatched consumables. The *Guide for Highway Bridge Fabrication with HPS 70W Steel*, recommended as a supplement to AWS D1.5 specifications by the joint HPS Steering Committee sponsored by the Federal Highway Administration, the U.S. Navy, and the American Iron and Steel Institute, and adopted by the AASHTO subcommittee on Bridges and Structures, states, “*Unless otherwise noted on the plans, filler metals for all fillet welds shall be in conformance with AWS D1.5, Table 4.1 (H8 maximum), for AASHTO M270 or ASTM A709, Grade 50W base metal.*”

In my opinion, qualification of weld metal for single pass fillet welds could be done with either Grade HPS 70W base metal, Grade 50W base metal, or a combination of both, since your proposed consumables meet AWS classification F7A2-EM12K-H8 specifications, and the test results recommended conform to the requirements for Grade 50W base metal.

Please keep in mind that final approval must be obtained from the Bridge Engineer for this project before proceeding with the above recommendations.

Inquiry 6

February 2000

INQUIRY: I have a question relating to the galvanizing of bent steel and the potential for hydrogen embrittlement. We are currently working on the rehabilitation of a truss bridge. The hangers that drape over the pins and support the floorbeams should be galvanized. The problem is the potential for hydrogen embrittlement. We would like to be able to fabricate the members first, then galvanize them. This would ensure a generous coating on the member; however, it would increase the possibility for hydrogen embrittlement, (HE). I am under the understanding that HE is more likely during cold bending, but what about heat forged or hot bent members? Should HE still be of concern? We also thought about the possibility of cutting the members from plates, (the hangers will be square bars), and then galvanizing. This creates another set of problems for threading and upsetting. My real question is: What are our options for fabricating a fracture critical member, which definitely should be galvanized, without sacrificing the zinc protection, increasing the difficulty of fabrication, or increasing the potential for HE cracking? Keep in mind that this member is non-redundant and fracture critical, therefore its protection is of great importance to us.

RESPONSE: Strain age embrittlement can occur in galvanized components at sites that have experienced cold bending to a relatively short radius prior to galvanizing. When the steel is hardened by the cold working process, and subsequently subjected to the elevated temperatures of the zinc bath (~850 degrees F), accelerated strain age embrittlement could occur in highly stressed areas, generally considered to be at locations where the bend radius is less than 3t for plates or bars, or less than 3d for round bars. Non-quenched and tempered members that are bent while heated to between 1100 degrees F and 1200 degrees F within 6" of the bend area prior to galvanizing should not experience the higher stresses of the cold worked material, and therefore should not be subjected to similar strain age embrittlement. Hydrogen embrittlement resulting from the galvanizing process is generally not considered a problem for steels and forgings routinely used in bridge construction. However, embrittlement resulting from release of hydrogen during the pickling (acid bath) process in fine grain materials with an ultimate tensile strength in excess of 150 ksi is possible.

Thermal Spraying or Flame Spraying should be considered as an alternate to hot dipped galvanizing. A super-heated coating material (may be zinc or other coating material) is applied by spraying to a relatively cold, abrasive blasted surface. The process can be applied to a variety of materials, including steel, plastics, wood, etc. in a manner similar to painting, and offers excellent corrosion protection considered to approach that of hot dipped galvanizing. More information on this process can be found in a publication by the American Welding Society entitled *Thermal Spraying - Practice, Theory and Application*. Based on my experience, the cost of thermal spraying or flame spraying is between that of painting and hot dipped galvanizing. However, please keep in mind that the coated shape and area significantly influence the cost. Other fabrication options include butt welding a fabricated eye to the square hanger bar, or connecting with a threaded coupler. The welded option should be properly welded and tested in accordance with AASHTO/AWS D1.5 *Bridge Welding Code*, including *Section 12, Fracture Control Plan for Nonredundant Members*. These options most likely will result in increased cost of fabrication, when compared to bending the ends of the hanger bar to form an eye.

Inquiry 7

March 2000

INQUIRY: We are in the process of specifying ASTM A709 Grade HPS 70W steel for a couple of bridges. The ASTM A709 specification requires quenching and tempering to achieve desired properties. Does anyone have experience with the Thermo-Mechanical Controlled Processing (TMCP) process? Bethlehem Steel claims this process meets A709 mechanical properties, has identical chemical properties and is more economical. Your feedback is appreciated.

RESPONSE: Currently, the latest ASTM A709 specification references only the HPS 70W Q&T product. However, the TMCP product is currently being developed by steel manufacturers using the same (identical) controlled specifications for mechanical, chemical and toughness properties that were used for the Q&T product.

The Q&T product is available in thicknesses to 4", and is restricted to lengths of 50' or less. The TMCP product is currently available in thicknesses to 2", but length is not restricted by the heat treatment process. Manufacturers are working toward providing plate lengths similar to conventional Grade 50W steel. The manufacturing process for the TMCP product is generally thought to be less costly than the heat treatment process used for the Q&T product. In addition, depending on the design of the girders, some economy may be realized with TMCP because of the reduced number of butt welded splices. Since mechanical and chemical properties of both the Q&T and TMCP are the same, the recommended welding processes and welding consumables for the TMCP are likewise the same. Stupp Bridge Company in Bowling Green, KY is currently fabricating the first bridge to use HSP70W TMCP in the US for the State of Tennessee DOR. I participated in performance of welding procedure qualification tests at the fabrication plant using matching weld consumables (Lincoln LA85 electrode in combination with Lincoln Mil800HPNi flux) for use in CPGW's, and undermatched weld consumables (Lincoln L61 electrode in combination with Lincoln 960 flux, straight polarity) for single pass fillet welds, all on TMCP base metal. Test results for both WPQR's conformed to all specification requirements, and CVN test results far exceeded minimum requirements. Stupp Bridge is currently running a WPQR using Lincoln LA85/Mil800HPNi consumables with HPS 70W Q&T base metal for comparison. Test results should be available soon.

A *Guide for Highway Bridge Fabrication with HPS 70W Steel* is available and can be downloaded from the AISI website <http://www.steel.org/>. This Guide has been adopted by the AASHTO Subcommittee on Bridges and Structures, and is recommended to be used as a supplement to the AWS D1.5, *Bridge Welding Code* whenever HPS 70W steel is specified. Please keep in mind that reference to the *Guide* must be included in the Contract documents by the Engineer to be a binding part of the agreement. The *Guide* currently references HPS 70W Q&T, but can be applied directly to TMCP. It is expected to be published by AASHTO soon.

Inquiry 8

June 2000

INQUIRY: This Steelworks question is from Benchmark Railway Services. I am rating an old steel railroad bridge constructed with Carnegie steel. I need to know the yield strength of this steel. Thank you

RESPONSE: An AISC publication, *Historical Record, Dimensions and Properties, Rolled Shapes, Steel & Wrought Iron Beams and Columns As Rolled in USA, Period 1873 to 1952*, lists unit stresses of steel produced by the Carnegie Steel Company between 1896 and 1903 as 16,000 psi for buildings, 12,500 psi for bridges.

Another section of the *Historical Record, History of ASTM Structural Steel Specification Stresses*, reads in part as follows:

Date	Specification	Remarks	Tensile Strength (psi)	Minimum Yield (psi)
1900	A7, Bridges	Rivet Steel	50000 to 60000	30000
		Soft Steel	52000 to 62000	32000
		Medium Steel	60000 to 70000	35000
1901-1904	A7, Bridges	Rivet Steel	50000 to 60000	1/2 TS
		Soft Steel	52000 to 62000	1/2 TS
		Medium Steel	60000 to 70000	1/2 TS
1905-1913	A7, Bridges	Structural Steel	Desired 60000	No Requirement
		Rivet Steel	Desired 50000	No Requirement
1914-1923	A7, Bridges	Structural Steel	55000 to 65000	1/2 TS
		Rivet Steel	46000 to 56000	1/2 TS
1924-1931	A7, Bridges	Structural Steel	55000 to 65000	1/2 TS, =>30000
		Rivet Steel	46000 to 56000	1/2 TS, =>30000
1932	A140-32T, Bridges	Plates, Shapes, Bars	60000 to 72000	1/2 TS, =>30000
		Eyebar Flats Unannealed	67000 to 82000	1/2 TS, =>36000
		Rivet Steel	52000 to 62000	1/2 TS, =>28000
1933	A7-33, Bridges	Structural Steel	55000 to 65000	1/2 TS, =>30000
		Plates, Shapes, Eyebars	60000 to 72000	1/2 TS, =>33000
1934-1938	A7-34, Bridges	Plates, Shapes, Eyebars	60000 to 72000	1/2 TS, =>33000
		Eyebar Flats Unannealed	67000 to 82000	1/2 TS, =>36000

Further, the following is from a section of the *Pocket Companion, Twenty-Third Edition*, published by the Carnegie Steel Company and dated January 1, 1923, entitled *American Bridge Company Specifications for Steel Structures, Design, Details of Construction and Workmanship*, adopted 1912:

Unit Stresses. All parts of structures shall be proportioned so that the sum of the dead and live load, together with the impact, if any, shall not cause the stresses to exceed the following amounts in pounds per square inch:

Tension, net section, rolled steel.....	16000	Shear on bolts and field rivets.....	10000
Direct comp, rolled steel, steel castings ..	16000	Shear-average-on webs of plate girders and	
Bending, on extreme fibers of rolled shapes,		rolled beams, gross section	10000
built sections, girders, steel castings	16000	Bearing pressure on shop rivets and pins	24000
Bending on extreme fiber of pins.....	24000	Bearing on bolts and field rivets	20000
Shear on shop rivets and pins.....	12000		

Inquiry 9

June 2000

INQUIRY: Dear Mr. DeLoach, I have stumbled upon, what I believe is a problem with the *Guide for Highway Bridge Fabrication with HPS 70W Steel* regarding the acceptance criteria for welding procedure qualification. The *Guide* (dated May 20, 1999) states the following:

"(6) Qualification Testing:

Filler Metal Qualification Test Requirements for welding of HPS 70W plates together are as listed in AWS D1.5, Table 4.1, for Grade 70W base metal. Qualification, Pretest and Verification Test Requirements for HPS 70W groove welds as determined using WPS Test Plates shall provide properties equal to or greater than Base Metal requirements as specified in ASTM A709-97b." (page A-2).

Based on this paragraph, the consumable qualification (Filler Metal Manufacturer's Certificates of Conformance) must follow AWS D1.5, Table 4.1 for Filler Metal Qualification Test Requirements, and that's not the problem. However, the second sentence says that the PQR properties shall be "...equal to or greater..." than the HPS 70W from the ASTM spec. This is an issue because all of the HPS 70W PQR's that I have seen used the AWS D1.5, Table 4.1 acceptance criteria for 70W material, and the AWS D1.5 and the ASTM requirements are not the same.

All of the following used the AWS D1.5 acceptance criteria rather than the ASTM A709 Gr. HPS 70W specification:

1. New York State Thruway Authority report entitled, *Summary of High Performance Steel Grade 70W Studies*
2. PQR's from Stupp Bridge
3. PQR's from Lincoln Electric conducted by Matt James

Here's the difference between the two acceptance criteria:

	<u>AWS D1.5, Table 4.1(70W)</u>	<u>ASTM A709 Gr. HPS 70W</u>
min. F _y :	74	70
F _u :	88 - 114	90 - 110
Elong.	17	19
CVN	25 ft lbs @ -25 deg. F	35 ft lbs @ -10 deg. F
(FCM zone III):		

A PQR could pass in accordance with one criteria and fail with the other. Therefore, this is a significant issue. Can you please clarify which acceptance criteria are to be used? I think that it makes sense to use the AWS D1.5 acceptance criteria for 70W rather than the ASTM HPS 70W properties.

