EMF Assessment of Welding Equipment

APPLICATION NOTE

AN_ASS_WELDING_EN_V1.00

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Index

Application Note

EMF Assessment of Welding Equipment

Addressed to

- Manufacturers of welding equipment.
- Users of welding equipment who wish to know how manufacturers must assess their equipment.
- Users of welding equipment who wish to use the results obtained by manufacturers to supplement their own workplace assessments.

Scope

This application note deals with the method for assessment of welding equipment in respect of human exposure to electromagnetic fields (EMF) through measurement of field levels, in accordance with the IEC 62822-1 [1], IEC 62822-2 [2] and IEC 61786-1 [18] reference standards.

It focuses specifically on magnetic fields and their non-thermal effects, i.e. their effects at low frequencies, within the 1 Hz to 400 kHz range.

This application note explains how to perform that assessment using the Wavecontrol SMP2 electromagnetic field measurement device and WP400-3 field probe.

PLEASE NOTE: *Wavecontrol will not be responsible for any errors that may be found in this document or for the results of any faulty application of regulations. This application note is meant to be used for assistance, but not under any circumstance as a replacement for the standards that it mentions. We recommend that you study those standards carefully.*

Introduction

The IEC 62822 standard is aimed at manufacturers of electric welding equipment for assessment of EMFs in connection with restrictions related to human exposure [1] [2] [3].

It is a product family standard for resistance welding equipment, arc welding equipment and allied processes meant for both professional and non-professional use.

The method described in this application note is based upon measurement of field values and may be used to assess equipment and demonstrate compliance with no need for complex calculations or modelling procedures.

IEC 62822 is not a workplace assessment standard, since the equipment manufacturer has no knowledge of the final work environment, meaning that they cannot assess total exposure and so are not responsible for the implications of the assessment of the workplace made by the user of their product.

Nevertheless, the enterprise using the welding equipment for its production activities is responsible for assessing its workplace, and it may use the figures for exposure obtained in application of this standard as an aid or supplement for that assessment.

No exposure restrictions are specified and the legal restrictions on exposure in each country must be observed. There are exposure restrictions for the general public and restrictions for workers (occupational).

1. Assessment requirements

1.1 Non-thermal effects (low frequency)

H-fields

Non-professional welding equipment (e.g. arc welding equipment designed in keeping with IEC 60974-6 [7]) must be assessed in respect of the restrictions for the general public.

Professional welding equipment (e.g. arc welding equipment designed in keeping with IEC 60974-1 [4]) must be assessed in respect of occupational restrictions and it cannot be used by non-professionals or in places open to access by the non-professional public.

Where occupational restrictions are exceeded, including in the case of a specific configuration, further measurements must be defined for the purpose of compliance: minimum safety distances, use of protective equipment, restrictions on manual use of the equipment, etc.

In any event, the manufacturer must specify the minimum distance for protection of the general public.

E-fields

Welding equipment designed in keeping with IEC 60974-1 [4], IEC 60974-2 [5], IEC 60974-5 [6],

IEC 60974-6 [7], IEC 60974-8 [8], or IEC 62135-1 [9] comply in theory with E-field restrictions, unless they involve any additional technology that might generate an electric field.

Where generation of E-fields is suspected, assessment must be made applying the methods specified in generic standard IEC 62311 [10] or another pertinent basic standard.

Output current

High frequency ripple components in the welding current may cause non-thermal effects.

Ripple currents with fundamental frequencies over 10 kHz may be ignored, provided that the peak-to-peak value of the ripple does not exceed:

- 100 A, for professional equipment;
- 10 A, for non-professional equipment with ripple frequencies up to 100 kHz;
- 10 A × 100 / f_{ripple} [kHz], for non-professional equipment with ripple frequencies over 100 kHz.

In all other cases, they must be assessed in keeping with the procedures detailed below.

1.2 Thermal effects (high frequency)

High frequency ripple components in the welding current may cause thermal effects.

Ripple currents with fundamental frequencies under 10 kHz may be ignored. Cases with higher frequencies may also be ignored if the peak-to-peak value of the ripple does not exceed:

- 100 A × 100 / f_{ripple} [kHz], for professional equipment;
- 10 A × 100 / f_{ripple} [kHz], for equipment for the general public.

In all other cases, assessment must be made applying the methods specified in generic standard IEC 62311 [10] or another pertinent basic standard.

The equipment must also be analysed to identify other potential sources of thermal effects (high frequency emissions), e.g. RFID readers or wireless communication modules. In that case, generic standard IEC 62311 [10] or another pertinent basic standard must be used.

