

# PC-BASED DATA ACQUISITION PROGRAM FOR AN ELECTRIC MOTOR DYNAMOMETER

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## ABSTRACT

A computerized, PC-based, data acquisition program that measures motor torque, speed, input/output power, power factor, and temperatures for an electric motor dynamometer test facility was developed to meet the user requirements for both education and research programs. The data acquisition program attempts to achieve that goal by incorporating features that include a menu-driven user interface, alternate default configuration files, context sensitive on-line help, windowed input forms, choice lists, scrollable display windows, and device independent graphics. The program has been used rigorously and has proven to be very user-friendly and efficient.

**KEYWORDS.** Data acquisition, Electric motors, Dynamometer instrumentation, Computer graphics, User-interface.

## INTRODUCTION

A computer-assisted laboratory facility was designed and assembled for use in determining electric motor performance. The facility was established to service the educational and research needs in the Agricultural Engineering Department at Kansas State University. The requirements to fulfill current and projected needs for the facility and the accompanying data acquisition software were as follows:

1. The facility must comply with IEEE motor testing standards (IEEE, 1982).
2. The collected data should be analyzed, displayed, and stored at the test location.
3. Calibration of sensors and verification of input signals read by the data acquisition system should be automated as much as possible.
4. Reconfiguration of the application program should be simple, and configurations stored for later use.
5. The application program should provide an intuitive user-interface.
6. Research needs require flexibility in specifying the type of output obtained from the system.

7. Educational use of the facility requires presentation of data in easily understandable formats such as graphical representations of results.

8. The structure of the program should be designed for easy modification and enhancement, since additional research requirements may develop.

To meet these requirements, a PC-based data acquisition system was used. The microcomputer provided the ability to collect, analyze, display, and store the data at the test location. The data acquisition software was menu-based: and incorporated on-line context-sensitive pop-up help displays, windowed input forms, and option selection choice lists to enhance user-friendliness. The data acquisition software incorporated routines to simplify calibration of sensors and provide verification of input signals read by the data acquisition system.

Since both educators and researchers would be using the system, ASCII configuration files were implemented to allow alternate system configurations without manually specifying program options each time a test was to be run. Program configuration options provided flexibility in selection of inputs, type and format of outputs, and data presentation styles. Results could be stored in ASCII files allowing easy importation to other programs for further analysis, and/or routed to scrollable display windows during data collection to provide immediate operator feedback. To aid understanding and interpreting of the data in both research and educational settings, support for graphical data representation was provided for both screen displays and printers.

Even though this discussion is limited to a specific application, many of the general user requirements of this application and the solutions presented here are applicable to other applications such as an instrumented IC test engine, spray nozzle test facility, etc.

## ELECTRIC MOTOR TEST FACILITY

The basic instrumentation of the test facility consists of a Magtrol\*, Model HD-700-8, electric motor dynamometer; a Clark-Hess, Model 256, digital, Volt-Amp-Watt meter; and thermocouples. A Zenith 158, IBM-PC compatible computer containing a Scientific Solutions LabMaster data acquisition system was used to obtain raw sensor data, perform any necessary analyses, and display and/or store the results.

The Magtrol dynamometer is a hysteresis type and provides an analog torque signal from a load cell and a

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\*The use of trade names in this publication does not imply endorsement of the products named.

speed signal as a stream of 60 TTL-level pulses per shaft revolution. The V-A-W meter has computer-switched functions and outputs a 0-1 VDC signal proportional to the displayed value. The LabMaster data acquisition system has the capability of reading analog signals, counting pulses from a speed sensor, and outputting TTL-level digital signals for control purposes (Wagner et al., 1989). A schematic of the computer-assisted, motor test facility is shown in figure 1.

The data acquisition system can automatically collect the following data:

**MOTOR TORQUE AND SPEED.** A manual control console for the dynamometer is used to set the desired load or speed of the motor. The analog torque signal is obtained through an analog to digital channel. The speed signal is counted with one of the 16-bit LabMaster counter/timers for a specified time interval to obtain motor rpm.

**AMBIENT AIR AND MOTOR WINDING TEMPERATURES.** Thermocouples are used to measure these temperatures. The thermocouple wires are connected to an analog to digital satellite expansion board (Wagner et al., 1989) containing an on-board temperature reference.

**MOTOR POWER, CURRENT, VOLTAGE, AND POWER FACTOR.** The V-A-W meter has the capability to measure each of these test parameters. However, it can read and display only one at a time. An analog output (0-1 VDC) on the V-A-W meter was used to read the displayed parameter with one of the data acquisition system's analog to digital channels. A remote control option on the V-A-W meter allowed the computer to select the function (current, voltage, etc.) to be displayed by pulling the selected control line to ground.

