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Welding — Determination of hydrogen in deposited weld metal arising from the use of covered electrodes for welding mild and low alloy steels

ADDENDUM 2 : Recommended methods of reporting single bead weld metal hydrogen contents

Addendum 2 to International Standard ISO 3690-1977 was developed by Technical Committee ISO/TC 44, *Welding and allied processes*, and was circulated to the member bodies in March 1982.

It has been approved by the member bodies of the following countries :

Australia	Egypt, Arab Rep. of	Japan
Austria	Finland	Korea, Dem. P. Rep. of
Belgium	France	Korea, Rep. of
Brazil	Germany, F.R.	Romania
Canada	India	Sweden
China	Ireland	Switzerland
Czechoslovakia	Italy	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Netherlands
United Kingdom
USA

In addendum 1 to ISO 3690, *Weld metal hydrogen levels and the definition of hydrogen controlled electrodes*, an acceptance level for hydrogen controlled electrodes was proposed. The level was fixed by common consent at 15 ml per 100 g of deposited metal measured according to the method specified in ISO 3690. Covered electrodes tested in this way would have to show values below 15 ml per 100 g before they could be described as hydrogen controlled electrodes.

When work on this subject first began the objective was to reach international agreement on the method of testing and the acceptance level. For these and also economic reasons, a simple single bead method of testing was used. As the work progressed, however, it became increasingly evident that the hydrogen levels produced purely for electrode classification purposes could also be used to assist the selection of welding procedures which avoided the risk of hydrogen cracking. For

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this reason the previous document also advocated the use of four categories of hydrogen level as indicated in table 1.

This recommendation recognised the fact that many electrodes could be dried or baked in such a way as to produce the low and very low hydrogen levels that are often necessary when welding high strength steels. In addition it was also found that other welding processes could be examined by the same testing technique so that the consumables used could also be classified as "hydrogen controlled" whenever necessary.

In certain circumstances, however, the method of reporting adopted in ISO 2560 and ISO 3690 may not be entirely suitable for procedure prediction purposes and the intercomparison of different welding processes. When seeking control of hydrogen levels for procedure prediction, account must be taken of multipass weldments. The ISO testing procedure employs a single bead for hydrogen measurement and this may not always give a good indication of hydrogen levels in practical multipass weld.

In the meantime it is emphasised that the methods of reporting hydrogen contents described below refer to experimental measurements on single beads. Careful judgement must be exercised when deciding how closely these represent multipass weld hydrogen levels. In multipass weld the hydrogen content may decrease due to diffusional losses or it may increase towards a single bead figure as successive passes are built up.

When comparing different processes, very different penetrations and dilutions are involved. Because of this the convention of reporting hydrogen concentration in terms of deposited metal may produce misleading comparisons between welding processes. Since normally only a small proportion (see figure 5) of the hydrogen present in the weld penetrates to the heat affected zone to cause cracking; it is better to select a fused metal basis for quoting hydrogen concentrations.

However, different considerations and rules may apply to the problem of transverse cracking in single, and more especially multipass, weld deposits. The unit mass of metal chosen for reporting hydrogen contents should depend on the use to which the results are to be put. They involve no alteration to the previously specified method of testing of electrodes and other consumables. The conclusions refer to the fact that, for electrode classification purposes, one basis of reporting has been chosen (deposited metal) while for comparing processes and predicting procedures, a different basis of reporting, which more closely approximates to true concentration, is recommended.

To avoid possible confusion between hydrogen levels reported on a deposited metal basis and the more accurate representation of concentration on a fused metal basis, two different sets of units are recommended.

a) **For the classification of covered electrodes :**

As in ISO 2560 and ISO 3690 using units of millilitres of hydrogen (mlH_2) (N.T.P) per 100 g of deposited metal and employing the symbol H_{DM}. This method is adequate and also convenient since the deposited metal may be determined directly by weighing (see figure 4).

b) **For the intercomparison of different welding processes and for use in selecting welding procedures :**

Hydrogen levels should be reported on the basis of the concentration in the fused metal using units of grams of hydrogen per tonne (gH/t) of fused metal and employing the symbol H_{FM}. This method gives a better representation of actual concentrations, it takes account of different dilutions in manual metal arc welds as compared with say submerged arc welds (see figure 6) and also provides a better basis for calculating hydrogen removal from the weld.

