213
9-30

1931
K-1817

A SOLID-STATE AUTOMATIC BEAM POSITIONER
FOR MASS SPECTROMETERS

H. C. Jones

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE GASEOUS DIFFUSION PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT** Contract W-7405 eng 26

**UNION
CARBIDE**

OAK RIDGE GASEOUS DIFFUSION PLANT
P. O. Box P
Oak Ridge, Tennessee 37830

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.95

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Date of Issue: August 16, 1971

Report Number: K-1817

Subject Category: INSTRUMENTS

A SOLID-STATE AUTOMATIC BEAM POSITIONER
FOR MASS SPECTROMETERS

H. C. Jones
Isotopic Analysis Department
Laboratory Division

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
Oak Ridge Gaseous Diffusion Plant
Oak Ridge, Tennessee

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ABSTRACT

An all-solid-state electronic beam positioner for isotopic ratio mass spectrometers has been developed and operated for several months without requiring service or adjustment. Low-frequency modulation of the spectrometer ion accelerating potential with phase sensitive detection of beam position is used to apply an automatic correction signal to the accelerating potential and maintain precise beam position in the collector slit. The operational amplifiers, power supply, and unijunction transistor oscillator utilized in the instrument are of all-solid-state design. Total power dissipation is approximately 12 watts which contributes to the temperature stability of the electronic control and measuring circuitry of the mass spectrometer.

CONTENTS

	<u>Page</u>
INTRODUCTION	4
SUMMARY	4
DESIGN CHARACTERISTICS	4
CIRCUIT DESCRIPTION	5
PERFORMANCE	7
REFERENCES	7

A SOLID-STATE AUTOMATIC BEAM POSITIONER FOR MASS SPECTROMETERS

INTRODUCTION

The design of an all-solid-state beam positioner was undertaken as part of a program to improve the operating efficiency of the automatic mass spectrometers in the Isotopic Analysis Department. Modernizing all of the instrumentation involved will increase reliability and measurement precision and accuracy. The vacuum tube model¹ beam positioner in use at this time has given satisfactory performance but requires periodic maintenance, primarily because of component failure from overheating. The solid-state model will completely eliminate this cause of failure and substantially reduce maintenance time.

SUMMARY

A solid-state electronic beam positioner has been designed, fabricated, and put into service. No maintenance was required by the unit during 12 months of almost continuous operation. This beam positioner will serve as a replacement for the vacuum tube model¹ which has been used by the Isotopic Analysis Department for several years.

DESIGN CHARACTERISTICS

The principle of operation of the solid-state electronic beam positioner is the same as the vacuum tube model¹ now in use by the Isotopic Analysis Department. The ion-beam accelerating potential in a mass spectrometer is modulated slightly by a 5-Hz signal causing the ion beam to oscillate in the collector slit. This technique was described by H. J. Lipkin and D. I. Porat in 1956². As the beam touches the edge of the slit, the ion current reaching the collector decreases. The current decreases and increases at a 5-Hz rate because of the 5-Hz movement of the beam. The 5-Hz signal resulting at the output of the collector current amplifier is further amplified and presented to a phase detector. The phase of the 5-Hz signal is determined by which edge of the collector slit the beam touches. The output of the phase detector is integrated, and the integrated signal is applied as a correction to the ion beam accelerating potential. The correction causes the ion beam to shift away from the edge of the collector slit, thereby keeping the beam automatically centered.

This beam positioner incorporates solid-state operational amplifiers by Philbrick/Nexus Research and Analog Devices, Inc.*, and a solid-state

*Brand names mentioned in this report are intended to be descriptive, not limiting. Another brand of comparable characteristics could perform equally well.

power supply by Salient Electronics, Inc. The total power dissipation of the beam positioner is approximately 12 watts. The power dissipated by the vacuum tube model is approximately 125 watts. This reduction in power dissipation assists in maintaining a lower overall temperature of the associated electronic components within the framework of the mass spectrometer and will improve the stability of those components and lengthen their useful life.

