AUTOMATED TEST SYSTEMS FOR TOXIC VAPOR DETECTORS *

by

C. B. Mattson, T. A. Hammond, and C. J. Schwindt
I-NET, Inc. /INI-15
Kennedy Space Center, FL 32899

ABSTRACT

The NASA Toxic Vapor Detection Laboratory (TVDL) at the Kennedy Space Center (KSC), Florida, has been using Personal Computer based Data Acquisition and Control Systems (PCDAS) for about nine years. These systems control the generation of toxic vapors of known concentrations under controlled conditions of temperature and humidity. The PCDAS also logs the test conditions and the test article responses in data files for analysis by standard spreadsheets or custom programs.

The PCDAS was originally developed to perform standardized qualification and acceptance tests in a search for a commercial off-the-shelf (COTS) toxic vapor detector to replace the hydrazine detectors for the Space Shuttle launch pad. It has since become standard test equipment for the TVDL and is indispensable in producing calibration standards for the new hydrazine monitors at the 10 part per billion (ppb) level.

The standard TVDL PCDAS can control two toxic vapor generators (TVG's) with three channels each and two flow/ temperature / humidity (FTH) controllers and it can record data from up to six toxic vapor detectors (TVD's) under test and can deliver flows from 5 to 50 liters per minute (L/m) at temperatures from near zero to 50 degrees Celsius (C) using an environmental chamber to maintain the sample temperature. The concentration range for toxic vapors depends on the permeation source installed in the TVG. The PCDAS can provide closed loop control of temperature and humidity to two sample vessels, typically one for zero gas and one for the standard gas. This is required at very low toxic vapor concentrations to minimize the time required to passivate the sample delivery system. Recently, there have been several requests for information about the PCDAS by other laboratories with similar needs, both on and off KSC. The purpose of this paper is to inform the toxic vapor detection community of the current status and planned upgrades to the automated testing of toxic vapor detectors at the Kennedy Space Center.

INTRODUCTION

SYSTEM OVERVIEW

The PCDAS used at the TVDL controls COTS vapor generators and a COTS FTH controller, both of which have been modified for computer control, in order to generate a fairly wide range of test vapors. The FTH controller has also been modified to extend the range of humidity downward to 10 percent relative humidity (%RH) and to allow the use of dry dilution air.

The data acquisition segment of the PCDAS provides 6 channels of 12-bit analog to digital converter (A/D) to record test article response at user selected sample rates.

SYSTEM HARDWARE

The PCDAS currently uses an 80486-based platform but it will run on an 8088 or newer platform depending on the number of test inputs and the desired sample rates. The computer must have at least two 8-bit bus slots available for the system control cards. One A/D input card and one digital to analog (D/A) control output card are used. The A/D card has 16 single ended 12-bit inputs. The D/A card has six 12 bit analog outputs and 24 digital outputs (1 bit), which control 24 relays located on an external card. All of the real-world interfaces are located in a single, enclosed interface panel with power supply and distribution located in an adjacent, enclosed panel. Cables connect the TVG's, FTH controllers, and TVD outputs to the interface panel. The interface panel is mounted on a small laboratory cart along with the control computer, strip chart recorder, and power conditioner/uninterruptable power supply.

Toxic Vapor Generation

The TVG's used in the PCDAS is a Kin-Tek Model 361 Precision Vapor Standard Generator, a 3-channel instrument using permeation-type vapor sources. The Model 361 comes with internal terminal strip connections and a front panel selector switch to select manual or automatic control. A MIL-type circular connector was added to the front panel and wired to the existing terminal strip to facilitate connection to the PCDAS interface. For use with hydrazines, an over-temperature interlock was added, which interrupts power to the TVG if the temperature control fails. This interlock uses a second thermometer in each oven (in series) to detect an over-temperature condition and a latching relay to interrupt power until the operator intervenes. The TVG uses nitrogen gas at 50 pounds per square inch (psi) to sweep the permeation devices continuously at 0.1 L/m, and dry clean air (TVDL instrument grade air at -20 C dew point) for primary dilution at one L/m in zero and span mode, none in standby mode.

Flow, Temperature, and Relative Humidity Control

The FTH controller as delivered had a humidity control range of about 35 to 95 %RH. The low end of the range was limited by the evaporation rate from the internal water supply at room temperature. The modification to extend the humidity range required adding two valves as well as relays to control the valves and turn off heaters if necessary. In one state, the valves mix dry air with the humidified air, inside the control loop, to give a second range of about 10 to 50 %RH. In another state, the valves deliver dry air only and turn off the heater in the internal water supply. The modifications provide an effective humidity range of 0 to 95 %RH.

