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SAND95-0961 • UC-901

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Printed July 1995

Modifications to the Finnigan Mat 271 Mass Spectrometer in the Inorganic Gas Analysis Lab

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Prepared by
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Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

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SF2900Q(8-81)

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SAND95-0961
Unlimited Release
Printed August, 1995

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MODIFICATIONS TO THE FINNIGAN MAT 271 MASS SPECTROMETER IN THE INORGANIC GAS ANALYSIS LAB

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ABSTRACT

This document presents an overview of the modifications that were done to the Finnigan MAT 271 mass spectrometer used in the Dept. 1823 Inorganic Gas Analysis Lab. Among the alterations to the spectrometer were addition of a new computer, interfaces to the power supply, addition of a multimeter and introduction of a Graphical User Interface software system to run the instrument. The impact of these improvements is also discussed. The appendix details a generic procedure for operating the instrument.

MASTER

I. Introduction

A. The inorganic gas analysis laboratory uses several pieces of equipment to analyze gas mixtures. The most sensitive of these is the Finnigan MAT 271 magnetic sector mass spectrometer (MS) Fig.1 is the general layout of the MS. No modifications or upgrades had been perviously performed on the Finnigan MS. It had become inoperable due to periodic electronic failures and an unreliable source of parts for repair. Hardware modifications and upgrades were required in the driving electronics, controlling computer, and detection systems to allow for reliable use of the MS.

Figure 1. General layout of the MAT 271 mass spectrometer

I. Hardware Modifications:

A. Driving electronics to the spectrometer

Figure 2 shows a block diagram of the new configuration for the MS. Each item in the diagram will be discussed in detail in the following sections.

Figure 2. Block diagram of the new electronics in the spectrometer.

* indicates equipment not changed.

1. Magnet current power supply

A Finnigan built power supply was originally used to control the analyzing magnet current. Since control of this power supply is difficult externally, it was replaced with a Hewlett Packard 6632A (100 watt) supply (fig.2 item3). This power supply is used to cover the 0.5 to 2 amperes used by the analyzing magnet. The HP3478A is used to measure the actual current in the magnet (Fig. 2 item 2). This allows the MS to cover the 2 to 50 amu (atomic mass units) range. The power supply and multimeter use the IEEE-488 parallel communication bus to communicate with the main computer. This power supply brings the flux of the analyzing magnet (monitored by a Hall sensor) up to specific settings near the mass peak to be analyzed.

2. High Voltage power supply

To scan over a specific mass, a combination of magnetic field and acceleration voltage is used. Once the magnet is set near the peak, the scan of the peak is done by varying the

ion acceleration voltage. The High Voltage Power Supply (fig. 2) provides the ion source with approximately 8 kilovolts (kV). The scanning is done by changing the input voltage (0 to 10v) to the HV supply. The HV supply uses $1\text{ v in} = 1\text{ kV out}$ with a range of 0 to 10 kV. A 16 bit digital to analog converter (DAC) board in the computer is used to control the HV supply and gives approx. 40 data points per peak. The DAC is mounted in the computer on the main buss.

3. Inlet control

The inlet is where the sample is introduced into the spectrometer (fig 2. item 4). An old 8086 microprocessor based controller was used to control relays for the inlet valves. After removing the HP9836 computer the 8086 controller as nonfunctional. They were replaced with the PC 486 type computer giving direct control of valves via an internal (to the computer) relay board along with manual switches on the control panel. An 8 channel relay board mounted in the computer on the main bus, is used to control a total of 8 solenoid valves. The existing solenoid valves are operated from this board along with 3 new valves (V6, V7 and V8) to give increased capability for inputting gas standards and samples. Figure 3 shows the valve arrangement.

Figure 3. Diagram of the inlet system on the spectrometer.

B. Output from the spectrometer

Outputs from the spectrometer (e.g., the ion detectors, the inlet pressure, and the analyzing magnet field strength) are read by a Hewlett Packard 3457A multimeter equipped with an 8 channel multiplexing board (fig. 2 item 1). The multimeter is set by the computer for auto ranging DCV. It is connected to the computer on the IEEE-488 parallel bus.

<u>Input</u>	<u>Signal Range</u>	<u>Channel</u>
High resolution Faraday Cup	0 - 5 V	0
Magnet Voltage	18 V	1
3 rd Baratron 100 Torr	0 - 10 V	2
2 nd Baratron 100 Torr	0 - 10 V	3
Low resolution Faraday Cup	0 - 5 V	5
1 st Baratron 100 Torr (inlet system)	0 - 10 V	6
Hall Sensor (field strength)	0 - 500 mV	7

Table 1. This shows the multimeter (fig 2 item 1) input, range and channel number.

Detector voltages from the faraday cups are read by the multimeter (Table 1). These voltages are used as the primary method of detection for the mass peaks scanned by the spectrometer.

Inlet pressure is detected with a capacitance manometer, the MKS Baratron model 170. The analog output voltage is sent to the multimeter (Table 1) and converted to a pressure in Torr.

Analyzing magnet field strength from the Hall sensor (Table 1) is used to jump to peaks with the analyzing magnet. A feedback loop using the field strength gives a repeatable setting for the current that drives the magnet. In this case field strength gives better repeatability than using only the magnet drive current. This allows the spectrometer to jump to the range of different peaks while skipping areas of little interest.

C. Computer

The original computer supplied with the spectrometer was a Hewlett Packard 9836 computer. The spectrometer required either a new control system or costly repairs to the old system. A PC with an 80486 CPU running at 33 MHz was selected as a suitable replacement. The communications bus used is the IEEE-488 parallel bus (GPIB). This communications system allows for connecting several pieces of equipment to the computer via parallel cabling. The DAC and relays that control the inlet valves are also installed in the computer.

