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DP-1193

AEC RESEARCH AND DEVELOPMENT REPORT

AN IMPROVED URANIUM COLORIMETER

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Instruments
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AN IMPROVED URANIUM COLORIMETER

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ABSTRACT

Savannah River Plant colorimeters used to monitor continuously liquid streams containing 0 to 10 grams of uranium per liter of solution have been redesigned to give uranium analysis correct within ±0.5 grams/liter. In the redesign, solid state logarithmic amplifiers, magnetic amplifiers, and closely regulated power supplies were used to achieve accuracy and stability. Meter and recorder indications were made linear to read in grams/liter of uranium. The optical portion was modified so the colorimeter could be calibrated without removing the sample cell.

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INTRODUCTION

Flow colorimeters for measuring the concentration of uranium in process streams have been in service at the Savannah River Plant since their development in 1960.[1] However, their readings were often unreliable because of inconsistent performance. Tests indicated that the electronic portion of the instrument required improvement. The electronic portion of the colorimeters has been redesigned to improve stability, accuracy, and ease of reading, and the optical portion has been modified to facilitate calibration.

PRINCIPLES OF OPERATION

The Savannah River Plant colorimeters[1] are flow colorimeters specially designed to continuously monitor the concentration of uranium in nitric acid. They are dual beam colorimeters in which one narrow wavelength of light (542 mμ), which is strongly absorbed by uranium, is used to measure uranium concentration, and a second wavelength of light (416 mμ), which is not absorbed by uranium, is used to compensate for changes in light intensity and turbidity in the sample. Both wavelengths come from one incandescent lamp and both pass through the sample cell. After passing through the cell the light is split with a partially reflecting mirror, and the wavelengths are separated by optical filters. The light intensity of each wavelength is measured with a vacuum photocell. The current from each photocell is then passed through logarithmic amplifiers. The linearized output signals from the logarithmic amplifiers are then sent to magnetic amplifiers. After amplification, the reference signal is subtracted from the measurement signal, and the difference is displayed on a panel meter and on a strip chart recorder.

MECHANICAL ARRANGEMENT

The arrangement of the optical portion of the colorimeters is shown in Figures 1 and 2. A filter holder (not shown in Figure 1) would be mounted on the top plate just in front of the half-silvered mirror. The mirrors and levers in the photograph were originally used to pass the light around the sample cell, but are no longer used. The sample cell is shown in Figure 3.

