

Influence of Lithium Compounds on Moisture Regain Properties of Low Hydrogen Type SMAW Electrodes

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Introduction

During welding with basic, low hydrogen, type welding consumables, one of the primary sources of hydrogen in the weld metal is moisture in the consumable coating. Thus the welding industry has been using the coating moisture of low hydrogen type shielded metal arc welding electrodes to assess the risk of hydrogen damage after welding.

Low Hydrogen electrodes contain a relative high percentage of moisture after extrusion. Most of the moisture is lost in the initial low temperature baking. The remaining moisture is more difficult to remove. Even after baking at high temperatures, typically up to 460 – 500 °C, a small amount of moisture remains in the coating. This moisture is crystalline moisture, which is chemically bound. The higher the baking temperature the less the coating moisture content. It has been shown by Chew [1] that increased baking temperature significantly reduced the diffusible hydrogen content of the weld metal deposit.

Moisture, which is absorbed by the coating, during exposure, does not bind as tightly as the initial moisture. This moisture can be removed through reconditioning as prescribed by the electrode manufacturer. Hirai et al. [2] has estimated that only 12% of the absorbed moisture enters the arc atmosphere as compared to 100% of the chemically bound or crystalline moisture. The raw materials which make up the electrode coating has a direct influence on the moisture content of the coating as well as the rate of moisture absorbed during exposure.

Electrode manufacturers are continuously striving to reduce and contain the moisture in the electrode coating in order to lower the potential for hydrogen in the weld metal.

The purpose of this paper is to report on the relative influence of different Lithium containing compounds on the initial coating moisture and the moisture regain or moisture absorption of basic low hydrogen type SMAW electrodes.

Absorbed moisture test

The AWS specification AWS A5.1-91 set the conditions for the absorbed moisture test. The electrodes are to be exposed to an environment of between 26.7 °C and 29.5 °C at a relative humidity of 80% to 85%, for a period not less than 9 hours.

The moisture in the coating can be determined by any suitable method but the specification also refers to a reference method in the case of dispute.

In this paper the infrared method of moisture determination was used.

Infrared determination of moisture in the electrode flux coating

The electrode flux sample is combusted in a stream of pure, dry nitrogen. The nitrogen carrier gas is exposed to infrared radiation at a specific wavelength and intensity. The H - O bonds in the water absorb energy thereby reducing the intensity of the infrared signal at the detector. The water content in the nitrogen carrier gas is inversely proportional to the intensity of the infrared energy signal [3].

The instrument is calibrated by exposure to a standard sample. Quantification of the unknown flux sample is by comparison with the infrared signal strength produced by the standard. Blank values are also obtained and subtracted from the measured values.

The instrument is programmable in terms of the heating rate, the start and end temperature, and the holding time at a specific temperature. The heating and cooling cycle takes approximately 7 minutes. For analysis a 0.25 grams of electrode flux coating is sufficient.

Experimental procedure

A standard E7018-1 electrode formulation which is currently produced, was used for the purpose of the experiment. The reference coating formulation contained approximately 21% Calcium Carbonate, 17% Calcium Fluoride, 31% Iron Powder, 6% Titanium Dioxide, 5% Potassium Feldspar and the remainder is made up of binders and deoxidizing elements. The standard liquid additions used were a mixture of Sodium Silicate, Potassium Silicate and water.

Electrodes of 3.15 mm diameter were manufactured in the laboratory. The wire to coating ratio was 1.73. After extrusion the electrodes were air dried for 24 hours followed by baking at 180 °C for 2 hours and the final baking at 460°C for 2 hours.

The electrodes were reconditioned, before exposure, at 370 °C for 90 minutes, allowed to cool in air and then exposed at a relative humidity of 80% +5% and 28 ± 1 °C. After exposure for the set time period the electrodes were placed in glass tubes, sealed with rubber stoppers.

Prior to analysis, the electrodes were removed from the glass tubes. The flux was removed from the wire and ground with a mortar and pestle. A sample of 0.2500 gram was weighed and then analyzed in the Leco RC412 moisture determinator using a heating cycle starting at 500 °C, ramping at 200 °C a minute up to 1050 °C and holding for 60 seconds at 1050 °C.