## DYNAMOMETER DATA ACQUISITION SOFTWARE

A flexible, modular, user-friendly, application program was needed for the electric motor dynamometer test facility, which was to be used for both research and educational programs. Thus, a data acquisition program written in the C language was developed specifically for this application. A commercial library package, Vermont Views†, was used to construct the menu system, input forms, choice lists, and the on-line context-sensitive help

system. The data acquisition routines controlling the LabMaster functions were developed in the Agricultural Engineering Department at Kansas State University (Wagner, 1988). The graphics functions were derived from a graphics support library by ICADA Technologies.‡

The main menu consists of four sub-sections and an exit option, which are described as follows.

### CALIBRATION MENU OPTION

Calibration constants for input readings are adjusted in this section. These inputs are the excitation voltage driving the dynamometer load cell; dynamometer torque and speed signals; V-A-W meter readings of current, voltage, power, and power factor; and thermocouple readings.

The load cell excitation voltage is monitored to facilitate automatic compensation of the load cell output for variations in excitation voltage. The calibration menu option allows the user to specify the resistor values used in a voltage divider network to measure the excitation voltage at the same analog channel gain as the load cell. A continually updated display of the excitation voltage measured through a resistor voltage divider network can be selected for calibration verification. If this voltage reading does not correspond to the value obtained with a calibration voltmeter, a scale factor can be adjusted to correct the displayed reading. The load cell excitation voltage calibration screen is shown in figure 3. Context-sensitive, on-line help is also available with the press of a function key to describe the necessary inputs for a particular input screen. Figure 3 shows a portion of the help screen for the excitation voltage calibration form.

The torque calibration option provides an input form that requests the arm length and mass used with a calibration beam for calibrating the load cell. Load cell readings then are obtained, converted to torque, and compared to the calibration value on the monitor display. A scale factor can be adjusted to correct the reading, if necessary.

The motor speed calibration option merely displays the motor rpm on the screen for comparison with an auxiliary measurement of motor speed such as a phototransducer.§

The V-A-W meter calibration option uses a sub-menu for manual selection of parameters measured by the Clark-Hess V-A-W meter. The value of the selected V-A-W meter reading will be displayed as obtained by the LabMaster board from the V-A-W meter's analog output. A scale

† Vermont Creative Software, Richford, VT 05476.

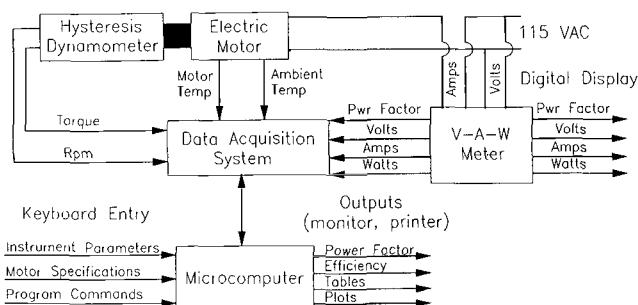


Figure 1—Schematic of computer-assisted motor test facility.

‡ ICADA Technologies, Inc., Manhattan, KS 66502.

§ An Ametek model 1726 photoachometer was used at this facility.

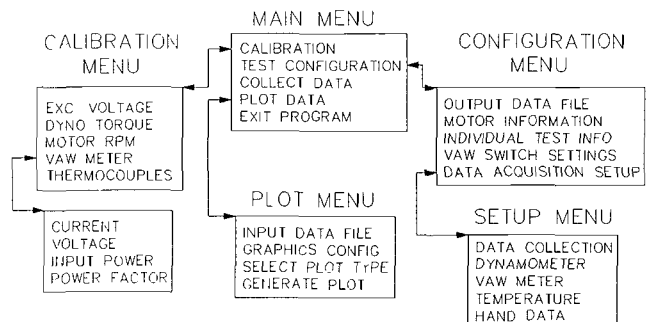


Figure 2. Flow diagram of dynamometer data acquisition program.