Inquiry 9 (cont'd)

June 2000

JDL RESPONSE: (Someone) uncovered what he thinks is a problem in the *HPS Fab Guide*. In the consumables qualification section, the guide states that we require properties equal to or greater than base metal requirements as specified in ASTM A709-97. In practice, fabricators and state engineers have chosen to use acceptance criteria from AWS D1.5, Table 4.1. The ASTM and AWS requirements differ. He wants to know which set of requirements should be used. Based on my recollection of the many discussions we had, I think the *Fab Guide* says exactly what we intended it to say. A key decision was that we were willing to accept 70 ksi min yield strength (versus 74 ksi required in D1.5, Table 4.1). Any other thoughts?

RT RESPONSE: As I understand it, the inquiry is based on evaluation of test results for 15 WPS's tested by (a manufacturer) in-house for use in both undermatched (11 test plates) and matching applications (4 test plates, 2 of which were MIG consumables) for HPS 70W base metal. I suggest the following response:

Thank you for your inquiry regarding criteria for evaluating WPS test results for HPS 70W consumables. You are correct in your statement that Appendix A, Paragraph 6 of the *Guide* provides for WPS acceptance criteria which differs from AWS D1.5, Table 4.1. The *Guide* states in part, "...Qualification, Pretest and Verification Test requirements for HPS 70W groove welds as determined using WPS test plates, shall provide properties equal to or greater than base metal requirements as specified in ASTM A709-97b." However, you must keep in mind that this provision applies to WPS's for HPS 70W matching groove welds only.

Test requirements for undermatched fillet welds and hybrid joints are not governed by this paragraph, but rather, by the provisions of Appendix A, Paragraphs 2.b.1, which reads, "...filler metals for all fillet welds shall be in conformance with AWS D1.5, Table 4.1...for...Grade 50W base metal." Further, Paragraph 2.b.3 reads in part, "Filler metals for all full penetration groove welds connecting a Grade HPS 70W plate to a Grade 50W plate shall conform to the requirements for Grade 50W base metal as listed in AWS D1.5, Table 4.1...". The criteria for evaluating the ultimate tensile strength and other mechanical properties of your WPS tests HPS7, HPS8, HPS9 and HPS10 is AWS D1.5, Table 4.1. Further, I understand that AWS D1.5, Table 4.1 is in process of being revised for the year 2001 publication to eliminate the upper boundary for ultimate tensile strength, and therefore, effectively resolve some of the concerns that you have regarding differences in the specifications. We appreciate your inquiry. If you have further questions, please do not hesitate to contact us.

Inquiry 10

July 2000

INQUIRY: **Re: UT Testing of HPS Welds** - Gentlemen; ... I gave a presentation to the NJDOT on High Performance Materials, including HPS, and a question came up from one of the attendees about problems they had read about when trying to test HPS welds with UT. Can any of you please tell me whether or not you have experienced any such problems; if so where and what were they; and if and how the problems can be resolved.

RESPONSE: Based on my experience with ultrasonic testing of HPS 70W steels, there have not been any reported problems. To the contrary, when testing butt welds in HPS 70W steel flanges welded with Lincoln LA-100/Mil800H SAW consumables, indications undetectable by radiographic examination were routinely reported by a certified ultrasonic technician. These discontinuities had a defect rating between +10 db and -1 db, and a length of only 1/8" +/-, and were subsequently verified by both excavation and destructive tests by an independent third party. Further, I would not expect any problems when tested in accordance with current codes. I am very interested in the reported problem, including the source, if you can provide more information.

Inquiry 11

July 2000

INQUIRY: Mr. Teal, we are currently putting together a bid request for the manufacturing of HPS 70W and hybrid girders of HPS 70W and A36/A572 Grade 50 dual cert. steel. My questions are: what type wire, flux, and electrode do we spec for the HPS 70W/HPS 70W connections (joints), and the HPS 70W/Grade 50 dual cert. hybrid girders?

RESPONSE: Currently, only the submerged arc and shielded metal arc welding processes are recommended for welding HPS 70W steel.

The Lincoln SAW consumables LA-85/Mil800HPNi and SMAW consumables E9018MR-H4, where applicable, are currently recommended and have been used successfully for matching strength welds joining HPS 70W plates. The Lincoln SAW consumables L61/960 have been used successfully for undermatched fillet welds and hybrid CPGW's. SMAW consumables E-7018MR-H4 or E-8018MR-H4, where applicable and as appropriate for corrosion resistance, have been used successfully for undermatched fillet weld applications. Other consumables should be allowed based on satisfactory completion of welding procedure qualification tests recommended by the Guide and AWS D1.5.

The AISI publication, *Guide for Highway Bridge Fabrication with HPS 70W Steel* provides recommendations for welding both matched and hybrid joints. It is currently available on the AISI website [<http://www.steel.org/>], and has been adopted by the AASHTO Sub-Committee on Bridges and Structures. I recommend that you include the following provisions in your Contract documents:

"All fabrication must conform to the latest edition of the *Guide for Highway Bridge Fabrication with HPS 70W Steel*, a supplement to ANSI/AASHTO/AWS D1.5.

"All welding must conform to the latest edition of the AASHTO/ AWS D1.5 *Bridge Welding Code*, except as modified by the latest edition of the *Guide for Highway Bridge Fabrication with HPS 70W Steel*, a supplement to AASHTO/AWS D1.5."

I have attached a copy of *Contract Special Provisions for use of HPS 70W Steel in Bridge Applications* that I have prepared for use by owners when requested. This may provide sample language for welding related specifications. It appears that you intend to use HPS 70W steel in a painted application, since you reference the use of dual certification Grade 50/36 steel. Please be advised that the current ASTM A709/A709M specification references Grade HPS 70W steel, but not Grade HPS70. Even though used in a painted application, I suggest that Grade HPS 70W be specified.

Inquiry 12

August 2000

The following four-part inquiry was initially addressed to AISC, with response by Mr. William McEleney (BM) of AISC and Mr. Roy Teal (RT) representing AISI. Please see the individual responses to the inquiries as marked below:

INQUIRY A: We are designing a HPS 70W steel superstructure and have a few fabrication and welding questions. During fabrication, is minimum preheating required for submerged arc welding using HPS 70W compatible consumables? If so, should we specify the electrode in our supplementary provision? What kind of special provisions [would] the fabricator would like to have?

BM RESPONSE A & B: Let me offer my thoughts on some of your questions and by copy of this e-mail, ask Roy Teal to add whatever he thinks is appropriate. As you may remember from the recent steel program at NJDOT, Roy is on the HPS Task Force.

Preheat may be required, depending on material thickness. Only a limited selection on welding consumables has been qualified for HPS. Other information is contained in the Fabrication Guide. An earlier version of the *Fabrication Guide* is located at http://www.steel.org/infrastructure/bridges/high_performance/hpsguide/index.html. You could look here to get an idea of what is contained in the Fab Guide. Roy Teal may be able to comment on what is changed in the AASHTO version. I would suggest the *Fab Guide* be referenced in your supplementary provisions because it will contain requirements that are specific for HPS and not included elsewhere.

RT RESPONSE A: **During fabrication, is minimum preheating required for submerged arc welding using HPS 70W compatible consumables?** Preheat may be required, depending on the ambient temperature, base metal thickness, and the diffusible hydrogen levels of the welding consumables, as recommended in the *Guide for Highway Bridge Fabrication with HPS 70W Steel*. For welding consumables with a diffusible hydrogen level of H4 or less, HPS 70W preheat requirements are reduced for base metal thicknesses over 3/4", when compared to the preheat requirements for Grade 70W steel in the AWS D1.5 *Bridge Welding Code*. Further, preheat requirements are reduced for base metal thicknesses over 1-1/2" when compared to the preheat requirements for Grade 50W steel in the AWS D1.5 *Bridge Welding Code*. When diffusible hydrogen levels exceed H4, the preheat requirements of AWS D1.5, Table 4.4 should be specified.

Inquiry 12 (cont'd)

August 2000

RT Response A: **If so, should we specify the electrode in our supplementary provision?**

I recommend that you invoke the provisions of the *Guide for Highway Bridge Fabrication with HPS 70W Steel* in your contract documents. This document contains the latest recommendations for welding consumables, and procedures for selection of alternate consumables. However, I do not recommend that you specify the welding consumables. Selection of welding consumables should be made by the fabricator, and then the appropriate welding procedure qualification tests should be ordered, based on the criteria explained in the *Fabrication Guide* and in the sample special provisions I have attached, as described below.

What kind of special provisions the fabricator would like to have? I have attached a copy of *Special Provisions for High Performance Steel, Grade HPS 70W/HPS485W for Bridge Applications* that I have prepared for use by other state agencies. Please feel free to use this document in its entirety, or in part, as you choose, in your contract documents.

INQUIRY B: AASHTO just published the *Guide Specifcaton for Highway Bridge Fabrication with HPS 70W Steel*. Did you have a chance to look over? I did not see it yet but saw draft copy. Should we incorporate it into our supplementary provisions?

RT RESPONSE B: The AASHTO draft of the *Guide for Highway Bridge Fabrication with HPS 70W Steel* is in the final review stages, but has not been published as of this date. Final comments are due to AASHTO in early September, and the document should be published soon thereafter. I recommend that you include a reference in your contract documents, and have included a reference to the *AASHTO Guide for Highway Bridge Fabrication with HPS 70W Steel*, an addendum to *AASHTO/AWS D1.5-95* in the attached special provisions.

INQUIRY C: Because of quenching and tempering, plate size is limited to 50 feet but the thermo-mechanically controlled process may produce the plate over 100 feet. Is it available commercially? If so, what is the price difference between this TMCP and QT processed steel. Should we specify it?

BM RESPONSE 3: Non Q&T material is available from Bethlehem/Lukens Steel up to 2" thickness at the same price as Q&T. You should confirm the pricing with Bethlehem (Bob Huzzard). The current ASTM A709 requires Q&T, so you would have to specifically allow the non Q&T (as an allowable substitute) in your contract specs.

Inquiry 12 (cont'd)

August 2000

RT RESPONSE 3: ASTM A709-00, Grade HPS 70W is a quenched and tempered plate product, available in thicknesses to 4" and lengths to 50 feet maximum. The Thermo-Mechanical-Controlled-Processed (TMCP) product is available in thicknesses to 2", and in lengths similar to Grade 50W, but is not included in the ASTM A709 specification. However, ASTM is currently considering a proposal to replace M270M/M270 with ASTM A709/A709M specifications. These potential revisions to the ASTM A709 specification include the addition of the HPS 70W TMCP product. The TMCP product meets all provisions of ASTM A709, including chemistry, mechanical properties and CVN toughness requirements, except that the rolling process is different, i.e., it is manufactured using a controlled rolling or accelerated cooling process. Until the TMCP product is included in ASTM specifications, it is necessary to allow Grade HPS 70W TMCP in the special provisions of the contract documents. Again, the attached Special Provisions for High Performance Steel, Grade HPS 70W/HPS485W for Bridge Applications contains provisions for allowing the TMCP product.

INQUIRY D: HPS has better weathering characteristics and weathering index = 6.5 compared to normal weathering steel = 6.0. Please explain to me what a weathering index is and if the 0.5 differences are significant.

BM RESPONSE D: The weathering index is an empirical evaluation based on the chemical composition of the material (somehow "benchmarked" by observation of actual samples over a long period of time in several locations). I don't expect it is precise enough that you should do anything different with your bridge just because HPS has an increase in its index of 0.5. Suffice it to say that HPS can be expected to exhibit improved weathering characteristics over the earlier versions of weathering steel.

RT RESPONSE D: High performance steel must have a corrosion index of 6.5 minimum, as described in ASTM G101, to be classified as high performance steel, compared with 6.0 for Grade 50W or Grade 70W steel. Therefore, HPS 70W steel is claimed to have enhanced corrosion resistance. The corrosion index is calculated as follows:

$$CI = 26.01(\%Cu) + 3.88(\%Ni) + 1.20(\%Cr) + 1.49(\%Si) + 17.28(\%P) - 7.29(\%Cu)(\%Ni) - 9.10(\%Ni)(\%P) - 33.39(\%Cu)^2$$

It is an empirical number that is derived from the heat analysis of HPS 70W steel. The first 28 heats of HPS 70W steel produced had an average corrosion index of approximately 6.8.

