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IN NUCLEAR SCIENCE ABSTRACTS

**SOLID STATE ELECTRONIC CIRCUITS
FOR THE LINE RECORDER MASS SPECTROMETER**

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**UNION
CARBIDE**

**UNION CARBIDE CORPORATION
NUCLEAR DIVISION**

Operating the

OAK RIDGE GASEOUS DIFFUSION PLANT	• OAK RIDGE NATIONAL LABORATORY
OAK RIDGE Y-12 PLANT	• PADUCAH GASEOUS DIFFUSION PLANT

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SOLID STATE ELECTRONIC CIRCUITS
FOR THE LINE RECORDER MASS SPECTROMETER

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Oak Ridge, Tennessee

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SPECTROMETER

Authors: H. A. Kermicle
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A B S T R A C T

New electronic circuits have been developed for the mass spectrometer known as the Line Recorder. This instrument is used as an analytical and control device throughout the gaseous diffusion plants. When compared with those in the original Line Recorder, the new circuits perform equally as well or better and have the advantages of using no batteries, of utilizing solid state devices almost completely, and of occupying about one-third of the panel space. The design of the circuits and their principal operating features are described.

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SOLID STATE ELECTRONIC CIRCUITS
FOR THE LINE RECORDER MASS SPECTROMETER

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SOLID STATE ELECTRONIC CIRCUITS
FOR THE LINE RECORDER MASS SPECTROMETER

INTRODUCTION

The Line Recorder mass spectrometer has been used throughout the gaseous diffusion processes since their inception for the analysis of the various gas mixtures encountered in the cascades. Many of these instruments have been modified from time to time for special applications involving both measurement and control. During the years of its use, the Line Recorder has proved to be both accurate and versatile.

The original Line Recorders at the Oak Ridge Gaseous Diffusion Plant were built to specification by the General Electric Company (1). The electronic circuits supplied with these units are presently more than twenty years old. During the expansion program of 1952, additional Line Recorder units were constructed by the Beckman Company (2). These units are fourteen years old. All of these instruments use vacuum tube circuits throughout and dry batteries in several applications.

Early in 1966 it was decided to undertake a program for the redesign of the Line Recorder electronic circuits. The basic impetus for this program was the deteriorated condition of many of the existing units. The combined effects of age and heat have dried out and embrittled many of the components and much of the wiring. Some of the recorders used are obsolete and no longer manufactured. Rather than rebuild the existing circuits or build new ones to the same design, the program called for a completely new approach with four primary objectives:

1. The elimination of all batteries.
2. The use of solid state circuit components to reduce heat and size.
3. A reduction in panel size and weight.
4. An improvement in performance and operational efficiency where possible.

These objectives have been realized in the Solid State Line Recorder. The remainder of this report is a description of the new instrument.

A secondary reason involves the possibility of further gaseous diffusion plant expansion in the near future. Should such a program become a reality, the need for analytical instruments of improved design and capability will be of paramount importance. The new Line Recorder panels will fulfill that need should it arise.

DESCRIPTION

Assembly

A complete set of the new solid state panels is shown assembled in a relay rack in figure 1.* Only the remote recorder is not shown and it is almost identical to the local recorder. The panel space required for this assembly is 45-1/2 inches compared with 96-1/4 inches for the Beckman and even more for the General Electric unit.

The new design eliminates the constant voltage transformer formerly required, further reducing space and weight. All external cable connectors on the new panels are identical with the previous design, making the external cables usable without modification. A pull-out writing table is provided just below the high voltage power supply. A drawer in the lower section provides data and equipment storage space.

All of the front panels except for the recorders are of photosensitive aluminum. The fabricated chassis and aluminum structural parts are also. All panel power cords are captive and use NEMA grounded plugs. All panels containing dangerous potentials are protected by metal covers. The panels can be installed in any standard relay rack provided they are operated from unregulated power.

