Modifications to the Control Unit to Enable a Computer to Control and Take Readings

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Keywords: Dilatometer, Control Unit

ABSTRACT: The manual version of the dilatometer control unit has been used successfully for over 25 years. The advancement in computers since its development enables a computer program to perform the same steps that have been done by hand. A computer program can use the previously recorded “A” and “B” reading data to estimate what the current pair will be. The nitrogen flow rate is slowed down when the pressure gets near the anticipated readings and the time lag for the pressure at the control unit to be the same as the pressure inside the blade is minimized. The computer records the data saving data entry time later.

1 INTRODUCTION

The dilatometer control unit was modified so that a computer can regulate the flow control valve and record the data. After the computer records at least five dilatometer tests with thrust, “A” and “B” readings, a database is established to predict the next “A” and “B” readings. The “A” reading is predicted from the thrust reading, and the “B” reading is predicted from a combination of thrust and “A” reading. The computer controls the flow rate so that it is slow near the anticipated “A” and “B” readings so that the lag for the pressure inside the blade to be the same as in the control unit will be minimized. Manual readings using the gauges can also be used as a check or manually recorded. The more homogeneous the soil is, the better the computer will predict “A” and “B” readings and thereby more accurately collect and record the data.

2 HARDWARE MODIFICATIONS

An auxiliary computer-controlled unit was manufactured to do the above tasks. With this unit, the nitrogen source connects to a quick fitting; the computer turns a motor, which turns the needle valve regulating the nitrogen flow; and the nitrogen exits back to the standard control unit.

For the initial readings needed to establish the database, the operator controls the flow using the computer’s mouse and a slide bar. Afterwards, the Auto DMT program computer communicates to a purposefully built microcontroller over another serial line. The microcontroller opens / closes the flow valve by controlling a stepper motor. The Auto DMT program, based on operator input or feedback from the pressure transducer, sends commands the microcontroller which then turns the stepper motor.

It is possible for the nitrogen to exit directly to the blade, but we chose to make use of the existing dial gauges. A short male-to-male quick-connect cable connects the computer-controlled unit to the standard control unit. A short ground cable also connects the two control units. On one end it has a male and female banana plug. The dilatometer cable plugs into a female quick-connect fitting on the computer-control unit. A photo of the computer-control unit is shown below in Figure 1.

A pressure transducer is connected to a “T” near where the dilatometer cable exits the computer-control unit. The transducer has a calibrated maximum pressure of 100 bars with an accuracy of ±0.01 bars.

A 9-pin serial port is connected to the pressure transducer, step-motor flow control valve, and the dilatometer signal. The switch in the blade is connected, via a pull-up resistor, to the Data Set Ready (DSR) line in the serial port connecting the computer to the microcontroller. When the switch opens or closes, the change in state of the DSR line is de

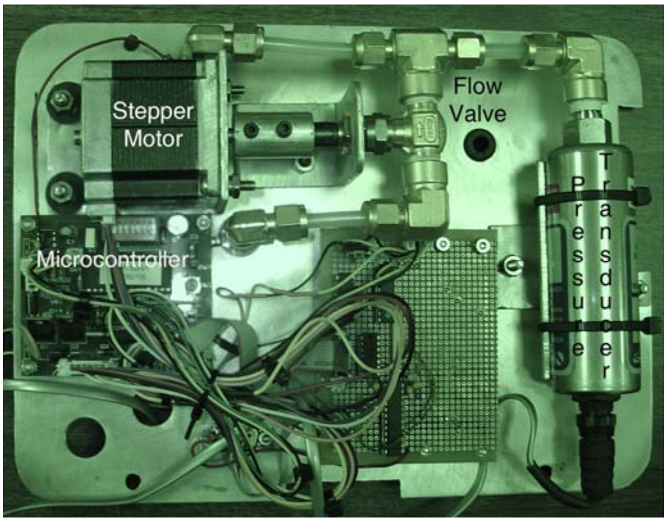

Figure 1: Computer Control Unit

tected by the computer. The computer polls the dilatometer signal to determine the “A” reading, which occurs when the electrical continuity is lost (switch goes from closed to open) and later for the “B” reading, when electrical continuity returns (switch goes from open to closed). If the switch is closed, an indicator on the screen of the computer is set to red. When the switch is open, the indicator is set to white. The pressure is read from the transducer and outputted to the computer through the serial port. The computer records the “A” and “B” readings, saving the operator data entry time.

