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New Code Requirements for Calculating Heat Input

Welders, inspectors, and engineers should be aware of the changes to QW-409.1 of ASME IX regarding waveform-controlled welding

BY TERESA MELFI

Welding waveforms are used to limit distortion, weld open roots, and to control HAZ properties. Waveform control is essential for common processes like uphill GMA pulse welding. Power sources that support pulsing (GMAW-P, GTAW-P, etc.) are the most common waveform- controlled power sources. Those marketed as synergic, programmable, or microprocessor-controlled are also likely to support waveform-controlled welding.

The correlation between heat input and mechanical properties is blurred when heat input is calculated using current and voltage readings from conventional meters. This includes external meters and even those located on the welding power source. It's not that the meters are incorrect — in fact, most are calibrated and tested to NIST standards. Rather, the inaccuracy involves the means of capturing and displaying the data.

Conventional DC meters display average voltage and average current. Conventional AC meters display RMS values. To accurately indicate the energy input to a weld, the voltage and current readings must be multiplied together at very rapid intervals that will capture brief changes in the welding waveforms. This frequency is in the order of magnitude of 10,000 times per second. Specialized meters are required to accomplish this.

Revisions to ASME Section IX provide a new method of calculating heat input that allows comparison of the heat input from various welding power sources and various welding waveforms. This will allow production welding to take place with a welding procedure specification (WPS) that specifies either conventional or waveform-controlled welding, which is supported by a procedure qualification record (PQR) using either conventional or waveform-controlled welding.

Calculating Heat Input

Many welding codes use the equation shown in Equation 1 to calculate heat input. Because the welding process (GMAW, SAW, etc.) is an essential variable, a process or efficiency factor is not included in the heat input calculation. The new equations that will be in the 2010 edition of ASME Section IX are shown in Equations 2 and 3, either of which gives equivalent results. Both equations are shown because some welding power sources and meters display energy values, and others display power values.

$$\frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed (in./min or mm/min)}}$$

Equation 1: Traditional heat input equation, ASME Section IX QW-409.1 (a).

$$\frac{\text{Energy (Joules)}}{\text{Weld Bead Length (in. or mm)}}$$

Equation 2: New heat input equation for meters displaying energy measurement (Joules), ASME Section IX QW-409.1 (c)(1).

$$\frac{\text{Power (Joules/s)} \times \text{Arc Time (s)}}{\text{Weld Bead Length (in. or mm)}}$$

Equation 3: New heat input equation for meters displaying power measurement (Joules/s or W), ASME Section IX QW-409.1 (c)(2).

Three examples from GMA welding are shown in Fig. 1. The axial spray waveforms are essentially constant, and the difference between the measurement methods is minimal. For the two waveform-controlled procedures, there is an error between the measurement methods that can be in a positive or negative direction. It is clear from the significant differences why a new measurement method is needed.