Inquiry 13

January 2001

INQUIRY A: Do you have regional cost data for HPS 70W? I would like to get some data to add to presentations I will be giving.

RESPONSE A: I do not have any regional cost data for fabricated HPS 70W steel. Further, I do not expect that there is a substantial difference in the cost of fabricated HPS 70W steel when comparing fabrication by experienced fabricators, regardless of their regional area. However, there are many factors that influence the bid price to owners. These include:

- 1) The design of the structure, i.e., whether the girders are hybrid, mixed or homogeneous. Hybrid girders are considered the most economical, and generally utilize HPS 70W steel only in the negative moment area of flanges where there is a need for increased strength. Mixed girders generally utilize HPS flanges in the negative moment area, and Grade 50W in the positive moment areas. Homogeneous girders utilize HPS 70W for both flanges and the entire web. Regardless of the type of design, Grade 50W steel is generally used for all welded attachments, including stiffeners and connection plates.
- 2) The actual quantity of HPS to be used in the structure.
- 3) The fabricator's experience with HPS 70W steel.
- 4) Contractor's bidding practices.
- 5) General business conditions may be different when comparing one region to another, and this may influence the actual bid price of fabricated steel in general.

Cost comparisons of HPS 70W and Grade 50W base metal indicate that, using Grade 50W steel as a basis, HPS 70W quenched and tempered (Q&T) base metal costs as much as 50% more than Grade 50W. At this time, use of the HPS 70W thermo-mechanical controlled processing (TMCP) product realizes approximately 10% savings when compared to the Q&T product. However, at least one fabricator has performed cost studies for owners, comparing the fabricated cost of a Grade 50W design with the fabricated cost of a HPS design, and regardless of the type of plate girder design (hybrid, mixed or homogeneous), the reduced weight of the HPS components provided for a reduced cost of fabricated girders, even though paying as much as a premium for HPS.

INQUIRY B: Can I find cost data for fabricated and erected bridge girders at the AISI website?

RESPONSE B: I am not aware that cost data exists on the AISI website, www.steel.org. However, this website contains the most recent information available regarding the use and welding of HPS steel.

Inquiry 13 (cont'd)

January 2001

INQUIRY C: I would like to make the case for using HPS 70W as a replacement for Grade 50W steels for corrosion resistance and durability, even in the cases where the strength is not fully utilized. Am I on shaky ground?

RESPONSE C: The minimum atmospheric corrosion index, calculated as described in ASTM G101 specifications, is 6.5 for HPS 70W, compared to 6.0 for Grade 50W steel. Since this index is based on evaluation of the chemistry of steel products, and the actual calculated index of typical HPS plate products averages nearly 7.0, you can conclude that the corrosion resistance of HPS 70W is enhanced when compared with Grade 50W. However, there have not been recent research studies in this regard. [A manufacturer] has developed and introduced for approval an alternate method of calculating the corrosion index which, in their opinion, more accurately reflects the actual corrosion resistance of steel products.

With reference to durability, HPS is manufactured using lower carbon, sulphur and phosphorus, with more controlled ranges of alloying elements, and a low hydrogen practice such as vacuum degassing, controlled soaking of ingots and billets, or a combination thereof. The end result is a product that has substantially improved CVN toughness when compared to conventional Grade 50W steel. CVN properties exceed FCM requirements for all zones, all thicknesses, with minimum notch toughness exceeding Zone 3 FCM requirements of 35 ft lbs at -10⁰F. In actual tests, CVN toughness generally ranges between 150 and 200 ft lbs at -10F. Research has shown that HPS has enhanced resistance to failure by fatigue and HAZ cracking. The end result is a product that is expected to far outperform other conventional steels in service with reduced life cycle costs based on the longer anticipated life of the structure, along with reduced maintenance costs resulting from enhanced corrosion resistance and enhanced toughness.

Further, the increased strength of HPS provides for other cost saving factors that are often overlooked by designers and owners.

- 1) Reduced substructure needs based on longer span lengths.
- 2) Possible elimination of shoulder piers when replacing existing structures with multiple simple spans, again reducing substructure needs while improving safety to the traveling public.
- 3) Replacement of existing structures with HPS girders may provide for increased vertical clearance with no or little modification of the approaches.

HPS has proven itself an asset to owners and designers alike where there is a need for increased strength requirements. Fabricators have learned that, once beyond an initial learning period, HPS is no more difficult to fabricate than conventional steels providing good low hydrogen practices are used.

Inquiry 14

February 2001

INQUIRY: What size limitations exist right now for the HPS 70W plates?

RESPONSE: HPS 70W Quenched and Tempered (Q&T) plates are available in thicknesses to 4 inches, and are restricted to a maximum length of 50 feet due to the Q&T process. HPS 70W Q&T is included in ASTM A709-00a specifications as Grade HPS 70W.

HPS 70W Thermo-Mechanical Controlled Process (TMCP) plates are currently available in thicknesses to 2 inches, and in lengths similar to A709 Grade 50W. Chemistry of the TMCP product conforms to HPS 70W specification. Please keep in mind that inclusion of the TMCP product is being balloted by ASTM, and is not included in A709-00a, Grade HPS 70W specifications [at this time].

Inquiry 15

February 2001

INQUIRY: I [would like] information on coating HPS. [Is there a] difference between coating HPS and conventional weathering steel.

RESPONSE: When it is necessary to apply a coating system to HPS to meet guidelines for corrosion resistance or for aesthetic reasons, cleaning, surface conditioning and application of paint, galvanizing or metalizing systems should be no different than those recommended for use on Gr 50W steel or the former Gr 70W steel.

Inquiry 16

February 2001

INQUIRY: Is it good/okay practice to bend Q&T steels with combination mechanical force and heat?

RESPONSE: My response to your inquiry addresses two definitions of the phrase, *hot bending with a combination of mechanical force and heat*.

- 1) The first definition presupposes that steel plates are heated to a certain specified temperature, and that basically unrestricted force is then used to cause the required bend. Typical examples of this hot bending include shaping of haunched I-girder flange plates at the bearing area, or fabrication of bent connection plates. Assuming this definition, there should not be a problem hot bending Grades 100, 100W or the former Grade 70W Q&T plates when work is done in accordance with the provisions of Section 11.4.3.3.3 of the AASHTO Standard Specifications for Highway Bridges. The Sixteenth Edition restricts bending temperatures to a maximum of 1100 degrees F for Grades 100 and 100W, and to 1050 degrees F for the Grade 70W (former A709 Grade 70W, or A852). With reference to Grade HPS 70W, since the mechanical and chemical properties of HPS 70W fit within and are more controlled than the prior Grade 70W specification, and the Charpy V-notch toughness properties of HPS 70W are substantially improved, in my opinion, there should be no difference hot bending HPS 70W steel, with exception that there may be greater resistance to fracture with HPS 70W steel when compared to Grade 70W, provided that heating temperatures are restricted to 1100 degrees F maximum. Further, it is important that applications of heat are controlled to provide thru-thickness heating without overheating the plate surface. To answer your question, in my opinion, it is acceptable practice to hot bend Q&T steels providing the work is done in accordance with the guidelines for the grade of steel to be used in the work.
- 2) The second definition is a possible misuse of the term, *hot bending*, but presupposes that a mechanical force or preload is applied to steel plates, then localized areas are heated to a certain specified temperature. Typical examples of this hot bending include heat curving, heat cambering or flame straightening applications. I'm certain that you are aware that the current AASHTO Standard Specifications for Highway Bridges do not allow heat curving steels with a yield strength in excess of 50 ksi, but do allow straightening of Grades 100, 100W and Grade 70W by application of heat in combination with mechanical force, using restricted temperatures as described in Article 11.4.7. With reference to HPS 70W applications, although preload stresses were not introduced, research done as part of a demonstration project during development of the suggests that HPS 70W Q&T can be subjected to localized heating to 1100 degrees F without significant degradation of base metal mechanical and toughness properties. In addition, recent studies by Dr. Yoni Adonyi of LeTourneau University resulted in similar findings for Q&T steel.

Inquiry 16 (cont'd)

February 2001

Again, it is important that applications of heat are controlled to provide thru-thickness heating as rapidly as possible without overheating the plate surface. In my opinion, there should be no problems associated with short term, localized applications of heat in combination with mechanical preload stress for purposes of heat curving, adjustment of camber or flame straightening applications of HPS 70W Q&T steel when allowed by the Engineer. However, it is important to control the preload stress to some level substantially below the yield stress of the base metal, to provide for reduction in the actual yield stress of the steel at elevated temperatures. Some owners have restricted this maximum preload stress prior to application of heat to $0.55(F_y)$ for the base metal to be used. It is equally important that once heating begins, no further adjustment of the preload be made until after the heated areas have cooled to ambient temperature.

Inquiry 17

February 2001

INQUIRY: Now that HPS 50W is available, we want to use [it] for a steel bridge. We are interested in the higher toughness, improved weldability and better weathering index. I request [information] regarding the fabrication and weldability, including consumables [for] HPS 50W.

RESPONSE: The chemistry of HPS 50W is exactly the same as HPS 70W, and processing options for this grade are most likely as-rolled or control-rolled, but may include thermo-mechanical control processed (TMCP) with or without accelerated cooling, and quenched and tempered (Q&T). Like Grades 50W and HPS 70W, HPS 50W is manufactured to a killed fine grain practice, and this grade will include supplemental toughness requirements for HPS 50W that correspond with the Zone 3 requirements for Grade 50W. Therefore, all of the desirable properties of HPS 70W, including enhanced CVN toughness, enhanced corrosion resistance, and enhanced resistance to HAZ cracking are the same for HPS 50W, except the yield strength and ultimate tensile strength, which are the same as conventional Grade 50 or 50W. Currently, ASTM is balloting a proposal to include HPS 50W in A709 specifications as an additional grade.

Fabrication techniques should be no different from those required for HPS 70W and Grade 50W. In general, the recommendations of the AASHTO Guide Specification for Highway Bridge Fabrication with HPS70W Steel combined with the AWS D1.5, *Bridge Welding Code*, can also be applied to fabrication of HPS 50W steel. I anticipate that the single most important factor when fabricating and welding Grade HPS 50W is to control diffusible hydrogen. I recommend that welding consumables be selected from those recommended for Grade 50W steel in AWS D1.5, Table 4.1, and that when welding, diffusible hydrogen be controlled to H4 whenever possible, and H8 maximum, as determined by the consumable manufacturer for the process and consumables used in the work.

Inquiry 18

March 2001

INQUIRY: [It appears that steel for a project was intended to be HPS, but was ordered and delivered as Gr 70W. The writer comments:] ... the mill has re-certified the material stating that it conforms to the requirements of ASTM A709 Gr. 70W. We will now be using FCAW as permitted by D1.5. Any comments?

RESPONSE: In my opinion, successful FCAW welding of Grade 70W base metal should focus on adequate heat input and control of diffusible hydrogen. I recommend that welding be done in accordance with the provisions of AWS D1.5, Table 4.1 for Grade 70W base metal, taking care to ensure that good low hydrogen practices are used.

You should be aware that there is a potential for substantial variation in diffusible hydrogen levels in FCAW consumables, due to the nature of the manufacturing process and the fabricator's electrode storage practices. Based on past experience, I suggest a minimum heat input of 40 kJ/in, although this is not a specification requirement. If I recall this project correctly, some members are designated as fracture critical. If this is true, electrodes must conform to diffusible hydrogen requirements of H4 or H8 maximum. Heat input may become more of a concern when welding with relatively small diameter electrodes, especially when welding small fillet welds using a relatively fast travel speed.

