

The Operation of Final Coat* Automobile Rust Protection System

Digby D. Macdonald

Distinguished Professor of Materials Science and Engineering
Director, Center for Electrochemical Science and Technology
Pennsylvania State University,
University Park, PA 16802, USA.

Recent experiments have shown that induced surface currents in the MHz range provide considerable protection against corrosion to galvanized steel of the type that is used in the construction of vehicles (private, commercial, and military). The evidence for the efficacy of the effect has been established through closely controlled experiments using the apparatus shown schematically in Figure 1. Briefly, the apparatus comprises a painted, galvanized steel panel upon which a salt water spray impinges, with the solution being collected in a trough below the panel. The panel is not in contact with the solution in the trough and no continuous electrolyte path exists between the two. The panel is connected to a pulse generator (the "Module") that provides a carefully designed, repetitive electromagnetic pulse. The Module, which is powered by a regular automobile battery, draws power in the milli-watt range. This power lever is smaller than that of clock that is already installed in many vehicles. The Module provides a pulse having the waveform shown in Figure 2.

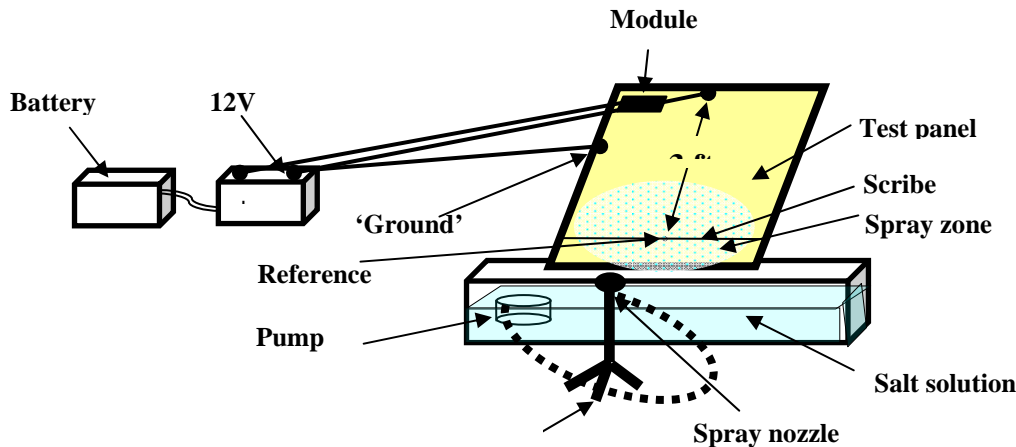


Figure 1. Schematic of the test apparatus.

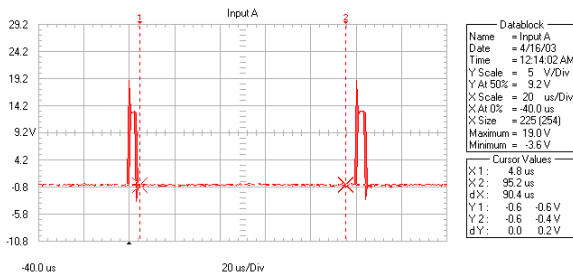


Figure 2. Captured waveform of the CM2000 module output. Note that each division corresponds to 20 μ s and that the pulses are 5 divisions apart, corresponding to a pulse frequency of 10kHz. However, the pulse itself can be represented by a Fourier series comprising a weighted sum of sine and cosine components at frequencies that are determined by the pulse width or 1-10MHz.

As noted above, the galvanized panel was painted with a high quality automobile paint and was scribed with a sharp tool, with the scribe penetrating the paint, the galvanized (Zn) layer, and into the underlying steel. All three components were therefore exposed to the salt water spray that was directed onto the front side of the panel only. In order to characterize the electrochemical state of the system, a small hole was drilled through the panel at the scribe, filled with a porous ceramic plug, and a Luggin probe was mounted on the back side of the panel leading to a Ag/AgCl, KCl(sat) reference electrode (Figure 3). The potential of the steel at the scribe was measured against the reference electrode using a high impedance digital voltmeter interfaced to a computer. A control panel, which was identical in every respect to the test panel, except that it was not connected to a Module, was set up to provide data for comparison with that from the test panel.

