INTERNATIONAL STANDARD ISO 3690-1977 / ADDENDUM 1

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

ADDENDUM 1

Addendum 1 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 1981.

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

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

Belgium
Norway
United Kingdom

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Annex

Weld metal hydrogen levels and the definition of hydrogen controlled electrodes

(This annex is not an integral part of the standard.)

A.0 Introduction

In spite of the publication of ISO 3690, other test methods will remain in force for a number of years. This is why it seemed useful to publish, in an annex to the International Standard, a comparative table making it possible to relate the results obtained by these various methods to the hydrogen content as determined by the ISO standard method.

Significant differences in the reported hydrogen levels exist because of differences in the method of carrying out the various tests. These latter differences are not discussed here since they are apparent from an examination of the details of each testing procedure. It is important, however, to be able to state how the results from these other procedures can be related to those obtained using the ISO method, since this method will provide the internationally agreed scale of values for hydrogen levels in weld metal.

The purpose of this document is to provide the necessary comparison table. The second task has been to establish a level of weld hydrogen below which a covered electrode may be termed "hydrogen controlled". For an electrode to carry this designation it would, when tested according to the ISO method, have to produce a weld metal hydrogen content below this agreed level.

A.1 Experimental considerations

Before presenting the comparison table and proposing the acceptance level, it is necessary to consider several important factors concerning the scope of the experimental procedure and the interpretation of the results. First of all, it must be emphasised that the testing procedure has been developed primarily for the estimation of weld hydrogen contents in metal deposited by unalloyed and low alloy steel covered electrodes.

The objective has been to devise a procedure which can indicate, in a simple and reasonably rapid manner, the hydrogen content of the weld metal immediately after welding. For this reason a single, rapidly quenched, bead is deposited and analysed. The standardized manner in which this operation is carried out ensures that different electrodes can be fairly compared, on the same basis and in such a way that their qualities, in terms of the amount of hydrogen introduced into the weld, can be characterized. It has been found that basically the same procedure can also be used to establish weld hydrogen levels occurring in other processes using gas shielding and solid or flux-cored wires and also for the submerged arc welding process. A single standardized procedure is therefore available for establishing and comparing the qualities of most welding consumables in terms of the as-deposited weld hydrogen level. Moreover the procedure is sufficiently simple, safe and rapid to be conducted in most laboratories.

In standardizing the procedure to be applied to covered electrodes, it is stated that those with 4 mm diameter core shall be used at a current 15A below the maximum recommended by the manufacturer. Clearly if other electrode diameters and welding currents are employed then slightly different hydrogen levels will be recorded. Since the test is being used primarily to characterize electrode coating characteristics, this is not considered a disadvantage, since 4 mm core wire diameter electrodes can always be used. When the test is applied to other processes where a much wider range of wire diameters and welding currents are encountered, then the problem of standardization becomes more difficult and further research work is required. For these processes, it seems very likely that agreement could be reached on standardized welding conditions for making the test if sufficient data can be accumulated. It has already been established that larger diameters of covered electrode, solid or cored wire and higher welding currents can be dealt with by slight increases in specimen size to accommodate the heavier weld beads. Such an increase in specimen size — as long as it does not require the construction of a new diffusible hydrogen collecting vessel — will probably not affect the measured mean hydrogen level if a constant heat sink is maintained.

So far, this document has been concerned with the primary objective of characterizing electrode quality or capability. Since the ISO procedure provides the best estimate of the initial weld hydrogen level, it provides the vital starting point when considering the likelihood of hydrogen-induced cracking, whether this is expected to occur in weld metal or heat affected zone (HAZ). Work on the diffusivity coefficient of hydrogen in various steels and weld metals indicates that it will soon become possible to predict the levels of hydrogen reaching the HAZ as a function of welding conditions and the initial hydrogen revealed by the ISO testing procedure. It thus becomes clear that the standardized procedure has an importance which goes beyond simply classifying covered electrodes. Its extension to other welding processes means that these can be investigated in the same way.