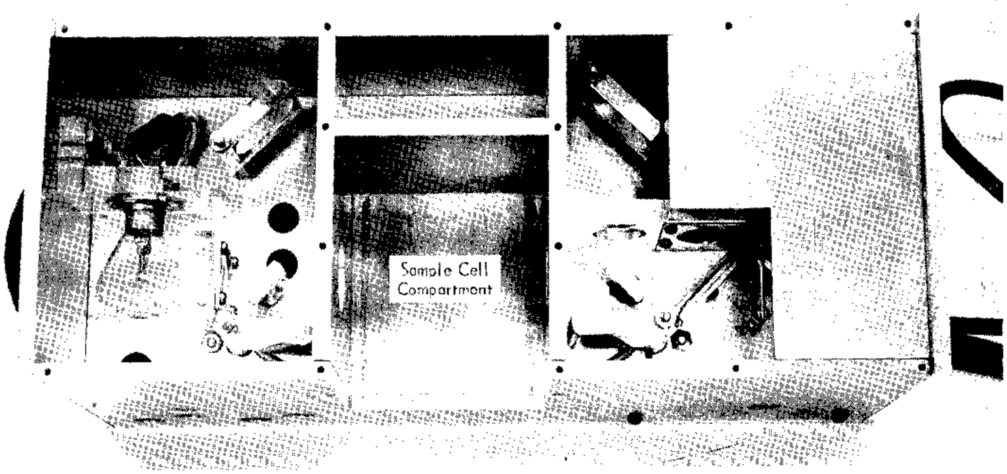


FIG. 1 OPTICAL PORTION OF THE COLORIMETER WITH TOP AND SAMPLE CELL REMOVED

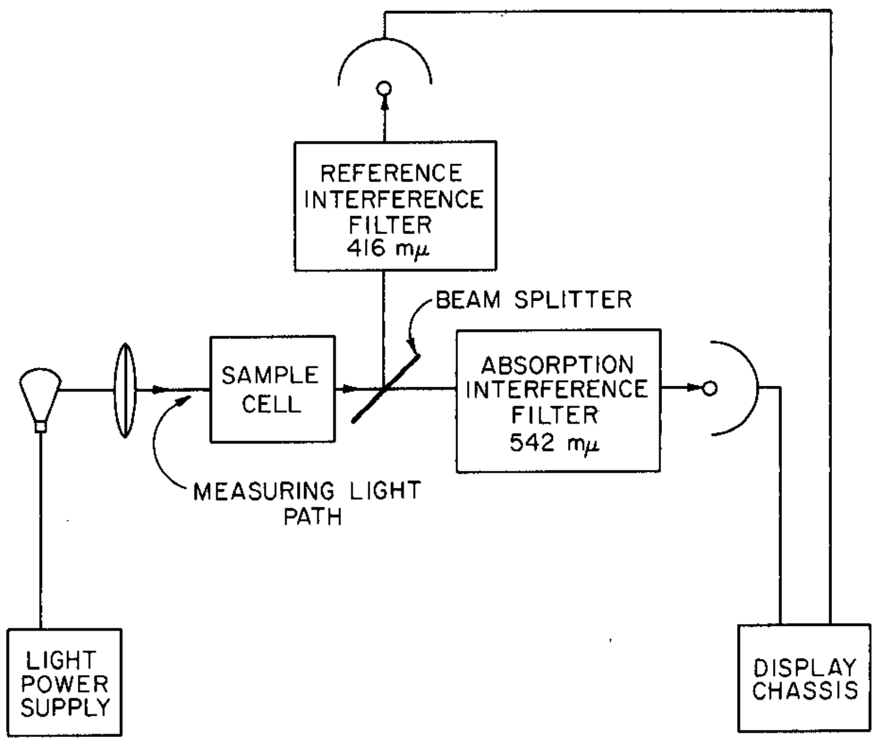
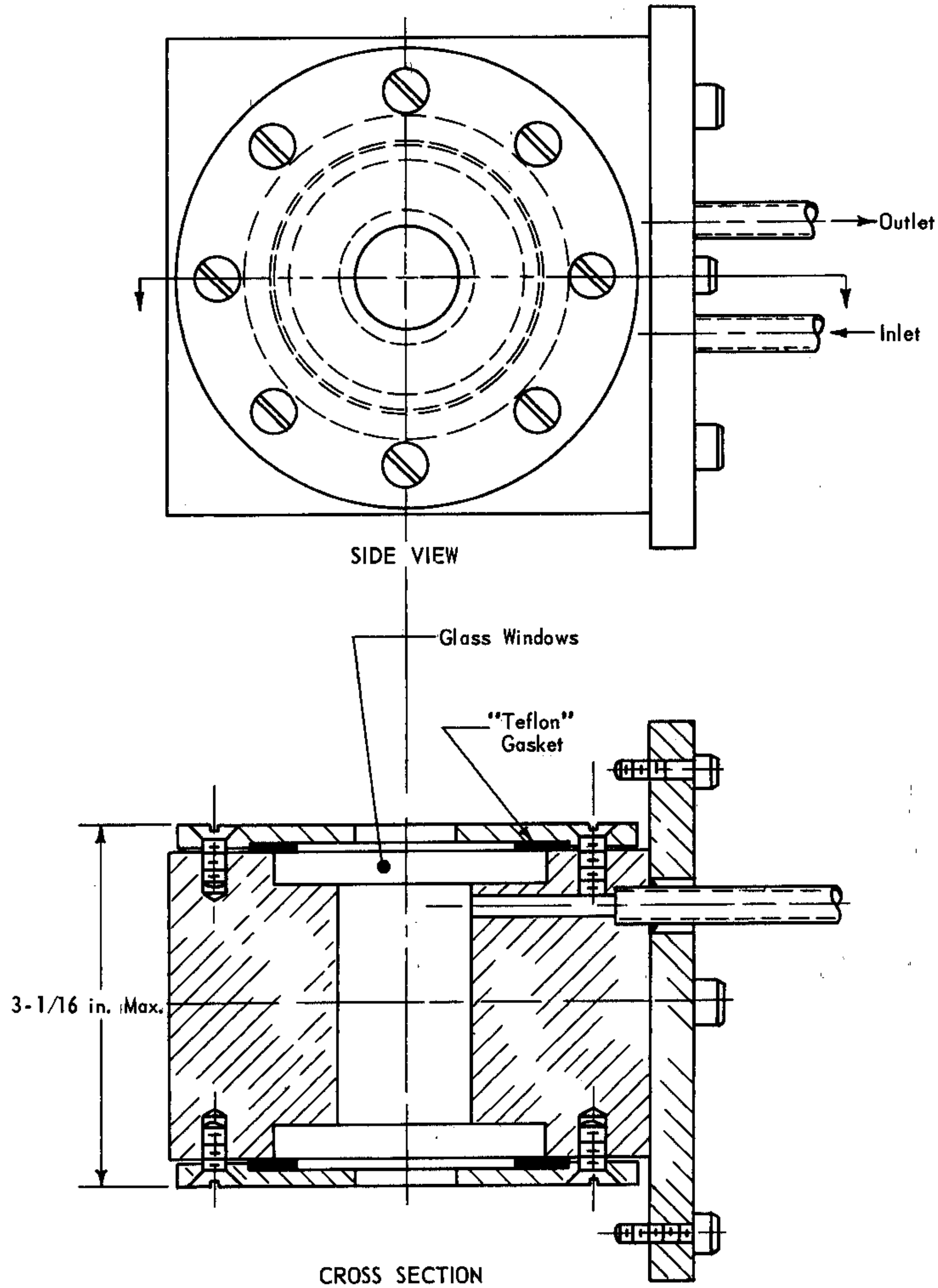