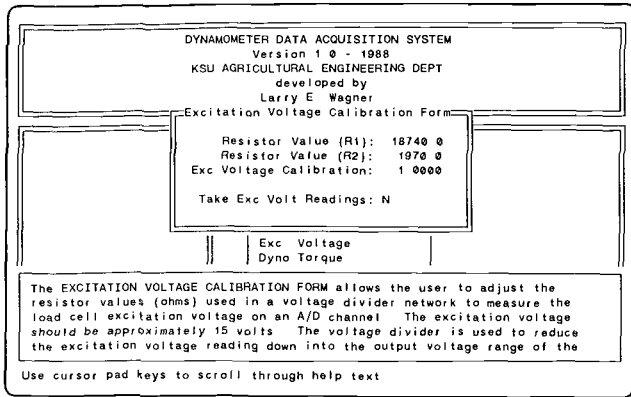


Figure 3—Load cell excitation voltage calibration screen.

factor may modify the result to equal the value displayed on the V-A-W meter or that measured with a standard instrument.

The thermocouples' calibration option displays the ambient, motor winding, and cold-junction reference temperatures to verify that each thermocouple and the temperature sensor are working correctly. They also may be checked against other standard temperature sensing devices.

#### TEST CONFIGURATION MENU OPTION

This section provides a menu that allows the user to select the output ASCII data file names as well as select input forms for entering information about the motor being tested and other pertinent test information. It also allows the user to specify The V-A-W voltage and current range switch settings not controlled by the computer.

All default parameters are obtained from an ASCII configuration file developed for the program. This allows the user to develop different default test configurations by constructing additional configuration files. This feature eliminates the need to specify common defaults for each test situation. A partial listing of an ASCII configuration file is provided in Table 1. It shows the format used to specify test options, comments, etc.

The output data file configuration option provides a data entry form to obtain the disk-drive, directory path, and file name for storing ASCII data collected by the program. The motor information option uses an input form for entering general information about the test motor such as rated speed and power, phase, type, supply voltages, service factor, etc. The individual test information option also provides an input form to include pertinent test information such as the test date, test number, name of operator, and comments.

External range switch settings on the V-A-W meter cannot be read by the data acquisition system. However, these settings can be entered through the V-A-W switch settings configuration option. Choice lists, containing the valid values for the selected voltage and current ranges, are displayed for operator selection.

The last option under the configuration menu is the setup menu. This menu allows the user to define data collection parameters, such as the number of collected and averaged samples per data point stored and the time interval between each individual sample. Other default

TABLE 1. Partial sample of ASCII configuration file

```
# initialize the help file's path
DYNO_HELP_FILE = dynocfg/dyno.hlp
# initialize the number of samples to take per reading
SAMPLE_NO=25
# select the types of data to collect (1=Yes, 0=No)
COLLECT_DYNO_DATA=1
COLLECT_VAW_DATA=1
WHICH_VAW_PWR_DATA=PWR
COLLECT_TEMP_DATA=1
COLLECT_HAND_DATA=0
# select whether data &/or motor files are initially open (1=Yes, 0=No)
OPEN_DATA_FILE=1
OPEN_MOTOR_FILE=1
# select the default VAW meter display (parallel port value, 0=current)
VAW_DEFAULT_DISPLAY=0
# select the VAW meter voltage range (200,100,20)
VAW_VOLTAGE_RANGE=200
# select the VAW meter current range (5000,500,50,5)
VAW_CURRENT_RANGE=5000
# select whether the VAW 1000:
  1 Transformer is being used (1=Yes, 0=No)
VAW_TRANSFORMER=0
# set the default motor rotation (CCW,CW)
MOTOR_ROTATION=CCW
# set the default calibration constants
TORQ_CAL=1.0
VOLTAGE_200_CAL=1.0
CURRENT_5000_CAL=1.0
```

parameters also may be reconfigured for each instrument. Examples include the analog to digital channels and gain settings, TTL-level ports and their I/O configurations, and counter/timer configurations necessary for each sensor.

The hand data option under the setup menu provides a simple method for expanding the data collection capability of the program without additional programming. A user-specified number of additional hand measurements (up to 8) may be entered into the program after each data sample is collected. Input prompts can be user-defined for each of the hand measured parameters.

#### COLLECT DATA

This main menu option initiates the data collection sequence. The program will continuously monitor and display the sampled data in "Continuous Data Monitor" windows. Pressing the return key records a data collection cycle while pressing the escape key stops the data collection sequence and returns the user back to the main