The ISO procedure requires that hydrogen levels are reported in terms of the number of millilitres of hydrogen per 100 g of deposited weld metal. For classification purposes any agreed system of units is acceptable and the deposited metal system has the merit of being now well understood and more easily used in practice. (The specimen is weighed before welding and again after analysis, the difference being the weight of deposited metal). An alternative method of presenting results is also referred to in the procedure and on this basis the hydrogen content may be quoted in millilitres of hydrogen per 100 g of fused metal. This method requires measurements of the ratio of deposited to fused metal on the end sections of the specimen. It is more time consuming and, for the purpose of classifying consumables, presents no advantages — although of course a different (lower) level of hydrogen is reported. It is extremely important to recognise however that, in considering hydrogen cracking and the selection of safe welding procedures, it is the fused metal and not the deposited metal that acts as the source of hydrogen. Hydrogen levels reported on a fused metal basis are thus of more fundamental use, since they will take account of the effects of different heat input, penetration and dilution levels in actual welding.

The implant method of testing is a powerful technique for assessing, not only the characteristics of the steel to be welded, but also the effect of changes in weld metal type, hydrogen content and heat input on the likelihood of hydrogen cracking. It is clearly desirable to standardize the method of carrying out the test so that results from different countries can be compared one against the other. It must be recognised however that variations of the test may be required for different purposes. For example, it may prove desirable to employ the "fused metal" basis of reporting hydrogen levels when discussing the implant test and when using weld hydrogen data to select welding procedures to avoid hydrogen cracking. The ISO procedure refers principally to the measurement of diffusible hydrogen which is perfectly adequate for classification purposes. However the procedure also states that the same specimen can subsequently be used to determine the residual fraction of hydrogen. The sum of these two quantities may be termed the "total hydrogen". For many situations the residual hydrogen amount is only a small fraction of the total, but it may prove necessary to consider total values when using weld hydrogen data for the above purposes.

For the definition of hydrogen controlled electrodes and for the results is in the comparison table below, the deposited metal basis of recording results is used and recommended.

Finally it should be noted that hydrogen concentrations are occasionally expressed in units of parts per million (ppm) for which the conversion is

1 ppm = 0,9 ml per 100 g.

Whichever system of units is used, it should be made clear whether deposited or fused metal is referred to, so as to avoid confusion.

A.2 Weld metal hydrogen levels

A comparison between weld metal hydrogen levels recorded using the ISO procedure and levels for the same electrodes but using other procedures is given in figure 3.

It can be seen that the ISO procedure gives results similar to those of the British Standards procedure, regardless of whether diffusible or total hydrogen is measured. The Japanese standard has been examined at three levels of hydrogen and the following relationship reported :

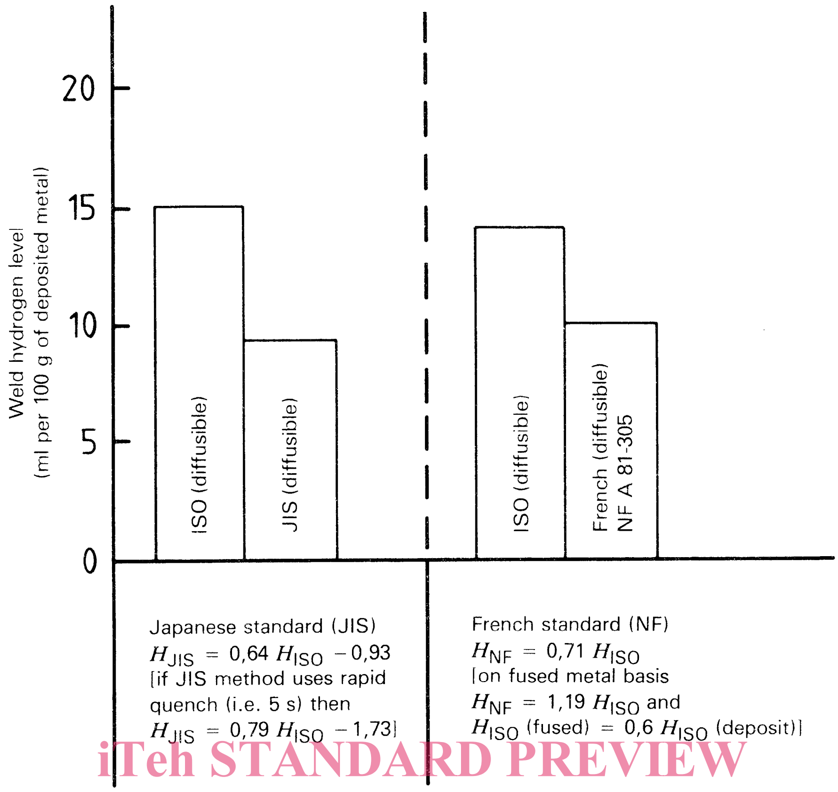
$$H_{\text{JIS}} = 0{,}64\, H_{\text{ISO}} - 0{,}93$$