FIG. 2 ARRANGEMENT OF COLORIMETER



"Teflon" is DuPont Trademark for flourocarbon resins.

FIG. 3 SAMPLE CELL

CIRCUITRY THEORY

Light Power Supply

The dual beam technique will compensate for any changes in light intensity (due to dirt on the optics, etc.), but the original electronic circuitry did not compensate for changes in light spectra (due to changing filament temperatures). Therefore a highly regulated (±0.05%) 5.5-volt dc power supply was added to operate the colorimeter lamp. This supply maintains a constant lamp temperature; thus, the ratio between the light intensity of the two wavelengths is stabilized.

Amplifiers

Because the absorption of light is an exponential function of concentration (following Beer's Law), the logarithm of the transmitted light intensity is used to obtain an output signal that is directly proportional to concentration. To obtain the logarithm of the photocell current, the logarithmic characteristic of silicon transistors[2] was utilized as seen in Figure 4. This characteristic is that the short circuit collector current is proportional to the exponential of the emitter-base voltage. In both the reference channel and measurement channel circuits, the output of the photocell is connected to the collector of a 2N2222 transistor and to the input of an operational amplifier. The amplifier output is connected to transistor emitter terminal. The amplifier maintains the emitter voltage (actually the emitter-base voltage because the base is grounded) at exactly the voltage necessary for the collector current to equal the input current. Under this condition the amplifier output voltage is proportional to the logarithm of the input current. The output voltage is about 60 millivolts per decade change in input current. Because the change in phototube current for a change in uranium concentration from 0 to 10 grams/liter is much less than one decade, the output from the operational amplifier is only a few millivolts. The 2N2222 transistors are kept in a miniature constant temperature oven for stability.

Magnetic amplifiers were used to amplify the low level signal from the logarithmic circuits, to permit "zero" compensation of each circuit, and to allow the reference channel output to be subtracted from the measurement channel output without interaction between the two channel circuits.