3 OPERATION

There are two modes of operation.

3.1 *Manual Mode*

Manual mode requires the operator to open or close the valve by using the scroll bar. This is akin to the operator manually opening the valve on a traditional DMT readout box. Also, the operator has to monitor the indicator on the screen to determine whether the A or B reading had been reached. The steps required to perform the test in manual mode are:

1. Advance to the desired depth.
2. Enter the thrust. After the operator has performed five previous readings, then the computer estimates the A and B readings when the thrust is entered.
3. Open the valve. The valve is adjusted using the scroll bar on the screen. When the slider is positioned to the far left of the scroll bar, the valve is closed. When the slider is positioned to the far right of the scroll bar, the valve is opened by two rotations. The valve may be adjusted any time during the test at that depth.
4. Press "Take A reading" to record the A reading when the indicator changes from red to white. At this point, the switch in the blade is open. This is similar to the buzzer going silent on the old DMT unit. After the operator has performed five previous readings, then the computer predicts the B reading after the A reading is recorded.
5. Press "Take B reading" to record the B reading when the indicator changes from white to red. At this point, the switch in the blade is closed. This is similar to the buzzer indicating that the B reading has been reached on the old DMT unit. Once the B reading is recorded the unit closes the valve, and the computer is ready to collect data for the next depth.
6. The operator vents nitrogen from the system or takes a “C” reading.

3.2 *Automatic Mode*

Automatic mode, which is available only after five readings have been performed, requires no input / control from the operator after the thrust is entered. In automatic mode, the unit estimates the A reading based on the thrust and controls the valve based on feedback from the pressure transducer. The goal is to reach the percentages listed in Table 2 at the specified time intervals. The computer will automatically take the A reading when the switch in the blade is opened. The computer then estimates the B reading, adjusts the valve, and records the B reading when the switch is closed.

A computer screen of the automatic mode is shown in Figure 2.

4 COMPUTER ESTIMATES OF “A” AND “B” READINGS

The first five readings of a sounding need to be taken manually to start to establish the computer‘s database. From the database a best fit linear relationship is found between thrust and the “A” reading. The thrust is measured at the test depth and entered into the computer. The computer estimates the “A” reading based on that best fit linear relationship.

From each prior test the I_D is computed. Plots of I_D versus thrust and “A” reading are created and the linear best fit relationships are generated for each plot. The operator can choose what percentages to assign the thrust and “A” reading components when determining the overall I_D prediction. The predicted overall I_D value is computed as:

$$I_D = (A\ \ I_D)(\%A) + (Thrust\ I_D)(\%Thrust),$$

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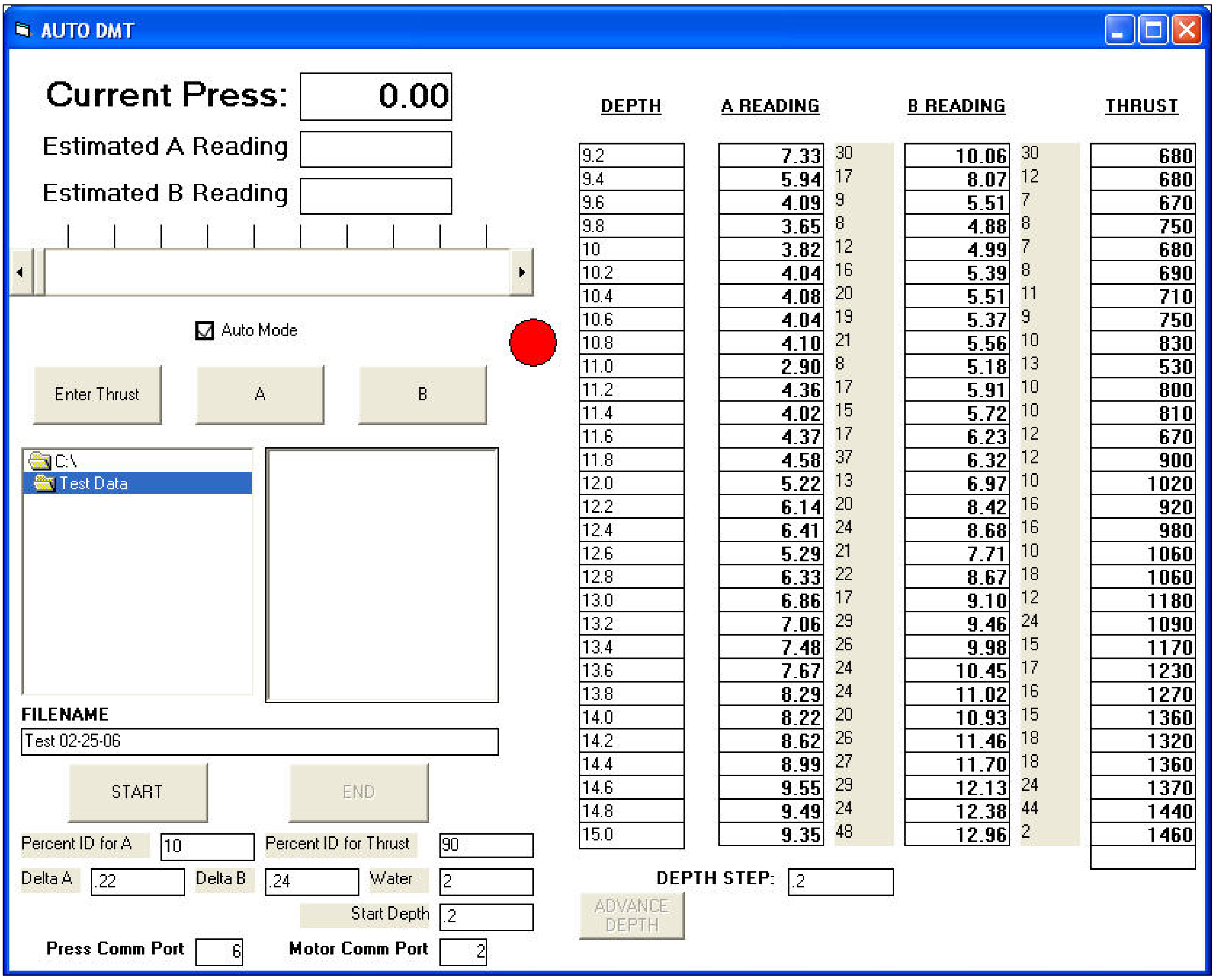

Figure 2: Screen shot of AutoDMT program

where A I_D is the predicted I_D based on the A reading, %A is the weighted percentage attributed to the A reading, Thrust I_D is the predicted I_D based on the thrust measurement, and %Thrust is the weighted percentage attributed to the thrust measurement. The sum of %A and %Thrust must equal 1.0. Based on the predicted overall I_D value, the predicted "B" reading is computed from the following:

$$B=\frac{I_D(1.05(A+\Delta A)+0.05\Delta B-U_0)+1.05(\Delta B+A+\Delta A)}{1.05+0.05I_D}$$

5 REVIEW OF EXISTING DATA

We analyzed five soundings with different geologic conditions to determine how many data points were needed to establish linear relationships for predicting the "A" and "B" readings. When determining the best linear fits, we reviewed the previous 5, 6, 7, 8, 9, 10 readings and all the previous readings. We found that the worst fits were when all the previous data were considered because the soil type and geostatic vertical and horizontal stresses change throughout the sounding. For predicting the "A" and "B" readings, the following table providing a summary of the review analyses:

Number of Previous Readings Used to Establish Best Fit	Number of Test Sites with Best "A" Reading Prediction	Number of Test Sites with Best "B" Reading Prediction
5	1	2
6	0	0
7	0	0
8	1	0
9	0	1
10	3	2
ALL	0	0

Table 1: Number of test soundings that had the best fit for the "A" and "B" reading predictions

Based on the review, we made additional adjustments to our method for predictions. For the thrust reading prediction of "A" and "B" readings, the best fit slope should not be negative. For the same type of soil, for higher thrust readings one should get higher "A" and "B" readings. We accepted negative slopes for predicting I_D based on "A" readings because a hard clay can have a higher "A" reading and a lower I_D value than a sand. The minimum value of I_D that we allowed for predicting the "B" reading was 0.1.

