DEFECT ASSESSMENT
USING CONFORMABLE ARRAY DATA

Quarterly Report
1 April 2003 to 30 June 2003

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July 2003

DOE Contract No. DE-FC26-02NT41644
SwRI® Project 14.06239

Prepared for

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ABSTRACT

This third quarterly report of the project presents the activity and conclusions reached to date. Specifically, the design of the conformable array was completed and work was started on obtaining the data acquisition hardware.

Southwest Research Institute (SwRI) and Clock Spring® staff met at the SwRI facilities in June 2003 to discuss the project. The Clock Spring representative was given the latest version of the data acquisition and analysis software for evaluation. Comments were received.

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1. INTRODUCTION

The conformable array data acquisition system consists of the array, the data acquisition and analysis hardware, and the data acquisition and analysis software. The following decisions were made in the development of the system.

Array design decisions include the following:

(a) The flexible array board will be approximately 8 by 12 inches square with the active coil section confined to a smaller 6-inch-square section at the center of the board. The outer edges of the board will be used for switching and other circuitry.

(b) The diameter of the array coils will be approximately 0.375 inch (9.5 mm).

Data acquisition strategy includes:

(a) The corrosion spots will be mapped by successive interrogations of the active section of the array board. Approximately 10,000 samples will be acquired for each coil. The 10,000 readings will be averaged to produce one lower-noise value for each coil. This will be repeated for each coil in the array in a sequential manner. The total corrosion image for the sector will be built from the individual coil data.

(b) Corrosion larger than the operational portion of the array board will be measured using a grid technique. Uniquely identified areas in the grid will overlay a corroded area, and data collected for each area will be connected by the display and assessment software to form a composite image for the corroded area.

(c) Defect assessment will be invoked on the corrosion image by "boxing" selected areas on the color contour map.

Software decisions consisted of selecting the appropriate LABVIEW modules running in a Windows XP operating system to obtain the required functionality.

2. EXPERIMENTAL

This work is a follow-on project from the Conformable Array for Mapping Corrosion Profiles, DOE Contract No. DE-FC26-02NT41644. Most of the fundamental experimental work was performed during the previous project, and the work in this project is to develop a prototype of the conformable array and the data acquisition software. Included in this work was a review of the literature on eddy current methods for imaging and evaluation criteria for assessing remaining strength in pipe.[1–4] The experimental work consists of component selection and performance enhancement for the conformable array and working with the appropriate LABVIEW modules to obtain the required functionality.

3. RESULTS

3.1 Data Acquisition Hardware

The components of the conformable array system hardware are shown in the artist concept image in Figure 1 and schematically in Figure 2. The hardware will consist of a computer, an interface box containing the power supply and electronics, the conformable array, and the necessary cabling. The acquisition process will consist of the following: five data sets will be acquired from each coil in the conformable array, the highest and lowest values will be discarded, and the three remaining data set values will be averaged to produce the value for that coil measurement. This process will be repeated for each coil in succession using a multiplexed data stream. It was determined earlier that taking five measurements at a time for each individual coil would be faster than taking single measurements for the coils in succession and repeating the process to obtain five measurements per coil.