The temperature range of the FTH controller as delivered is from ambient room temperature to a few degrees above ambient, due to heat losses in the external tubing. In order to extend the operating range for temperature, it is necessary to put the FTH controllers, the sample vessels, and the TVD's into an environmental chamber. The environmental chamber effectively changes the "ambient" temperature for the FTH controller and allows operation at a higher temperature. The TVG's are always kept in the fume exhaust hood. Suitable tubing is used to deliver the vapor standard to the environmental chamber and return it to the hood for disposal. Dosimeter badges or separate TVD's are used to monitor the interior of the environmental chamber for any toxic vapor which may leak from the sample delivery system. This arrangement effectively provides a temperature range of 0 to 50 C.

A MIL-type circular front panel connector was added to connect the FTH controller to the PCDAS interface panel. Front panel switches were also added to select manual or automatic control of flow, temperature, and humidity independently. A rotary switch on the front panel allows selection of wet, mixed, or dry output or automatic control of the splitting valves. All

original manual controls of the FTH controller are preserved in the modifications, in addition to providing manual control of the humidity range.

The FTH controller uses compressed air at 45 psi and up to 50 L/m. The air also provides pressure for a tank of deionized water which supplies the humidity controller. See Figure 1 for the typical installation of the PCDAS in a fume exhaust hood. On the left is the control computer cart with the interface panel (on the back), UPS, and strip chart recorder. Inside the hood there are three TVG's and one FTH controller. On the floor to the right is the pressure vessel with deionized water for the FTH controller. The TVD's are on the cart in front of the hood.

Toxic Vapor Sample Delivery

Generation of the stable concentration of toxic vapor is only part of the problem. The vapor must be delivered to the TVD's without loss or degradation by the tubing and valves. Hydrazines in particular tend to react with some types of tubing, some of which can completely destroy a "standard" in as little as 3 or 4 feet of tube. Acceptable tubing includes most Teflon types, and Bev-A-Line IV. Bev-A-Line V is particularly unacceptable because it destroys the hydrazine vapor completely and cannot be passivated. All materials in contact with the toxic vapor need to be passivated to prevent fractional losses of the initial concentration.

The output from the TVG and one FTH controller are mixed in a tee fitting and fed into one port of an inverted glass round-bottom flask with 4 or 5 ports. The probe to measure sample temperature and humidity is placed into a second port. A third port is connected to a 3-way valve which delivers the sample to the TVD's. The remaining ports are used as open atmospheric vents.

The output from the other FTH controller is fed into another flask with its own temperature and humidity probe. The output is then connected to the 3-way valve . The 3-way valve connects the TVD's to either the zero or standard vapor flask under computer control. In this way the amount of material which must be passivated is minimized when switching from "zero" to "span".
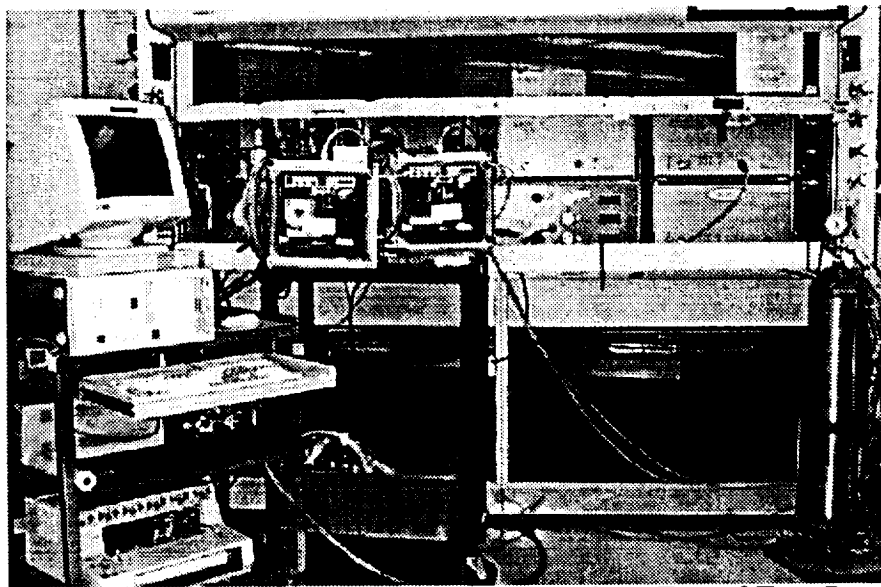

Figure 1. The PCDAS Installation Configured for a Test of Two Paper Tape Type Hydrazine Vapor Detectors.

INPUTS AND OUTPUTS

The analog data collected by the control computer includes temperature and humidity of the two sample vessels: temperature, humidity, and flow from the two FTH controllers: and responses from up to six TVD's for a total of 16 analog inputs. Analog outputs include flow, temperature, and humidity control to two FTH controllers for a total of six analog outputs. Digital outputs include four relay controls to one or two TVG's and two solenoid controls to one or two FTH controllers.

