DESIGN & APPLICATIONS OF CONSUMABLES FOR WELDING WITHOUT HYDROGEN CRACKING

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INTRODUCTION

Electric arc welding has been with us for a very long time. Because of its verstality, its appears that this process will dominate the field of joining metals and alloys for many more years.

The first steps in electric arc welding were taken by Bernados and Olszewaki in 1885 when they patented a method of welding using an arc struck between a carbon electrode and the workpiece. The direct use of a metal-arc electrode was patented in the U.K. by N. Salvianoff in 1890.

The first reference to a welding application in the 'Journal of the Iron & Steel Institute' appears in 1901 and describes the welding of cast iron and wrought iron at Furstenwald near Burlin using the Salvianoff process and a flux of powdered glass plus 1% of ferromanganese.

The first patent for covered electrode was filed in the year 1907 by O.Kjellberg, followed by another patent in the year 1912, Strohmenger in 1911 patented an electrode wound with asbestos yarn impregnated with sodium silicate.

In 1914, another patent was filed by Jones for a covered electrode. The covering is as per the patent, was extruded on to the wire under pressure.

Between 1908 and 1918 the stage had been set for the manual metal arc welding electrode (MMAW). The first all welded barge was launched in June 1918.

The '20s and early '30s were very much years of experimentation and trial as far as electrode coverings are concerned.

The first version of basic type of covered electrode was developed during early '30s. The covering of the electrode had high proportion of lime and fluorspar. In Germany, basic type of electrodes were used during World War II for welding of armour plate as an effective substitute for the austenitic types.

One of the most successful modern rutile-based general purpose electrode was first developed in 1941 for welding in shipyard. It is still one of the largest selling electrode in most of the countries. During 30's, 40's and 50's large number of electrodes were developed depending on application requirements. Based on Flux coating formulations, these electrodes can be classified broadly as under in Table 1.

Achieving high quality welds

Achieving high quality welds is the objective of every fabricator and it is a minimum requirement of his client. Deposited weld metal can be termed as high quality weld provided the weld metal fulfills following requirements.

(a) Deposited weld are free from defects.

(b) Deposited weld have required performance.

(c) Deposited weld meet required standards and specification.

Types of electrodes and mechanical properties of the deposited weld metal.

Various types of electrodes conforming to respective AWS/SFA classification fulfill the code requirements with respect to chemical composition of the weld metals, mechanical properties of the weld metal, and usability and soundness tests requirements.

TABLE I

Type of Covering	Classification
1. Cellulosic coated electrode	E6010, E6011
2. Acid type-High iron oxide with or without iron powder.	E6020, E6022 E6027, E7027
3. Rutile, Rutile cellulosic type Electrode with or without iron powder	E6012, E6013, E7014 E7024, E7014-1
4. Low hydrogen electrode with or without iron powder in the flux coating	E7015, E7016, E7018, E7028, E7048, E7016-1, E7018-1, E7018M
5. Iron oxide with titaniam.	E6019

Table 2 gives details of impact test requirements for various types of electrodes

TABLE - 2

AWS/ SFA Classification	Charpy V-Notch Impact Requirement, Minimum
1 E6012, E6013, E6020, E6022, E7014, E7024	Not specified
2 E6019, E7028, E7024-1	27J at -18°C
3 E6010, E6011, E6027, E7015, E7016, E7018, E7027, E7048	27J at -29°C
4 E7016-1, E7018-1	27J at -46°C
5 E7018M	67J at -29°C

Hydrogen content of the weld metal and type of electrodes

Only Low-hydrogen basic type of electrodes such as E7015, E7016, E7018, E7048, E7028, E7016-1, E7018-1 and E7018M have been designed to deposit weld metal having low level of hydrogen. Hydrogen content in the deposited weld metal depends on many factors these aspects will be dealt with separately in this paper.