If you are concerned about hydrogen cracking in the final product, you may want to consider ordering ultrasonic testing of the completed welding procedure qualification test plates. In addition, you may want to consider ordering spot checks of CPGW using ultrasonic tests, and spot checks of fillet welds using dry magnetic particle tests, yoke technique, in the AC output mode. These tests are not part of AWS specification requirements, and most likely would be considered extra work unless included in your contract documents, but may be helpful in determining if hydrogen cracking has occurred.

Inquiry 19

March 2001

INQUIRY: I need to use the AASHTO designation on some bridge plans that we are preparing, and I need to be sure that what I am using is correct. I see that the AASHTO LRFD Bridge Design Specifications, 1998 with 1999 and 2000 Interims, in Section 6.4.1, Table 6.4.1.1 (page 6-11), does not have an AASHTO Designation, but the Equivalent ASTM Designation is: ASTM A709, Grade HPS 70W. (in English units).* Does AASHTO have a designation for HPS 485W steel? Please clarify this for me.

RESPONSE: To the best of my knowledge, AASHTO now uses the ASTM A709 Grade HPS 70W designation. ASTM A709 uses the dual designation Grade HPS 70W/HPS 485W. I have explained the modifications to these specifications below. Please be aware that the ASTM A709 Grade HPS 70W/485W specification applies only to the Q&T product at this time. The TMCP product is currently being balloted by ASTM, but is currently not included. When an owner desires to allow use of the TMCP product, special provisions should be included in the contract documents.

The AASHTO Standard Specifications for Highway Bridges, 16th Edition thru the Interim 1999 specifications, and the AASHTO LRFD Bridge Design Specifications, 2nd Edition, contain provisions applicable to Grade 70W quenched and tempered steel, including restrictions that do not apply to HPS70W steel. These AASHTO design specifications have and continue to be reviewed to make the necessary modifications that apply to Grade HPS70W steel, as follows:

1. The 2000 Interim Revisions to Standard Specifications for Highway Bridges includes revisions to Table 10.2A. References to M270 Grade 70W and ASTM A709 Grade 70W were revised to ASTM A709 Grade HPS 70W, respectively and a footnote was added that reads, "Grade HPS70W replaces AASHTO M270, Grade 70W. The intent of this replacement is to encourage the use of HPS steel over conventional bridge steels due to its enhanced properties. AASHTO M270M, Grade 70W is still available, but should be used only with the owner's approval."
2. The AASHTO LRFD Bridge Design Specifications, 2nd Edition, - 2000 Interim Revisions, added a paragraph to Section C6.4.1 Structural Steels, which reads, "ASTM A709, Grade HPS 70W has replaced AASHTO M270, Grade 70W in Table 1. The intent of this replacement is to encourage the use of HPS steel over conventional bridge steels due to its enhanced properties. AASHTO M270, Grade 70W is still available, but should be used only with the owner's approval. The available lengths of ASTM A709M, Grade HPS70W are a function of the processing of the plate, with longer lengths produced as as-rolled plate."
3. The Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 20th Edition, includes AASHTO M270M/M270-00, which is identical to ASTM A709/A709M-00; both specifications reference only Grade HPS70W quenched and tempered steel.

Inquiry 19 (cont'd)

March 2001

Please be aware that the 2000 ASTM Book of Standards includes A709/A709M-97b1, and that ASTM A709/A709M-00 and ASTM A709/A709M-00a are available as separate printed documents. Modifications were made to the HPS70W properties in the updated ASTM A709/709M-00 and AASHTO M270M/M270-00 documents, and include:

1. Wider chemistry ranges, although still substantially more controlled than the prior Grade 70W specification
2. The requirement for minimum ultimate tensile strength was revised from 90 ksi to 85ksi. The upper limit remains at 110 ksi.
3. Grade 70W steel was deleted.
4. A few editorial errors remain, including references to Grade 70W steel, but do not limit the use of the specification.

ASTM A709/A709M-00a was published to correct the errors mentioned in (4) above, and to remove all references to Grade 70W steel.

The AASHTO Subcommittee on Materials meeting met on August 8, 2000, and discussed making revisions to AASHTO M270M/M270 comparable to ASTM A709/A709M revisions being balloted by ASTM. These revisions include the addition of the HPS70W TMCP product, and addition of new HPS Grade 50W, all of which were discussed in detail at recent ASTM, AASHTO T14, and HPS Steering Committee meetings. I am uncertain when these modifications will be published.

Inquiry 20

June 2001

INQUIRY A: What are the benefits of fabricating hybrid girders using HPS 70W to HPS 50W instead of HPS 70W to Grade 50W? (This is a multi-girder bridge where the webs would be Grade 50W)?

RESPONSE A: The primary advantage of HPS 50W, when compared to Grade 50W, is that the chemistry is more controlled, resulting in improved Charpy V-notch toughness and improved corrosion resistance that compares to HPS 70W. HPS 50W may have improved weldability and the potential for lower preheats when diffusible hydrogen is controlled. The chemistry of HPS 50W is exactly the same as HPS 70W, but the rolling process differs, since the higher mechanical properties are not required, and the steel is required to be produced using a low-hydrogen practice, such as vacuum degassing. ASTM A709-01 permits HPS 50W to be furnished as-rolled, or allows mechanical properties to be obtained by controlled rolling, TMCP with or without accelerated cooling, or quenching and tempering.

INQUIRY B: Are you aware of any problems welding HPS 70W to Grade 50W?

RESPONSE B: I am not aware of any problems welding Grade 50W to Grade HPS 70W. Submerged arc welding consumables specified in AWS D1.5, Table 4.1 for Grade 50W base metal are considered matching strength consumables for applications joining Grade HPS 70W to either Grade 50W or Grade HPS 50W. As stated in Note 1 of Table 4.1, "In joints involving base metals of two different yield strengths, filler metal applicable to the lower strength base metal may be used." Further, single pass fillet welds up to 5/16" are considered to be adequately diluted by the base metal during welding, and need not conform to the requirements of Table 4.3 for Exposed Bare Application of Grade 50W Steel.

INQUIRY C: We have a person here that is telling us that if you use a 50 ksi yield steel with HPS 70W, it must be HPS 50W. Do you agree.

RESPONSE C: I do not agree with this person's interpretation. Practically all, if not all, hybrid and mixed girders built to date have been fabricated by joining Grade 50W steel to HPS 70W steel, and in all cases, I am not aware of any welding concerns. Until very recently, HPS 50W was not available, and is currently available from only one manufacturer, to the best of my knowledge. I am interested in the reasons for this person requiring HPS 50W. If possible, please request this FHWA person to contact me or any other member of the HPS Steering Committee to discuss this issue.

Inquiry 21

June 2001

INQUIRY: Currently, I am working on a seventy-five meter, two span welded plate girder bridge. Originally, we were going to use Grade HPS 70W over the pier and Grade 50W in the positive moment regions. It has been decided to substitute Grade HPS 50W for the Grade 50W. I have a copy of the HPS Designers' Guide published by the FHWA. In it are sample Special Provisions for Grade HPS 70W steel. I was wondering if anything similar had been developed for Grade HPS 50W. Any help you could give me in this matter would be greatly appreciated.

RESPONSE: Thank you for your inquiry regarding the use of Grade HPS 50W high performance steel. The sample Special Provisions that you reference in the HPS Designers' Guide appear to have been downloaded from the AISI website, <www.steel.org>, and could be used for fabrication of components using HPS 50W steel with slight modification to allow the material and reference minimum welding requirements, although this has not been done to date. I have attached my recommendations for Special Provisions for fabrication of structural components fabricated with HPS 70W or HPS 50W steel for your use. These recommendations appear in two forms: one is a lined edition showing modifications made to the HPS 70W Special Provisions, and the other is a final edition without editorial markings. Please be advised that these recommendations are intended to be tailored to your specific project needs.

The primary advantage of HPS 50W, when compared to Grade 50W, is that the chemistry is more controlled, resulting in improved Charpy V-notch toughness and improved corrosion resistance that compares to HPS 70W. HPS 50W may have improved weldability and potentially lower preheats when diffusible hydrogen is controlled. The chemistry of HPS 50W is exactly the same as HPS 70W, but the rolling process differs, since the higher mechanical properties are not required, and the steel is required to be produced using a low-hydrogen practice, such as vacuum degassing. ASTM A709-01 permits the HPS 50W to be furnished as-rolled, or allows mechanical properties to be obtained by controlled rolling, TMCP with or without accelerated cooling, or quenching and tempering. Submerged arc welding consumables specified in AWS D1.5, Table 4.1 for Grade 50W base metal are considered matching strength consumables for applications joining Grade HPS 70W to either Grade 50W or Grade HPS 50W. As stated in Note 1 of Table 4.1, "In joints involving base metals of two different yield strengths, filler metal applicable to the lower strength base metal may be used." Further, single pass fillet welds up to 5/16" are considered to be adequately diluted by the base metal during welding, and need not conform to the requirements of Table 4.3 for Exposed Bare Application of Grade 50 Steel.

Inquiry 21 (cont'd)

June 2001

As I understand it, the first edition of the High Performance Steel Designers' Guide that you reference was recently issued by M. Myint Lwin of the FHWA Western Resource Center, written based on his understanding of interviews, data from research reports, conference proceedings, technical presentations and websites, and then summarizing this understanding in a HPS Designers' Guide. At Mr. Lwin's request, the High Performance Steel Steering Committee, Welding Advisory Group and Design Advisory Group, sponsored jointly by the American Iron and Steel Institute, Federal Highway Administration and the US Navy, and authors of the AASHTO Guide Specifications for Highway Bridge Fabrication with HPS 70W Steel, agreed at their last meeting in mid-June to review the HPS Designers' Guide for conformance with the AASHTO Guide Specifications and current research, and provide recommendations to Mr. Lwin. Since ASTM A709 now includes Grade HPS 50W steel, it is likely that the Committee's recommendations will include comments on the use and welding of Grade HPS 50W steel.

Inquiry 22

October 2001

INQUIRY: Is it necessary to make a calibration block out of HPS 70W material for UT testing? My opinion was no. After all, we don't have 3 different blocks made for A-36, A-572, and A-588. What do you think?

RESPONSE: In my opinion, any of the standard IIW calibration blocks permitted for use on other grades of steel by the governing codes can be used to calibrate or testing Grade HPS 70W steel. For example, the AWS D1.5 *Bridge Welding Code*, Figure 6.4A & B, details permitted calibration blocks, and specifies that the blocks be made from M270 (A709) Grade 36 or acoustically equivalent.

I need to acknowledge that sound attenuation in a given material may be effected by the alloy content, heat treatment and degree of hot or cold working due to forging or rolling. However, the resulting attenuation should not be significant in like materials within the same general hardness range, i.e., structural steel for bridges. On the other hand, materials such as a 302, 304 or 410 stainless steel will exhibit substantially different attenuation, sound velocity and acoustic impedance characteristics.

One test to determine whether calibration considerations need to be made is to compare the acoustic impedance of the materials. First, the acoustic impedance of a given material is generally considered the product of its density and longitudinal wave velocity. The density of steel may vary slightly based on its composition and heat treatment, but the industry standard is 490 lbs/cf, regardless of grade, for steel plate and shapes commonly used in the bridge industry. The longitudinal wave velocity is simply considered a ratio between Young's modulus of elasticity and the density of the material, which is considered a constant for all steel, regardless of grade. Since both the wave velocity (longitudinal or transverse) and the density are relatively constant for all steel, we can conclude that the acoustic impedance for all steels is constant, resulting in Grade 36 being acoustically equivalent to Grade HPS 70W.

Inquiry 23

October 2001

INQUIRY: Are there any special considerations needed to weld studs on HPS 70W? Is Section 7 of AWS D1.5 sufficient?

RESPONSE: The chemistry of HPS 70W steel, although more controlled, is within the envelope of the older ASTM A709 Grade 70W quenched and tempered steel. Grade 70W was recently removed from the A709 Specification, and replaced with Grade HPS 70W.