The Lithium compounds used in this investigation were Lithium Alginate, Lithium Carbonate and Lithium Hydroxide. To study the effect of Lithium Alginate, experimental electrodes containing no Lithium Alginate, 0.6%, 0.9%, 1.2% and 2% Lithium Alginate by weight were made in the laboratory. These electrodes were exposed for 0, 9 and 24 hours at relative humidity of 80% +5% and 28 ± 1°C.

Experimental electrodes containing no Lithium Carbonate, 0.5%, 1.5% and 3% Lithium Carbonate were made to study the effects of Lithium Carbonate. These electrodes were exposed at relative humidity of 80% + 5% and 28 ± 1 °C for 0, 9, 24, 48 and 120 hours.

For the study on the effects of Lithium Hydroxide electrodes containing 0 ml LiOH and 30 ml LiOH were made. These electrodes were exposed at relative humidity of 80% + 5% and 28 ± 1°C for 0, 9, 24 and 48 hours.

Results and discussion

Lithium Alginate Lithium Alginate was added to the standard flux formulation in amounts of 0.6%, 0.9%, 1.2% and 2% by weight. The average absorbed moisture results for Lithium Alginate additions are given in Table 1 and Figure 1.

Table 1. Average coating moisture contents for Lithium Alginate additions.

Time	0%	0.6%	0.9%	1.2%	2%
0	0.15	0.16	0.16	0.15	0.10
9	0.53	0.72	0.79	0.6	0.31
24	0.56	0.79	0.86	0.61	0.43

From the results it is clear that adding Lithium Alginate in quantities up to 1.2% by weight has a detrimental effect on the moisture regain properties. At Lithium Alginate levels of 2% an improvement in the moisture regain properties are observed.

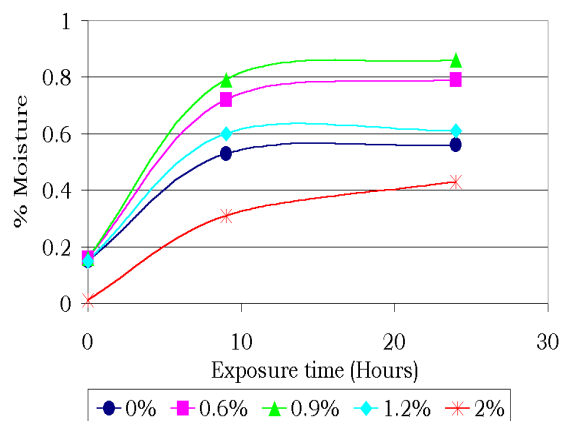


Figure 1. Influence of Lithium Alginate on moisture regain properties.

After 9 hours exposure an improvement of approximately 40% compared to the electrodes with no Lithium Alginate was observed.

From figure 2 it is clear that the average moisture regain increase with an increase in Lithium Alginate up to a maximum of approximately 0.9% by weight. Thereafter a decrease in the moisture regain is observed. Additions of Lithium Alginate up to 1.2% does not effect the initial moisture after baking and reconditioning. At levels of 2% Lithium Alginate there is a reduction of approximately 33% in the initial moisture content compared to when no Lithium Alginate is added.

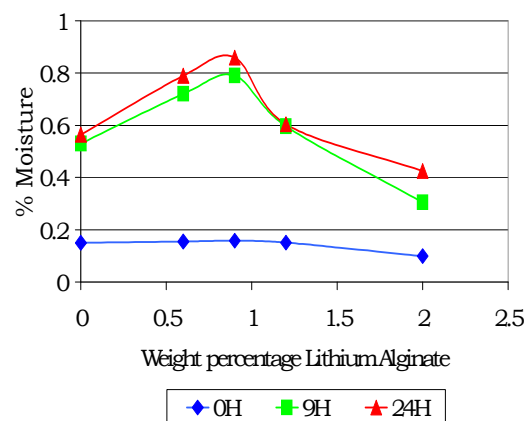


Figure 2. Influence of Lithium Alginate on moisture regain properties.

Lithium Carbonate Lithium Carbonate was added to the standard flux formulation in amounts of 0.5%, 1.5% and 3% by weight. The average absorbed moisture results are given in table 2 and Figure 3.

Table 2. Average coating moisture contents for Lithium Carbonate additions.

Time	0%	0.5%	1.5%	3%
0	0.1	0.06	0.05	0.05
9	0.69	0.28	0.15	0.16
24	0.73	0.37	0.22	0.21
48	0.92	0.42	0.29	0.22
120	1.13	0.84	0.36	0.33

From table 2 and Figure 3 it is apparent that additions of Lithium Carbonate to the standard flux formulation proved to be beneficial for the moisture regain properties.