Hydrogen in the weld metal and susceptibility to cold cracking in ferritic welds

Defects in Welds

Welds defects are broadly classified in two types

A Defects induced by the welder due to low skills, difficult working environment etc

B. Defects due to the metallurgical characteristics of the material

Hydrogen induced Cracking in welds

Hydrogen cracking in the weld metal as well as in the parent metal has been the subject of intense research for many years. However it is still the most common defect found in the welded structure. The cost of repairs due to hydrogen cracking is on a worldwide basis, enormous. Traditionally, hydrogen cracking occurs in the hardened coarse grained HAZ region of ferritic steels but the advent of lower carbon steels has seen a significant increase in weld metal hydrogen cracking HAZ, hydrogen cracking requires four conditions which are as under

1) Hydrogen

2) Susceptible microstructure in the coarse grained HAZ

3) Stress

4) Ambient temperature

If any one of the above is removed, then it would be possible to prevent the cracking of the weld metal or HAZ cracking

Even though all 4 factors which are mentioned above have equal importance, hydrogen is an elusive element which affects cold cracking susceptibility in ferritic welds. Hence control of hydrogen in the weld metal is of paramount importance

Hydrogen

Hydrogen in the weld metal can be introduced from a number of sources. The most likely sources are as under

I) Moisture in the electrode coating or moisture in fluxes

II) Moisture on the steel surface

III) Water combined with rust, oils and other greases on the workpiece or filler wire

IV) Organic degreasing agents used for cleaning

V) Moisture present in the atmosphere

VI) Residual hydrogen in the steel - especially in thick section material

In the case of manual metal arc welding, the main source of hydrogen is the moisture contained in the electrode coating. During welding dissociation occurs and the atomic hydrogen thus formed dissolves in the molten pool

During cooling much of the hydrogen escapes from the solidified bead by diffusion but some quantity diffuses in to the HAZ and the parent metal. The amount which does so depends on several factors such as

Typical Examples

Defects due to welder	*Defects due to Metallurgical Characteristics*
a) Lack of side wall fusion	a) Hydrogen cracking
b) Lack of penetration	b) solidification cracking
c) Undercutting at toes	c) Lamellar tearing

the original amount absorbed, the size of the weld the decreasing solubility and time-temperature conditions of the cooling

In general, the more hydrogen present is the metal the greater the risk of cracking Control over the hydrogen level of the weld metal may be achieved by minimising the amount initially absorbed or by ensuring that sufficient time is allowed to escape by diffusion before the weld cools Often a combination of both measures provides the best practical solution

The moisture in the Flux coating of electrodes may be present as absorbed water loosely combined water of crystallisation or more firmly bound molecules in the silicate structure All these forms can break down to produce hydrogen

Defination of Low-hydrogen electrode

Understanding of the role of diffusible hydrogen in the delayed cracking of welds in carbon steels and low alloy steels began to develop at least as long ago as the 1940's Indeed classification of Low-alloy steel electrodes designated as "Low hydrogen" was introduced into AWS specification A5 5-48T (ASTMA316-48T) in 1948 along with a diffusible hydrogen test using collection of hydrogen from a quenched weld bead over glycerine The Low-hydrogen electrode was defined as one meeting a maximum limit of 0 1 cubic centimeter of gas collected per gram of deposited weld metal (10ml/100g, in units commonly used to-day for expressing diffusible hydrogen)

Shortly after this specification was published Stern, Kalinsky and Fenton cast doubt on the suitability of collection of hydrogen over the glycerine by showing that collection over mercury produced considerably

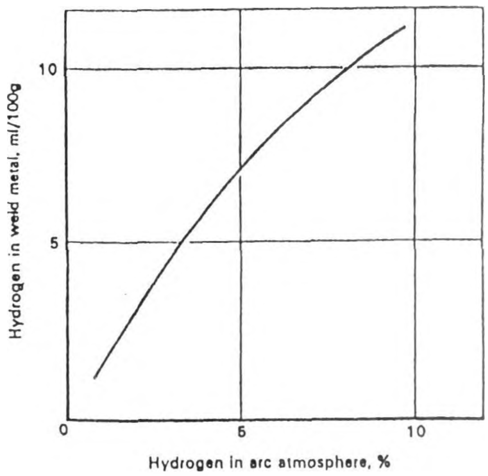

Fig 1 Amount of hydrogen absorbed by molten weld pool varies with concentration in atmosphere surrounding arc Solubility at 1900°C