Based on prior history and experience with Grade 70W steel, and based on the current history of stud welding on at least 22 structures fabricated with HPS 70W and placed in service to date, it is my opinion that there should be no problems encountered when welding studs, providing all work is done strictly in accordance with the provisions of AWS D1.5, *Bridge Welding Code*. Welding HPS 70W steel, like many other steels commonly used in the bridge industry, can be accomplished successfully when good low hydrogen practice is observed, and diffusible hydrogen is controlled.

Inquiry 24

October 2001

INQUIRY A: Mr. Teal, we are investigating the potential use of HPS 70W for a four span curved girder bridge. We will be looking at a variety of configurations, but it appears at this point that the most economical arrangement is to use the HPS in the flanges of the negative moment regions.

RT RESPONSE A: Many designers have reported that it is most economical to use Grade HPS 70W in the negative moment areas of the flanges in combination with Grade 50W in the positive moment areas of the flanges, plus the entire web. However, the economical use of Grade HPS 70W may vary based on the actual application.

INQUIRY B: The owner has forwarded the Special Provisions, which modify the AASHTO/AWS Guide Specs. for this material.

RESPONSE B The Special Provisions that I provided are intended as a suggested addition to the contract documents for the project, and include the most recent recommendations of the High Performance Steel Steering Committee and the HPS Welding Advisory Group, as well as references to the most recent ASTM standards. The special provisions are modified on an as-needed basis based on the most recent research and experiences with High Performance Steel. Additional information is available on the American Iron and Steel Institute (AISI) website. The Guide Specifications for Highway Bridge Fabrication with HPS 70W Steel was developed by the HPS Steering Committee and adopted and published by AASHTO in September, 2000. AWS has not currently adopted this publication, although representatives of the HPS Steering Committee and HPS Welding Advisory Group are currently working to provide suggested revisions to AWS D1.5 for fabrication with HPS.

INQUIRY C: The owner said that you might be able to help us contact other DOT's with experience using this material, so we can help the DOT benefit from their experience and to get a better handle on the costs associated with the use of HPS for bridges.

RESPONSE C: The HPS Scoreboard contains contact information for the HPS structures listed, when known. [The latest edition can be obtained from the AISI website, www.steel.org].

Inquiry 24 (cont'd)

October 2001

INQUIRY D: Should I expect any problems when welding studs to high performance steel?

RESPONSE D: The chemistry of HPS 70W steel, although more controlled, is within the envelope of the older ASTM A709 Grade 70W quenched and tempered steel, which was recently removed from the A709 Specification and replaced with Grade HPS 70W. The AWS D1.5 Commentary advises that stud welding is routinely exempt from the requirement for preheating because of the relatively high welding heat input, and in many applications, the consideration that studs are welded in areas not subject to applied tensile stress. Further, stud welds are generally considered less susceptible to hydrogen cracking because of the limited size of the weld and associated heat affected zone.

In my opinion, this does not negate the concern for good low hydrogen practice, especially in applications where studs are welded in areas of applied tensile stress, or the stud welds are subject to the potential for rapid cooling. We must consider condition of the work site: storage and condition of consumables, including studs and ferrules; condition and adjustment of the welding equipment, heat input, and ambient temperature and conditions, all part of what is commonly considered good low hydrogen practice.

Considering the above, and based on prior history and experience with Grade 70W steel, plus the current history of stud welding on at least 22 structures fabricated with HPS 70W and placed in service to date, it is my opinion that there should be no problems encountered when welding studs, providing all work is done strictly in accordance with the provisions of AWS D1.5, *Bridge Welding Code*. Welding HPS 70W steel, like many other steels commonly used in the bridge industry, can be accomplished successfully when good low hydrogen practice is observed, and diffusible hydrogen is controlled.

Inquiry 25

October 2001

INQUIRY A: We are investigating the use of HPS 70W steel for the negative moment sections of a 4-span curved girder. One of the fabricators with whom we have discussed this idea has told us that they have had difficulty producing the correct camber in welded plate girders "due to the high residual stresses in the HPS." As a result, the cost is increased by about 15% to 20% over the 50ksi weathering steel cost and thus, even with the weight reduction of the [HPS 70W] design, the total cost is significantly increased. Would you have any information you could share with us regarding these problems?

RESPONSE A: With regard to [your] question regarding camber concerns from one fabricator, I recall talking about this issue with [a fabricator] on one of their first HPS structures. As I recall, they were finding little or no movement when trying to adjust camber on girders fabricated with Q&T material, similar to the initial experiences of [another fabricator] on several first-time bridges fabricated with Q&T HPS. The [latter] issue was simply resolved by allowing camber to somewhat exceed shop tolerances provided field camber tolerances were maintained. I believe that [the owner you are referencing] resolved the issue in a similar manner. Since those initial concerns, I am not aware of any reports of additional problems with camber or residual stress when fabricating with HPS. Since there are at least three fabricators with prior HPS experience that routinely bid [your] work, I feel that normal bidding practices will result in this being a non-issue, since the states routinely award to the lowest bidder.

INQUIRY B: Is there any issue with erection of the HPS 70W sections that may make erection more tedious?

RESPONSE B: With regard to erection concerns, Section 4(h) of the *HPS Fab Guide, 1st Edition*, cautions that additional bracing may be required when handling HPS girders because of the lower moment of inertia of the members.

Inquiry 26

November 2001

INQUIRY: The AASHTO guide for HPS70W [AASHTO Guide Specifications for Highway Bridge Fabrication with HPS70W Steel] has a supplemental provision that Cbr certification be required to work with HPS70W. Do you know the reference in AASHTO and any background?

RESPONSE: The inquiry refers to the AASHTO *Guide Specifications for Highway Bridge Fabrication with HPS70W Steel [HPS Fab Guide]*, published by AASHTO in September 2000 as an Addendum to AASHTO/AWS D1.5, *Bridge Welding Code*. This document is based on the work of the HPS Steering Committee and Welding Advisory Group, which was done under a cooperative agreement jointly sponsored by the Federal Highway Administration, the US Navy and the American Iron and Steel Institute, and provides recommendations to owners, designers and fabricators for fabricating and welding HPS70W steel.

The *HPS Fab Guide*, Appendix A4, AISC Certification, reads as follows: "*Only fabricators meeting the requirements of the Major Steel Bridges (Cbr) category of the AISC Quality Certification Program, or approved equal, may be used to fabricate HPS70W steel.*" This document has not been adopted by the AWS D1 Committee as of this date, but work is underway to update the AWS D1.5, *Bridge Welding Code* for fabrication and welding using HPS70W steel. When owners choose to use the *HPS Fab Guide*, reference to its use must be included in the Contract documents.

In addition, the *HPS Fab Guide* is currently in process of being updated to include the latest research and production experiences using Grade HPS70W steel.

Inquiry 27

February 2002

INQUIRY: What are the effects of multiple, short term applications of heat on high performance steel for purposes of camber correction?

RESPONSE: The effect of short term applications of heat on quenched and tempered HPS70W steel was studied as part of the NYS Thruway Authority Demonstration Project No. TE-50, High Performance Steel for Bridges. These tests were intended to demonstrate the effects of corrective heating on base metal mechanical properties, including hardness and Charpy V-notch impact toughness, using routine shop practice defined by the Standard Specifications for Highway Bridges, Sixteenth Edition. Single applications of heat were applied at temperatures between 1100 and 1250 degrees F, and multiple applications of heat (3 heating/cooling cycles) simulating overlapped or reheated areas were applied at 1100 and 1200 degrees F. Multiple applications of heat were allowed to cool naturally to ambient temperature before reheating. Based on these tests, it was determined that application of localized, short term heat up to 1250 degrees F had no apparent effect on the ultimate strength, yield strength, elongation or Charpy V-notch toughness of HPS70W steel. This data was submitted to the HPS Steering Committee for evaluation as part of a Demonstration Project report entitled *Summary of High Performance Steel Studies-Final Report for Corrective Heating*. The Steering Committee chose a conservative approach, and, as part of the *Guide Specification for Highway Bridge Fabrication with HPS70W Steel*, limited application of heat to 1100 degrees F.

Dr. Yoni Adonyi, Professor, LeTourneau University, has performed tests in a laboratory setting subsequent to the NYSTA Demonstration Project, and has reported similar findings for Q&T and TMCP plate. In addition, the HPS Steering Committee is addressing this issue as part of an Action Item to duplicate NYSTA Demonstration Project tests using TMCP plate. The specimens have been prepared, and are currently being tested by the USN Surface Warfare Center, Carderock Division. Tests are expected to be complete before March 1, 2002.

Inquiry 28

August 2002

INQUIRY: I was at [a] meeting last week and heard comments [that recommended] to make the diffusible hydrogen limit H4. What do you think?

RESPONSE: I agree that a suggestion [was made] to reduce the maximum diffusible hydrogen level to H4 for all consumables used to weld HPS 70W steel. It seemed to me that [the suggestion] was founded on a desire to avoid confusion in understanding when to allow a diffusible hydrogen level of H4 or H8 when welding HPS 70W steel in accordance with the recommendations of the *HPS Fab Guide*, and thereby simplify the document by specifying the more conservative diffusible hydrogen level of H4.

While this may be applicable to HPS structures previously fabricated exclusively with HPS 70W steel using matching weld metal, we have found that HPS is most effectively used in hybrid designs, and the use of weld metal that is matching for the lesser strength base metal in a hybrid joint, or undermatched for fillet welds, provides the most cost effective design.

I think we must understand the background for recommending the various Hd levels, and the effect this will have on allowable consumables for welding HPS. The AWS D1.5 *Bridge Welding Code*, Sections 12.6.5 and 12.6.6 restrict diffusible hydrogen levels to a maximum of H16 when welding base metals with a YS of 50 ksi or less, and to a maximum of H8 when welding base metals with a YS greater than 50 ksi. Based on research and experience of the HPS Steering Committee and the Welding Advisory Group, we have learned that diffusible hydrogen must be limited to a maximum of H8 to successfully weld HPS using the routine preheat temperatures required by AWS D1.5, Table 4.4. When diffusible hydrogen levels have exceeded H8, cracking in the weld metal and HAZ has been experienced. Further, research and experience has shown that HPS 70W may be welded using preheat temperatures substantially less than AWS D1.5, Table 4.4, i.e., 50 deg F for base metal to 3/4" thickness, 70 deg F for base metal over 3/4" to 2-1/2" thickness, which may mean that the base metal can be welded with no preheat when the ambient temperatures exceed these requirements if the welding consumables are limited to a diffusible hydrogen level of H4. However not all welding processes and welding consumable combinations can consistently meet the lower Hd requirements.

The following are electrode or electrode/flux combinations routinely used to weld HPS, along with the Hd levels certified by the manufacturer, although lower Hd levels may be possible in specific tests:

LA85/MIL800 HPNi - H2 - SAW, matching strength weld metal routinely used for CPGW's joining HPS 70W to HPS 70W base metals.

Inquiry 28 (cont'd)

August 2002

LA-75/960 - H8 - SAW, matching strength, corrosion resistant weld metal used for CPGW's joining HPS 70W to Grade 50W, and when making multiple pass fillet welds joining HPS 70W or Grade 50W to Grade 50W base metals. Also, undermatched, corrosion resistant weld metal used for CPGW's and single or multiple pass fillet welds joining HPS 70W to HPS 70W.

L-61/AXXX10 - H8 - SAW, same applications as LA-75/960.

L-61/960 - H8 - SAW, matching strength weld metal used when making single pass fillet welds to 5\16" joining HPS 70W or Grade 50W to Grade 50W base metals. Also, undermatched used when making single pass fillet welds to 5\16" joining HPS 70W to HPS 70W.

E-9018 MR - H4 - SMAW, matching strength weld metal used for short repairs to HPS 70W, and other applications requiring short, matching strength weldments.