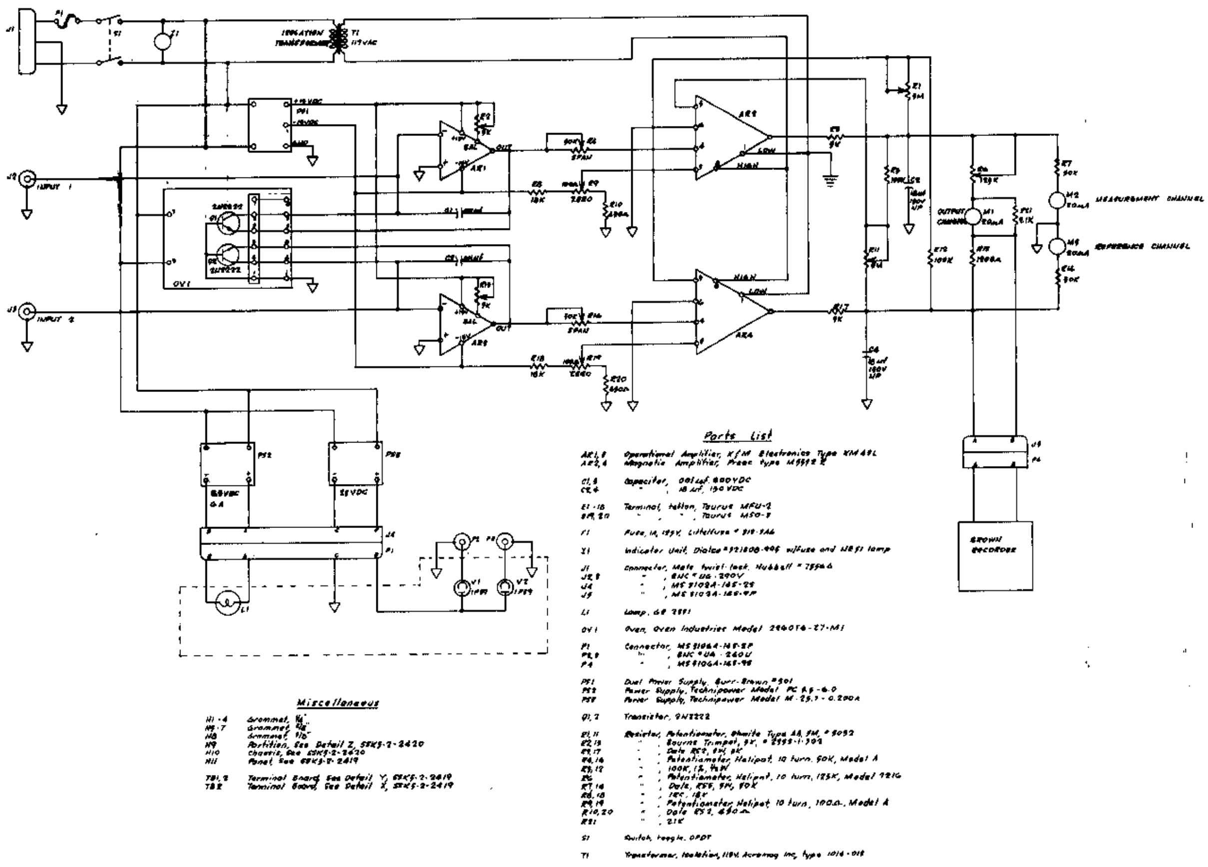


FIG. 4 IMPROVED URANIUM COLORIMETER

Output Display

The signals from both the measurement channel and the reference channel are displayed on small front panel meters to facilitate calibration of each channel circuit (Figure 5). The difference between the two signals, which is the output signal, is displayed on a large panel meter, which has a linear scale calibrated from 0 to 10 grams/liter. A signal is also supplied for a strip chart recorder (see Figure 4).