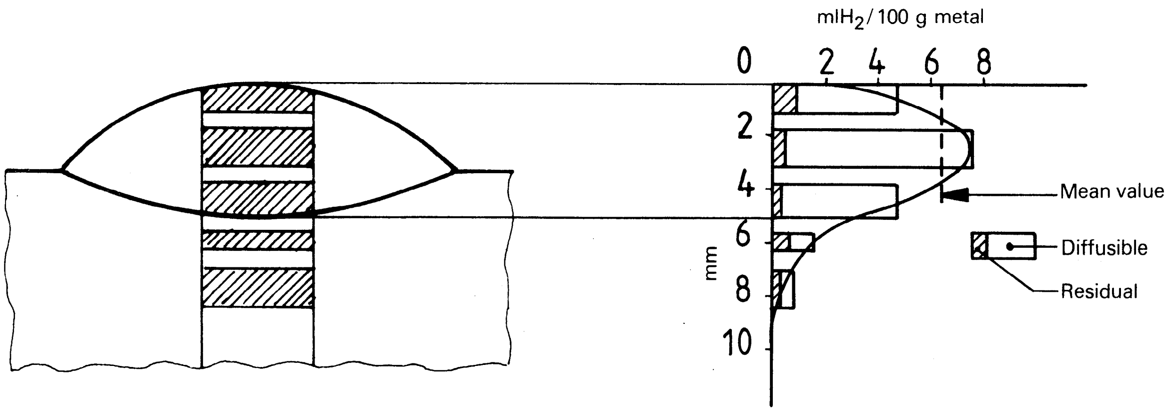
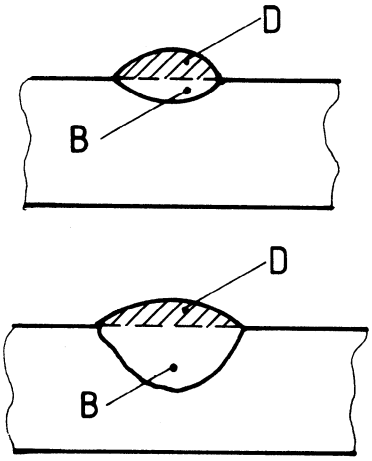


Figure 5 — Example of measured hydrogen distribution



D = excess of fused metal
B = penetration of fused metal
B + D = fused metal (fused metal = deposited metal + dilution)

Figure 6 — Low and high dilution

c) **For comparison with hydrogen contents encountered in steel :**

The same units are used in b), i.e. gH/t of fused metal and using the symbol H_{FM}.

The new unit of gH/t has been chosen to indicate clearly that the weld hydrogen content has been calculated on the basis of the mass of fused metal rather than the mass of deposited metal. There will be however, little change in the numerical values since :

1 g per tonne = 1 ppm = 1,11 ml/100 g.

Commentary

Table 1 below can now be expanded to describe hydrogen levels also on the fused metal (g/t) basis. For basic electrodes (⌀ 4 mm) for which an average conversion factor of D/B + D close to 0,6 has been adopted and the hydrogen concentration so obtained have been rounded up to the nearest whole number. Thus table 2 combines and summarises the recommendations of both this and also earlier documents.

Table 1 — Values contained in addendum 1 to ISO 3690

Description	Weld hydrogen content (ml/100 g of deposited metal)	
High	> 15	
Medium	⩽ 15 but > 10	Classified as
Low	⩽ 10 but > 5	H controlled
Very low	⩽ 5	electrodes in ISO 2560

Table 2 — Electrode classification limits (H_{DM}) and approximate corresponding hydrogen concentrations (H_{FM}).

Description	Weld hydrogen contents for electrode classification (H_{DM}) (mlH_2/100 g (N.T.P.) deposited metal)	Weld hydrogen contents for comparing processes (H_{FM}) (gH/t of fused metal)
High	> 15	> 9
Medium	⩽ 15 but > 10*	⩽ 9 but > 6
Low	⩽ 10 but > 5*	⩽ 6 but > 3
Very low	⩽ 5*	⩽ 3

* Electrodes showing these levels are H-controlled according to ISO 2560

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