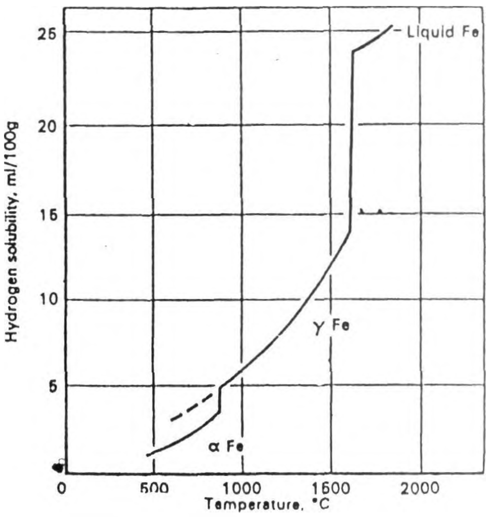

Fig 2 Solubility of hydrogen in weld metal decreases as temperature falls

more hydrogen because hydrogen is soluble in glycerine By the 1954 revision of AWS 5 5, the glycerine test was withdrawn from the specification and it was replaced in 1964 revision by definition of Low-hydrogen as those having no more than 0 6 percent coating moisture by weight with lower limits for higher strength electrode classification This definition of low-hydrogen electrodes by 0 6 percent coating moisture became the mandatory portion of AWS A5 1 specification in the 1981 revision

AWS A5 1 specification was further revised in the year 1991 and in this specification Diffusible hydrogen test is required for E7018M electrodes where as for other low hydrogen basic coated electrodes, Diffusible hydrogen test is only required when diffusible hydrogen designator is added to classification

For example

E7018H4
E7018H8
E7018H16

As per new classification system, upper limit for diffusible hydrogen is 16ml/100g which fits well with the correlation of 0.6 percent coating moisture. As per AWS/SFA 5.1 specification Diffusible hydrogen content of the weld metal is to be tested in accordance with ANS1/ AWS A4.3 specification "Standard methods for Determination of the diffusible hydrogen content of Martensitic, Bainitic and ferritic weld metal produced by Arc welding".

As mentioned above diffusible hydrogen testing is required as per AWS/SFA5.1 specification for all Low hydrogen type electrodes when diffusible hydrogen designator is added to the classification. Diffusible hydrogen limits for weld metal is given in Table 3.

TABLE - 3

AWS Classification	Diffusible Hydrogen designator	Diffusible hydrogen content Avarage $ml(H_2)/100g$ Deposited metal, max
E 7018M	None	4.0
E 7015		
E 7016	H 16	16.0
E 7016-1		
E 7018	H 8	8.0
E 7018-1		
E 7028	H 4	4.0
E 7048		

Determination of the diffusible hydrogen content of the weld metal by mercury method as against glycerine method.

It was recognised long ago that glycerine dissolves not only some hydrogen but it dissolves oxygen, nitrogen, carbon dioxide and water. M.A. Quintana showed that, as the glycerine bath aged, the concentration of hydrogen in the gas collected form a diffusible hydrogen test decreases from about 70 percent to about 50 percent. As the apparent diffusible hydrogen of the test specimen increased the concentration of hydrogen in the gas collected over glycerine increased from about 55 percent at 6ml/100g to about 75 percent at about 10ml/100g. The remainder of the gas collected is the other dissolved gases which are displaced from the glycerine by the dissolved hydrogen.

At very low hydrogen level, no gas is collected. All of the hydrogen dissolves without displacing any other dissolved gases.

The Japanese have conducted at least three studies of correlation between the glycerine test and the IIW method. In the first study, the test weld was quenched 30 seconds after the arc was extinguished - The following correlation equation was obtained.

Hjis = 0.64 Hiiw - 0.93 ....(1)

In the second study, the test weld was quenched 5 seconds after the arc was extinguished.

The second study provided slightly higher hydrogen and equation is given below.

Hjis = 0.67 HIIW - 0.80 ....(2)

More recently Japanese have moved to adding a run-on and a run-off tab to the test specimen. They produced a third equation which is as under.

Hjis = 0.79 Hiiw - 1.73 ....(3)

The three equations are plotted in fig. 3 which shows that there is very little difference among them.

Correlation between coating Moisture and Diffusible hydrogen

In evaluating correlation between coating moisture and diffusible hydrogen, it is important to keep in mind that any correlation can not be perfect because several factors can influence the relationship. Few factors which can influence the relationship are as under :

(a) At the same coating moisture level, an electrode with a heavy coating would deliver to the arc more hydrogen than would an electrode with a thin coating.

(b) The addition of fluorides to an electrode slag system will cause removal of some hydrogen. As a result, to otherwise similar electrode at the same coating moisture level, will yield different diffusible hydrogen level if one is appreciable higher in fluoride than the other.

HIRAI and co-workers developed a predicting equation which related IIW diffusible hydrogen to as baked coating moisture (a1 percent), moisture picked up by exposure (a2 percent) and partial pressure of water vapour in the air at time of welding (b,mm of Hg) for E7018 type electrode.

