

## IX. ELECTRONIC INSTRUMENTATION\*

### Academic and Research Staff

Dr. D. H. Steinbrecher  
Prof. K. Biemann†

Prof. J. I. Glaser  
Dr. R. E. Lovins†

### Graduate Students

J. M. Steele  
N. T. Tin  
R. Y. Tung

### RESEARCH OBJECTIVES

The purpose of the Electronic Instrumentation Group is to fill the gap between state-of-the-art technology in electronics and the electronic instruments now being used in many areas of scientific research. Our group is concerned not only with improving the precision, sensitivity, and ease of operation of present electronic instruments but also with the creation of new instruments.

The present effort is directed toward electronic instrumentation for high-resolution mass spectrography. The specific goals are: to improve the resolution of the CEC 21-110 mass spectrometer by placing it in a controlled environment, and to replace the present photographic plate detection scheme by an electronic interface so that the information contained in the ion-beam output can be read directly into a digital computer for processing. Any improvement in resolution will permit a more accurate determination of unknown chemical compounds, and the electronic interface will eliminate the time now required for removing, developing, and optically scanning the photographic plate.

During the past six months significant progress has been made both in the environmental control problem and the electronic interface problem. The instrument has been installed in Room 56-031, M.I.T., which is electrically shielded and isolated from the external environment and has a vibration-controlled instrument mount, as well as temperature and humidity controls. The success of the electrical isolation has been verified by noise measurements taken in the room; these are described in Section IX-A. An attempt is being made to provide a stable DC power supply for the electric-field sector voltage; this progress is described in Section IX-B. The interface development has had two phases: (i) investigation of the feasibility of using some commercially available miniature electron-multiplier tubes mounted in the focal plane as individual ion detectors, and (ii) design and construction of low-noise miniature integrated circuit amplifiers for each electronic multiplier tube, as well as associated logic circuitry for counting ions and reading the counts into a digital computer. The construction of a prototype for the amplifier and logic circuitry is under way and is described in Section IX-C. The theoretical problems associated with the effects of electrical noise on the performance of the system, as well as the limitations on resolution imposed by the ion-generation method and ion optics have been studied with the aid of computer simulation of the instrument. Progress in this area is described in Section IX-D.

D. Steinbrecher, J. Glaser

---

\*This work was supported principally by the National Institutes of Health (Grant 1 505 FR07047-01).

†Professor K. Biemann and Dr. R. E. Lovins, of the Department of Chemistry, M.I.T., are collaborating with the Electronic Instrumentation Group of the Research Laboratory of Electronics in research under NIH Grant 1 505 FR07047-01.

## (IX. ELECTRONIC INSTRUMENTATION)

### A. SHIELDED ROOM FACILITY

This report briefly describes the completed shielded room facility in Room 56-031, M. I. T., as well as the noise measurements that verify the effectiveness of the shielding. The room was designed to provide maximum environmental control and maximum electrical isolation for the instrument.

#### 1. Description

The room was constructed by the Sprague Electric Company from 3/8" wrought iron plate, chosen for its magnetic shielding properties; the physical exterior dimensions are: floor 17' 7" × 16' 3", ceiling 8' 3/4". Structural stability is maintained by 6" I-beams. The walls and ceiling are covered with acoustical tile, and the floor consists of light weight 2" cement fill on top of the wrought iron. Four 6" × 24" metal ducts provide air intake and exhaust vents between the interior of the room and a 7 1/2 ton capacity air conditioner that controls the temperature and humidity. Five 12" × 3" wrought iron pipes in the wall act as feed-throughs for the rubber vacuum leads between the instrument and the pumps, which are located outside the room. Five 8" × 1" wrought iron pipes in the ceiling act as water lines to the instrument and electrical feed-throughs. The entire instrument rests on a mount supplied by Barry Controls, Inc., which damps out vibrations above 1 Hz through a nitrogen pneumatic control system. The room is Cd-welded to a wrought iron conductor that is connected to the 40' steel piling of Building 56, which provides a low-resistance ground. The room itself rests on a fiberglass mat, which was initially 2" thick. Electric power for all equipment in the room is supplied by a 5 KVA synchronous motor-generator set that is mounted above the room. The motor is electrically isolated from the generator by a fiber shaft. The generator has a brushless permanent magnet rotor and supplies 3-phase 120-VAC output. Each of the 3 phases is isolated by means of 3 autotransformers connected in a Y-star configuration, which provides six-wire 3-phase output. Each phase is then separately filtered and regulated by a General Variac motor-driven regulator. The telephone lines leading to the room are also filtered, and the lighting consists of 12 150-Watt 150-Volt lights that are operated from a special DC power supply.