Changes in ASME Section IX

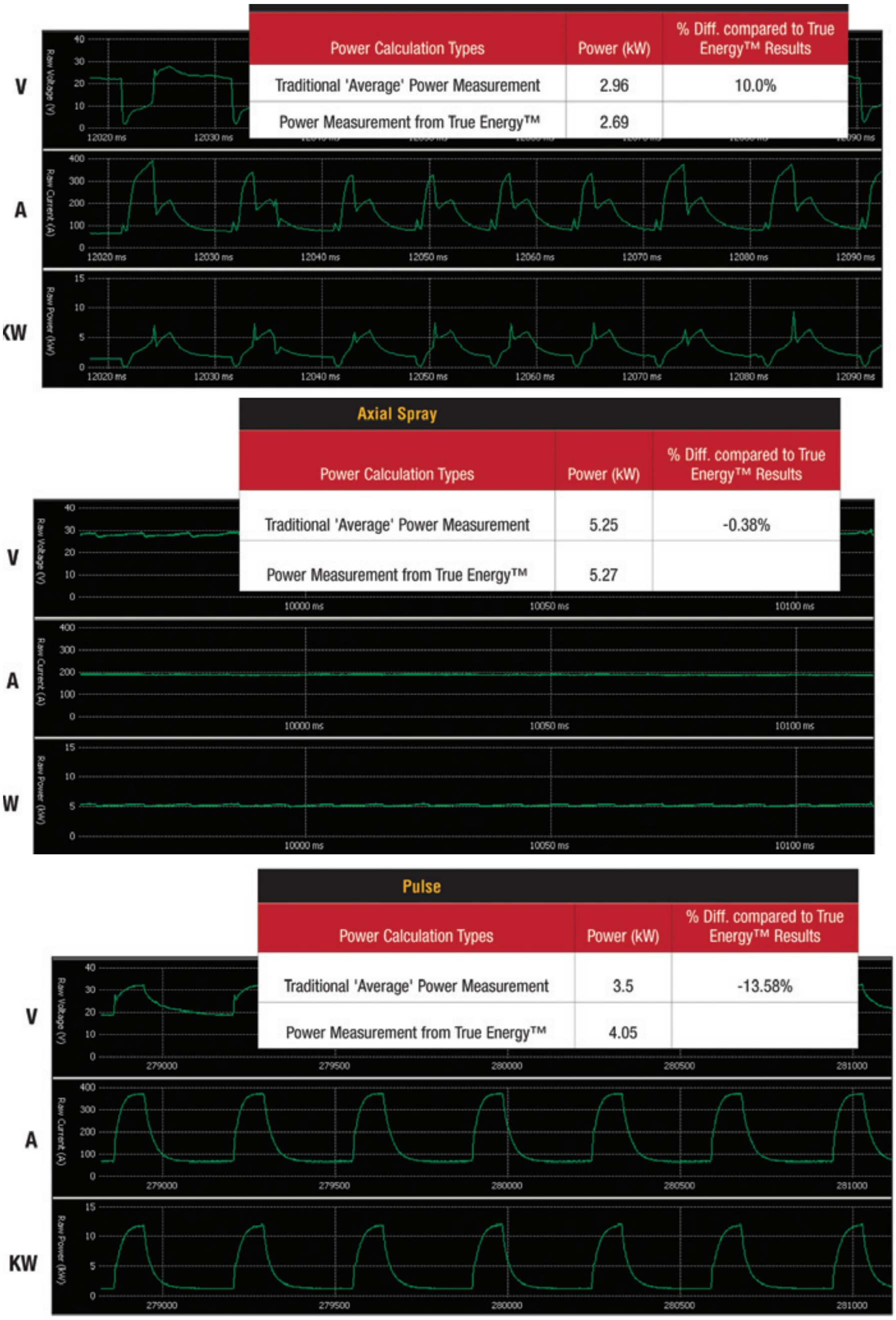
ASME codes and standards have a long history, now in their 125th year. The rules for welding were removed from the construction codes when ASME Section IX was published in 1941. ASME Section IX has become a global standard, referenced by the ASME construction codes, owners, engineering firms, and other fabrication and construction codes.

The ASME IX Standards Committee has subcommittees that address procedure and performance qualifications, materials, general requirements, and brazing. More than three years ago, a task group was formed to work on issues surrounding welding with complex waveforms from microprocessor-controlled power sources. The first result of this group's work will be a change to the measurement and calculation method for heat input.

QW409.1 is the main Section IX variable that deals with heat input. Currently, there are two ways to calculate heat input. Method (a) is the traditional heat input equation shown in Equation 1. Method (b) is a measurement of the volume of weld metal deposited. A new method (c) is added in the 2010 edition, which includes Equations 2 and 3.

Any of the methods can be used when welding following procedures that are not waveform controlled. When welding following waveform-controlled proce-

TERESA MELFI is with The Lincoln Electric Co., Cleveland, Ohio. She is chair of the AWS A5B Committee on submerged arc welding, a member of the AWS A5 Committee on filler metal specifications, a member of ASME Section IX, including the materials subgroup and a working group on advanced waveform welding, and is the U.S. delegate to the International Institute of Welding commission that covers pressure vessels, boilers, and pipelines.



Power Calculation Types	Power (kW)	% Diff. compared to True Energy™ Results
Traditional 'Average' Power Measurement	2.96	10.0%
Power Measurement from True Energy™	2.69	

Axial Spray

Power Calculation Types	Power (kW)	% Diff. compared to True Energy™ Results
Traditional 'Average' Power Measurement	5.25	-0.38%
Power Measurement from True Energy™	5.27	

Pulse

Power Calculation Types	Power (kW)	% Diff. compared to True Energy™ Results
Traditional 'Average' Power Measurement	3.5	-13.58%
Power Measurement from True Energy™	4.05	

Fig. 1 — Heat input differences calculated using Equation 1 vs. Equation 2.

Fig. 2 — With the proper software installed, access to the energy reading entails pressing the menu option "Display Energy."

Fig. 3 — The real-time energy is continuously incremented while welding, and the final energy is displayed until the next arc start.

dures, only methods (b) or (c) are permitted. With these methods, it is possible to determine the compliance of a production weld made using a waveform-controlled welding procedure to an existing qualified procedure, even when the procedure qualification was performed using nonwaveform controlled welding. An appendix to ASME Section IX has been provided to guide users through these code changes. The appendix provides guidance with new procedure qualifications, existing qualified procedures, and comparing heat inputs between waveform-controlled and non-waveform-controlled welding. ASME Section IX does not mandate separate performance qualifications for waveform-controlled welding.