The test control sequence is read from a text file which contains a loosely formatted list of times and events to occur at those times. The test control file serves as a readable test procedure for review and documentation purposes and directly controls the operation of the PCDAS. Another file, called the sensor file, contains identification and scale factors for the TVD's to convert the voltage input to engineering units. The identification is used in the output log files to identify the TVD response data.

Current values of data from test conditions and instrument responses displayed on the screen and are recorded on a strip chart recorder as well. Event times, states of the system, and all physical variable values are recorded in log files, which can be used to verify that the control sequence was executed correctly. In addition, some calculated data are recorded, usually average values and the standard deviation of the steady state TVD response, plus rise and fall times of the TVD to changes in toxic vapor concentration.

SYSTEM SOFTWARE

The PCDAS software is written in Pascal. Pascal was chosen because it is structured, modular, easy to use, and easy to maintain and there are very good compilers and software tools available. At the time the system was initially built, there were no rapid development programming languages available. Program modules were written and tested separately to control the vapor generators, to time the sequence of events, to write data to disk files, and to evaluate response and recovery times for the TVD's. The program does not use interrupts or direct memory addressing. This ensures the sequence of events will proceed as programmed and there will be no hardware conflicts if the program is run on a different computer.

Development proceeded in three stages with three principal authors. The basic I/O and hardware controls, data structures, file structures, and displays were programmed by Carl Mattson. A major revision by Terry Hammond added rise time and fall time calculations; and a second revision by Chris Schwindt added more versatile event timing, separate control files, and a menu-driven user interface. The basic PCDAS software runs in DOS and can be run in a DOS window of a more complex operating system.

SYSTEM OPERATION

In order to operate the PCDAS, the test procedure must be written in the test control file. This can be done using any text editor or using the menu-driven test programming capability of the user interface. The identifiers to be used for the TVD's being tested are written into the sensor file along with scale factors to convert their voltage output to engineering units. These two text files are part of the test documentation and should be filed along with the test data.

The operation proceeds as follows. The vapor generators are turned on and set to run under automatic control. The TVD's and strip chart recorders are connected. The program is started and the operator uses the menus to select the test file to run and the directory where the test data is to be stored. There is a menu option to test individual functions of the PCDAS which may be used for an end-to-end check of the system, if desired, and for troubleshooting. When all of the hardware is configured and the test software is loaded, the RUN option is selected from the menu and the test is started.

The test will run unattended until it is finished, at which time the computer will set TVG's and FTH controllers to a standby state which may be left unattended for days if necessary, for example,. over a week end.

RESULTS AND DISCUSSION

Qualification and acceptance testing require many repetitions of the same test under controlled test conditions. The PCDAS has allowed the automation of the most tedious work involved in routine testing of TVD's at KSC. The TVDL has four PCDAS systems that run almost continuously during a project requiring tests and can produce data 24 hours a day, leaving the scientists free to do the data analysis and reports.
A typical acceptance test for a new Interscan cell for 10-ppb hydrazine takes 14 hours. Using the PCDAS to perform the actual test procedure and log the data ensures that tests performed on different days will be nearly identical in test conditions and results. In addition, the person conducting the automated test has time free to analyze the data from previous tests and write the necessary reports. The overall result is that automated testing performed with the PCDAS can be completed with about one third the man hours, compared to the manual method.

A fifth PCDAS is being built for the Shuttle calibration laboratory which will be used to calibrate 10 ppb hydrazine sensors. The system is being updated with signal conditioners which convert the TVD output from 0 to 0.1 Volt to 0 to 5 Volt, the input range of the PCDAS. In addition, a Graphical User Interface (GUI) is being written in Visual Basic to make the system operation easier for technicians who are less familiar with the system.

At least two other Government laboratories have expressed an interest in using copies of the PCDAS to perform long test procedures that require repeatable performance over a long period of time. One laboratory (which prefers not to be named) has requested that NASA build eight similar systems to perform a large qualification test program. These have been built and six were delivered to the users. The other two will be operated at the NASA TVDL in support of the test program.

CONCLUDING REMARKS

The TVDL at KSC has been using computer controlled test procedures for toxic vapor detection for about nine years. The PCDAS is used to conduct qualification tests and for side-by-side comparison tests of COTS instruments. The use of a Personal Computer based Data Acquisition and Control System has increased the effectiveness of the TVDL by permitting a large number of tests to be conducted under identical conditions with greatly reduced time required from laboratory personnel. In the testing and calibration of 10-ppb instruments for the hydrazines, the PCDAS has been instrumental in maintaining constant test conditions, in particular constant temperature and humidity, over the course of the tests and calibration procedures.