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INSTRUMENT RESEARCH AND DEVELOPMENT

QUARTERLY PROGRESS REPORT

FOR PERIOD ENDING OCTOBER 20, 1952

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INSTRUMENT RESEARCH AND DEVELOPMENT REPORT

CHEMISTRY DIVISION

C. J. Borkowski F. Porter
E. Fairstein J. K. East
R. Stone

The circuit development of a new linear amplifier was completed during the last quarter. The design appears to be successful in that it has about 10 to 20 times the overload capacity of the A-1 amplifier and can tolerate about 10 times its counting rate for a given energy-resolution degradation. A pilot model will be constructed to determine how well the instrument functions under actual operating conditions. The design characteristics were described in an earlier quarterly report.

The circuit for a scintillation-counter-regulated high-voltage supply that uses an r-f oscillator for the voltage source was developed. This circuit has a number of advantages over the earlier design (1) the coil used in the oscillator is very simple and of noncritical design, (2) the high voltage does not appear at the terminals of the oscillator tube, with the result that a low-power receiving type of tube can be used, and (3) the operating efficiency is quite high, resulting in low heat dissipation. Unfortunately, the nature of the design is such that it is not economical for use in a self-contained unit. However, it is economical for use in an amplifier–high-voltage-supply combination where a low-voltage supply already exists.

The alpha-energy analyzer began to give trouble after three years of continuous operation. Most of the difficulty was caused by the argon filling gas stocked by the Laboratory. The last month was spent in changing the instrument in a way that would prevent a future recurrence of the trouble. The operation of the analyzer was greatly improved in the process of change, and it is now giving better results than ever before.

A 404A tube tester and ager was designed and built with the cooperation of the Instrument Department. Until now, the service group has not had an adequate means of conditioning 404A tubes, which are used in quantity in scintillation spectrometers.

The multichannel analyzer that incorporates a Hathaway galvanometer has been tested using ten channels. Excellent stability has been obtained with the system. In order to increase the speed of the system so that the amplitude of 1000 pulses/sec can be measured accurately, a pulse with both positive and negative polarity will have to be fed into the transformer that drives the galvanometer. In this way the shift of the base line, which is now present, will be eliminated.

A method of simulating scintillation pulses is being developed that uses a Hathaway galvanometer and a light-integrating sphere to diffuse the light over a photomultiplier photocathode. It is hoped that some of the factors that govern the energy resolution of photomultipliers will be determined by the use of the constant source of light flashes.

INSTRUMENT DEPARTMENT

SPECIAL PROJECTS GROUP

H. E. Banta

The effort during the past quarter was expended largely on preparations prior to moving the 2-Mev Van de Graaff generator from Building 2011 to Building 5500. The move has been made during the current quarter. The small Van de Graaff generator has been installed in the new location and all essential services have been supplied. It has been operated as an electrostatic generator at 3 Mev, although it is not anticipated that the top operating energy will be this high. The accelerator tube, which was not in the machine during the voltage test, was designed for a maximum operating energy of 2.5 Mev.

A LOW-DRIFT DIRECT-CURRENT AMPLIFIER

J. P. Palmer L. A. Meeks

The need for an inexpensive, low-drift, d-c amplifier comparable to existing models of a much

higher price range led to the design of the new instrument. The total drift of the amplifier, referred to the input, is ±5 μv with a d-c loop gain of 2000. The d-c input signal is modulated, amplified, demodulated to direct current, and stabilized through d-c feedback. Modulation and demodulation occur within a single converter, thus eliminating the need for two converters operating synchronously, or one converter and a phase detector. In this system, one set of contacts in the converter samples the signal and the other set demodulates the signal. The amplifier contains two dual triode tubes that operate in cascade and the output stage is transformer-coupled. The band pass of the amplifier is 0 to 10 cycles. The characteristics of the circuit demand that one side of the feedback loop be kept grounded at all times. The grounding discourages capacitive coupling between the input and output chopper contacts, which would result in over-all positive feedback in the a-c part of the amplifier, thus causing oscillation. For this reason, the a-c portion of the amplifier gain has been limited to 40,000 and antihunt circuits have been included in the design.