HD = $[260a1+30a2+0.9b-10]^{1/2}$ ....(4)

For freshly backed electrode, the exposure term of equation (4) could

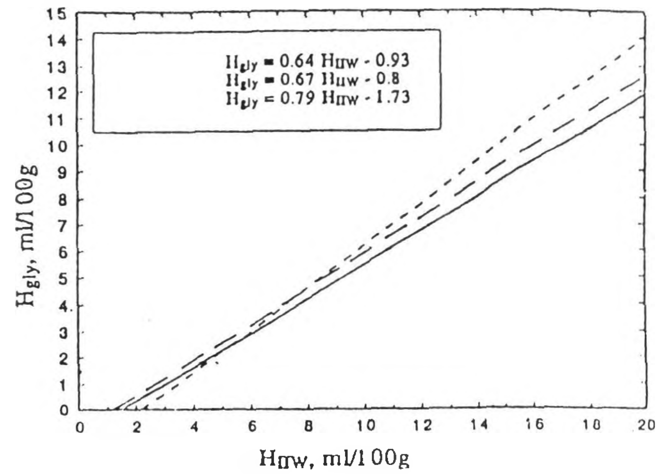

Fig 3 : Diffusible hydrogen by glycerin versus IIW mercury

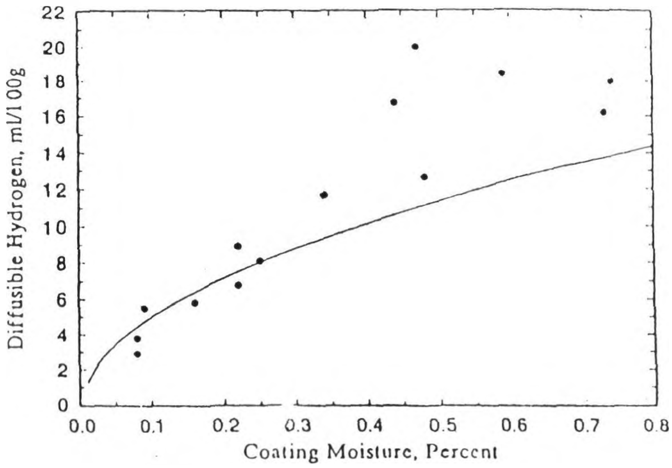

Fig 4 The correlation holds good for coating moisture below 0 3 percent

be zero and atmosphere condition for the welding amounted to about 10 mm Hg partial pressure of water. Based on the results correlation between diffusible hydrogen versus coating moisture for E7018 is plotted in fig 4

Effect of basic coated electrode exposure on the diffusible hydrogen content of the weld metal

As manufactured coating moisture of the basic coated electrode is likely to be more concentrated in the interior of the coating than on the surface because, in baking the electrode, moisture must diffuse outward through the coating thickness in order to escape. Conversely, moisture picked-up during exposure must enter the electrode coating from outside surface, and diffuse inwards. This surface moisture could be less tightly bound to the coating than the as manufactured moisture which servived a high temperature baking. In other words rehydrated moisture picked-up during exposure will be less effective in introducing diffusible hydrogen into the weld metal than will be the as-manufactured moisture. Dr. Evans provided the results of basic coated electrodes Diffusible hydrogen versus coating moisture on Drying and on exposure which are given in fig 5.

Correlation of diffusible Hydrogen with cracking

Evans and Christense and Christense and Simonsen examined the critical cracking stress by the implant test of a variety of steels as a function of hydrogen content of the weld metal.

An example of their data is shown in fig. 6. This data was obtained from a steel of 0.17C, 1.36Mn. Both rutile and basic coated electrodes were used to obtain various hydrogen levels

The hydrogen levels reported are based upon fused metal (deposited metal plus melted basemetal)

Critical cracking stress is plotted two ways, directly against hydrogen content of the weld metal and against the logarithm of the weld metal hydrogen content via a semilogarithmic plot

For all steels examined, the critical cracking stress, under otherwise identical conditions, is a linear function of the logarithm of hydrogen content of the weld deposit. It is not a linear function of the hydrogen content. In particular a small change in hydrogen content is much more important at a low hydrogen level that at a higher level. At a given preheat temperature, the critical carbon equivalent for crack free welding varies as a function of the diffusible hydrogen content of the weld metal. Yurioka conducted experiments on above lines and his results are reproduced in fig 7A & 7B.