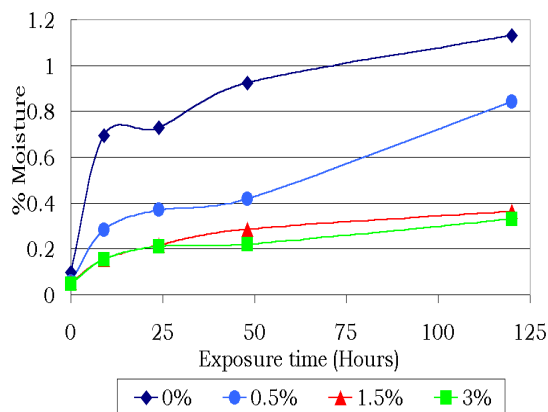


Figure3. Influence of Lithium Carbonate on the moisture regain properties.

From Figure 3 it can be seen that up to 24 hours exposure the flux moisture values are almost identical. For exposure times longer than 24 hours, additions of 3% Lithium Carbonate gives slightly lower average flux moisture values than additions of 1.5% Lithium Carbonate.

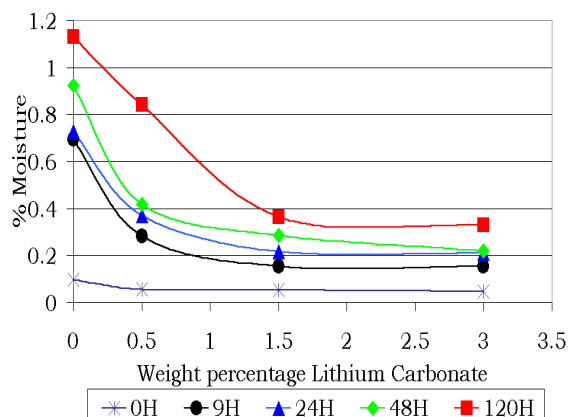


Figure 4. Influence of Lithium Carbonate on the moisture regain properties.

From Figure 4 it clearly can be seen that a minimum in the average flux moisture content is reached at approximately 1.5% Lithium Carbonate additions. This holds true for all exposure times from 9 hours up to 120 hours exposure. Thus it seems for this particular flux formulation 1.5% Lithium Carbonate is the optimum in terms of moisture regain properties.

The initial moisture in the electrode flux coating after reconditioning and before exposure showed an approximate 50% decrease with additions of Lithium Carbonate. It seems if even a small amount, 0.5%, is added a significant decrease in the initial coating moisture is experienced. If more than 0.5% Lithium Carbonate is added, no additional benefit in terms of the initial moisture is observed. Additions of Lithium Carbonate above 1.5% seems not to lower the average flux moisture after exposure much more than additions of 1.5% Lithium Carbonate.

After 9 hours exposure, 0.5% Lithium Carbonate addition resulted in a 60% improvement in the average flux moisture content. 1.5% Lithium Carbonate addition resulted in a 78% improvement in the average flux moisture content. After 24 hours exposure the improvements are 50% and 70% respectively. After 48 hours exposure the improvements are 54% and 68% respectively. After 120 hours exposure the improvements are 26% and 68% respectively.

The improvement gained in average flux moisture content after exposure by Lithium Carbonate additions of 1.5% is approximately 70% regardless of the exposure time. The improvement gained in average flux moisture content after exposure by Lithium Carbonate additions of 0.5% was approximately 55% up to 48 hours exposure. At the longer exposure time of 120 hours the improvement dropped significantly from average 55% to approximately 26%.

Lithium Hydroxide Additions of 30 ml of a 20% solution of Lithium Hydroxide was made to the standard formulation.

Table3. Influence of Lithium Hydroxide.

Time	0 ml	30 ml
0	0.08	0.08
9	0.39	0.30
24	0.84	0.57
48	1.07	0.73

Addition of Lithium Hydroxide does not influence the initial flux moisture after conditioning of the electrodes.