2. Arc welding equipment

The IEC 62822-2 standard specifies the methods for assessment of human exposure to the magnetic field produced by arc welding equipment. It covers the non-thermal effects between 0Hz and 10 MHz.

2.1 General evaluation factors

Weighted Peak Method

The only applicable method under the IEC 62822-2 [2] standard is the Weighted Peak Method, WPM, described in ICNIRP [11] and IEC 62311 [10], considered the most appropriate for assessment of the fields produced by pulsed or non-sinusoidal welding currents.

The weighted peak method may be applied in the frequency domain or the time domain. The two ways of applying it are mathematically equivalent and give the same results if they are applied correctly. However, where it must be applied to many spectral components or to analysis of a complete signal, application in the frequency domain is much more complex.

In the case of the Wavecontrol SMP2 device, the weighted peak method is applied used digital processing techniques in the time domain, in real time, making it surprisingly easy for the user to obtain the exposure assessment result: the device gives a single final value for exposure as a percentage, referred to as the Exposure Index, EI, (e.g. EI = 75%), representing the degree of compliance with the restriction.

You will find further information on how to use this method with the SMP2 device and the WP400 or WP400-3 probe in an application note on that device's capacity [20].

The great potential of this method is due to the fact that it requires the device to perform substantial internal calculation but no further calculations by the user, who obtains the result of the assessment for the full signal, with all its spectral components, each weighted in respect of its limit value. In addition, that weighting may be made in respect of the desired limit, to be selected from an extensive list (ICNIRP, IEEE, European Directive 2013/35/EU, Safety Code 6...).

Maximum exposure level

Time-weighted averaging is not allowed; except in the case of a specific requisite of a standard or applicable law, the aim is always to obtain the maximum exposure level.

Spatial averaging

Spatial averages must be made as detailed in section 2.2 below, unless specified otherwise in a preferential standard.

Restrictions
The restrictions most commonly used are the following:

- **ICNIRP**
  - ICNIRP DC Guidelines 2009 [12].
  - ICNIRP LF Guidelines 2010 (occupational and general public) [13].

- **European Union**
  - European Recommendation 1999/519/CE (general public) [14].
  - European Directive 2013/35/EU (occupational) [15].

- **IEEE (USA)**
  - IEEE standard C95.1-2005 (occupational and general public) [16].
  - IEEE standard C95.6-2002 (occupational and general public) [17].

Layout and environment
The field measurements must be made with the cables carrying the I_t test current straight. The return cables must be placed to minimize any influence of the return current on the measured field.

Where there is a metal floor, the cables must be placed on a non-metallic support at a height of at least 0.8 m. Any other metal object that might distort the magnetic field must be at a horizontal distance of at least 2 m from the measurement points.

We recommend taking a measurement before starting up the equipment to assess the presence of background levels. Those levels, not related to the welding equipment being tested, must be minimized, removing the equipment from the sources of the fields or making the measurement in a shielded enclosure.

Measurements must be made using devices that meet the requirements of the IEC 61786-1 [18] standard. In addition the field probe must have a measurement area of 3 cm^2 ± 0.6 cm^2. The SMP2 + WP400-3 combination meets those requirements.

2.2 Measurement points
Taking into account the different parts of the body and their specific (shape, type of tissue, dimensions and distance from the emission source), certain standard configurations are considered covering the assessment positions needed to ensure compliance for exposure of the head, trunk and limbs.

Compliance with all the applicable configurations must be demonstrated, and otherwise minimum distances must be established. Where the manufacturer considers it appropriate, other configurations may be assessed, for example, to provide information on exposure at other distances.

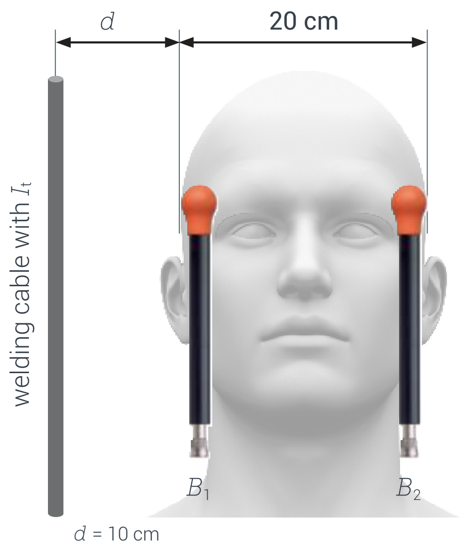
Those configurations do not apply with equipment meant exclusively for automated (robot) applications; in that case, the minimum distances needed to avoid overexposure must be defined.