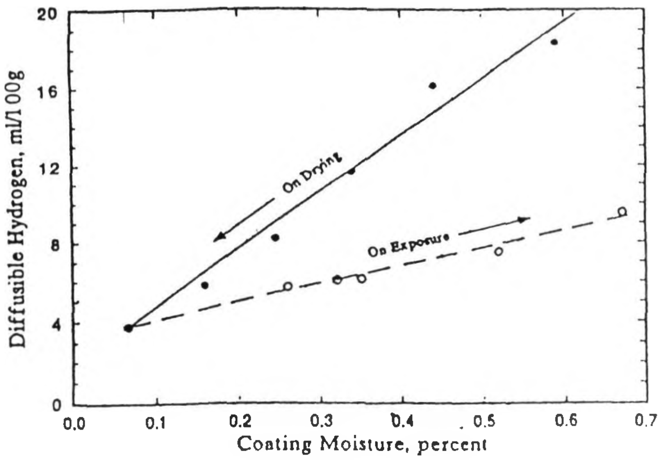

Fig 5 Diffusible Hydrogen vs Coating Moisture on Drying and on Exposure

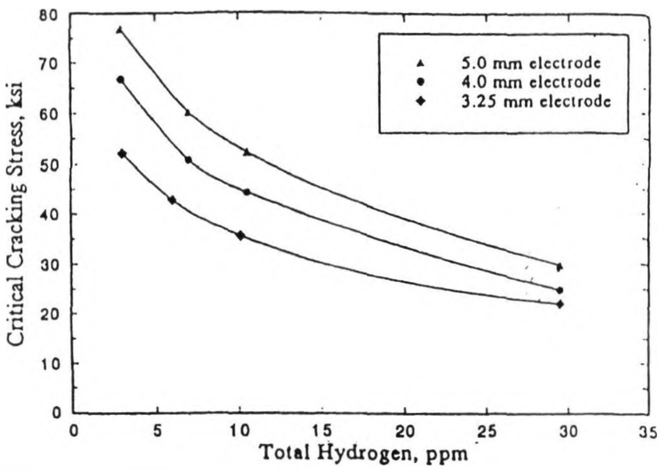

Fig 6A Critical Cra ersus Total Hydrogen, Implant ests of Carbon Steel

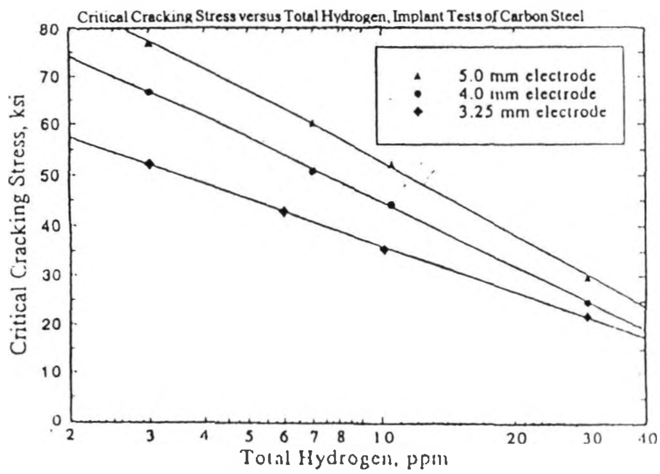

Fig 6B : Critical Cracking Stress versus Total Hydrogen, Implant Tests of Carbon Steel Logarithmic Hydrogen Axis

Welding Consumables

Basic coated electrodes

In order to minimise risk of cold cracking during welding of carbon steel and low-alloy steels, lot of developments have taken place during last decade. Designs of the basic coated consumables cover following four aspects

I) Low, very low *and extra* low level of hydrogen in the weld metal

II) Response to redrying

III) Resistance to moisture reabsorption characteristics

IV) Special Packaging

By using most updated in house technology most advanced extra low hydrogen type of electrodes having following classifications have been developed

E 7016	**E7018**
E7016-1	**E7018-1**

These electrodes have following unmatched properties :

The weldability that WELDERS really enjoy

Recently developed Low-hydrogen basic coated electrode features the best easy handling in all positions. *The deposited weld metal* has uniform ripples and absolutely no spatter. An end to difficult positional welding and lack of fusion on vertical up welding position.

The mechanical properties that Welding engineers really appreciate.

