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TO: Sally Anne McInerny, Ph.D.
Department of Mechanical Engineering

FROM: Matthew J. Begneaud

COPY: John Guillory, Ph.D.
Department of Mechanical Engineering

SUBJECT: Electrical Resistance of an Aqueous Soluble Salt Solution

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INTRODUCTION

This memorandum is meant to convey the findings of an experiment conducted to observe the effects that depth and separation distance of electrodes have on the resistance of a fluid solution. The objectives of this experiment are to:

- Measure the electrical current in an aqueous soluble salt solution caused by two electrodes, positioning the electrodes at various combinations of depth and separation distance
- Use Ohm's Law to calculate the resistance at each recorded configuration using the current recorded
- Develop a regression model to predict the resistance of the solution at given configurations

In this experiment, the electrode depth parameter is measured from the surface of the solution to the bottom of the electrode, and the separation parameter is the center-to-center distance between the two cylindrical electrodes. The resistance should somewhat closely resemble that of a solid in terms of parameter effects; as such, it is expected that the regression should be somewhat similar to that of solids [1], seen in Equation (1) where ρ is density, L is length of the solid, and A is the cross-sectional area normal to which the electrical current travels. The regression model proposed for the system is shown by Equation (2), where S is separation distance, d is depth, R_o is the resting-state resistance of the system without the solution present. It is expected that the exponent $b1$ will be negative.

$$R = \rho \frac{L}{A} \tag{1}$$

$$R - R_o = a d^{b_1} S^{b_2} \tag{2}$$

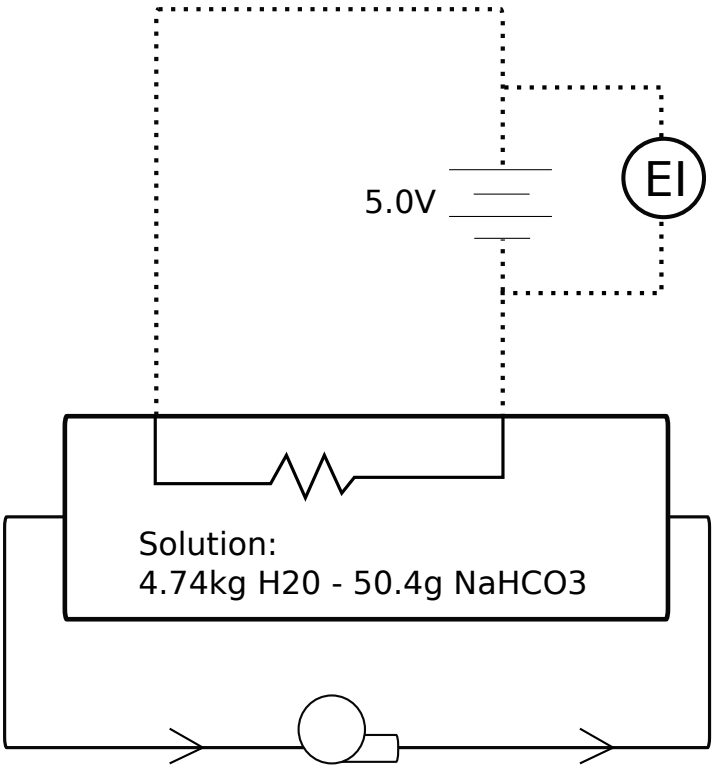

Figure 1: System Diagram

PROCEDURE

The system diagram is shown in Figure 1. The system consists of a voltage source, two cylindrical electrodes, a fish-tank pump, and the $H_2O - NaHCO_3$ solution itself. A Latin-Squares matrix is chosen to build a database which equally represents the effects of both parameters on the resistance.

As shown in Figure 1, an electric current is induced in the solution via the electrodes and is recorded by observation of a current indicator device. A fish-tank pump is used to keep a consistent flow of the solution which keeps the resistance uniform throughout the experiment. The recorded current is then used along with the recorded excitation voltage to calculate the equivalent resistance of the system.