NOTES:

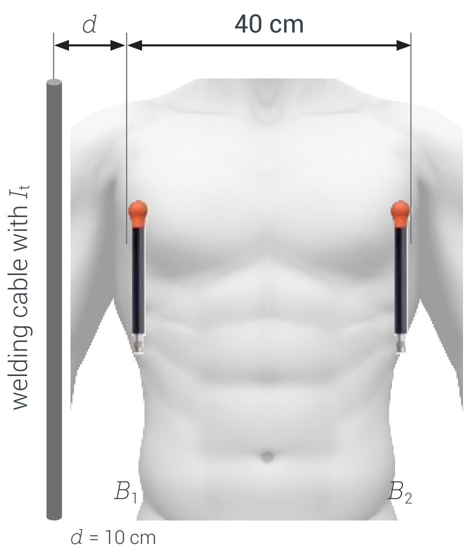
- *Any of these configurations may be omitted if they are expressly excluded from the applicable domestic or international standard.*
- *Where the applicable standard requires configurations other than those defined here, the manufacturer must establish configurations following equivalent principles.*
- *Where the applicable standard expressly excludes spatial averaging, the measurement must be taken at distance d (worst case scenario).*

Measurements must be taken in accordance with the following illustrations:

2.2.1 Head exposure

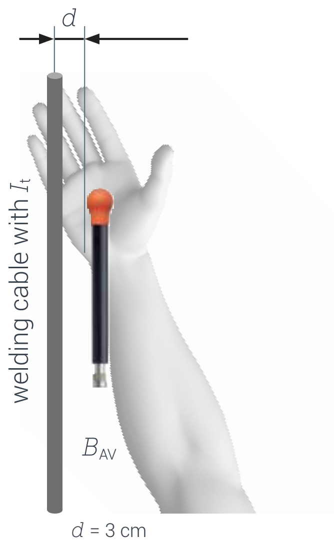


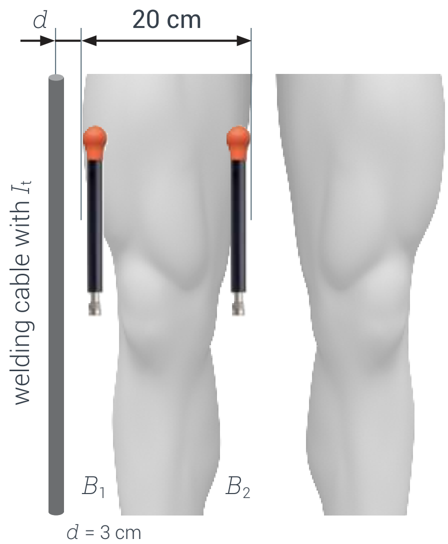
2.2.2 Trunk exposure



2.2.3 Limb exposure

The highest level of localised exposure of limbs is found in the hand that holds the welding gun and in the thighs, which may be very close to the welding cable.





In all cases except the hand, the arithmetic average of the measurements should be taken to obtain the resulting field, B, for comparison with the limit:

$$B = \frac{B1 + B2}{2}$$

2.3 Conditions of the welding current

One of the following operating modes must be chosen:

- Single operating mode.
- Multiple operating modes.
- Worst case.

Remember that if the output current ripple does not meet the criteria for exclusion specified in section 1 above, it must also be assessed.

The waveform of the welding current must be established by measurement or, for example, by programming the different parameters in digital sources (see section 2.3.4).

2.3.1 Single operating mode

The equipment is assessed under conditions that cause maximum exposure, taking into account the configuration of the equipment at the time of assessment.

Those conditions must be based upon technical knowledge of the equipment on the part of the manufacturer, taking into account at least the following parameters:

- Rate of change in the value of the welding current (d_i/d_t).
- Amplitude of that current.
- Pulse cadence (where applicable).
- AC frequency (where applicable).

If the equipment conditions change (for example, if new welding programs or functions are added), the assessment must be repeated.

2.3.2 Multiple operating modes

The manufacturer may choose to assess the equipment in different operating modes, to avoid the need for users who operate it in modes that generate lower levels of exposure to take actions or apply restrictions only required for other operating modes, e.g. DC TIG welding, as opposed to TIG welding with square wave AC.

If the equipment conditions change (for example, if new welding programs or functions are added), the assessment must be repeated.

2.3.3 Worst case

Of the current waveforms that the source can generate, given its intrinsic properties, the equipment is assessed using the waveform with the greatest possible d_i/d_t.

In the case of DC equipment, the change of current from 0 to I_{2max} or from I_{2max} to 0 is assessed.

In the case of AC equipment, the change of current between $I_{max\ neg}$ and $I_{max\ pos}$ is assessed.