CIRCUIT DESCRIPTION

Figure 1, a simplified schematic of the solid-state beam positioner, shows the basic functions of the amplifiers and their interconnections. The 5-Hz signal used within the beam positioner is generated by a uni-junction transistor oscillator circuit. The generated signal is roughly triangular and is shaped into a reasonably distortion-free sine wave by an operational amplifier with a parallel-tee filter network as the feedback element. The parallel-tee network is tuned to present a high impedance feedback path at 5 Hz. The gain of the amplifier at 5 Hz is limited by a 500-K resistor shunting the feedback network. This improves the stability of the amplifier and prevents spontaneous oscillation by the amplifier.

The output of the wave-shaping amplifier is presented to the input of a summing amplifier. The normally grounded negative lead of the accelerating potential power supply is returned to the output of the summing amplifier and not to ground. This causes the accelerating potential to be increased, or decreased, by the value of the output of the summing amplifier; therefore, the accelerating potential is modulated at 5 Hz without affecting the regulating section of the accelerating potential power supply. The position of the ion beam in the collector slit is thus changed at a 5-Hz rate. If the ion beam drifts to one side of the slit, the number of ions striking the collector will vary at a 5-Hz rate. Therefore, the signal output of the collector current amplifier varies at 5 Hz. The phase of the 5-Hz signal is determined by the side of the slit which is attenuating the ion beam. This 5-Hz signal, which is the result of an error in the beam position, is further amplified by an operational amplifier with a parallel-tee filter network as the feedback element. This network is tuned to 5 Hz and is shunted by a 100-K resistor to limit the closed-loop gain of the amplifier to a reasonable value. The prime purpose of this amplifier is selectivity (not signal amplification); the gain at frequencies above and below 5 Hz is much lower than the signal gain. Following this amplifier is a second amplifier connected in a practical derivative configuration, making it less frequency-selective than the preceding one but permitting a much higher gain at the signal frequency (5 Hz). The output of the second amplifier is then presented to a phase detector network. The reference signal for the phase detector is obtained from the wave-shaping amplifier by way of a driver amplifier. A variable phase shift network in the feedback path of the driver amplifier is used to phase match the reference signal and the error signal. The output of the phase detector is a dc signal with

Figure 1
SOLID-STATE BEAM POSITIONER

polarity determined by the phase relationship of the reference and error signals. This dc signal is integrated by an operational amplifier connected as a time integrator, and the integrated signal is fed to the input of the summing amplifier. The summing amplifier applies the correction to the accelerating potential to move the ion beam back into the center of the slit. The summing amplifier simultaneously modulates the accelerating potential at 5 Hz and applies the correcting potential to hold the ion beam centered in the slit.

In some applications the signal level of the ion beam focused through the collector slit may vary from 0.2 to 5 volts. In order to have the ion beam positioner perform properly in these cases, it is necessary to change the gain of the derivative-taking signal amplifier. This is done automatically by using a relay to switch a shunt resistor in the feedback network of the amplifier when a more intense ion beam is positioned in the slit. The drive signal for the relay comes from a program controller which is used to switch the ion beam. A delay circuit is added to delay the relay dropout which increases the amplifier gain. This prevents overloading of the signal amplifier.

PERFORMANCE

The efficiency with which the beam positioner works depends to a large extent upon the shape of the ion beam in the slit. An ion beam that *tails* to any great degree will delay the beam positioning process; a well-defined ion beam will be positioned much more rapidly.

REFERENCES

1. Hanson, M. L., *Integral Control for Automatic Beam-Positioning in Mass Spectrometers*, Goodyear Atomic Corporation, Portsmouth, Ohio, July 22, 1960 (GAT-T-588/Rev. 1).
2. Lipkin, H. J. and Porat, D. I., "Automatic Beam Positioning for Mass Spectrometers," *Rev. Sci. Inst.* 27, 208 (1956).