DATA PRESENTATION & ANALYSIS

The raw data recorded during the experiment can be seen in Appendix A1. The calculated resistance data is also depicted in Figure 2 as a function of depth and separation distance, with depth on the abscissa and separation distance as a chosen parameter. The coefficients for the model proposed in Equation (2) have been calculated using Microsoft Excel, as shown in Equation (3). The regression model has been superimposed on the data plot in Figure 2 for the minimum, max-

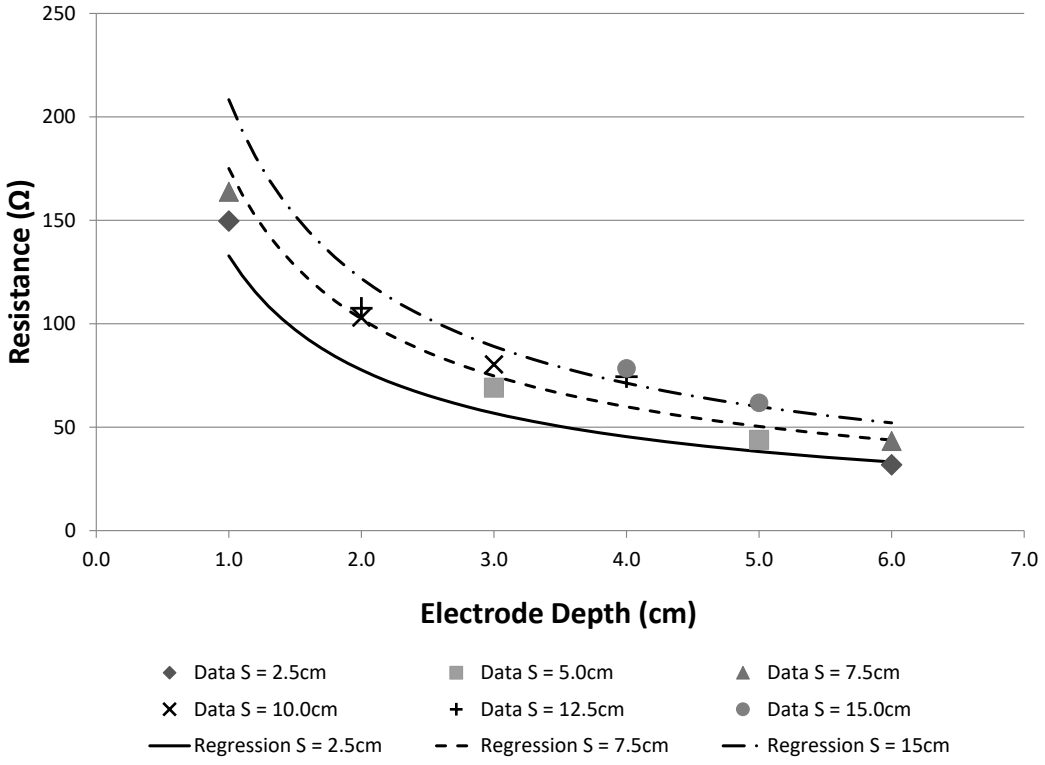

Figure 2: Resistance Data & Regression Model

imum, and one intermediate level of electrode separation.

$$R - R_o = 105.5 \frac{S^{0.25}}{d^{0.77}} \tag{3}$$

The correlation coefficient calculated for the model is $r_{xy} = 1.02$. The f-statistic calculated is $f = 136.7$, corresponding to a probability $P_r << 0.1\%$.

DISCUSSION

It can be seen graphically that the regression matches the data well. The correlation coefficient, calculated to be $r_{xy} = 1.02$, gives notice that the model may be "overfitted," however it can be seen that both parameters have a clear effect on the resistance of the system. As secondary feedback for the accuracy of the model, the f-statistic is calculated to be $f = 136.7$, which implies that the P_r is much less than 0.1%. This means that there is a very low chance that either of the independent variables analyzed carries no relationship with the resistance of the system. In other

words, the chances of the Null Hypothesis being true is almost zero, so the model can be considered to be accurate with consideration to the two parameters analyzed.

CONCLUSION

- It has been shown that the resistance of the aqueous soluble salt solution can be modeled by similar means as for a solid material.
- The proposed regression model accurately depicts the behavior of the system analyzed in this experiment, graphically, as shown in Figure 2.
- The values in the model have been calculated and are shown in Equation (3).
- There is basically no chance, as indicated by the calculated f-statistic, that the Null Hypothesis is true for the proposed model.

REFERENCES

[1] Halliday, D., Resnick, R., and Walker J., 2008, *Fundamentals of Physics*, 8^{th} ed. Extended, John Wiley & Sons, Inc., Hoboken, NJ, Chap. 26.

APPENDIX

A1

Table 1 Experiment Data

diameter (cm)	separation (cm)	current (mA)
1	2.5	33.4
1	7.5	30.5
2	10	48.5
2	12.5	46.5
3	5	72.3
3	10	62.2
4	12.5	67.2
4	15	63.7
5	5	114
5	15	80.9
6	2.5	157.2
6	7.5	115.4