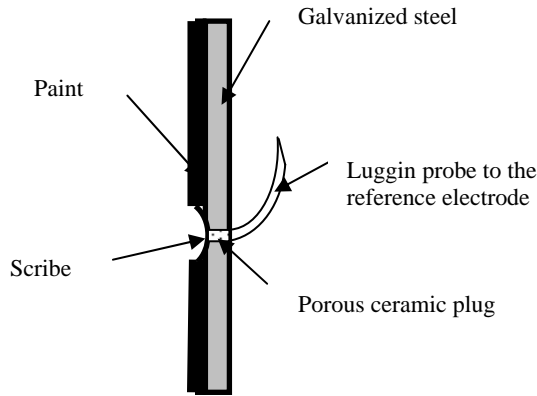


Figure 3. Schematic of the reference electrode assembly including the Luggin probe. Note that the Luggin probe that is used for monitoring the corrosion potential is mounted on the dry backside of the panel and is in electrolytic communication with the scribe, which is in contact with the scribe, via a porous ceramic plug. Thus, the corrosion potential that is monitored is that of the scribe, which is in contact with the salt solution that is sprayed onto the front side of the panel.

The experiment has been run numerous times and consistent results have been obtained. Shown in Figure 4 are the potential data from one run. It is seen that both the test panel and control panel potentials was initially $-0.7V$ to $-0.8V$ vs $Ag/AgCl, KCl(sat)$ as a result of the zinc galvanizing acting as a sacrificial anode and polarizing the steel in the negative potential direction. However, with increasing time, the potential of both panels drifted in the positive direction (downward) toward a value of about $-0.6V$ as a result of passivation of the zinc and hence the zinc being gradually less effective in protecting the steel, resulting in rust. After about 50 hours, the potential of the test panel (the panel equipped with a Module) began to drift back in the negative direction while that of the control panel, which was not equipped with a Module, remained constant at about $-0.6V$. *These data demonstrate that the function of the Module is to restore the efficacy of the galvanizing (zinc) in protecting the underlying steel (Test Panel), in the face of the processes that cause passivation of the zinc to render the galvanizing less effective (Control Panel).*

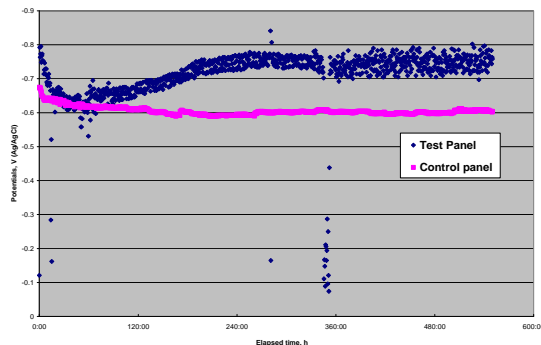
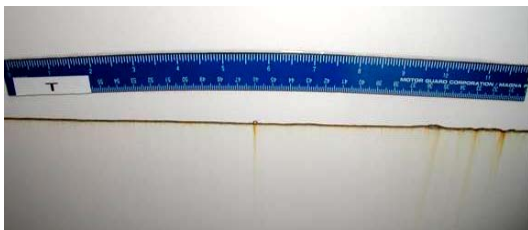
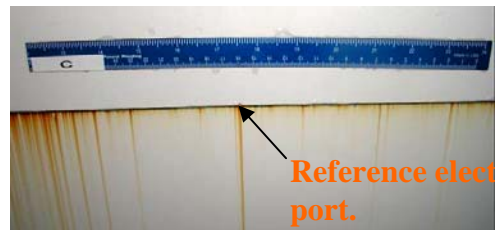


Figure 4. Potential –versus-elapsed time curve (Test No. 1). Note that the test panel was equipped with a module but the control panel was not. **The action of the module appears to be to depassivate the zinc, thereby rendering the galvanizing much more effective in protecting the steel.**



Test Panel



Control Panel

Figure 5. Comparison of the appearances of the Test Panel (equipped with the Module) and the Control Panel (not equipped with a Module) after completion of a 500 hour experiment.