E-8018-C3 MR - H4 - SMAW, matching strength, corrosion resistant weld metal used for repairs and short CPGW's joining HPS 70W to Grade 50W, and when making short multiple pass fillet welds joining HPS 70W or Grade 50W to Grade 50W base metals.

E-7018 MR - H4 - matching strength weld metal used when making short, single pass fillet welds to 5\16" joining HPS 70W or Grade 50W to Grade 50W base metals, or repairs to the same. Also, undermatched used when making short, single pass fillet welds to 5\16" joining HPS 70W to HPS 70W or repairs to the same.

In my opinion, Special Provisions should not be revised at this time to restrict consumables to a maximum diffusible hydrogen level of H4 for all applications, but should revert to the proposed wording recommended by the *HPS Fab Guide*. Please keep in mind that HPS structures to date have been very successfully fabricated using the recommended Hd levels.

Inquiry 29

May 2003

INQUIRY: I found your link on the AISI site and would like to address the following question: Is it necessary to apply protective coating to faying surfaces for friction grip joints using HPS70W steel? The joints are designed as AASHTO class B with a 0.5 friction factor.

RESPONSE: The mechanical properties are similar to the former Grade 70W, with the exception that Charpy V-notch toughness tests are substantially improved and the corrosion index of HPS 70W is somewhat improved. The basic chemistry of HPS 70W steel is within the parameters of Grade 50W and the former Grade 70W, although the chemistry ranges are more closely controlled.

Regarding the actual design of the splice, I wish to refer your question to Dr. Dennis Mertz, Chairman of the HPS Design Advisory Group, for his recommendation and comments on the latest research for splice design with HPS 70W. If you have further questions regarding HPS 70W, please do not hesitate to contact me.

Inquiry 30

May 2003

INQUIRY: Can HPS be heat straightened following typical heat straightening guidelines if the heat is kept below 1100 degrees F? Are there any other things I should look out for?

RESPONSE: HPS can be heat straightened using standard heat straightening guidelines except that the maximum temperature should be 1100 deg F.

This maximum temperature has been established based on tests simulating short term application of heat for the purpose of curving, cambering and heat straightening. Tests on Q&T were part of a demonstration project by the NYSTA on Q&T, and duplicated in further research by Dr. Yoni Adonyi at LeTourneau University. Tests on HPS TMCP were [also done] with evaluation by the Naval Surface Warfare Center, Carderock Division under supervision of John DeLoach, and again duplicated in further research by Dr. Yoni Adonyi at LeTourneau University. In general, these tests have shown that there is no significant degradation of mechanical properties, including hardness, at temperatures up to 1250 deg F. This also applies to multiple application of heat at the same location (tests repeated heating to prescribed temperatures three times). However, the HPS Steering Committee has taken a conservative approach and recommended a maximum temperature of 1100 deg F for short term applications of heat, consistent with keeping the temperature below the actual tempering temperature for Q&T of approximately 1250 deg F. Further, fabricators have reported that reducing the maximum allowable temperature to the recommended maximum for the former Grade 70W Q&T steel restricts response of the member, and causes a significant increase in the number of heat applications required.

Inquiry 31

May 2003

INQUIRY: Does the AWS D1.5 code require weld heat affected zone (HAZ) Charpy tests?

RESPONSE: The short answer to your question is a qualified no, the [AASHHTO/AWS] D1.5 *Bridge Welding Code* does not generally require CVN tests for the HAZ.

However, Section 5.4.3.5 reads in part, "*WPS qualification tests for welds on steels with minimum specified yield strength of 485 MPa [70 ksi] or greater shall measure strength, ductility, toughness, and soundness of the weld metal. When specified in the contract documents, qualification tests for steels shall also measure the CVN test values of the coarse grained area of the HAZ. The minimum CVN test energy, test temperature, orientation of the notch, and other necessary details shall be specified in the contract documents when HAZ testing is required.*"

Section C5.4.3.1 of the Commentary also states in part, "*CVN testing of the HAZ is rarely done for WPS qualification for bridge applications. Therefore, when the contract documents require HAZ toughness testing, detailed instructions shall be provided on the testing procedure. CVN testing of the HAZ can determine if the properties of the base metal have been affected by the heat generated from welding. Quenched and tempered steels achieve their high strength and good toughness, in large part, to fine grain produced by the heat treatment. High welding heat inputs that subject the HAZ to high temperatures for long periods may cause the HAZ grains near the fusion line to grow, or coarsen. Grain coarsening generally reduces toughness. The most serious degradation in toughness occurs within 2 mm [1/16 in.] of the fusion line. Details of testing should specify the CVN test specimen notch location and provide other details so that the fracture will sample the weakest part of the HAZ. Precise location of the CVN notch in the coarse grained area requires a high degree of metallographic skill and is extremely difficult under the best of conditions.*"

Inquiry 32

May 2003

INQUIRY: With much emphasis, a max hydrogen limit of H8 is imposed for all HPS welding [by the HPS Fab Guide, 2nd Edition]. If a fabricator chooses to use normal preheats, why is this necessary, especially for F_y 50 material?

RESPONSE: The [*HPS Fab Guide, 2nd Edition*], references HPS 70W only, which generally is either TMCP or Q&T material, although other manufacturing processes, including as-rolled and controlled rolled are referenced in the ASTM A709 specification. Based on research and experience, the Steering Committee recommends that consumables with a maximum diffusible hydrogen level of H8, as tested by the manufacturer, should be used. At the same time we recognize that actual diffusible hydrogen levels of consumables may be somewhat higher as received from the manufacturer, and certainly will be somewhat higher in production, even though fabricators diligently use good low hydrogen practice.

Since Section 4 of [the AASHTO/AWS D1.5 *Bridge Welding Code*] is silent on allowable diffusible hydrogen levels, the HPS Steering Committee and Welding Advisory Group have chosen to recommend a maximum level of H8, consistent with research, experience and maximum diffusible hydrogen levels allowed by the fracture control plan for steel with a yield strength greater than 50 ksi.

This recommendation does not apply at this time to Grade 50W or Grade HPS 50W materials. AWS D1.5, Table 4.4 preheats seem to be adequate to control hydrogen related cracking without imposing more stringent controls on diffusible hydrogen levels.

Inquiry 33

June 2003

INQUIRY A: [Someone] brought up the inconsistencies in the [conversion of metric units to English units for] AASHTO zone temperatures in [AASHTO/AWS D1.5 *Bridge Welding Code*], Tables 4.1 & 4.2. Sometimes (-) 30⁰ C is (-) 20⁰ F and sometimes (-) 25⁰ F. Actually, it's only (-) 25⁰ F in the case of Gr. 70W; it's (-) 20⁰ F everywhere else. Two questions to consider:

1. Would HPS 70W have the same requirement or would (-)20⁰ F do?
2. If (-) 22?⁰ F (-30⁰C) is an acceptable testing temperature for Gr 70W, why not (-) 20⁰ F? What was the basis for the initial distinction?

RESPONSE A: The increased toughness requirements for the former Grade 70W steel should be 34 J @ (-) 30 C (25 ft lbs @ (-) 25 F) to remain consistent with the 1996/1995 D1.5 *Bridge Welding Code*. Although not addressed in the 2002 commentary, the 1988 Commentary states that good toughness is required to resist brittle fracture. The increased toughness requirement for the Q&T product seems consistent with this thought. HPS routinely far exceeds this requirement.

INQUIRY A1: The toughness requirement is tightened both by raising the toughness requirement and by lowering the testing temperature. Conversions being what they are, both (-) 25⁰ F and (-) 20⁰ F come out to (-) 30 C. So anyone operating in an SI framework doesn't get the benefit of lowering the testing temp. Does this matter to anyone?

RESPONSE A1: It appears that this issue may be going away for most states. Based on the 2003 State Bridge Engineer Questionnaire conducted recently by AASHTO, 46 states are using English units, 3 states are using metric units, and 1 state is using dual units. I suggest that those states using metric units should be more specific in their contract documents if rounding of the toughness values and temperature is important to them.

INQUIRY B: The *HPS Fab Guide* says that if AISC considers them separate plants, then we should too, with regard to sharing PQR's and procedures. Is that new to the *HPS Fab Guide* or did it come from someplace else? And come to think of it, how does that jive with the fact that the PQR doesn't need to be done with the same welder or piece of equipment that will be used in fabrication?

RESPONSE B: The *HPS Fab Guide* recommends, "*Procedure Qualification Records should not be transferable to other fabricators. However, fabricators with multiple plants audited as a single facility by the American Institute of Steel Construction (AISC) as a part of their Quality Certification Program, or other owner-approved Quality Assurance program, should be considered one location. When operated with common welding equipment, welding training, and supervision, they should be allowed to perform PQR testing only once per combination of consumables as if operating at one location. Multiple plants not included in the AISC or other single audit should be considered separate facilities and PQR tests should be required for each plant.*" As an example, the *HPS Fab Guide* recommends that a fabricator who operates a facility with multiple fabrication shops at the same site, operates using common

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supervision, equipment and QA/QC and is audited as a single facility by AISC, should not be required to perform multiple PQR's per consumable for use at that facility. If that same fabricator has another facility in another city, and operates independently of the first facility, even though under the same general management, and is audited by AISC as a separate facility, that second facility must perform the required tests as if were a completely separate company.

INQUIRY B1: My question was twofold. (1) Is this philosophy unique to the Fab Guide, or does it come from someplace else? (2) Given that the equipment and personnel used in production are not necessarily those used in the qualification test, what does this limitation add?

RESPONSE B1 (1) This philosophy is the policy of some owners. However, the printed recommendation appears to be unique to the *HPS Fab Guide*. The recommendation seems like a reasonable requirement for frequency of all PQR testing. (2) I do not see this as a limitation, but rather a recommendation for owners for frequency of performing PQR testing. In my opinion, this recommendation should help to reduce the number of tests that could be required by some owners. Equipment and personnel may differ within a given owner and plant, but general policy within a given company should remain a constant.

INQUIRY C: Revised HPS 70W provisions [in the proposed AASHTO/AWS D1.5 *Bridge Welding Code* do not address] using a HPS 70W only PQR for hybrid joints. What's the latest [opinion]?

RESPONSE C: PQR's for hybrid joints should use base metal that conforms to the requirements of [the current] AASHTO/AWS D1.5 *Bridge Welding Code*, Section 5.4. For hybrid joints, this generally can be interpreted to mean that one side of the test plate is the HPS 70W steel, while the other is Grade 50W, as applicable.

INQUIRY D: [The *HPS Fab Guide* states,] "*For undermatched SMAW applications, E7018R or E8018-C3R electrodes are acceptable, as applicable.*" Does that override the "anything for 50W" implication [in Section 3.2.5, Welding for Hybrid Designs]?

RESPONSE D: Consumables listed in AWS D1.5, Table 4.1 for Grade 50W base metal are considered to be matching strength for hybrid designs where HPS 70W base metal is joined to 50W base metal. The use of undermatched consumables is recommended for all fillet welds joining HPS 70W to HPS 70W plates, to reduce the potential for hydrogen cracking. The *HPS Fab Guide* recommends E7018R or E8018-C3R for undermatched applications.