This relationship for an ISO level of 15 ml per 100 g is shown in figure 3. A similar relationship can be applied to the ASTM, the Lloyds Unified Rules since they all employ (like the JIS method) a larger specimen and collection of hydrogen over glycerine or paraffin for 48 h at 45 °C. The French standard employs a totally different method of sampling in that weld metal is deposited onto the core wire of covered electrodes in a copper mould. A comparison of results is given in figure 3 and it should be noted that the French standard gives a fused metal hydrogen level only and the results appear quite close to the ISO method if these are also expressed in terms of fused metal.

A.3 The acceptance level for hydrogen controlled electrodes

As mentioned above, an important task has been to agree on a level of weld hydrogen (diffusible millilitres per 100 g deposited metal) below which an electrode tested according to the ISO procedure must fall in order to be termed "hydrogen controlled". The option of thus classifying an electrode is referred to in ISO 2560 where a tentative level of 15 ml per 100 g was proposed.

Figure 4 has been prepared as an aid in summarizing the present position of standardization. The upper part of the diagram indicates the range of weld hydrogen levels observed when the ISO procedure is applied, not only to covered electrodes but also, with slight modifications, to other welding processes. The general pattern of these hydrogen levels in different welding processes will of course change as the quality of the consumables used improves and also if slightly different testing procedures become standardized for each process. Nevertheless the diagram provides the best comparison between processes that is available at present. It should be noted that the scale refers to millilitres of hydrogen per 100 g of deposited metal. A conversion scale giving the approximate equivalent values for millilitres of hydrogen per 100 g of fused metal is placed at the foot of the diagram. This conversion only applies to the hydrogen results obtained when testing covered electrodes.



NOTE — The method described in British standard BS 639 is the same as that specified in ISO 3690.

Figure 3 — Comparison of ISO procedure with those of various national standards for measuring weld hydrogen level

The tentative classification level previously contained in ISO 2560 is given in the band (a) and examples of the coding system for electrodes are also given. The grey portion of the code is the mandatory part. The second band (b) refers to the present document regarding the acceptance level for "hydrogen controlled electrodes" and this is exactly in line with ISO 2560. It is emphasised that this classification indicates the capability of electrodes to be treated before use so that appropriate weld hydrogen levels may be obtained. It indicates that care should be taken with these electrodes to protect their coatings but it is not meant to imply that 15 ml per 100 g is a sufficiently low level of hydrogen to ensure freedom from cracking in practice in all circumstances.

Safe weld hydrogen levels can only be specified by taking into account many other details of each application. This is a matter for discussion between the manufacturer who will supply details of steel and joint type, proposed heat input etc, and the electrode manufacturer who will advise on pre-drying treatments for the electrode to achieve permissible hydrogen levels.

The ISO test procedure and scale of values can however be used to assist this task and for this reason the terminology given in band (c) of figure 4 is proposed. The four terms :

very low	$\leqslant$ 5 ml	per 100 g of metal deposited
low	$>$ 5 ml $\leqslant$ 10 ml	
medium	$>$ 10 ml $\leqslant$ 15 ml	
high	$>$ 15 ml	

can be used to describe permissible hydrogen levels for a welding problem, regardless of the particular process being used. For example, the successful welding of a particular steel and joint type may be found to require a low weld hydrogen level (5 to 10 ml per 100 g on the ISO scale). Such a level may be achieved using any of four processes listed in the upper part of the diagram and success will depend on the quality of the consumables used in each case. By using this terminology, it will be universally understood that the words "very low", "low", "medium" and "high" refer to specific weld hydrogen levels on the ISO scale.

The terminology proposed is already in use in discussing the implant test. It is being incorporated in welding procedure standards being formulated by the British Standards Institution and is very similar to that adopted in a recent publication entitled "Welding steels without hydrogen cracking" of the Welding Institute in the United Kingdom.