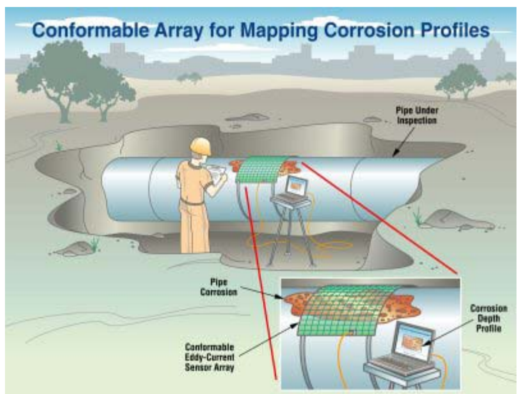

Figure 1. Artist concept image

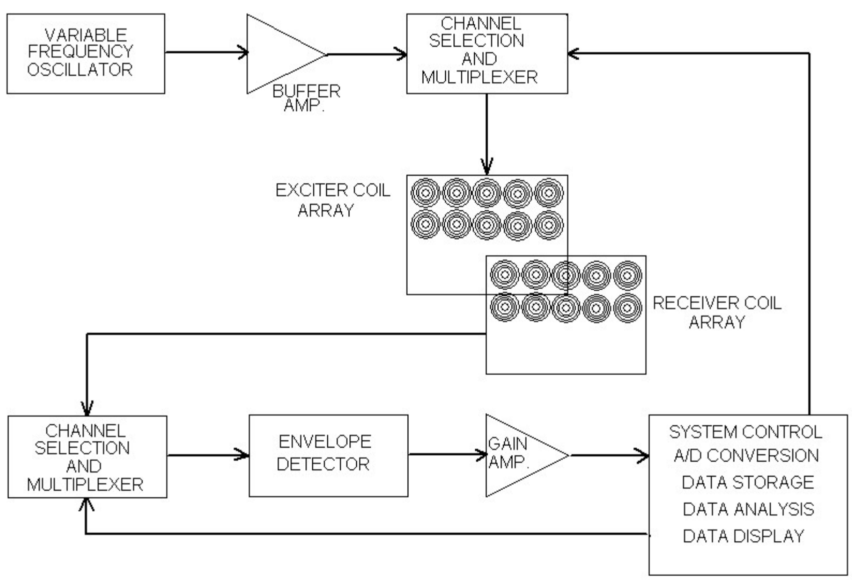

Figure 2. Data acquisition hardware schematic

An E-series data acquisition device (DAQ) was purchased from National Instruments for the acquisition hardware. It provides 100-kS/s analog channel sampling as well as eight digital I/O lines. Four digital output lines will be used (three for channel selection and one to enable the device) and one analog input line (to sample coil voltage). The channel selection signals will switch the multiplexer output to the detection stage for transmission to the computer, so that only one channel of the 256 discrete sensor coil channels in the conformable array is ever active. The only remaining issue with the DAQ is the selection of a suitable cable that can carry four digital signals, one analog signal, and power without crosstalk.

3.2 Changes in Driver Circuitry

At the beginning of this reporting period, the device was designed to operate at a frequency of approximately 100 kHz, a frequency that we believed would maximize transformer coupling and, therefore, the output signal voltage. A major drawback to this approach is that the effective reactance of the primary coil was on the order of 1 ohm, necessitating the use of 256 separate amplifiers, one for each coil. During the prototyping process for the device, it was noted that the frequency could be increased to greater than 1 megahertz if a capacitor was placed across the secondary coil. The addition of a capacitor forms a resistor-inductor-capacitor (RLC) oscillator circuit that allows for the creation of pseudo-voltages much larger than typically would be present. The frequency of the variable frequency oscillator (currently 4.3 MHz) is tuned to drive the RLC circuit in resonance when the coil is in contact with the surface of the pipe. The RLC circuit will detune (drop from the resonant state) when over a pit, with a large drop in the signal amplitude. An example of this is seen in Figure 3**.** The measured signal will look like Figure 4. Note that there is a large change in the signal level at small depths, with decreasing changes in signal amplitude as the depths increase, until the limit is reached which corresponds to throughwall or air. This decreasing response from pits of greater depth makes it difficult to discriminate between pits of larger (on the order of 3/8 inch and greater) pits. Additionally, operation at this frequency means that a small liftoff of the sensor from the pipe wall will result in large errors at deeply pitted areas, so extra care must be taken in attaching the sensor array firmly to the pipe.

Measurement of the small voltage changes described above will be achieved by acquiring data at a very high rate (on the order of 50 kHz) and then averaging the acquired data points on an individual coil basis to improve the resolution. The current reliable upper limit for pit depth using data averaging is 3/8 inch in depth. The signals from pits greater than 3/8 inch deep are so similar to the signal from a 3/8-inch-deep pit that it is difficult to discriminate between pits in this range. This is a result of the decreasing signal from pits of greater depth discussed in the preceding paragraph, but it is hoped that the limit can be increased to 1/2-inch depths. Resolution has not yet been addressed.