We also found that the "A" reading was a better predictor of the "B" reading than the thrust. We preliminarily suggest using 70 to 80% of the "A" reading prediction and 20 to 30% of the thrust prediction when making the overall I_D prediction.

6 FLOW VALVE CONTROL

To get accurate data from the dilatometer tests, the engineer must accurately measure the pressure in the blade at the "A" and "B" signals. It takes some time for the pressure that is applied and measured at the surface to travel to the dilatometer blade. However, when the rate of flow is slow when the signals occur, these lag effects are minimized. With good programming a computer can do a better job at controlling the flow rate than an engineer.

We developed a program that uses the estimates of the "A" and "B" readings, described in the above sections, to determine flow rates. The following table contains the default inflation rates used by the computer:

Percent of Estimated "A" or "B" Reading	Elapsed Time (seconds)
50	3
60	4
70	5.5
80	8
90	11
100	15
>100	Same rate as from 90 to 100%

Table 2: Programmed flow rate for "A" and "B" readings

The default elapsed times are based on using an 18-meter long cable. For longer cable lengths the elapsed time factor should be changed (default value is 1.0). We suggest using a factor equal to the cable length divided by 18.

If the reading occurs in less than 3 seconds, the program considers the data to be poor and does not record them. The next test depth will have a default value of 0.1 meters more than the current depth.

After the "B" reading is obtained, the computer stops flow to the dilatometer blade. The operator has the choice of either venting the system with the toggle valve or deflating slowly and manually measuring the "C" reading. The "C" can then be input into the computer.

7 PROGRAM OPTIONS

The initial depth is assumed to be 0.2 meters and the initial test depth increment for the next test is assumed to be 0.2 meters. The actual test depth can be overwritten by the operator. The test depth interval for the next test will be the current test depth minus the previous test depth.

The groundwater depth in meters is input. The hydrostatic groundwater level, U_0, is used to predict the "B" reading and it is computed in bars as follows:

$$U_0 = (\text{test depth} - \text{groundwater depth})/10.2 \geq 0$$

The thrust measurement is manually read and input by the engineer. We chose this simplistic approach because of the variety of readout boxes for load cells. The computer always records the "A" and "B" readings. The data file is saved after each test.

The engineer can choose how many of the previous readings will be used for computing the estimated "A" and "B" readings. The default and suggested minimum value is 5. When the soil type changes, the engineer can reduce the number of readings to include only those readings from that soil type. This new number of readings now becomes the default value. The engineer can decide what percentage will come from the correlation with thrust and what remaining percentage will come from the "A" reading correlation. The values for the current test become the default value for the next test.

Before and after each sounding, the engineer is asked to input the ΔA and ΔB calibration readings. The program will then average the readings using the rounding down procedure (Marchetti, 1999) and save these values. If the membrane is torn while performing the sounding, the new values for ΔA and ΔB can be input if the sounding is continued. The initial ΔA and ΔB are used up to that depth; the new ΔA and ΔB readings are used below that depth.

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8 INTERFACING WITH WINDMT PROGRAM

The final saved file will be an ASCII file that can be read by "WinDMT". At the start of the sounding the user is asked to input the heading information and analyses parameters. The information from the last sounding is used as the default values for the current sounding. The user may change any of these values. The file name is the job number plus sounding name. The file name can only be used once.

9 FIELD TEST

At the GeoService's test sites, which is the location of the conference's field exercise, we performed one dilatometer sounding using the manual control unit and one dilatometer sounding using the computer control unit. The soundings were 1.5 meter apart. The results of those sounding are presented in Figure 3.