The low-drift amplifier does not require a regulated power supply or regulated line voltage for its operation. The tubes have a-c heated filaments that eliminate considerable expense in construction. Saturation of the amplifier, caused by a-c pickup from the filaments, is prevented by controlling the heater coupling in the input stage. This is accomplished by the use of a potentiometer connected across the secondary winding of the heater transformer. The center tap of the potentiometer is grounded and controlled for minimum signal. By proper positioning of the potentiometer arm, a-c pickup from the first stage may be reduced to approximately 20 μv. Any remaining pickup is caused primarily by capacitive coupling to the input grid and is consequently out of phase with the chopper action. Therefore, no demodulation products will be produced.

A modified version of the amplifier has been incorporated in the derivative polarograph recently constructed by the Instrument Department, and described below.

A DERIVATIVE POLAROGRAPH (Q-1338)

L. A. Meeks M. T. Kelley
J. P. Palmer D. J. Fisher

The derivative polarograph (Q-1338) provides a highly sensitive means for determining the concentration of two reducible ions by taking derivatives of the current waves obtained from a polarographic cell. When the ion half-wave potentials are close together, it is difficult to resolve the waves from a conventional polarogram if both ions are present in dilute sample solutions. A derivative plot yields two sharp peaks, the heights of which are proportional to the concentration of each ion present in the solution. The derivative is obtained through the use of a d-c current amplifier of the feedback type that amplifies the cell current to a level high enough to drive a 1-sec, R-C, derivative-taking network. The output of the derivative-taking network is connected to a Brown strip-chart recorder.

Preliminary results on a temporary setup indicate that the derivative waves are well defined and independent of the relative concentration. The same degree of reproducibility and sensitivity that was obtained in the high sensitivity polarograph (Q-1160) has been maintained in this instrument. Construction of the Q-1338 derivative polarograph has been completed. More details regarding operating results and circuit features will be presented in a later report.

THE R-VOX (Q-1319)

F. M. Glass H. N. Wilson

The R-Vox is a portable integrating type of personnel radiation monitor designed to give an audible signal when the wearer has been exposed to radiation that exceeds a preset tolerance level.

The instrument may be worn on a belt or waist band. It is light and compact, weighing less than 300 grams. The approximate dimensions are 4 by 3 by $1\frac{1}{2}$ inches. The audible alarm signal is produced by a modified-cone type of crystal head-set unit mounted in the front of the case. After the

instrument has reached a given tolerance level and is exposed to additional gamma radiation, it produces a sound that resembles a siren.

The R-Vox is essentially a gamma-detecting device, and employs a hermetically sealed ion chamber filled with dry nitrogen to approximately 1-atm pressure. The electrometer tube is mounted inside the sealed ion chamber so that leakage on the tube base and insulator under varying conditions of humidity is minimized. No connection to the inner electrode of the chamber is necessary because grid current is drawn when the outer electrode is raised to the charging potential. The required negative potential is effectively placed on the grid when the outer electrode is returned to ground potential.

Sufficient capacitance has been built into the ion chamber so that any error due to grid current and leakage will represent only a small per cent of the total calibration of the instrument. This has been accomplished without seriously affecting the over-all size of the ion chamber. The capacity-to-volume ratio has been selected to give 100-mr sensitivity when the chamber is filled to a pressure of about one atmosphere.

The circuit consists of a type-5803 Victoreen electrometer tube with a simple gas diode relaxation oscillator connected in the plate circuit. The grid of the electrometer tube is connected directly to the inner electrode of the ion chamber. The ions collected in the chamber reduce the charge on the inner electrode and cause the tube to conduct. Thus the voltage at the plate is reduced, which in turn increases the voltage across the relaxation oscillator. The voltage increase causes the neon tube (NE-2) to conduct, thereby starting oscillation. As long as the electrometer tube continues to conduct, the relaxation oscillator oscillates at an audiofrequency. The initial low-pitched tone increases in frequency to a high-pitched note as the charge on the ion chamber is reduced. Regardless of the intensity or further accumulation of radiation, the oscillator will not block and the peak frequency always remains in the audible range.

The alarm may be tested or the ion chamber recharged without the danger of accidentally discharging the chamber by closing a pair of contacts located inside the case with the insertion of a plunger in a small hole located directly over the contacts.

The instrument can be made to give an alarm at various radiation levels by varying the voltage applied to the grid by means of a potentiometer connected to the charging battery. Also, the user is able to determine at any time the fraction of the daily tolerance of radiation already received, without destroying the accumulated information.

