INSTRUMENTATION AND CONTROLS DIVISION

SEMIANNUAL PROGRESS REPORT

FOR PERIOD ENDING JULY 31, 1956
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INSTRUMENTATION AND CONTROLS DIVISION

SEMIANNUAL PROGRESS REPORT

For Period Ending July 31, 1956

C. J. Borkowski, Director

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CONTENTS

HRT Instrumentation ........................................................................................................... 1
An Automatically Recording Laboratory Balance ................................................................. 7
A Self-Heating Resistance Thermometer Temperature Controller ................................... 9
In-Line Instrumentation Program ........................................................................................ 11
A Factor Affecting the Count Rate of the Windowless Gas-Flow Proportional Counter ...... 14
Differential-Pulse-Height Distribution of BF$_3$ Neutron Counters ...................................... 14
High-Voltage Instrumentation .......................................................................................... 15
    Millimicrosecond Neutron Spectrometry ..................................................................... 15
ORNL Scaler Development ................................................................................................. 16
ORNL Applications of Magnetic Memory Cores .................................................................. 17
    Coincident Current Memories ...................................................................................... 18
    256-Channel Time-of-Flight Spectrometer .................................................................... 18
Model Q-1212C Mercury Relay Pulse Generator ............................................................... 22
Mobile Air Monitor Q-1740 ............................................................................................... 24
The HRT reactor has been the major effort of the HRP Instrument Section for the past two years and is the system toward which our component development program has been directed.

Initial testing of the reactor plant is now under way. A 3000-psi hydrostatic test has been completed and rinse solutions have been circulated.

The process instrumentation and controls system has been installed and checked. The nuclear instrumentation is complete except for remote area monitoring and the installation of the chambers and their positioning mechanism.

The critical experiments will follow an estimated three months of component testing and aqueous solution circulation.

The scope of the instrumentation and control system is indicated by the following cost estimates:

1. Labor and materials costs were $381,000 as of April 1; approximately $400,000 should complete the job.

2. Electrical and instrument equipment costing $200,000 has been purchased; of this amount, $100,000 was for valves and valve operators.

Figure 1 is a basic flow sheet of the system. Shown are the core vessel, where the heat is generated; the heat exchanger, where the heat is removed in the form of steam which goes to a turbine generator and then to an air cooled condenser at power levels above the rating of the turbine; the circulating pump, which circulates the fuel at 400 gpm; and an electrically heated pressurizer which prevents boiling in the circulating stream.

Included is a secondary stream, consisting of gas and entrained liquid from the gas separator, which flows to the low-pressure dump tanks and gas recombiners through the letdown valve. The liquid loss from the high-pressure system is made up by the continuously operating feed pump.

The blanket flow system is identical to the fuel flow system, but will circulate heavy water at 200 gpm during initial operation.

Several key control loops are indicated in Fig. 2. Shown are:

1. control of core system pressure at 2000 psi from sensed pressure by the time-proportioning of power to electric heaters,
2. similar control of the blanket pressure by a core-blanket differential pressure signal, and
3. control of the liquid level in the pressurizer from sensed level by pneumatic control of the letdown valve. Electrical control actions from pneumatic transmitter signals and transducers are derived from pressure switches. Electrical interlock control of the pneumatic signals to final control elements is achieved by means of solenoid-actuated pilot valves.

Other control loops include:

1. control of reactor power by a manual or turbine-governor signal to a valve that throttles steam from the core heat exchanger,
2. control of core-system average temperature by the control of solution concentration; that is, the circulating fuel solution can be concentrated or diluted by pumping water or more concentrated fuel to the reactor core (nominal core outlet temperature at 5 Mw is 300° C), and
3. control of blanket temperature by a signal derived from the difference between core temperature and blanket temperature; this signal controls the blanket-heat-exchanger steam valve.

The main control board and console are shown in Fig. 3. Here are located only those instruments necessary for the safe operation of the reactor. These are arranged in a visual aid form to reduce operational errors and facilitate the training of operators. This "graphic" section is essentially a simplified schematic representation of the chemical process flow sheet with instruments, control switches, and valve-position indicators located in positions corresponding to their location or function in the actual system.

The pneumatic instruments on the main control board are of the plug-in variety and may be removed for maintenance during operation.

The patch panel on the extreme left of Fig. 3 is a jumper board which is a schematic representation of the electrical control circuits. Not shown in
Fig. 1. Basic Flow Sheet.
Fig. 2. Key Control Loops.

Fig. 3 are lines representing interconnecting wiring. Provision is made for jumpering certain individual contacts in the control circuit with a plug; lights are provided to indicate the position – open or closed – of the contact in the system, regardless of whether or not it is jumpered. This board is valuable for making control circuit alterations necessary for experiments; is an aid in familiarizing operators with the electrical control circuitry; and, since the lights indicate contact position, is an operations aid during startup. The jumper board is placed on the main control board so that any jumper used is in full view of the operator. Protection for sustained power operation is also offered by the removal from control of startup circuits.

Annunciators are placed in the control board directly over the instrument or portion of the system on the graphic board with which their signal is associated.

Key measurements are displayed on recorders in the center section of the panel and include the following: a fuel temperature recorder, a multipoint temperature recorder, a multiarea radiation monitoring recorder, the reactor power recorder, the log N amplifier and CRM signal recorder, and the blanket temperature recorder.

Switches and controls on the console are restricted to those necessary for nuclear startup, steady-state power operation, and emergency.