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- INQUIRY E:** If [AASHTO/AWS] D1.5, Table 4.4 was used rather than the *HPS Fab Guide*, Table 3, then Table 4.4 becomes the reference for production welding. A footnote to Table 3 says that if a higher preheat than Table 3 was used during qualification, that preheat is the minimum for production. Does this translate into "When welding with HPS 70W, the preheat used in qualification is the minimum preheat for production"? Or do you just mean that if the preheat had to be upped to somewhere between the Table 3 values and the D1.5 Table 4.4 values, then that's the new preheat? Would the preheat ever need to be higher than the Table 4.4 values for non-FC?
- RESPONSE E:** The note reads, "*If satisfactory results are not achieved with the above minimum preheat and interpass temperatures during development of the Welding Procedure Specification (WPS), and an increased preheat temperature is used to provide a satisfactory Procedure Qualification Record (PQR), the higher preheat temperature should be the required minimum during bridge fabrication.*" If it is necessary to increase preheat to any level (FCM, non-FCM or other) to obtain satisfactory test results, that increased preheat should become the required minimum for all production work using the given weld test parameters.
- INQUIRY F:** The old Fab Guide, Section A3 allowed straight transition [of girder flange width]. Is a radiused [flange width transition] now the recommendation or was this omitted?
- RESPONSE F:** This provision was deleted in the 2nd Edition of the *HPS Fab Guide*. Although there is most likely not a significant reason for requiring a radiused transition for HPS steel, the thought was to follow the requirements of the AASHTO/AWS D1.5 *Bridge Welding Code*. Secondly, it seems that most fabricators default to the radiused transition for transitions in flange width.
- INQUIRY F1:** [AASHTO/AWS] D1.5, Section 2.17.5.3 disallows the straight transition [of girder flange width] for Gr 70W and Gr 100W. If there's no significant reason for requiring it for HPS, why do so? In particular, why allow it in the last edition and then disallow it?
- RESPONSE F1:** I'm not sure that it is disallowed at this time. Straight transitions for HPS 70W joints are not specifically addressed in AASHTO/AWS D1.5. Therefore, it appears to me that a straight transition should be allowed if preferred by the fabricator.
- INQUIRY G:** Isn't the [recommendation] to specify CVN testing of HAZ redundant with whatever's already in [AASHTO/AWS] D1.5 for anything Gr. 70 or higher?
- RESPONSE G:** This reminder to owners has been removed from the sample Special Provisions in the 2nd Edition of the *HPS Fab Guide*.

Inquiry 33 (cont'd)

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- INQUIRY H:** Is there a recommended heat input restriction for SMAW welding of HPS 70W? SAW has 40-90 and FCAW/GMAW list specific HI for specific consumables.
- RESPONSE H:** The *HPS Fab Guide, 2nd Edition*, has an added sentence that reads, "Welding parameters for SMAW consumables should be as recommended by the consumable manufacturer."
- INQUIRY I:** What about undermatched GMAW? Not recommended at all? I'd think it would be, since there's an overall trend to prefer the lower-strength consumables.
- RESPONSE I:** The only GMAW consumables recommended are Metal-Cored electrodes that performed well in research studies. At this time, this does not include any that would be considered undermatching.
- INQUIRY J:** The old version [of the *HPS Fab Guide*] said E7018R is recommended. [The *HPS Fab Guide, 2nd Edition*,] says use anything listed for 50W, but still has the E7018R recommendation. How would you resolve that?
- RESPONSE J:** By reference to Table 4.1, various SMAW electrode specifications are allowed. The *HPS Fab Guide, 2nd Edition*, makes specific recommendations, although owners can certainly choose to approve others. The *HPS Fab Guide, 2nd Edition*, reads, "AASHTO/AWS D1.5, Sections 2.1.6 and 4.1.1 permit undermatched weld metal strength for all fillet and PJP welds when consistent with design requirements, and CJP welds for limited applications. For undermatched SMAW applications, E7018R or E8018-C3R electrodes are acceptable, as applicable, and their use is encouraged."
- INQUIRY K:** [The last paragraph of Section 3.1 of the *HPS Fab Guide, 2nd Edition*,] says the maximum interpass [temperature] is 450⁰F. Does this override [AASHTO/AWS] D1.5, Section 4.2.2 that gives thickness-dependent temperatures?
- RESPONSE K:** The intent is to recommend a maximum preheat and interpass temperature of 450 F when welding HPS. The *HPS Fab Guide, 2nd Edition*, does not override other specifications, but rather makes recommendations to owners and designers. The owner or designer can choose to adopt this *HPS Fab Guide* in whole or in part.
- INQUIRY K1:** When they adopt it in whole [*HPS Fab Guide, 2nd Edition*], would they be overriding [AASHTO/AWS D1.5, Section] 4.2.2 that gives thickness-dependent temperatures?

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June 2003

RESPONSE K1: I would think that adopting the *HPS Fab Guide, 2nd Edition* in its entirety would override other specification requirements, unless certain sections are specifically exempted. The recommendation for a maximum preheat and interpass temperature of 450 F, regardless of thickness, is made to provide adequate time for hydrogen to dissipate from the HAZ of the weldment without causing cracking. It would seem to me that the increased limit would be even more important on the thinner materials, which generally cool faster than thicker materials.

INQUIRY L: Table 3 is for both fracture-critical and non-FC applications. What about undermatching? Section 3.3 doesn't really get into H designation vs. which table to use.

RESPONSE L: [The *HPS Fab Guide, 2nd Edition*], Table 3 applies to welding HPS steel, regardless of whether matching or undermatching consumables are used. If the lower preheat and interpass temperatures of Table 3 are used, it is recommended that diffusible hydrogen levels not exceed H4. If the higher preheat levels of Table 3 are used (same as [AASHTO/AWS] D1.5, Table 4.4), it is recommended that diffusible hydrogen levels not exceed H8.

INQUIRY L1: For non-FC only?

RESPONSE L1: Section 1.1 of the *HPS Fab Guide, 2nd Edition* reads, "*The superior toughness of HPS 70W steel, combined with the requirements specified herein, suggest that fabrication in accordance with this HPS Fab Guide will produce structural members that meet Fracture Critical Member (FCM) specifications. At this time, it is necessary to fabricate fracture critical members, when identified as such in the contract documents, in accordance with AWS D1.5, Section 12, AASHTO/AWS Fracture Control Plan (FCP) for Nonredundant Members. Otherwise, fabrication of conventional, non-fracture critical HPS 70W components can be successfully completed when work is done in conformance with AWS D1.5 combined with the recommendations of this HPS Fab Guide. It is important to keep in mind that the HPS Fab Guide recommends consumable handling in accordance with AWS D1.5, Section 12.6.5 for the SMAW process, Section 12.6.6 for the SAW process, and Section 12.6.7 for the FCAW and GMAW Metal Cored process, to control the diffusible hydrogen levels to H8 maximum. Otherwise, no other provisions of the Fracture Control Plan are recommended, unless the component is specifically designated a FCM.*" Therefore, the answer to your question appears to be yes, unless you choose to use the recommendations of the *HPS Fab Guide, 2nd Edition* for FCM's, in which case Table 3 may apply to FCM's.

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June 2003

INQUIRY M: Is the general idea that whenever one is welding HPS 70W, one should be following the [AASHTO/AWS D1.5, Section] 12 storage and handling requirements [for welding consumables]? Or just when using the reduced preheats? In [the *HPS Fab Guide, 2nd Edition*], it doesn't say much for SAW, seems to recommend it for all cases for FCAW and GMAW, and requires it for SMAW only for reduced preheat.

RESPONSE M: Section 1.1 *HPS Fab Guide, 2nd Edition*, reads, "*It is important to keep in mind that the HPS Fab Guide recommends consumable handling in accordance with AWS D1.5, Section 12.6.5 for the SMAW process, Section 12.6.6 for the SAW process, and Section 12.6.7 for the FCAW and GMAW Metal Cored process, to control the diffusible hydrogen levels to H8 maximum. Otherwise, no other provisions of the Fracture Control Plan are recommended, unless the component is specifically designated a FCM.*"

Inquiry 34

November 2003

INQUIRY: [A fabricator] used an unapproved weld metal to join HPS 70W components of a FCM truss. Please advise whether the unapproved weld metal can be allowed, and, if so, procedures required to approve it.

RESPONSE: The following is my understanding of events that led to rejection of certain components of [an FCM truss] based on our telephone conversation.

1. The components in question are I-shaped vertical members of a fracture critical truss subject to direct tension or direct compressive loading.
2. The weldments in question are 5/16" fillet welds that join HPS 70W flanges to the HPS 70W web of the vertical members.
3. The approved WPS for these weldments required the use of matching SAW consumables Lincoln LA85/MIL800HPNi.
4. The welds were made with the submerged arc welding process using a Lincoln LA75 electrode in combination with Lincoln 860 flux, in lieu of the matching strength consumables approved. Preheat was in accordance with AWS D1.5, Table 4.4 or Table 12.4, as applicable. Heat input was 55.5 KJ/in in lieu of the 80 KJ/in referenced in [the fabricator's] proposal. Based on The Lincoln Electric Company's annual certificate of conformance for this SAW combination, the diffusible hydrogen level is 4.3 ml/100g.
5. You state that your designer does not require matching strength consumables to meet strength requirements, and that undermatched consumables would meet design requirements for this application.
6. [The fabricator] has not performed a PQR for the SAW consumables LA75/860 with HPS 70W base metal.

The *Guide Specification for Highway Bridge Fabrication with HPS 70W (HPS 485W) Steel*, 2nd Edition, commonly referred to as the *HPS Fab Guide*, recommends the use of SAW consumables Lincoln LA85/MIL800HPNi for matching strength applications joining HPS 70W steel to HPS 70W steel. These consumables are typically used for transverse CPGW's joining HPS 70W plate, and other groove and fillet weld where necessary to meet matching strength requirements, as identified by the designer.

Section 3.3 of the *HPS Fab Guide* further states that AWS D1.5, Sections 2.1.6 and 4.1.1 permit undermatched weld metal strength for all fillet welds when consistent with design requirements, and that the use of undermatched consumables is recommended for all fillet welds joining HPS 70W to HPS 70W plates, to reduce the potential for hydrogen cracking. Filler metals recommended for Grade 50W base metal should be used to ensure the welds are undermatched but not significantly understrength, i.e., minimum ultimate tensile strengths are near 70 ksi, and weathering characteristics will be similar for unpainted applications.

Inquiry 34 (cont'd)

November 2003

[The fabricator] proposes in their letter to conduct a PQR using Lincoln LA75/860 consumables, with parameters in accordance with those used in the work, and testing in accordance with AASHTO/AWS D1.5-02, plus additional ultrasonic testing of the weld and associated heat affected zone. This proposal appears to be generally consistent with the recommendations of the *HPS Fab Guide* for undermatched consumables. As a condition of acceptance, I recommend that testing be done in accordance with the recommendations of the *HPS Fab Guide*, including Section 3.3, and with AASHTO/AWS D1.5-02, Section 5.13, Production Procedure WPS, using the actual weld parameters used in the work, preheat as used in the work, and HPS 70W base metal. The diffusible hydrogen level of the consumables must not exceed H8, as determined by manufacturer's tests. For this application, testing should also be consistent with the requirements of AWS D1.5, Section 12, Fracture Control Plan, which may include specific heat and lot tests. The test plate should be consistent with AWS D1.5, Figure 5.1, except that the requirement for reduced section tension specimens and side bends should be waived for undermatched consumables as described in AWS D1.5, Section 5.15.1.

[The fabricator] proposes to use this SAW combination for the remaining work. Assuming successful test results and a diffusible hydrogen level of H8 or less, this proposal would again appear to be consistent with the recommendations of the *HPS Fab Guide*, providing the weldments meet all strength requirements as determined by the designer.

The additional magnetic particle testing proposed by [the fabricator] far exceeds the testing requirements specified by AWS D1.5, and the recommendations of the *HPS Fab Guide*.

Inquiry 35

January 2004

INQUIRY: [I have a question] about the approved welding rods allowed in the HPS Fabrication Guide. Right now, only Lincoln Electric's rods are [recommended]. What we'd like to know is, have there been any other approved rods added since it was first developed, or are there any others going through an approval process at this time?

RESPONSE: The *HPS Fab Guide, 2nd Edition* currently recommends Lincoln LA85/MIL800HPNi consumables for matching strength weld metal using the SAW process based on research and experience, and further recommends that alternate SAW consumables conform to the AWS electrode/flux classification F9A4-EXXX-X with 1% nickel minimum in the weld deposit, with the optional diffusible hydrogen designator H8 or less, and preheat appropriate for the diffusible hydrogen level as described in Table 3 of the *HPS Fab Guide*.