Recently developed Low-hydrogen basic coated electrodes guarantee high mechanical properties in comparison with other non-alloy basic coated electrodes

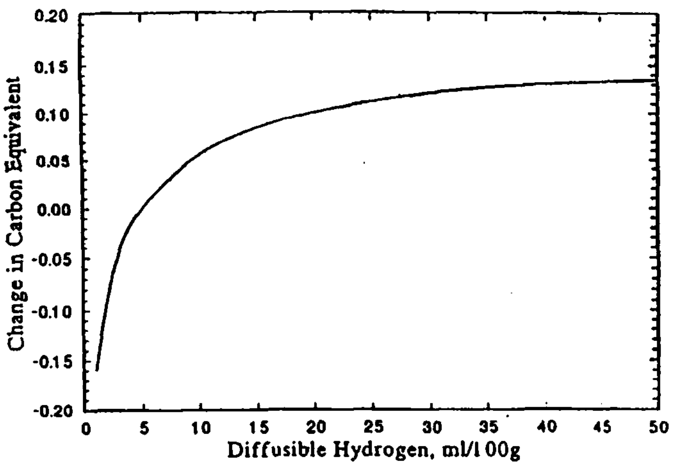

Fig 7A Carbon Equivalent Adjustment

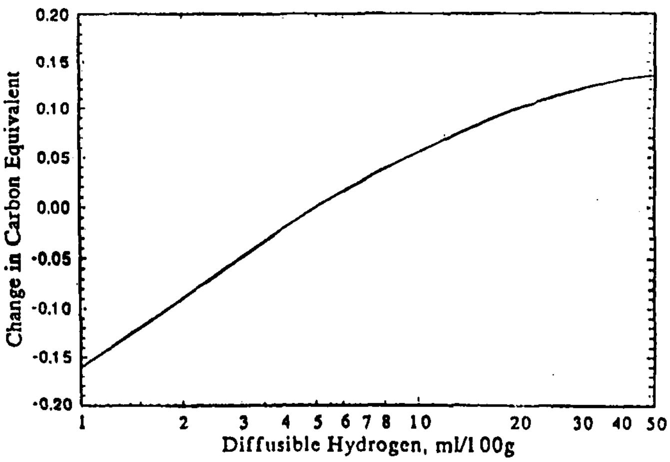

Fig 7B . Carbon Equivalent Adjustment Logarithmic Hydrogen Axis

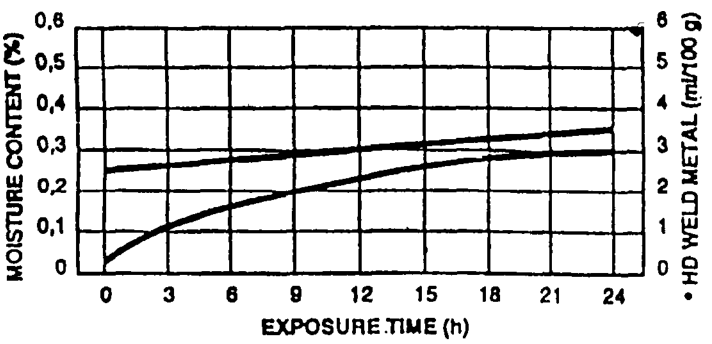

Fig 8 Moisture absorption versus exposure time for recently developed E7018 class of electrodes.

Extra Low-level of Diffusible hydrogen

The flux coating of these electrodes have a unique feature, a barrier to moisture absorption and diffusible hydrogen to the weld metal. After 9 hrs of exposure at 27°C at 80% RH, the max moisture in the flux coating is 0.20% and diffusible hydrogen is less than 4ml/100g of the weld metal.

Moisture resistant electrodes

Recent years have seen much emphasis on developing coated electrodes whose coating resist moisture pick-up. Such developments have permitted the user to test the electrodes for moisture pick-up with a view to extending the exposure time permitted by the structural welding code steel and other fabrication standards

Moisture resistant basic coated electrodes in accordance with **AWS/SFA 5.1-91** specification are designated by adding suffix letter **R** after four digit classification number

As per the specification, a letter **"R"** is a designator used with the low-hydrogen electrode classifications. The letter **"R"** as used to identify electrodes that have been exposed to a humid environment for a given length of time and tested for moisture absorption in addition to the standard moisture test required for classifications of Low-hydrogen electrodes

As per the specification "R" designated sufficient electrodes are exposed to an environment of 26.7°C (80°F) and 80% relative humidity for a period of not less than 9 hours by any suitable method. The moisture content of the electrode covering is then determined by any recommended method. The moisture content of the exposed covering should not exceed 0.30%, maximum specified moisture content for the electrode.