Electronic Pump Power Supply

The electronic pump power supply shown in figure 2 furnishes 20 microamperes at 3,300 volts dc, and up to 200 milliamperes at lower voltages. Basically it is a simple voltage doubler circuit with the inherent "soft" regulation required for this application. If the pump draws excessive current, the output voltage will fall and prevent damage to the pump. An output voltmeter and a five range current meter are provided for monitoring the pump operation. This current is a direct measure of the pump pressure. The two relays associated with these parameters provide further protection by shutting down this supply, together with the high voltage power supply and the emission regulator, in case the pump draws a current of more than 20 milliamperes or if the high voltage drops below 2,500 volts. This protection can be overridden during pump startup or for test purposes. A fault light indicates relay operation.

* The automatic leak control panel has not been redesigned, and is not considered in this report. The reasons for this omission are: 1) it is not a part of the relay rack assembly, being located on the tube rack, and 2) a program to improve the vacuum gauge associated with sample flow control is presently in progress, and redesign awaits the conclusion of this program.

Local Recorder

The local recorder, shown schematically in figure 3, is the new Leeds and Northrup Speedomax W. This type of recorder was chosen because its internal operation made it compatible with the main control circuit and because its physical size is attractive. It is a self-balancing potentiometer with six points and a 100-millivolt sensitivity dictated by the output of the direct current amplifier. All of the measuring and reference supply electronics are solid state.

In the Speedomax W input channel selection is accomplished by relays with relay operation controlled by a rotary selector switch. Printing occurs once every 12 seconds. Normally, these relays are mounted on a printed circuit card, together with the relay dc power supply, and are contained in a housing attached to the rear of the recorder case. This housing on the rear of the recorder protrudes to the extent that the assembly will not fit in the standard relay rack. Therefore, the relay card has been incorporated into the sensitivity-suppression panel, and the relay power supply is mounted in the main control panel.

The choice of a six-point recorder was made after discussions with process operations' personnel indicated that the monitoring of four masses was sufficient for proper analysis of the gases in the cascade. The fifth and sixth recorder channels are assigned to monitor amplifier zero and the sample flow (Pirani). A plug-in pin program board is mounted on the rear of the recorder to allow any of the six channels to be printed out on any of the six recorder points. This program board takes the place of the familiar "program plug" used on the present Line Recorder.

This recorder uses the same width paper as the current Speedomax G; however, its printing method is quite different. Instead of using a single color ink with various symbols for point identification, the Speedomax W uses a different colored numbered dot for each point. The ink pads are furnished as an inexpensive throw-away wheel and can be changed in a few seconds. A reproduction of a sample of a recorder chart is shown in figure 4.

Because in this system the local recorder and any remote recorder are operated with their inputs in parallel, there is no retransmitting slide-wire.

Remote Recorder

The remote recorder (figure 5) is in most respects identical with the local recorder. The only difference lies in the inclusion of additional circuits in the remote recorder. Here the input relays and power supply are built in rather than being located in other panels. There is also a circuit for synchronizing the printing of the remote recorder with the

local unit. If the recorders are not synchronized, relay KAl will pull in, stopping the remote recorder printing motor until synchronization occurs.

A junction box is included to allow the operation of two remote recorders at the few locations where this is necessary.

Sensitivity-Suppression

Figure 6 shows the sensitivity-suppression diagram. Card PC1 contains the relays which select the input channel for the recorder. These relays also select the high voltage relay in the main control panel. The multi-vibrator MVI delays application of the signal to the recorder after the channel selection for two to three seconds to allow the previously selected signal to decay.

The controls have been revised so that, when recording mass signals in the point check mode, the same sensitivity and suppression network is in the circuit at all times. This makes it unnecessary to set all of the selector switches to the same position during this type of operation.

One additional slight enhancement is the addition of two higher steps of suppression, making it possible to suppress 550% of the recorder range rather than the previous 450%.

Except for the millivolt range which has been halved, the sample flow control circuit is identical with that of the present Beckman Line Recorder.

Emission Regulator

The primary change in emission regulation is the use of dc power rather than ac for filament heating. This simplifies the circuit, figure 7, by allowing shunted pass transistors to be used for filament current control. The differential operational amplifier A1 monitors the emission current flowing through R59 and in turn controls the pass transistors TR1 and TR2. PS1 supplies the ionizing voltage.

Note that the J5 focusing control has been included in this panel, placing all of these controls in a group. The range of these controls has also been somewhat expanded for a greater adjustment range.