It is important to bear in mind that the worst case scenario is sought, and so it is not valid to assess only the predefined programs or waveforms. If the assessment is made taking into account the worst case scenario for the source by design, there will be no need for any further assessment when new programs or operating modes are used.

2.3.4 Measurement of the welding current

To measure the current waveform, a conventional load, a constant voltage load or real arc conditions may be used.

The welding current inductance, including cables and load, depending on the case, must be less than 10 µH within the pertinent frequency range.

It is necessary to check that the current transducer and the oscilloscope used have sufficient capacity within the pertinent frequency range, particularly in respect of resolution and peak level. We do not recommend use of resistive shunts.

The sampling rate of the oscilloscope must be established with a high enough value to allow spectral analysis of the largest pertinent frequency component.

Another way to obtain the current wave form is to use the design parameters of the current source or of the welding programs.

To check whether the output current ripple amplitude meets the criterion for exclusion (see section 1), it must be assessed at the nominal current and with a 100% duty cycle. Where there is no nominal current for a 100% duty cycle, it should be assessed at 50% of I_{2max}.

2.3.5 Frequency range

The assessment must be made from 0 Hz (DC, as the case may be) up to a maximum frequency defined as the highest applicable value from among:

- 1 kHz for single-phase transformer-rectifier type equipment.
- 3 kHz for three-phase transformer-rectifier type equipment.
- 10 kHz for thyristor controlled equipment.
- 10 times the ripple frequency for inverter type equipment.
- 10 times the AC welding current frequency.
- The frequency (fmax) defined by the minimum rise time or fall time (tmin) of the maximum welding current (from 10% to 90%, from 0 to I2 max pos or I2 max neg).

$$f_{max} = 10 \times \frac{1}{(4 \times t_{min})}$$

The manufacturer, based upon their knowledge of the product, may choose to assess up to higher frequencies (e.g. in the case of a square wave source).

The highest frequency considered in this standard is 10 MHz.

The criterion of maximum frequency based upon the ripple frequency may be ignored if the criterion for exclusion given in section 1 above is met.

2.3.6 Measurement uncertainty

Any measurement of exposure to electromagnetic fields must be accompanied by its measurement uncertainty.

Taking the measurement made (L_m), first of all the expanded measurement uncertainty (U_m) must be calculated. You may find information on how to do so in the specific application note for calculation of measurement uncertainty [19].

For assessment of exposure, the concept of "shared uncertainty budget" must be applied. This means that the value measured for the instrument concerned (the reading obtained, L_m) may be compared directly with the standard restriction (L_{lim}), provided that the expanded measurement uncertainty is lower than the values given in Table 1.

Table 1 - Permissible expanded uncertainties

Frequency range	Measurement	Calculation
< 10 kHz	+ 58 %, - 37 % (± 4 dB)	± 50 %
10 kHz to 1 MHz	+ 41 %, - 30 % (± 3 dB)	± 50 %
1 MHz to 10 MHz	+ 41 %, - 30 % (± 3 dB)	± 40 %

If you are working with % and you need to consider asymmetric values (e.g. +58%, -37%), you must use the value of the possible underestimation. In the case of combined assessment procedures, you must use the higher value.

Example:

Instrument used: Wavecontrol SMP2 + WP400.

Measurement range considered: 10 Hz - 10 kHz.

Expanded measurement uncertainty calculated (U_m): 0.66 dB (7.92%). See application note [19].

Since ±0.66 dB is less than ±4 dB (the greatest permissible uncertainty), we can compare the measured value L_m directly with the limit L_{lim}.

If you are making measurements using the weighted peak method, the value measured will be in % and the limit will be 100%.

If we obtain a reading of 90%, we will have:

- L_m = 90%
- L_{lim} = 100%

- $L_m < L_{lim}$ and therefore the equipment COMPLIES with the standard restriction.

If, on the other hand, the measurement method used has a measurement uncertainty of 50%, you will need to apply a penalty that reduces the limit with which you need to make the comparison. The formula to apply is the following:

$$L_{lim} \times \left(\frac{1}{1 - \frac{U_p}{100} + \frac{U_m}{100}} \right)$$

U_p is the maximum permissible uncertainty; in our example and according to the table: 37%

U_m = 50%

$$L_{lim} \times \left(\frac{1}{1 - \frac{37}{100} + \frac{50}{100}} \right)$$

Therefore, we need to reduce the limit used for comparison by a factor of 0.88.

- L_m = 90%
- L_{lim} = 100% x 0.88 = 88%

- $L_m > L_{lim}$ and therefore the equipment DOES NOT COMPLY with the standard restriction.

In any event, the assessment must be made using representative samples of the equipment being assessed.