A novel feature of the oscillator circuit is the method used to couple the signal to the output. The Rochelle-salt crystal in the aural monitoring phone is used as the capacitance in the relaxation oscillator circuit as well as performing the intended function in the phone, thus serving dual purpose. This eliminates signal loss due to coupling and is responsible for the high efficiency in the instrument. The approximate output power is 0.6 milliwatt. Filament battery life expectancy is 100 hr at 12 hr per day, and for high-voltage batteries the life expectancy is the shelf life of the battery.

Discharge tests on the R-Vox that were conducted in a background of 0.025 mr/hr for periods of 72 hr indicate an extrapolated discharge time of about 1600 hr, assuming a linear discharge rate.

Three pilot models of the instrument have been constructed and it is anticipated that a contract for the manufacture of a compact model will be awarded in the near future.

THE AUTOMATIC TITRATOR (Q-945)

M. T. Kelley J. R. Tallackson
J. L. Horton O. Eason

The automatic titrator is to be employed in the analysis of radioactive materials where samples must be kept to a minimum size because of radiation hazard and where exposure to the radiation produced by the samples might exceed the tolerance level for operating personnel. The new instrument is an improvement over previous models in that it is sufficiently flexible for any type of potentiometric titration, and it is considerably more accurate.

Precise micro or macro titrations are conducted by means of an automatic feed system that varies the flow of titrant in accordance with the requirements of the titration. The progress of the titration is automatically recorded by a specially modified strip-chart recorder. The titrant solution is automatically injected by means of a power

feed drive unit, an electronically controlled magnetic clutch, and a precision-designed microburet or injecting syringe. The solution is stirred by means of a magnetic agitator that is attached to the container. The electrode potential is measured by a converted Brown amplifier (with high input impedance) that positions the pen of the strip-chart recorder. The chart-drive mechanism of the recorder is made to follow changes in rate of titrant injection by means of a selsyn drive. As the titrant is added to the sample solution by the syringe or special buret, the potential created across the electrodes within the solutions is plotted against the volume of titrant added. As the titration progresses toward the end point, the voltage curve deviates up-scale, thus causing a change in signal voltage to the Brown amplifier. The signal energizes a pair of thyratrons that disengage the magnetic clutch, thus preventing the syringe drive from injecting titrant into the solutions until the reaction rate has reached a point that allows additional injection without danger of overshoot. When the end point is approached, the titrant is added to the solution in a series of incremental steps until the exact amount is added to obtain optimum quantitative results.

A REVERSING-CYCLE POWER SUPPLY

W. G. James

Some available data indicate that a better plating finish can be obtained in a plating bath if current of one polarity is used $\frac{5}{6}$ of the time and current of the opposite polarity the other $\frac{1}{6}$ of the time. The reversing-cycle plating power supply has been constructed to facilitate investigation of this phenomenon.

The power supply takes advantage of the high-speed and good current-handling capabilities of a Western Electric single-pole, double-throw, mercury-contact relay by employing it as an electromagnetically switched full-wave rectifier. However, by suitable circuitry, the relay is made to rectify only two out of every three cycles of the 60-cps voltage supply. The third cycle is permitted to pass through the relay and plating bath as a full sine wave. This results in a plating current consisting of five, half sine waves of one polarity and one, half sine wave of the opposite polarity. This is the desired ratio of forward to reverse current for the plating bath.

The circuit consists of a dual-control pentode (6AS6) that actuates the rectifying relay, a center-tapped transformer connected to the relay that supplies the plating current, and a multivibrator that produces an output that prevents the pentode from actuating the relay during the appropriate cycle. One control grid of the pentode is connected to a voltage source of 60 cps that attempts to turn the plate current on during each positive cycle. The plate current actuates the rectifying relay. However, on every third cycle, a large negative pulse from the multivibrator arrives at the second control grid of the pentode and prevents the flow of plate current. This prevents the relay from switching and thereby permits a full sine wave of current to flow to the plating bath. The multivibrator, which operates at 20 cps, is synchronized with 60 cps to ensure that its output arrives at the pentode at the proper cycle.

THE QUINTECTOR (Q-1267)

W. G. James F. M. Glass
D. D. Walker

The need for a portal radiation monitor having good stability and reliable operating characteristics led to the design and construction of the Quintector. The instrument will simultaneously monitor five separate areas of halls or doorways and will produce both an audible and visual signal when an excess of radioactivity is present in any one, or in all five areas. Improvements over previous portal monitors include

1. simplification and improvement of the circuit design,
2. degeneration of connecting cable capacity, thus providing longer life to GM tubes,
3. calibration and adjustment simplification,
4. visual indication of the activity level for each area,
5. high voltage to each GM tube can be read from a single panel meter.