That the Module provides protection to the steel is easily seen from the panels themselves, because the scribes produce red/brown corrosion products [“red rust”, $Fe(OH)_3$, $FeOOH$], as shown in Figure 5. The amount of corrosion product produced by the Test Panel (equipped with the Module) is significantly

less than that produced by the control panel (not equipped with a module). Other experiments gave similar results.

The work summarized above has demonstrated the general efficacy of the method. In doing so, we stress that the corrosion control technology is **NOT conventional, impressed current cathodic protection (CP), because: (1) A direct current is not employed; (2) No return electrolyte path to an anode exists on the surface between the area protected (the scribe) and the connection to the panel on the dry backside; and (3) No anode exists (note that the connection of the Module to the panel is on the back side and the connection is made directly to the galvanized steel)**. Instead, the mode of action is the induction of surface currents in the panel by electromagnetic radiation, which restore the ability of the galvanizing to protect the underlying steel in the face of zinc passivation. Work at the Ohio State University Electrosciences Laboratory confirmed the presence of induced surface currents and found that the currents were uniformly distributed over an entire automobile body. Note that the frequency is sufficiently high that the “skin effect” is operative, in which the current density is concentrated close to the surface. Since corrosion is a surface phenomenon, the skin effect likely is important in concentrating charge transfer processes exactly where they are needed to activate the zinc.

The application of this technology is simple; a carefully-designed, high frequency, battery-driven oscillator is connected at any point on the structure to be protected, with the induced current being uniformly distributed over the whole body as demonstrated at the Ohio State University Electrosciences Laboratory. In an advanced version of this technology, the signal characteristics might be tuned for a particular structure to achieve maximal protection.

In answer to claims that Final Coat might be harmful to an automobile and hence that its use might void a Warranty, I respond as follows:

- No DC current flows across any metal/electrolyte interface and hence Final Coat cannot induce an electrolysis reaction that would result in enhanced corrosion. On the contrary, the experiments to date show that Final Coat protects automobile panels from corrosion without any detected deleterious side effects.
- Because it is not an impressed current cathodic protection system and, hence, does not have an anode to accept a current flowing in the external environment, or require a conductive electrolyte phase to be present on the panel surface for efficacy, the action is local. That is, the induced currents protect the steel only at points where damage extends from the surface through the coating and the zinc galvanizing into the underlying steel. In other regions, the induced currents simply circulate harmlessly in the metal with no impact on the mechanical properties or surface coatings. In other words, Final Coat is benign unless damage exists, in which case it facilitates the effectiveness of the galvanizing in protecting the underlying steel.
- Many other sources of induced current already exist in automobiles. For example, spark ignition systems generate electromagnetic fields that induce currents in all metal structures in close proximity (witness the interference with radios, because of induction of noise into the antenna). Furthermore, the use of any device that emits electromagnetic radiation, such as CB radios and cell phones, will result in the induction of currents into a vehicle body, which also acts as an antenna. Indeed, driving through a region that has been invaded by radio and TV broadcasting electromagnetic signals (essentially every position on the land masses of Earth) will result in induced currents. The difference between these sources and that produced by Final Coat is that the signal from the latter is designed to inhibit corrosion. Nevertheless, should starting the engine of a vehicle (spark ignition noise), operating a CB radio or a cell phone, or driving in a region invaded by broadcast radio and TV signals void the Warranty? I think not, but this is a crucial question, because, fundamentally, the sources noted above are no different than what is produced by Final Coat, except for the signal design.
- **Final Coat is fundamentally different from other electronic automobile rust protection devices that I have examined. Many of those other systems are impressed current, cathodic protection systems, which cannot work because of the limited throwing power of the current. To render them effective, it would be necessary to place closely spaced anodes over the entire automobile body, thereby destroying its aesthetic appeal.**

*** The Final Coat / Defender Plus technology identified by the following US and Foreign patents was the topic of this evaluation.**



The aforementioned independent product evaluation that was performed by Dr. Digby Macdonald solely provides his unbiased scientific and professional findings as to the effectiveness of the patented electronic corrosion control technology sited above.