#### 2. Noise Measurements

In order to ascertain the effectiveness of the power-line isolation, several measurements were made. Spot-frequency measurements with signal generators indicated total isolation in excess of 150 dB from 10 kHz to 1 GHz. Measurements of power-line noise inside the shielded enclosure were made with the instrument "off" and the

(IX. ELECTRONIC INSTRUMENTATION)

instrument "on."

The results of the measurements are shown in Fig. IX-1. The vertical axis shows the measured noise power in dB relative to  $kT_0$  (-204 dBW/Hz) measured by a Singer-Metrics NF-105 receiver at an impedance level of 50  $\Omega$ . The frequency range is from

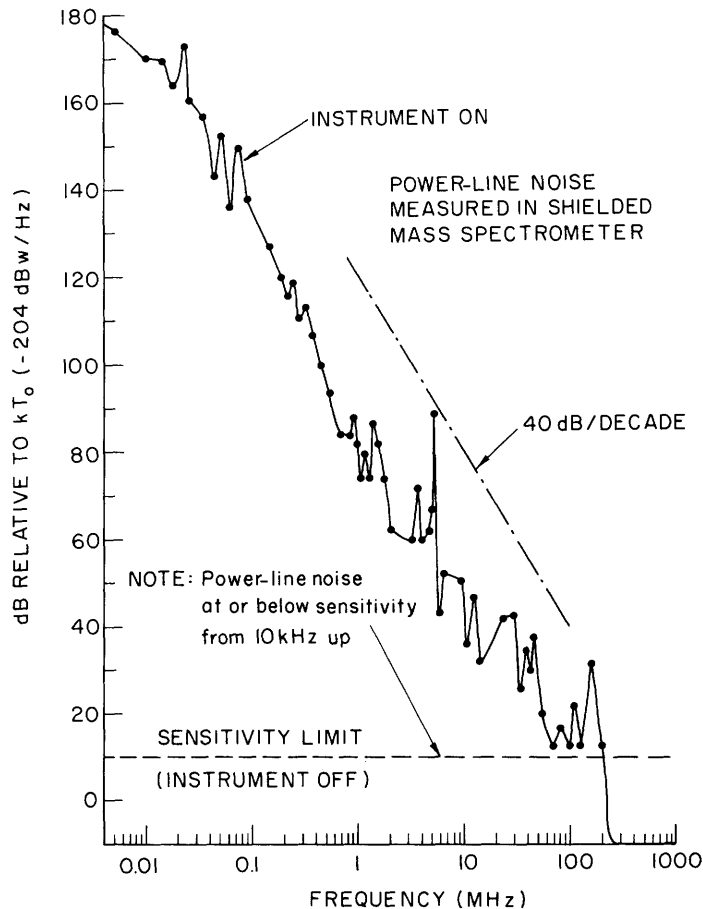


Fig. IX-1. Normalized noise power vs frequency.

14 kHz to 1 GHz. Note that the mass spectrograph contributes all of the measurable noise over the entire frequency range.

D-C magnetic field measurements were made and recorded on a strip chart over a period of a few days. Fluctuations caused by the local subway facilities were reduced almost one order of magnitude (to 3 mG) from those observed outside the room.

Future plans include the measurement of electrical noise from DC to 15 kHz, which requires the modification of existing test equipment.

R. E. Lovins, D. Steinbrecher

## (IX. ELECTRONIC INSTRUMENTATION)

### B. CONTROL OF INSTABILITIES

#### 1. Electric Sector

The effect of instabilities in the DC voltage supplied to the radial electric sector is being investigated. A comparison measurement will be made on the stability of the ion beam output, by substituting for the present DC supply two precision DC power supplies with calibrated and monitored output.

#### 2. Magnetic Field Instabilities

Any 60-cycle magnetic leakage fields from transformers in the instrument may degrade the resolution of the instrument by modulating the ion trajectories. In order to detect 60-Hz magnetic fields in the shielded room, a battery operated magnetic field detector is being designed. A small loop will act as the field probe and the induced voltage will be detected by a sensitive 60-Hz phase-locked receiver.

D. H. Steinbrecher, R. Y. Tung

### C. ELECTRONIC INTERFACE

#### 1. Detectors

At the present time, an investigation of the Bendix "channeltron," a miniature electron multiplier tube, as a possible ion detector is being made. A "channeltron" is being mounted in a vacuum chamber and will be tested in order to determine whether or not it will function in vacuum; the extent to which it will detect ions instead of electrons; whether its performance will be degraded by ion bombardment; the stability of its response; and the effect of magnetic fields on its response. The possibility of employing a small low-noise integrated circuit to amplify the output of each ion detector will also be investigated.

