LINCOLN ELECTRIC ENGINEERING REPORT

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TITLE:	**POCK MARKING WITH SUBMERGED ARC FLUXES**
SUBJECT:	Electrode Specification Report

SUMMARY: Pock marks are depressions in the surface of a weld with voids in the slag directly over them. The depression and void are caused by gas bubbles created by the welding process. Listed in this report is information on how to reduce or eliminate this problem.

KEYWORDS: SAW, Fluxes, Pock Marks

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POCK MARKING WITH SUBMERGED ARC FLUXES

I. What are they?

Pock marks are depressions in the surface of a weld with voids in the slag directly over them. Both the depression in the weld surface and void in the slag are caused simultaneously by a gas bubble. This gas bubble (oxygen and/or carbon monoxide) forms in the weld puddle and must escape through the slag to the atmosphere.

II. What causes this gas?

The first source of this gas is the flux itself. Fluxes may contain manganese ore (Mn_3O_4), traces of iron oxide (Fe_2O_3), carbonates or carbon. The second source of this gas is the steel plate itself. All steels contain carbon. Most steel plates are covered with mill scale (FeO) due to hot rolling. During yard storage, some of these plates rust ($Fe_2O_3 \cdot xH_2O$). Some steel is contaminated with oil, grease, and other lubricants during shearing or forming operations. These organic materials contain large quantities of carbon. All of these materials go into the weld puddle and react with one another. Some of these reactions are shown below:

(1) $2Mn_3O_4 \xrightarrow{heat} 6MnO + \overline{O_2}$ (gas)

(2) $FeO + C \xrightarrow{heat} Fe + \overline{CO}$ (gas)

(3) $Fe_2O_3 \cdot xH_2O + C \xrightarrow{heat} 2FeO + \overline{CO}$ (gas) $+ \overline{xH_2O}$ (gas)

III. What determines the level of pock marking?

Obviously, the amount of mill scale, rust, oil, etc. determines the tendency for pock marking. It is very difficult to visually determine the thickness of scale or rust on the steel. The same welding procedure can produce different results from one weld to the next because the amount of scale or rust varies from plate to plate. We can control the level of pock marking by the following methods:

a. Killing agent - Silicon is very effective in eliminating pock marking in most cases. This is because it decreases the amount of gas produced in the weld puddle. An example is given below:

$2FeO + Si \xrightarrow{heat} 2Fe + SiO_2$ (slag)
(scale)

Silicon decreases the O_2 available to react with carbon to produce gas.

The silicon needed to control pock marking can be increased without changing the welding procedure by using a higher silicon electrode (e.g. L-61, L-50). The second source of silicon is the flux. Increasing the amount of flux melted will increase the silicon in the weld puddle. The most effective method of increasing the amount of flux melted is to increase the arc voltage. This increases the amount of flux melted for a given amount of electrode melted. Remember that an increase in welding current increases the amount of electrode melted. This will normally increase pock marking due to a decrease of silicon in the weld puddle. Increases in current must be matched by comparable increases in voltage to keep an adequate level of silicon in the weld metal. The flux is a greater source of silicon than the electrode. However, procedure limits the maximum usable voltage. For this reason, high silicon electrodes are very helpful to increase the weld puddle silicon.

The joint will also have an effect on the pock marking. Narrow joints do not permit as much flux to melt for the same current and voltage. This increases the pocking tendency.

b. The second important factor in determining the level of pock marking is the slag freezing (solidification) rate. The gas bubbles that form in the weld puddle must have time to escape through the liquid slag. If the slag freezes (solidifies) too rapidly, some of the gas is trapped between the weld and slag and forms a pock mark. The slag freezing rate is controlled by welding speed, joint thickness, joint position, and flux design. Increased welding speeds cause faster slag freezing and increased pock marking. For the same welding procedure, an increase in plate thickness will cause the slag to freeze faster and increase pock marking. Horizontal fillets or 3 o'clock welds where the slag tends to run away from the top edge will cause pocking along this top edge. This is due to the thin layer of slag along this top edge which freezes faster. In addition, small welds on heavy plate are extremely prone to pocking due to the fast freeze resulting from low heat input. Fluxes that freeze quickly are excellent for out-of-position welding, but usually poor with regard to pock marking. A slow freezing slag is the most desirable to combat pock marking. It should be noted that when slag freezing rate is the primary cause of pocking, a high silicon electrode may increase pocking. This is due to the fact that high silicon electrodes cause agglomerated fluxes to freeze faster.

Finally, the best flux in our product line to resist pock marking is 781.

SUMMARY:

Pock marking gets worse if -

1. Voltage is decreased.
2. Speed is increased.
3. Current is increased (unless very low heat input is encountered).
4. Included angle of joint is decreased.
5. Stickout is increased for the same current and voltage.
6. Mill scale, rust, or oil contamination increases.
7. Low silicon electrodes are used.
8. Flux burden (pile height) is increased.

Pock marking is decreased if -

1. Voltage is increased.
2. Speed is decreased.
3. Current is decreased.
4. Included angle of joint is increased.
5. Stickout is decreased for the same current and voltage.
6. Mill scale, rust, and oil are completely eliminated (sand blast, grinding, etc.).
7. High silicon electrodes are used (L-61 and L-50).
8. Flux burden is decreased.