Diffusible hydrogen test

In addition to absorbed moisture test, the basic coated low-hydrogen electrodes designated by an optimal supplemental diffusible hydrogen designator are tested according to one of the methods given in ANSI/AWS A 4.3 Standard Methods for Determination of the Diffusible Hydrogen content of Martensitic, Bainitic and Ferritic steel weld metal.

For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of water vapour per pound (1.43 g/kg) of dry air at the time of welding. The actual atmospheric conditions is to be reported along with the average values for the test according to ANSI/AWS A 4.3-86 specification.

Two types of analytical apparatus are used for analysis of diffusible hydrogen.

I) Mercury filled eudiometer

II) GAS cromatograph

The test specimen confined within its isolation chamber is held at the hydrogen evaluation temperature as per following details.

Metallic mercury and mercury vapours are hazardous and can be absorbed into the body by inhalation, ingestion or contact with the skin. Therefore all precautions involving the handling of mercury should be observed during measuring hydrogen by mercury method.

On the other hand, gas chromatography procedure is quite safe and is used by many Europian and Japanese manufacturer of basic coated low-hydrogen electrodes. Since gas chromatography, procedures vary from instrument to instruments, it is necessary to study carefully instructions and calibration procedures recommended by gas chromatography apparatus manufacturers.

The IIW mercury method may require 14 to 21 days for complete collection of all of the diffusible hydrogen in a test specimen at room temperature. The AWS method requires 72 hours at 45°C or 6 hrs at 150°C for collection of nearly all of the diffusible hydrogen escape from the weld metal. Clearly elevated temperature speeds the hydrogen escape from the weld deposit, but hydrogen does escape from solid steel at room temperature.

Effect of Diffusible hydrogen content on tensile and ductility of the weld metal. Diffusible hydrogen in the weld metal could reduce tensile and ductility in a slow strain rate test.

Weld metal from a particular batch of E7018 electrodes which typically produces less than 5ml/100g of diffusible hydrogen, averaged 27.3% elongation in the "as welded" condition and 28.5% in the "aged" condition.

However, differences in measured tensile, elongation between "as-welded" and "aged" conditions become much more important when higher strength electrodes are used.

Resistance to Moisture absorption characteristic of Low-hydrogen basic coated electrodes.

As mentioned earlier basic coated low-hydrogen type electrode have been developed having moisture resistant coating. These electrodes have been developed based on some of the following measures :

(a) Optimised granulametry of the coating flux ingredient

(b) A newly developed binder system

(c) Correct procedure used for removing almost entire quantity of moisture from the flux coating.

These electrodes after baking have very low level of moisture in the flux coating. It is always less than 0.1 percent and typical value is as low as 0.04 percent. These electrodes when exposed to atmosphere having temp 27±2°C and 80% RH absorb moisture very slowly. These electrodes are designated with suffice "R" letter according to AWS/SF A 5.1-1991 specification.

Special packaging for Low-hydrogen basic coated electrodes

It was shown by franks in 1950 that Low hydrogen type covering pick-up moisture when openly exposed to humid atmospheres and that different electrodes absorb different amounts of water under identical conditions. Smith studied the phenomenon in detail and demonstrated that different brands of electrodes have different tolerances to moisture absorption.

TABLE 4

Minimum hydrogen diffusible times at acceptable temperatures

Diffusion temperature, c(f)		Minimum diffusion time hrs
±3°C	±5F	
45	(113)	72
150	(302)	6

While manufacturing low hydrogen basic coated electrodes enough care is taken during baking operation so that almost all quantity of moisture is removed from the flux coating. Freshly baked electrodes can have as low as 0.04% moisture in the coating. Since flux coating of low hydrogen basic coated electrode is hygroscopic in nature, different manufacturer use different mode of packing.

(a) Low hydrogen basic coated electrode are packed in polythene bags and then in carboard cartons. These carboard cartons are further shrink-packed.

(b) The electrodes are hermetically packed into the metal tin immediately following production baking. These metal tins may have sufficient quantity of dessicant which can lower the relative humidity in the tin to below 8% ensuring that the electrode coating does not absorb moisture during storage.