A third position has been added to the meter function switch S4. This CONTROL position allows the monitoring of the pass transistor control current and insures that the circuit is always operating near the center of the control band. This current can be adjusted by R62 which may be necessary when a source filament is changed.

An improvement in operation and panel construction results from the use of plastic case meters for indicating the filament and emission currents. These meters are designed to withstand the full accelerating potential, such that it is not necessary to mount them on a isolated subpanel.

Direct Current Amplifier

The direct current amplifier circuit shown in figure 8 also makes use of operational amplifiers. Amplifiers A2 and A3 are both located in the preamplifier housing, leaving only the power supplies, controls, and indicators in the relay rack panel. The electrometer tube V1 has been retained, making this instance one of only two in which vacuum tubes are used.

One of the major changes in this unit is the selection of a new amplifier output level. Whereas the present Line Recorder dc amplifier has a full scale output of from 20 millivolts to 20 volts, this circuit provides 10 millivolts to 10 volts, a range dictated by operational amplifier capability. In order to retain the same basic sensitivity, the input resistances have been halved. This results in a decrease in the time response of the system allowing point selection to occur at twice the former rate.*

Main Control

Many new features are present in the main control panel of figure 9. The potentiometers in the main divider network are of the new ceramic-metal material which is said to result in a resistance of greater stability than the wirewound units. Since the high voltage power supply is infinitely variable, the high voltage adjustment has been reduced to a single adjustable control. There is now a pilot light associated with each divider potentiometer which glows when that control is selected, instantly identifying it.

Mass programming is achieved through cables and jacks on the rear panel of the unit, making program revisions simple. The high voltage relays are hermetically sealed in cans containing an atmosphere of inert gas, a type of construction which should minimize relay failure. A large, accurate meter indicates the high voltage with an increased readability.

High Voltage Power Supply

The high voltage power supply is a commercial unit which is modified to eliminate the normal metering circuits and to make its front panel match the other front panels in the Line Recorder. Figure 10 is a schematic diagram of the Calibration Standards power supply which is used in the prototype and the first two Solid State Line Recorders built at the Oak Ridge Gaseous Diffusion Plant. This power supply is of solid state

* For an excellent discussion of time response as it applies to the Line Recorder, see UCNC report K-1294 (3).

design except for four pass vacuum tubes, the second and only other place they are used in the entire instrument. It has a continuously adjustable output voltage from 0 to 3,110 volts and is exceptionally stable and well regulated.

PERFORMANCE

The operating performance of the Solid State Line Recorder has not yet been evaluated under plant operating conditions. The prototype unit has been in service for several weeks in the Instrument Development Department laboratory at the Oak Ridge Gaseous Diffusion Plant. One of the two instruments shown in figure 1 was installed in the corrosive gas test facility in the Chemical Development laboratory. This application is considered to be one of the most severe in the plant from the standpoint of the required resolution and stability. After an initial shakedown period, the performance of the unit has been excellent. The second unit is presently being installed in the K-29 building and will be watched closely for the next several months.

CONCLUSION

The Solid State Line Recorder has many improvements compared with its predecessors. Besides being smaller and lighter and requiring no batteries or stabilizing transformer, the instrument has many features which should make it attractive from the standpoint of its operators. These include larger, more readable and accurate meters, controls with a wider range grouped for easier selection, an increased high voltage adjustment capability, improved electronic pump protection, easier programming of both the recorder and the mass selection, and improved indication of mass recording. It is hoped that it will prove to be a worthy successor to the many Line Recorders now in use.

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Figure 1
SOLID STATE LINE RECORDER ASSEMBLY

Figure 3
LOCAL RECORDER
SCHEMATIC DIAGRAM

Figure 4
SAMPLE OF SPEEDOMAX W RECORDER CHART

Figure 5
REMOTE RECORDER
SCHEMATIC DIAGRAM

Figure 6
SENSITIVITY-SUPPRESSION
SCHEMATIC DIAGRAM

Figure 7
EMISSION REGULATOR
SCHEMATIC DIAGRAM

Figure 8
DIRECT CURRENT AMPLIFIER
SCHEMATIC DIAGRAM

Figure 9
MAIN CONTROL
SCHEMATIC DIAGRAM