How to Comply with ASME Code Changes

To use method (c) of the code, a reading of energy (Joules) or power (Joules/s) must be obtained using a meter that captures the brief changes in a welding waveform and filters out extraneous noise. The simplest place to obtain this is from the welding power source. Many power sources that output pulsing waveforms will display these readings, although some might require software upgrades to enable this. Details and software upgrades for Lincoln Electric's Powerwave "M" series and several other models are available free of charge at *www.powerwave software.com*. For a power source that doesn't support the display of energy or power, external meters are available. A meter with demonstrated accuracy in this application is the Fluke® 345 Power Quality Clamp Meter.

With the proper software installed, it is simple to access the energy reading — Fig. 2. In the setup menu, enable the option to "Display Energy." When an arc is started, the energy value will begin to increment. The value will continue to increase, showing the real-time energy put into that weld — Fig. 3. When the welding stops, the final energy value will be displayed until welding resumes again. This value represents

Assist Chart for ASME IX QW-409.

PQR qualified with:	Qualifies for welds produced with:
Non-waveform controlled welding using conventional volt and ammeters and QW-409.1(a)	• Non-waveform controlled power supply using conventional volt meters and ammeters and QW-409.1(a). • Non-waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and QW-409.1(c).
Non-waveform controlled welding using instantaneous energy or power and QW-409.1(c)	• Non-waveform controlled power supply using conventional volt meters and ammeters and QW-409.1(a). • Non-waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and QW-409.1(c).
Waveform controlled welding using instantaneous energy or power and QW-409.1(c)	• Non-waveform controlled power supply using conventional volt meters and ammeters and QW-409.1(a). • Non-waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and QW-409.1(c).
Waveform controlled welding using conventional volt and ammeters and QW-409.1(a) (qualified prior to 2010 code change)	• Non-waveform controlled power supply using conventional volt meters and ammeters and QW-409.1(a). • Non-waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply displaying instantaneous energy or power measurement and QW-409.1(c). • Waveform controlled power supply which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and QW-409.1(c). ***Note:*** *In some cases, it might benefit the user to amend a PQR to show the heat input calculated using instantaneous power or energy. This can be done by welding a simple bead on plate using the same parameters (mode or program, voltage, current, etc) as were used in the procedure qualification. Utilizing either a welding power source or external meter that displays instantaneous energy or power, the heat input may be calculated per QW-409.1(c) based on those readings.*

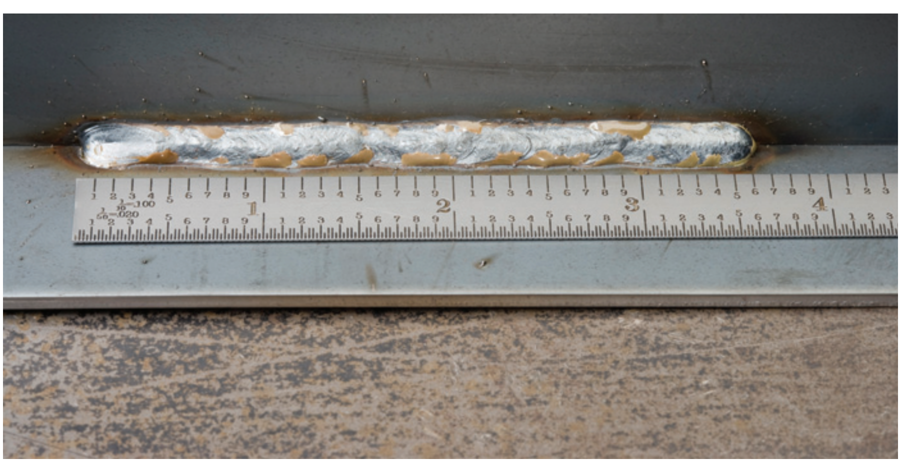


Fig. 4 — The heat input is calculated by taking the final energy value and dividing it by the length of the weld.

the amount of energy that went into that weld, from arc start to arc stop.

To calculate the heat input, the final value is simply divided by the length of the weld — Fig. 4. In this case, the heat input would be 22.3 kJ/3.6 in., or 6.2 kJ/in.

A detailed matrix has been developed showing how a PQR qualified with either waveform or nonwaveform-controlled welding may be used to support welding with waveform or nonwaveform-controlled procedures and QW-409.1(a) or QW-409.1(c). This can be downloaded from www.lincolnelectric.com.

Summary

The ASME Section IX welding and brazing standard is widely used by public agencies and private companies concerned about the safety and integrity of welds. Just as specifications change when new materials are developed, ASME Section IX has changed to recognize modern welding waveforms. The changes involve the measurement of energy or power made at very rapid intervals, and the use of these to calculate heat input. These code changes establish the relationship between heat input across a range of power sources and welding waveforms.

Welders, inspectors, and engineers should be aware of the new ways to calculate heat input. While no code can guarantee good workmanship, these changes make it easier for welders to use waveforms that help improve their welds. The new method will allow flexibility in the way one compares the heat input used in procedure qualification and in production welding.♦