II. Software modifications

The original controlling computer was an HP 9836 using a HP Basic program. Which was limited in its capabilities since the graphics consisted of lines and dots in black and white. Operation was only by typing commands at a command line interface that resulted in having to memorize commands and limited capabilities. Furthermore the software didn't allow for the addition of the extra inlet valves.

The early tests were done using Microsoft Quick Basic. These tests were performed to characterize the power supplies and the magnet requirements of the MS. It became clear that the Quick Basic program was not sufficiently advanced for the required procedures so a GUI based programming language Visual Basic from Microsoft was selected. The early version of Visual Basic was not complete so various subroutines were obtained to run sub systems such as the relay cards and the DAC (see appendix B). MicroHelp Muscle, provided a subroutine that was used to communicate with the relay board to operate the inlet solenoid valves. The manufacturer of the DAC board Computerboards Inc., supplied the subroutines used to control the DAC.

Data is stored in arrays within the program and then analyzed. The peak value and pressure information are then sent to a DOS file created for each test run.

III. RESULTS

A. Gains and Losses

By using off-the-shelf electronics, updated systems were introduced to the MS. due to these updates any repair work will be much easier to perform. Another benefit from this upgrade is an intimate understanding of the software, since we wrote the program. By using modular software, changes and additions are greatly simplified and have more control over and can customize the data analysis. By using current software, our system is now compatible with other Windows based programs. However, a majority of the factory support has been lost.

B. System performance:

Peak acquisition, running calibrations and then a sample for one peak, took approximately 15 minutes. However with the new software the same routine requires approximately 3 minutes which reduces the problem of differential pumping of different mass gases. Data analysis in the manual system was limited to the accuracy of the measurement of the peak

height. The new system uses all the points (~30) of the peak and performs a least squares curve fit and gives an averaged peak height with background corrections.

IV. SUMMARY

Since the Finnigan MAT 271 mass spectrometer was modified with a new computer and new sub systems the spectrometer is not only operational again but more flexible in the number and types of data collection with no loss of sensitivity. Data can easily be plotted and analyzed with a wide variety of different windows programs.

V. ACKNOWLEDGMENTS

The authors would like to thank S. Thornberg (1823) for his work in editing this paper and W. F. Hammeter (1846) for the time allotment during the development of the system.

APPENDIX A

Operation of the Finnigan MAT 271 Mass Spectrometer

1. Turn on the computer and bring up the Visual Basic editor. Select the "Finnms8.mak" program and start.
2. The main chamber ion gauge pressure should read $< 1 \times 10^{-8}$ torr to give good data. If it is not the data will have a high background and the filament life will be shortened.
3. Set the emission current to 0.040 mA. If the current will not come up from the initial 0.005 mA or reads 0.000 mA, the filament is probably burned out.
4. Turn on the High Voltage with the button on the System Control panel. Check the voltage on the voltmeter. It should be 8 kV.
5. Make sure the HP multimeter and power supply are on.
6. Connect the sample bottle to the inlet manifold.
7. From the main screen (Fig. A-1) on the computer select the evacuate button and reduce the pressure in the inlet manifold to < 0.01 millitorr.
8. When the pressure is reduced, introduce a sample and select the sample button (1, 2 or 3) on the main screen (Fig. A-1). The inlet system will make an aliquot and expand it in the inlet volume.
9. Select the menu button and from the menu screen (Fig. A-2) select the masses to be run. Also give the run a test file name and sample name. Select the detector and push the LOAD button to enter the selections.
10. This will bring you back to the main screen (Fig. A-1). At this time the MS scan can be started by selecting the SCAN button.
11. The data will be sent to the named file in the "Data" subdirectory. (i.e. C:\data)
12. If you want an instant plot of the peak "GRAPH on" should be selected on the main screen (Fig. A-1). After this the Graph Screen (Fig. A-3) will appear after the mass has been scanned.

Figure A-1. The Main Screen.

FINNIGAN MASS SPECTROMETER SETUP MENU		
☐ 2	Standard Runs ☐ H2, He ☐ HC's ☐ AIR ☐ ALL ☐ T Blanchet ☐ T Guess	Calibration Background 10%H2/N2 1%H2/N2 .1%H2/N2 100PPM H2/N2 10 PPM H2/N2 ☐ 1% MIX ☐ 0 AIR ☐ RMA
☐ D2		
☐ 4		
☐ 12		
☐ 13		
☐ 14		
☐ 15		
☐ 16		
☐ 17		
☐ 18		
☐ 20	DETECTOR DCII low res ☐ DCIII hi res ☐	☐ 1% MIX ☐ 0 AIR ☐ RMA
☐ 28		
☐ 32		
☐ 35		
☐ 40		
☐ 44		
Sample name: <input type="text"/>		<div>LOAD</div>
Test File Name: <input type="text"/>		
Test File Name has to be filled in with the date of analysis. The Sample Name doesn't need the date in it. Run the cals in the order shown above. Run sample in their numerical order.		

Figure A-2. The Setup Menu.

Figure A-3. The Graph Screen., showing a hydrogen peak.

APPENDIX B

Equipment List

HP 3457A Multimeter
 HP 6632A DC Power Supply
 HP 3478A Multimeter
 Thor 486-33 VLB Computer
 IOtech AT488 IEEE488 interface board
 Advantech PCLab PCL725 Relay Actuator card
 Computerboards CIO-DDA06/16 Digital to Analog Converter card
 MKS Type 270 Baratron

Software

Windows 3.1
 DOS 6.21
 MS Visual Basic Professional Ver. 3.0
 MicroHelp Muscle subroutines

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