3. Resistance welding equipment

The requirements for assessment of resistance welding equipment will be described in a future standard, IEC 62822-3 [3], now in preparation.

When that standard is published, those requirements will be added to this application note.

4. Instructions for use and information

The equipment must be accompanied by the following information:

- Whether it is for **professional or non-professional use** (taking into account which exposure restrictions it complies with). That information must be available to the user in advance of acquisition.
- **Clear identification of the limits used** for assessments, specifying the full title and date of the reference publication. That information must be available to the user in advance of acquisition.
- **Operating requirements to comply with restrictions**.
- **Exposure indexes** for each case assessed: single operating mode, multiple operating modes, or worst case. Use of the SMP2+WP400-3 is especially practical, since the peak weighting method allows you to obtain the exposure indexes directly.
- **Safety distances for head, trunk and limbs**, as the case may be. It must be stated whether standard configurations were used and whether compliance was demonstrated. Otherwise, it must be stated which configurations were used and instructions must be given for use and safety distances.
- In the case of equipment for professional use, the **distance after which the exposure index drops to less than 20%** and the **distance from the source after which the restrictions for the general public are complied with**.
- Even where compliance with the basic exposure restriction can be demonstrated, **if the reference levels are exceeded, the pertinent information must be included** in the documents concerning the equipment.
- Likewise, **the pertinent information must be included if sensorial limits are exceeded**.
- The instruction manual must include a warning on the need to **make a special assessment, with the participation of a medical expert, in the event that a welder has a pacemaker or another type of implantable medical device**, since the degree of immunity for such devices can vary substantially.
- Information on the **projectile risk** for ferromagnetic objects in the case of resistance welding devices.
- **Advice on reduction of user exposure**, including recommendations for installation, layout of the welder cable, etc., in addition to the necessary precautions in the event of maintenance or repair.

If the equipment fails to comply with restrictions in its standard configurations and minimum safety distances are established, the equipment must be marked with the proper warning symbols for electromagnetic field risk.

5. Final recommendations

- Assess the worst case scenario for the current source, to cover all possible configurations.
- If the equipment has various configurations with different waveforms, assess each of them and provide the information. This will make life easier for the user, who will take the appropriate measures depending on use.
- Use a measurement device with a "weighted peak method" function, such as the SMP2+WP400-3 combination. This will make your life much easier.

References:

[1] IEC 62822-1:2016, Electric welding equipment - Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz) - Part 1: Product family standard.

[2] IEC 62822-2:2016, Electric welding equipment - Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz) - Part 2: Arc welding equipment.

[3] IEC 62822-3:XXXX, Electric welding equipment – Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz) – Part 3: Resistance welding equipment (expected to be published November 2017).

[4] IEC 60974-1:2017, Arc welding equipment - Part 1: Welding power sources.

[5] IEC 60974-2:2013, Arc welding equiment - Part 2: Liquid cooling systems.

[6] IEC 60974-5:2013, Arc welding equipment - Part 5: Wire feeders.

[7] IEC 60974-6:2015, Arc welding equipment - Part 6: Limited duty equipment.

[8] IEC 60974-8:2009, Arc welding equipment - Part 8: Gas consoles for welding and plasma cutting systems.

[9] IEC 62135-1:2015, Resistance welding equipment - Part 1: Safety requirements for design, manufacture and installation.

[10] IEC 62311:2007, Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz).

[11] International Commission on Non-Ionising Radiation Protection, Guidance on Determining Compliance of Exposure to Pulsed and Complex Non-Sinusoidal Waveforms below 100 kHz with ICNIRP Guidelines, Health Physics, Volume 84, Number 3, March 2003, p.383-387.

[12] International Commission on Non-Ionising Radiation Protection, Guidelines on Limits of Exposure to Static Magnetic Fields, Health Physics, Volume 96, Number 4, 2009, p.504-514.

[13] International Commission on Non-Ionising Radiation Protection, Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz), Health Physics, Volume 99, Number 6, 2010, p.818-836.

[14] Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), Official Journal L 199, 30.07.1999, p.59-70.

[15] Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC, Official Journal L 179, 29.06.2013, p.1-21.

[16] IEEE Std C95.1-2005, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, The Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, New York, NY 10016-5997, USA.

[17] IEEE Std C95.6-2002, IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz, The Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, New York, NY 10016-5997, USA.

[18] IEC 61786-1:2013, Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings - Part 1: Requirements for measuring instruments.

[19] Wavecontrol Application Note, Calculation of the Total Measurement Uncertainty of a Field Strength Meter.

[20] Wavecontrol Application Note, SMP2+WP400 Measurement Capacities.

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