(c) The electrodes are vacuum packed using special qualities of pouches and these vacuum packed electrodes are further packed in plastic or carboard containers.

The metal tin containers used for hermetical packing or pouches used for vacuum packaging are specially designed to provide maximum protection for the electrodes during handling and storage.

Table 6 provide details of moisture level in the flux coating, shelt life of the electrodes for different packing conditions.

Saving in welding cost

Welding costs which varies from one fabricator to another fabricator depend upon following factor.

(a) Drying of electrodes.

(b) Storage of electrodes

(c) Preheating (power, Labour cost)

(d) Reduced labour productivity because working on heated work pieces is more difficult.

(e) Post weld heat treatment

Recently devoloped low hydrogen basic coated electrodes-which are either hermetically packed or vacuum packed, deposit weld metal having very much reduced level of diffusible hydrogen in the weld metal as well as in the heat affected zone. Such very low level of hydrogen increases tolerance to hardness in the heat affected zone and stresses applied to weld metal without increasing risk of cold cracking.

For many applications, where moderate preheat is usually required for eliminating risk of cold cracking, recently developed vaccum packed basic coated Low-hydrogen electrodes either eliminate preheating totally or reduce preheating temperature to a greater extent. Reducing preheating or eliminating preheating produces saving which is often equal to the cost of welding consumables.

Example

For welding of A516 Gr 70 steel plate thickness 40 mm

For X meter length of welding A516 Gr 70 steel thickness 40 mm

(A) Cost of Normal E7018 electrodes Rs. 5000/-

(B) Cost of Vacuum packed E7018 electrodes Rs. 8000/-

(C) Cost of preheating - Maintaining inter pass temperature (1.5 time cost of electrodes) Rs. 7500/-

(D) Cost of storage, baking/drying of electrodes, (30% cost of electrodes) Rs. 1500/-

**** Fabricators pay Rs. 3000/- more for vaccum packed electrodes whereas he saves Rs, 9000/-.**

Hydrogen controlled consumables and Indian capability and experience

Indian manufacturers of basic coated electrodes have kept pace with the technological development taking place on other countries especially Europian one. They manufacture moisture resistant electrodes of various classification and these electrodes are now available in vacuum packed condition.

Vacuum packed electrodes, even though cost about 40 to 50 percent more than normal carboard packed electrodes, these electrodes have much longer shelf life and can be

TABLE 6

No	Packing condition	Moisture in the flux coating	Shelt life
(1)	Carboard packing with plastic inside and or outside the carton	Depends on storage conditions	To consult manufacturer
(2)	Hermatically closed tin containers	Usually less than 0.1%	5 years
(3)	Vacuum packed	Usually less than 0.1%	5 years

used straight on the job after opening the pack However care should be taken so that entire quantity of the packet is consumed within 4 to 6 hours after opening the pack.

Recently developed basic coated low-hydrogen electrodes have improved toughness properties hence these electrodes have unique feature called resistance to ageing of the weld metal For manufacturing these electrodes, electrode manufacture adopt following measures :

1) The use of extremely clean wire
2) The use of extremely clean minerals, ferroalloys and oxides
3) The use of an optimised coating system with a high basicity index
4) Control of Non-Metallic oxide inclusions in the weld metal which controls the nucleation process during solidification of the liquid metal and favours the formation of a more fine grained structure.

It is expected that designers and consultants would demand increasing quantities of various recently developed Low-hydrogen basic coated electrodes which are either hermetically tin packed or vacuum packed for eliminating cold cracking of the weld metal of HAZ of the parent metal.

CONCLUSIONS

1)* Hydrogen is an elusive element affecting cold cracking susceptibility in feritic welds.
2) Hydrogen control assumes criticality as the hardenability increases
3) There can not be a compromise on hydrogen control
4) Procedural differences in measurement of hydrogen does require perfect understanding and careful comparitive interpretations
5) Low-hydrogen basic coated electrodes, which are available in the market, deposit weld metal having low, very low or extra low level of hydrogen in the weld metal
6) Moisture resistant Low-hydrogen basic coated electrodes are now available in the market.
7) In order to have longer shelf-life and cut down cost of welding, fabricators prefer vacuum packed basic coated low-hydrogen electrodes
8) Recently developed Low-hydrogen basic coated electrodes deposit weld metal having improved toughness properties and very low level of hydrogen

These electrodes almost eliminate risk of cold cracking

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