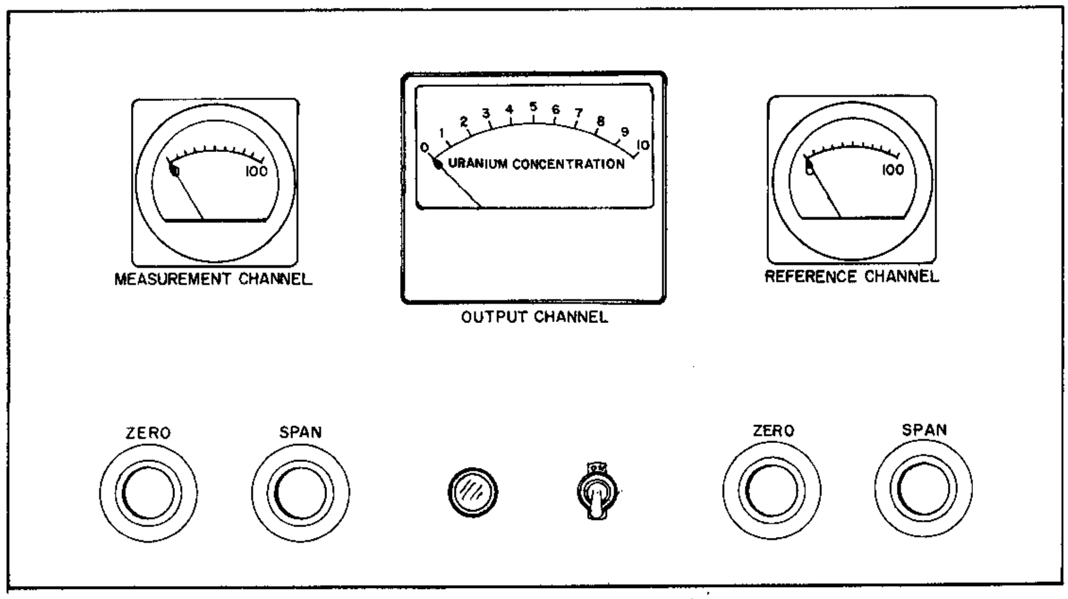


FIG. 5 FRONT PANEL OF COLORIMETER

CALIBRATION

To ensure reproducibility, a filter holder was added so the monitor could be calibrated without removing the sample cell. Colored glass filters are used for routine calibration. A calibration curve for laboratory-standardized uranium solution of various concentrations is shown in Figure 6.

Performance of a prototype colorimeter has been satisfactory during eight months of plant service.

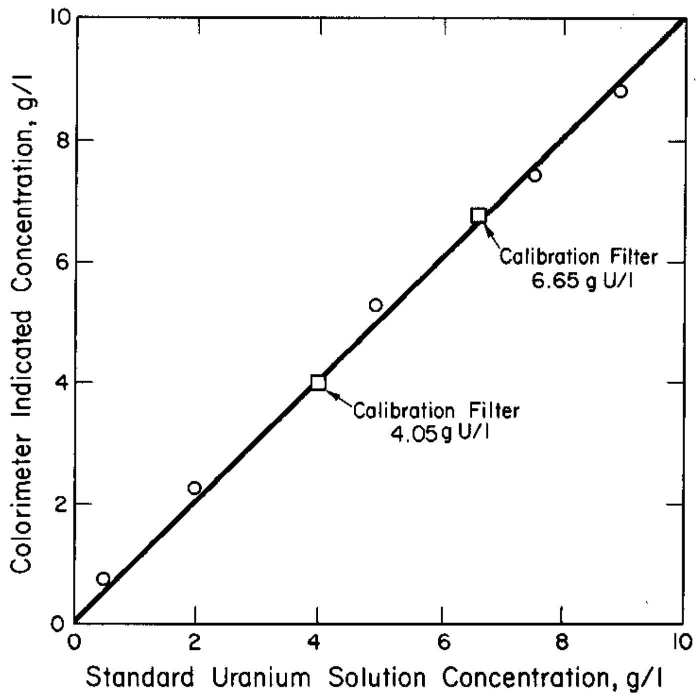


FIG. 6 COLORIMETER RESPONSE

REFERENCES

1. D. W. Colvin. A Colorimeter for In-line Analysis of Uranium and Plutonium Solutions. USAEC Report DP-461, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, S. C. (1960).

2. J. F. Gibbons and H. S. Horn. "A Circuit with Logarithmic Transfer Response Over Nine Decades." IEEE Transactions of the Circuit Theory Group CT-11(3) (1964).