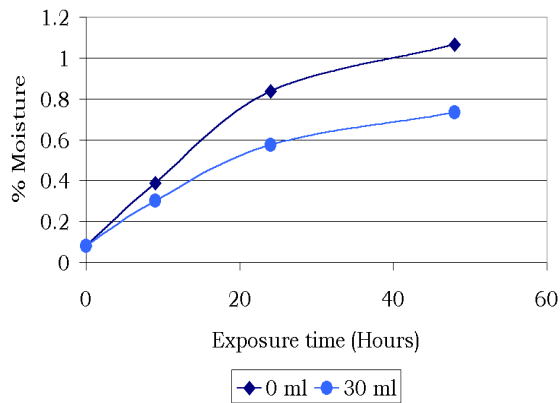


Figure 5. Influence of Lithium Hydroxide on the moisture regain properties.

After 9 hours exposure the addition of Lithium Hydroxide has resulted in a 23% decrease in the average flux moisture content. After 24 hours exposure the decrease was 32%. After 48 Hours exposure the decrease was still 32%.

Practical implications. At the start of the paper it was mentioned that the initial moisture content of the coating contributes to the diffusible hydrogen content of the deposited weld metal. The lower the initial moisture content, the lower the amount of diffusible hydrogen in the deposited weld metal.

Electrodes with 0.5% and 1.5% addition of Lithium Carbonate were manufactured in the laboratory to evaluate the weldability characteristics, the moisture regain properties as well as the diffusible hydrogen content.

The moisture regain properties are given in Table 4 and Figure 6.

The weldability of all the electrodes were acceptable and similar to that of the standard production electrodes.

The initial moisture of the electrodes which contain 1.5% Lithium Carbonate is 27% lower than that of the electrodes containing 0.5% Lithium Carbonate.

Table 4. Influence of Lithium Carbonate

Time	0.50%	1.50%
0	0.15	0.11
9	0.29	0.28
24	0.47	0.44
48	0.66	0.45
120	0.74	0.52

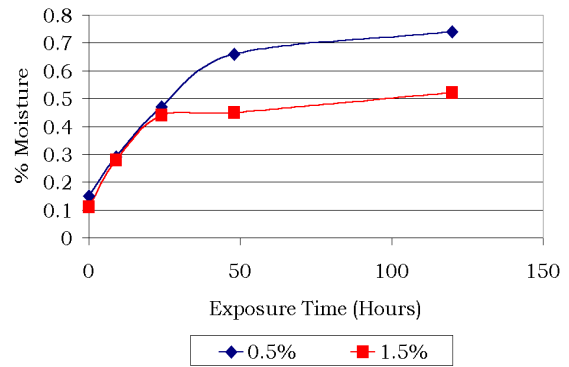


Figure 6. Influence of Lithium Carbonate on moisture regain properties

From Figure 6 it is clear that the coating moisture contents are similar up to 24 hour exposure. Thereafter the coating moisture content of the electrodes containing 1.5% Lithium Carbonate is significantly lower than that of the electrodes which contains 0.5% Lithium Carbonate.

The diffusible hydrogen content of the deposited weld metal is 6% lower when the electrode coating contains 1.5% Lithium Carbonate (0.11% initial moisture) compared to that of the electrode containing 0.5% Lithium Carbonate (0.15% initial moisture). Thus a reduction of 27% in the initial moisture resulted in a 6% reduction in the diffusible hydrogen content of the deposited weld metal.

Conclusions

The influence of three Lithium containing compounds on the moisture regain properties of low hydrogen type SMAW electrodes has been examined. As a result of the investigation the following conclusions have been drawn :

- Lithium Alginate at first has a negative influence on the moisture regain properties up to additions of 1.2%. Additions of 2 % have a beneficial effect on the moisture regain properties.
- Lithium Hydroxide has a beneficial effect on the moisture regain properties.
- Lithium Carbonate has a beneficial effect on the moisture regain properties.
- The optimum Lithium Carbonate addition is 1.5% for this formulation.
- Of the three Lithium containing compounds, Lithium Carbonate is the most effective followed by Lithium Hydroxide and the Lithium Alginate.

- In practice, adding 1.5% compared to 0.5% of Lithium Carbonate to the formulation has resulted in a 27% decrease in initial moisture and a 6% decrease in the diffusible hydrogen content of the deposited weld metal.

References

1. B. Chew. Welding Journal. 55(5):127-s to 134-s
2. Y.Hirai, S.Minakawa and J. Tsuboi. Prediction of diffusible hydrogen content in deposited weld metals with basic type covered electrodes. IIW Document II-929-80.
3. Leco Instruction Manual RC-412 Multiphase Carbon/Hydrogen/Moisture determinator. 7-1 to 7-2.