Use of a higher frequency has multiple benefits. The most significant benefit is that the reactance of the primary coil increases to 40 ohms at the higher frequency, making it possible to use a single amplifier, which in turn reduces the chip count by 92 percent and the chip cost by over 50 percent. It also has the added bonus of cleaning up any ringing in the circuit due to stray capacitance and seems to remove any signal change issues based on the area of the pipe.

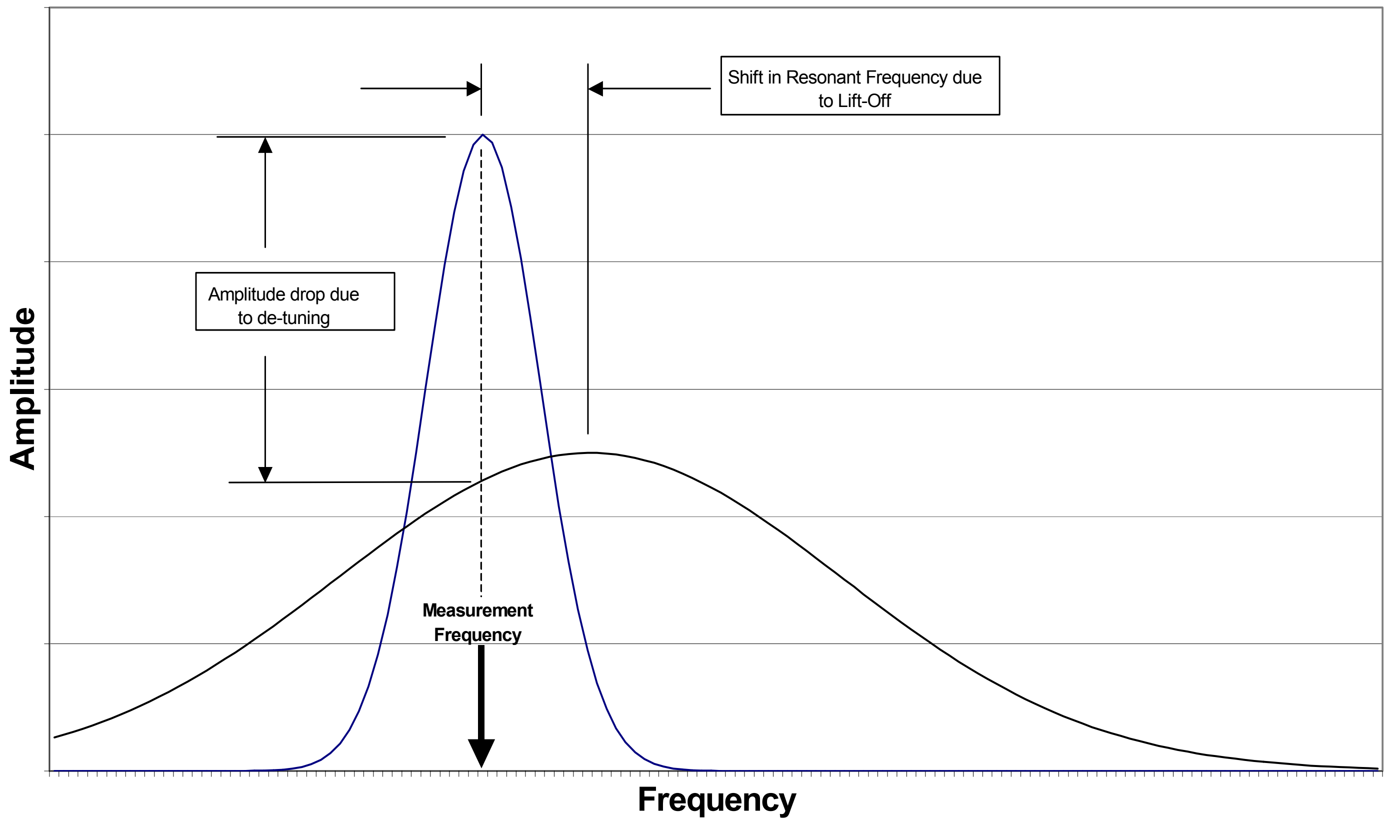

Figure 3. Resonant frequencies

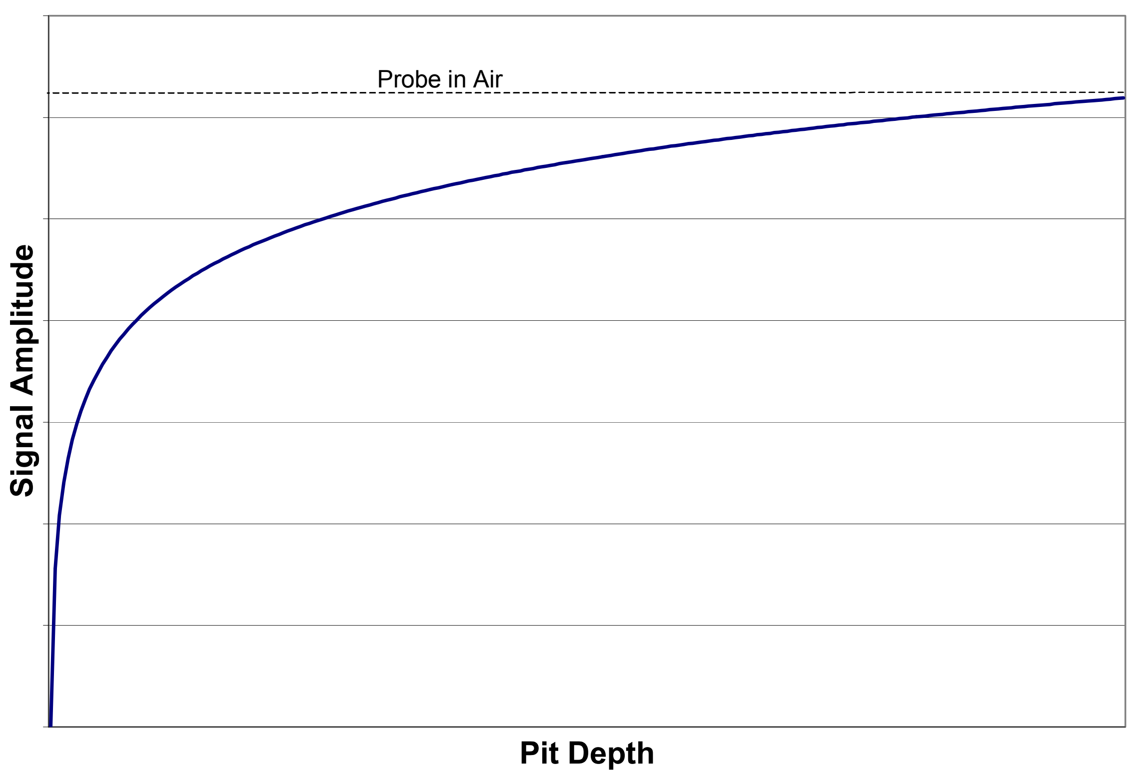

Figure 4. Pit depth curve

3.3 Conformable Array Board

The design is complete and the board is currently in the routing stages. Final preparations are being completed to order parts for the board, and all prototyping has been completed.

3.4 Future Work

Some final modifications must be made to the software as well as to the hardware after the board has been fabricated. The hardware will need to be evaluated at different resonant frequencies by changing the capacitor in an effort to maximize the output signal-to-noise ratio. The software must have calibration curves added for the chosen frequency. There is also the possibility of adding a 0.85 area curve and pressure calculation to the software, which is being discussed with Clock Spring, and there are several approaches on ways to power the device. Because development is in the prototype stage, it was decided that the board currently should run off of a 120-Volt supply; however the power requirements of the board are so low that the computer could be used. Some thought should be given to this if the device is commercialized.

A calibration procedure will be developed.

Other future work includes enhancing the program with the addition of a series of warning and status messages informing the operator of the pipeline condition with the current data. For example, one message will inform the operator that the pipe is running in an unacceptable range if the operating pressure is above a safe level. These warning and status messages are intended to increase the utility of the array and the application.

4. CONCLUSION

The project activities are consistent with those laid out in the proposal. The next quarter will see completion of the fabrication of the conformable array board, completion of the data acquisition and analysis hardware, and completion of the software enhancement in preparation for the field demonstration. The demonstration is currently planned for late August or early September.

5. REFERENCES

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