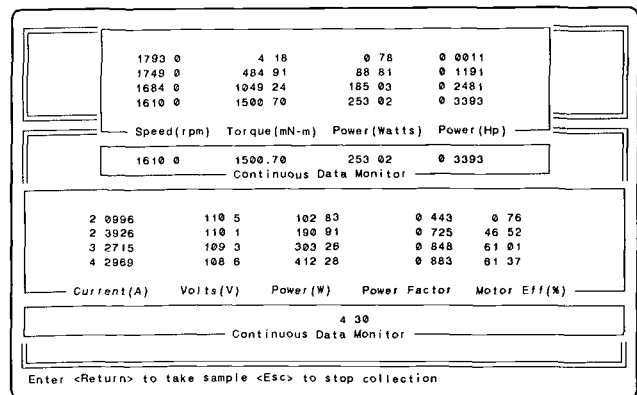


Figure 4—Typical data collection screen display.

menu. Scrolling windows display the previously recorded data samples, providing the operator with a visual record of progression into the current test sequence. The visual display of the collected data also helps the operator verify the validity of the data already collected. A typical data collection screen is shown in figure 4.

#### PLOT DATA MENU OPTION

This section provides for the selection of an input data file, an output graphics device, display/drawing resolution for that device, and the type of graph to produce. The graph may then be displayed or printed on the selected device. An example of the graphical output is shown in figure 5.

The graphics library currently supports the following graphics devices: 1) standard PC graphics display adapters such as the Hercules graphics card, color graphics adapter (CGA), enhanced graphics adapter (EGA), and video graphics adapter (VGA); 2) dot matrix printers such as the Epson FX and LQ series and the Okidata 90 series; and 3) laser printers such as the HP LaserJet II. Multiple drawing resolutions are available for each supported device capable of them. This allows the user to choose high quality (high graphic resolutions) or draft quality (low graphic resolutions) plots.

A selection, from a list of predefined plots, can be made from the appropriate plot menu option. The plots currently available are listed in Table 2.

#### SUMMARY

The data acquisition software for the motor dynamometer facility has been used extensively for tests of variable speed, fan motors. At least six individuals have been trained to conduct tests.

The menus and scrolling data display windows were vital in making the program relatively easy to learn and operate. On-line explanation of program functions, available from the press of a function key, speed the learning process. Previously collected data displayed in

scrollable windows have been most important for managing the data collection process. Probably the most important feature for research use is the on-line, real-time display of data in the data collection and calibration routines.

Several areas for future modification or enhancement have been identified.

- Increased accuracy for measurement of power factor. Direct calculation of power factor from input watts, current, and voltage is more accurate than the measurement obtained from this V-A-W meter. This modification has already been incorporated into the program.
- Graph types available are currently hard-coded in the program. The graph type choices should be simplified by including only the typical ones used in dynamometer testing. A graph-types definition, configuration screen could be developed to provide the ability to describe additional graphs necessary for individual applications.
- Error checking capability should be incorporated to flag obvious data collection inconsistencies, such as power factor > 1, motor efficiency > 100%, etc., and to warn the operator with a sound from the speaker or visually with a screen message. The configuration file also could be enhanced to include user adjustable limits for each measured variable for flexible error checking ability.
- Currently, the ASCII default configuration file can only be modified with an editor. The capability to update the configuration file from within the program would simplify the process and reduce the chance to introduce syntax errors into the file.

TABLE 2. Available pre-defined graph types

|                                                |
|------------------------------------------------|
| Torque vs. Speed                               |
| Power vs. Speed                                |
| Torque & Power vs. Speed                       |
| Power & Input Watts vs. Speed                  |
| Motor Eff. & Power Factor vs. Speed            |
| Motor Eff. & Power Factor vs. Torque           |
| Torque & Current vs. Speed                     |
| Total, Main, & Aux. Winding Currents vs. Speed |

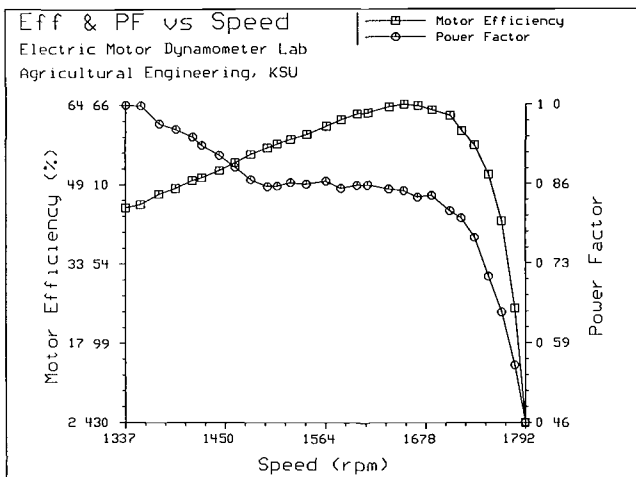


Figure 5—Sample graphical representation of collected data.

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