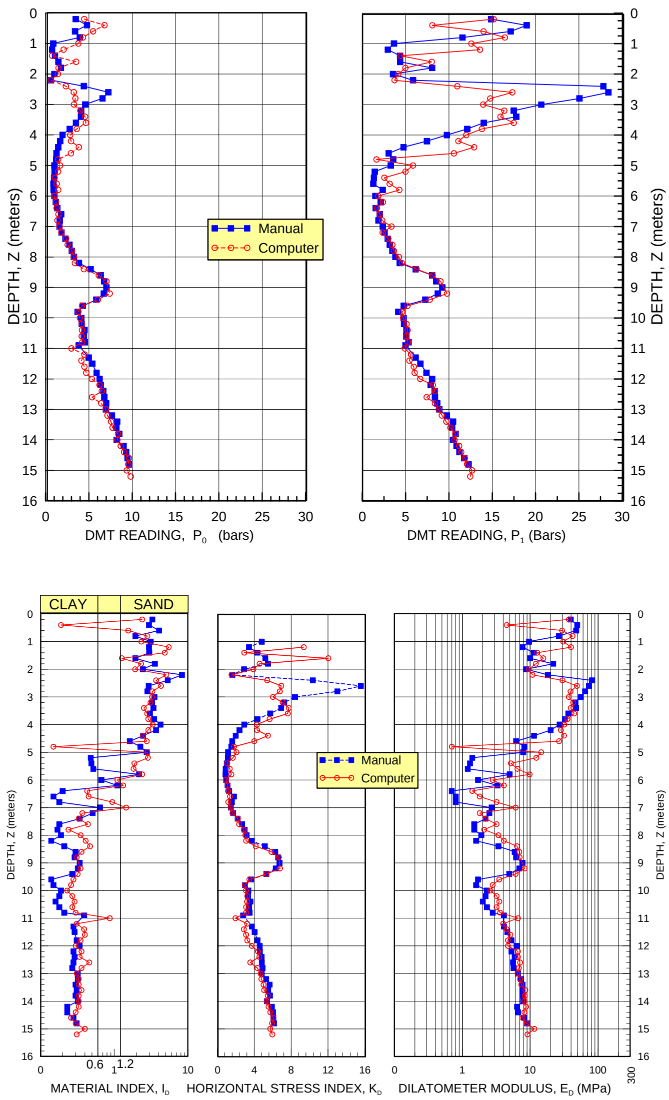

Figure 3: Dilatometer results from field tests

10 FUTURE UPGRADES:

1. Solenoid valve. The current setup of using a stepper motor closing and opening a valve worked well. However, there was still some flow with the valve fully closed, ie the stepper motor lacked the torque to completely close off the valve. For most soils the amount of flow was minimal enough to not pose a problem. However, in very soft soils it is conceivable that the flow could cause the A reading to trip before the program was able to detect it. A solenoid valve in conjunction with the stepper motor controlled valve would solve this potential problem. The solenoid valve would allow "C" readings to be taken automatically by the computer.

2. Microstepping motor. It was determined through field testing that a microstepping motor is better suited to various soil types than the current stepper motor. A microstepping motor with approximately 2000 steps / revolution would allow tighter control of the flow than the current motor which had 200 steps / revolution. This is especially true in soft soils where even minute changes in the flow can cause a percentage increase in the pressure that is beyond the desired speed.

3. Offloading of the stepper motor control to the microcontroller. In the current setup, the stepper motor is controlled by the PC reading the pressure every 100 ms. Based on the change in pressure, the computer sends a command specifying the motor position to the microcontroller. The microcontroller then advances the motor in the specified direction. If the pressure were to be read by the microcontroller, the lag time between reading the pressure and adjusting the motor could be reduced.

4. Replacing the digital pressure transducer with an analog pressure transducer. Coupled with #3 above, the microcontroller could read the analog output of a pressure transducer and convert it to digital in a fraction of the time required to read the pressure over the serial line. This would further reduce the lag time between reading the pressure and adjusting the motor. Furthermore, it would reduce the overall cost of the system.

5. Interfacing the thrust transducer to the unit. This will eliminate the requirement of the operator entering the thrust manually.

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6. Adding sound to the program. While the indicator functions well enough to alert the operator to the change in state of the switch in the blade, an audible indicator may provide added "comfort" to operators familiar with the traditional DMT unit.

11 CONCLUSIONS

- The computer controlled dilatometer unit makes it easier to take and record the data. The test is less operator dependent and more accurate.
- Data processing time is reduced.
- Data comparisons between the computer control unit and the manual control unit from an experienced operator were excellent as was anticipated.

12 REFERENCES

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