#### 2. Sampling and Retrieval of the Spectrum

A description of a possible interface system between the electron multipliers and the computer has been presented elsewhere in Quarterly Progress Report No. 85 (pages 36-37). A tentative design has been worked out with commercially available integrated circuitry. A small prototype is being built and will be tested soon. The final interface will work as follows: Initially, the magnetic field and the radial electric field of the instrument will be electronically preset; therefore, ions entering the instrument of zero initial energy will exit at points in the focal plane corresponding to their mass-to-charge ratio. In other words, each point in the exit focal plane corresponds to a given mass-to-charge ratio. (Because the ions will have an initial energy, there will be some spread to the exit distribution for an input of ions having the same

## (IX. ELECTRONIC INSTRUMENTATION)

mass-to-charge ratio.) Each ion detector will generate a pulse when an ion strikes its aperture. These pulses will be counted during some preset integration time, and the individual counts will be stored in the computer. Then, the magnetic field and the radial electric field will automatically be set to new values so that each point in the exit focal plane will correspond to a new mass/charge ratio of input ions of zero energy. The counting will be repeated during the same preset integration time and the new counts stored in the computer. The procedure will be repeated a given number of times. Finally, the computer will take the counts obtained during each "scan" and mathematically reconstruct the distribution of ions in the exit focal plane. A theoretical study has been made concerning the number of scans and number of detectors necessary for the computer to reconstruct the distribution of ions in the focal plane. The processing is essentially the reconstruction of a function from sampled data points and will be described briefly. The sample taken by each ion detector is an integral of the ion distribution over distance in the focal plane corresponding to the effective aperture of the detector. If the detectors are equispaced by  $X_s$  and each has an aperture  $X_w$ , the number of ions collected during the integration by the  $k^{\text{th}}$  detector is given by

$$S(k) = \int_{kX_s - X_w/2}^{kX_s + X_w/2} N(x) dx,$$

where  $N$  is the distribution of ions in the focal plane.  $N(x)$  presumably will be a Gaussian-like distribution centered about each discrete mass/charge point in the focal plane for a given magnetic and radial electric field setting. A computer study indicates that a single Gaussian distribution can be reconstructed when  $X_s$  and  $X_w$  are approximately equal to the standard deviation of the Gaussian. For a 250-mm focal plane and standard deviation of  $2.5 \mu$ ,  $10^5$  data points are necessary.  $10^5$  ion detectors would not fit in the 250-mm focal plane, and their cost would be prohibitive. Two hundred of the Bendix "Channeltron"-type detectors would fit in the focal plane, but 500 scans would be needed to obtain the required number of data points. On the basis of empirical data, each scan would require at least 0.2 sec, so that 100 sec would be required to complete the spectrum.

N. T. Tin, J. Steele

### D. MASS SPECTROMETER RESOLUTION

#### 1. Present Status

The object of this study is the improvement of the resolution of the mass spectrometer by eliminating many of the factors that degrade the resolution and by mathematically processing the detected ion beam output of the instrument in order to extract

## (IX. ELECTRONIC INSTRUMENTATION)

the maximum amount of information. To determine the factors affecting resolution and the mathematical character of the ion-beam output distribution, a computer simulation of the instrument has been programmed. The simulation allows the user to determine the distribution of ion positions in the exit focal plane for random or nonrandom distributions of ions in position, mass, and velocity in the input focal plane. The output distribution appears as a histogram. A description of the program and theory appeared in Quarterly Progress Report No. 87 (pages 17-24).

### 2. Future Plans

In order to use the computer simulation in conjunction with the actual instrument, the simulation must correspond closely to the instrument in its performance. Because fringing fields were neglected in the analysis used for the simulation, it remains to modify the actual parameters given to the computer in order to account for any discrepancies between the real and simulated instrument.

The effect of 60-cycle hum on resolution will be included by calculating the trajectory of ions in the radial electric section, under the assumption that a small hum voltage is added to the electric sector voltage.

The technique of determining mass locations by crosscorrelating the output distribution with a theoretical distribution will be investigated, and the improvement in resolution achieved by this method will be evaluated.

An attempt will be made to vary the parameters supplied to the computer, such as field strengths and dimensions, in order to determine whether or not the instrument is truly a "double-focusing" mass spectrometer.

J. I. Glaser