The HPS Steering Committee and Welding Advisory Group has repeatedly invited consumable manufacturers to submit or develop other matching strength consumables for evaluation. However, to date, there has been no other SAW matching strength consumables from other manufacturers that have performed successfully in either research, fabrication or in service. This is apparently the result, in part, from some manufacturer's decision not produce these consumables based on the limited market for the product.

The *HPS Fab Guide, 2nd Edition*, does not make name specific recommendations for undermatched weld strength applications using the SAW process. Research and experience has shown that SAW consumables that conform to AWS D1.5 *Bridge Welding Code*, requirements for welding Grade 50W base metal have been used successfully for undermatched weld metal applications, regardless of manufacturer.

Based on research [at this time], the *HPS Fab Guide, 2nd Edition*, recommends name specific consumables for the FCAW and GMAW Metal Cored processes. ITW/Hobart's FCAW consumable TM-95K2, ESAB's FCAW consumable DS II 101H4M and ITW/Hobart's GMAW-Metal Cored Metalloy 90 are recommended for matching strength applications. For undermatched weld metal applications, ITW/Hobart's FCAW consumable TriMark TM-771 is recommended. The use of alternate FCAW or GMAW consumables is not recommended at this time.

The *HPS Fab Guide, 2nd Edition*, recommends SMAW consumables with diffusible hydrogen levels of H4 or H8 maximum, depending on the level of preheat. This recommendation is not manufacturer specific.

Inquiry 35 (cont'd)

January 2004

In answer to your question, the *HPS Fab Guide* recommendation for consumables is an ongoing process, based on research and experience. Initially, only SAW and SMAW consumables were recommended, without regard for manufacturer. Consumables were selected based on AWS classification in accordance with the requirements of the AWS D1.5, *Bridge Welding Code*. Diffusible hydrogen levels were controlled as described in AWS D1.5 for non-fracture-critical applications. On one of the first HPS structures fabricated, a fabricator experienced hydrogen induced cracking, as determined by a team of HPS Steering Committee and Welding Advisory Group experts. Lincoln Electric's SAW combination LA100/Mill800H, with a diffusible hydrogen level of H4, was determined to be the short term resolution to the cracking issues, and found to produce consistently sound weld metal, although it was an overmatched consumable. As a result, Lincoln MIL800HPNi flux was developed, and used with the Lincoln LA85 electrode. This SAW combination has consistently produced sound, matching strength weld metal when handled using good low hydrogen practice. Another manufacturer's SAW electrode was selected, but they did not produce a compatible flux. Research was conducted with this electrode in combination with Lincoln's MIL800H flux, and was initially recommended. However, discontinuities occurred in the weld metal during fabrication, which were undetectable by RT, but major rejectable indications when detected by UT. Further evaluation by the Department of the Navy suggested that the indications were microcracks. As a result, recommendation of this SAW combination was rescinded by the HPS Steering Committee. It is the intent of the HPS Steering Committee and Welding Advisory Group to recommend alternate consumables whenever possible, based on ongoing research. Research continues with ongoing agreements to evaluate other name specific consumables. However, alternate consumables are considered very carefully before being recommended. Other manufacturers, contractors and fabricators are encouraged to develop and/or use alternate consumables consistent with the parameters necessary to successfully join high performance steel. However, as stated previously, lack of alternate consumables is, in part, the result of some manufacturer's decision not produce these consumables based on the limited market for the product.

Inquiry 36

February 2004

INQUIRY: I have learned of a project where all elements of the steel girders are HPS 50W. The fabricator has previously approved welding procedures for conventional Grade 50W steel, and wants to apply those to the current HPS 50W project. The question arises as to whether or not new welding procedures are needed. I would like to be able to point to a printed source or website source for guidance on welding HPS 50W steel. Any assistance you can offer here would be appreciated.

RESPONSE: Currently, there are no special published recommendations for welding HPS 50W steel. The primary difference between HPS 50W and Grade 50W is the more controlled chemistry, significantly improved Charpy V-notch toughness and a potential for improved corrosion resistance of HPS 50W.

In support of your need for a printed source for guidance, I offer the following: The AASHTO/AWS D1.5M/D1.5:2002, *Bridge Welding Code* does not include requirements for welding steel designated HPS 50W at this time. As such, strict enforcement of the Code will require the base metal for PQR's to be HPS 50W, as described in Section 5.4.3, *Use of Unlisted Base Metals*. However, steel designated as HPS 50W could be dual certified as Grade 50W/HPS 50W, i.e., it is possible for a steel manufacturer to issue a certified mill test certificate for HPS 50W that conforms in all ways to the requirements for Grade 50W steel. When thus designated, PQR's could be welded and production welds made in conformance with the Code without any question. Therefore, it is recommended that the Engineer accept HPS 50W and Grade 50W as equivalent base metal specifications for PQR applications that conform to all other requirements of AWS D1.5. It is recommended that procedure qualification tests for consumables joining HPS 50W plates conform to AWS D1.5, Section 5.7, with filler metal in conformance with AWS D1.5, Table 4.1 or 4.2, as applicable for Grade 50W base metal, providing heat input is in accordance with the consumable manufacturer's recommendations, and preheat and interpass temperatures conform to AWS D1.5, Table 4.4 for Grade 50W base metal.

In further support of your need for a printed source, the specified mechanical properties of HPS 50W and Grade 50W are the same, as evidenced in Table 1 of ASTM A709/A 709M-01 and later. The chemical requirements of HPS 50W steel are more controlled, and within the limits of chemical requirements for Grade 50W steel, including manganese when the reduced carbon content of HPS 50W is considered, as evidenced by comparing Tables 4 and 6 respectively in ASTM A 709/A709M-01 and later. The Carbon Equivalent (CE) range of HPS 50W is 0.48 to 0.64 using the chemical requirements listed in ASTM A709. AWS D1.5, Section 5.4.2 (1) allows test plates and backing with a CE of 0.45 minimum to qualify all AASHTO base metals with a yield strength of 50 ksi or less providing the carbon content is 0.12 minimum. Currently, an AWS Task Group is actively working to include both HPS 50W and HPS 70W in the next AWS D1.5 publication, assumed to be in 2005 or 2006.

Inquiry 37

March 2004

INQUIRY: Why is HPS becoming more difficult to obtain from the mill and more costly?

RESPONSE: With the recent merger of steel mills and the improving economy, the lead times for all mill orders has been extended for all grades of steel used in the bridge industry. HPS should be no more extended than conventional grades, except the Q&T adds 2 weeks, if required. The price of HPS 70W is reported to have actually dropped over the past year compared to Grade 50W and approximately \$0.10 to \$0.18 per pound more than Grade 50W, depending on the manufacturer. All plate pricing for all applications have increased this year with base prices and surcharges being announced by all steel producers of all products.

Inquiry 38

April 2004

INQUIRY A: Please confirm: [A diffusible hydrogen level of] H8 is required for all welding of HPS 70W. Hybrid joints, undermatched, all processes, all preheats?

RESPONSE A: A diffusible hydrogen level of H8 maximum is [recommended] for welding all HPS 70W applications, as described in Section 1.1, Section 3 and Table 3 of the *Guide Specification for Highway Bridge Fabrication with HPS 70W (HPS 485W) Steel, 2nd Edition (HPS Fab Guide)*.

INQUIRY B: Please confirm that 1% nickel is required for all welding of HPS 70W? This would rule out some SMAW electrodes, all GMAW, and most FCAW. Does it apply to entire classifications that aren't defined to meet the requirements, or would a typical certification indicating 1% nickel do? (This means we'd have to recheck this every year.) If we go strictly by classification, for undermatching and hybrid joints, the following would be ruled out: All the A5.1 electrodes: E7016-A1, B2L; E7018-A1, B2L, W1; E8018-W2; all the A5.17 electrodes; A5.23 A & B series, Ni1, Ni5, F1 thru F4, and W; all FCAW except A5.29 E9XT1&5 K2 & K2M series; all GMAW except A5.28 ER80S-Ni2, Ni3. Was that the intent?

RESPONSE B: The HPS Fab Guide recommends 1% nickel in the SAW weld deposit when qualifying alternate consumables. This minimum nickel content is recommended to obtain adequate corrosion resistance of the weld metal, and is intended to apply to unpainted applications only. When HPS 70W is used in painted or coated applications, it may not be necessary to require the specified nickel content. Therefore, the list of consumables above may be acceptable if adequate weld metal toughness is obtained for bridge applications. Further, work is underway at this time to evaluate the consumables designated as 1% nickel by the manufacturer for undermatched applications, which may ultimately change this recommendation to allow such consumables in lieu of measuring nickel in the weld deposit.

INQUIRY B1: Your recommendation at this time, then, would be require the 1% Ni only for SAW, for both exposed and painted applications?

RESPONSE B1: At this time, the *HPS Fab Guide, 2nd Edition*, recommends 1% nickel in the SAW weld deposit when qualifying alternate consumables. There are no recommendations for qualifying consumables for other processes. In my opinion, if an owner chooses to allow qualification of consumables for processes other than SAW, the above recommendation of minimum 1% nickel in the deposited weld metal remains valid for those consumables to maintain adequate corrosion resistance when used in unpainted applications.

Inquiry 38 (cont'd)

April 2004

INQUIRY C: Please confirm that the [heat input recommendation] of 40-90 kJ/in only applies when reduced preheats are used?

RESPONSE C: In my opinion, the restricted heat input recommended by the *HPS Fab Guide* is intended to apply to all SAW applications when welding HPS 70W, regardless of preheat. Selected consumables for other processes have specific heat input recommendations based research.

INQUIRY D: Please confirm that the *HPS Fab Guide*, Appendix A requirement 3.03.D (UT of PQR plates) is now [recommended] only in case of reduced preheat?

INQUIRY D: The *HPS Fab Guide* recommends that owners include UT testing of PQR's as part of their special provisions, regardless of preheat. The UT test is routinely done on all PQR's for all base metals prior to cutting specimens, but test results are not reported unless specified in the contract documents.

INQUIRY E: If one runs an undermatched HPS 70W PQR, should that serve to qualify Grade 50W procedures with the same electrodes?

RESPONSE E: PQR's for undermatched weld metal run on HPS 70W base metal should not also qualify the consumables for use with Grade 50W base metal. Separate tests should be used, as specified in AWS D1.5 Table 4.1, primarily based on the CE of the base metals. The CE of HPS 70W is routinely less than that of Grade 50W. Mechanical test results of the weld metal must correspond to the strength requirements for matching lesser strength base metal, i.e., for Grade 50W base metal.

INQUIRY E1: What is typical CE of Grades 50 or 36 as compared to PS 70W? Is the problem that it's not enough of a "worst case"?

RESPONSE E1: In my opinion, the CE of HPS 70W is too low to qualify Grade 50W base metal. The C max for HPS 70W is 0.11, vs. 0.19 for Gr 50W.

INQUIRY F: The last advice I got for qualifying procedures for hybrid joints was that either the undermatched HPS 70W PQR or a hybrid PQR would do, but that an all-Gr. 50 (or 50W) wouldn't. Is that still the case?

RESPONSE F: That advice is still valid, and conforms to the requirements of AWS D1.5, Section 5.4.

INQUIRY G: [Can SAW] flux be used without baking if it's taken directly from a hermetically sealed container? This is an exception to [AASHTO/AWS D1.5, Section] 12.6.6.3.

RESPONSE G: This is intended to apply only to non-fracture critical applications, as described in Section 1.1 of the *HPS Fab Guide*. However, manufacturers recommendations, including restricted maximum baking temperatures for SAW flux, must be adhered to regardless of the application. In my opinion, the provisions do not supercede the requirements of the fracture control plan at this time.