It would have been additionally useful to be able to specify hydrogen controlled electrodes in terms of the moisture content of the coating material, measured in accordance with the ISO procedure. It has been found, however, that the correlation between moisture and weld hydrogen, although following a general trend, is not sufficiently specific to permit this. Further studies are required. Moisture levels would not of course prove as useful as weld hydrogen levels when the latter are used to assist welding procedure selection as described above.

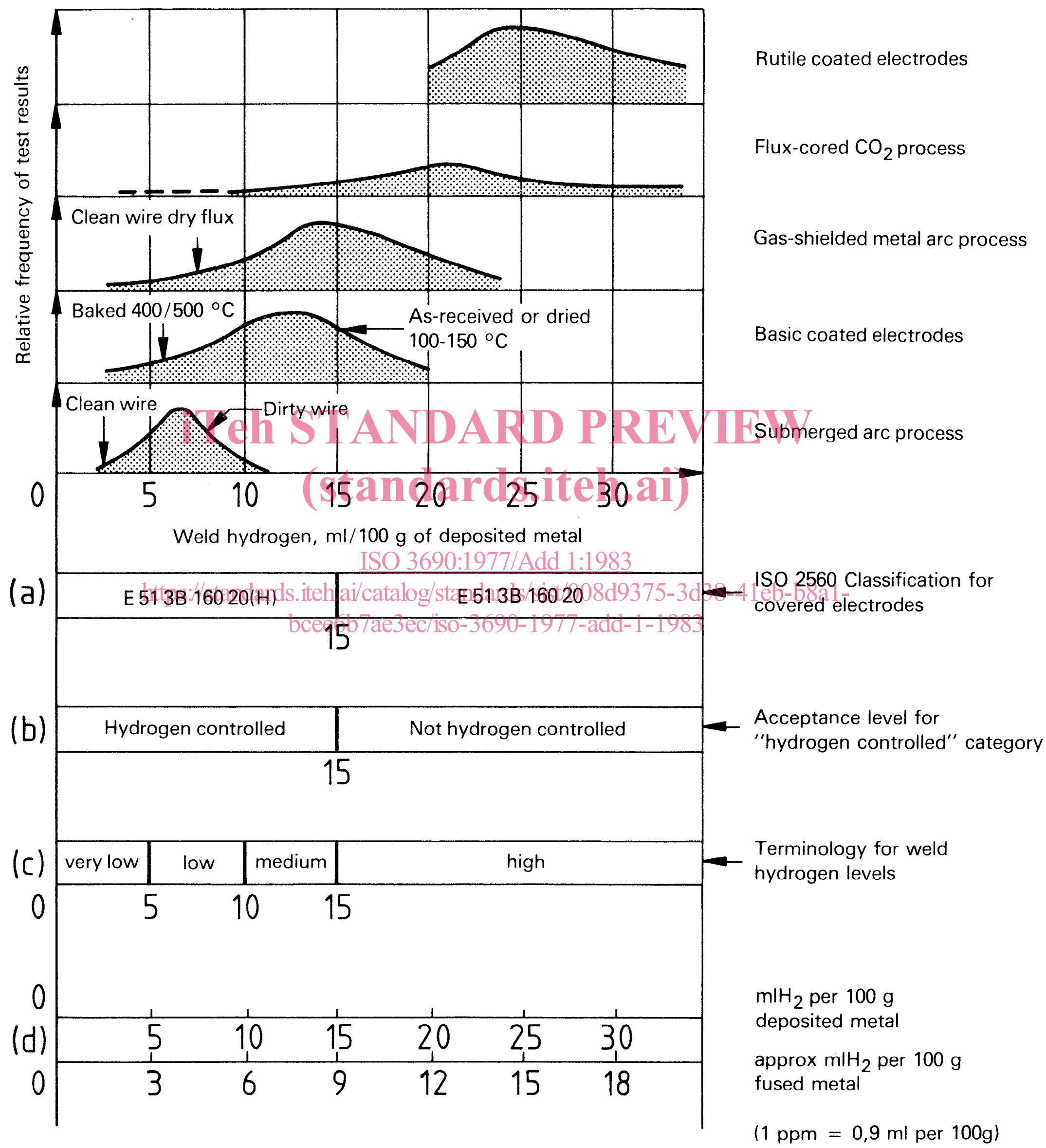


Figure 4 — Acceptance level for hydrogen controlled electrodes and definition of weld metal hydrogen levels

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