The five externally-located GM tubes are connected to the Quintector through special double-shielded cables for each channel. The inner shield of the cable is connected to the cathode-follower input stage in each channel in such a way that the capacitance of the cable is degenerated, thereby increasing the useful life of the GM tubes. Individual adjustment of the alarm level for each channel is made possible by the use of Sym-ply-trol

meter-type relays mounted on the front panel. The actuating coils of the relays are connected in each plate circuit of the output stages in the rate-meter circuits. The pointers on the Sym-ply-trol meters indicate the activity rate in a given area at all times.

An alarm bell, actuated by any of the five Sym-ply-trol relays, rings when the activity in any of the areas increases above the tolerance setting.

LIQUID-LEVEL INDICATOR (Q-1331)

R. D. Sidnam

The measurement of the liquid level of non-conducting liquid in a closed container presents a problem that is difficult to solve by ordinary methods. Water and water solutions or suspensions have a high dielectric constant, a property that lends itself to detection. Since the relative dielectric constant of water is much larger than that of air, a probe in the form of a condenser can be made to exhibit a large change in capacitance with changes in the per cent immersed. The liquid-level indicator, Q-1331, is designed to operate on this principle.

The method of measuring changes in probe capacitance, or liquid level, was complicated by the requirement that the probe must be located approximately 100 ft from the indicating unit. Therefore, a Clapp-type oscillator circuit was selected because its characteristics are such that it can be made to include a large cable capacitance in its resonant circuit. A null system of indication was selected because it is inherently more linear, operates with higher gain and is therefore more sensitive, and is relatively stable. Retuning of the oscillator was accomplished by means of a 2000 $\mu\mu f$ air-variable condenser located in the indicator unit.

In the cycle of operation of the indicator unit (1) a change in liquid level, with a corresponding change in capacitance in the probe, changes the oscillator frequency, (2) the change in oscillator frequency produces a polarized d-c error voltage, (3) the error voltage is fed into a modified Brown amplifier that in turn drives a Brown balance motor, and (4) the Brown motor drives the air-variable condenser that is connected to return the oscillator to its fundamental frequency. In this manner the amount of probe capacitance necessary to retune the oscillator is read directly on the chart of the Brown recorder and is used as the liquid-level indication. The instrument is now in service and is yielding satisfactory results.

A NEUTRON-SENSITIVE THERMOMETER

T. R. Herold J. T. DeLorenzo

A neutron thermometer is needed for research to replace the units heretofore employed that utilize B^{10} as the heat reservoir. Several B^{10} thermopile units, supplied to the Laboratory by the Brown Instrument Company, have been tested in both the ORNL graphite reactor and the LITR. These thermopiles contain the standard Brown Instrument Company radiation pyrometer thermocouple assemblies that are composed of 10 chromel-alumel thermocouples arranged in series and that form a circular network with the hot junctions concentrated at the focus. The hot junctions are coated with approximately 2 mg of B^{10} suspended in Sauereisen adhesive. The Sauereisen adhesive has proven highly successful as an application medium for B^{10}. The actual longevity of Sauereisen in high neutron flux is not yet known, however, the models tested have thus far survived four months of immersion in a neutron flux greater than 10^{11} neutrons/cm^2 sec with no observable change in thermal or electrical properties. Additional information on the results obtained with the neutron thermometer will be included in a later report.

404A TUBE TESTER AND AGER (Q-1344)

E. Fairstein D. M. Collier

The Western Electric vacuum tube 404A, a high-transconductance pentode, is used in trigger-pair circuits in numerous applications, such as pulse-height selectors. For consistency of triggering, the tubes should be matched in pairs. For continued consistency of operation, the tubes must be aged enough for the transconductance not to change markedly after the tubes are placed in service, since the matched pairs become unmatched with use.

A tube ager and tester has been built by the Instrument Department. Provisions are made for operation of 11 Western Electric 404A tubes simultaneously, with the normal electrode voltages applied. Each tube can be tested in its aging position for the value of plate current, grid current, and transconductance under actual operating conditions. The tubes may be aged for 50 to 100 hr and matched in position for use in any circuit where matched 404A's are required. The measurements are accurate to within 2%.