Data collection instruments and the transducers that drive the miniature pneumatic slave recorders on the graphic panel are located in an auxiliary instrument gallery beneath the main control room, along with a 548-point thermocouple patch panel, relay panel, nuclear amplifiers, and nuclear instrument power supplies.

Other panels located near their respective equipment in the building include the steam control station, the turbine control panel, two sampler control panels, and the refrigeration system control station.

Figure 4 shows the steam control station. Here are mounted the valve switches which control the flow of steam to the steam killer and turbine, and the gages indicating pressures and flows.
Fig. 3. Main Control Panel and Console.
Fig. 4. Steam Control Station.
Design features of the system include the following:

1. Duplicate transmitters are provided. The output of the noncontrolling unit of the duplicate transmitters is displayed on an adjacent indicator. A valve allows the output of either transmitter to be fed into the controller.

2. Control rods and fast electronic circuitry are not necessary because of the high negative temperature coefficient of reactivity — about \(-2 \times 10^{-3} \Delta K_{\text{eff}}/^\circ \text{C}\) at 280°C. Functions similar to those performed by rods but without exacting speed response requirements are performed by valves controlling either the concentration of the fuel, the steam removal rate from the heat exchangers, or the discharge of the fuel to noncritical low pressure storage tanks.

3. To prevent the escape of radioactive material, all lines through the shield wall are blocked by valves which are actuated by a signal of high shield pressure. Normal pressure in the weld-sealed reactor tank is 1/2 atmosphere.

4. A 48-v d-c supply, consisting of batteries, is used for control of circuit power and for the operation of key pilot solenoid valves which in turn control the air to the critical valves.

5. In the event of compressor failure an emergency control-air system is provided by the use of nitrogen cylinders. The supply is adequate for an orderly shutdown.

6. During power operation, a 300-kva turbine generator operated by reactor steam is used to provide alternating current for sustained operation.

7. All critical core and blanket system transmitters (except electrical level transmitters and thermocouples) are located in two shielded instrument cubicles located just outside the main reactor tank. The instruments are located in vertical tanks, 5 ft in diameter and 15 ft long to avoid opening the main tank for instrument servicing. This arrangement also provides a location for instrument components which cannot be protected readily from water flooding of the main tank during remote maintenance operations. However, the cubicles are sealed and shielded to the same degree as the reactor tank.

8. The radiation sensing chambers are located in two 5-in.-dia pipes and two 3-in.-dia pipes which are all in a 30-in.-dia cylinder 26 ft long, which slopes diagonally down from just outside the control room, through a 5-ft-thick sand and water shield, into the reactor cell. This cylinder is filled with a mixture of lead shot and water to reduce the gamma background from 250,000 r/hr to a value of 250 r/hr for proper operation of the compensated ion chambers. At 5-Mw core power, the thermal neutron flux will be approximately \(10^{11} \text{neutrons/cm}^2/\text{sec}\) at the chambers when they are at the bottom of their thimbles. The fission chambers may be pulled back to achieve a \(10^4\) reduction of flux. The chamber thimbles are filled with water for shielding purposes and to permit ready withdrawal.

9. The critical dump circuit and pilot solenoid valves may be checked during operation by a test panel. Solenoid valves in this circuit are also duplicated. The system is designed so that a bona fide dump signal occurring during a test overrides the test signals.
AN AUTOMATICALLY RECORDING LABORATORY BALANCE

T. M. Gayle  J. A. Jockel

Two automatically recording analytical balance systems were developed for the Chemical Technology Division. The lack of a commercially available instrument with the desired sensitivity and dependability made the development necessary. The principle of operation is illustrated in Fig. 5. The systems were designed to seek and maintain equilibrium on a chain-type laboratory balance, and to record the position of the chain — and hence the amount of weight — required for balance. The system consists of an Ainsworth or Voland balance, a Type 100 SL Schaevitz differential transformer, a Brown balancing motor, and a modified Brown amplifier. The system employing the Voland balance is shown in Fig. 6 and operates as follows.

The linear differential transformer is the sensing element in a null-seeking servo loop. A change in displacement due to a change in weight causes a 100-mg chain to be repositioned to maintain zero displacement. The position of the chain is transmitted to a recorder by a conventional bridge circuit consisting of a 10-turn potentiometer geared directly to the chain drive, with a 200-ohm slide-wire in the recorder.

Fig. 5. Automatically Recording Analytical Balance.
Fig. 6. The Voland Balance System.
With loads up to 50 g, sensitivity and repeatability of better than 0.5 mg have been obtained. For stable operation of the servo loop, it is necessary to limit the balance speed to 40 mg/min which is slightly lower than the speed of response of the beam) and to damp the motion of the beam. The particular applications for which the system was originally developed pertained to gas absorption rates on solids and chemical kinetic studies of oxygen-UF₆ reactions in the Fluorox process.

A SELF-HEATING RESISTANCE THERMOMETER TEMPERATURE CONTROLLER

J. F. Potts

The self-heating resistance thermometer temperature controller was designed to meet requirements of members of the Chemistry Division for the study of solution absorption spectra over the temperature range of 50 to 250°C. Initially, a survey of commercial equipment was made. It was found that the modifications necessary to adapt these systems to the problem appeared to be as involved as designing the complete control equipment. The results of an attempted modification on one controller supported this conclusion.

It is necessary to minimize optical distortion caused by temperature gradients in the solution by maintaining boundary temperatures of the solution container as uniform and time-independent as possible. A short time variation in the range of 0.01 to 0.1°C is considered a reasonable specification. Uniform solution heating is provided by equidistant, symmetrically placed heater windings embedded in a close fitting copper annulus surrounding the cylindrical container. The separation of the windings is kept small relative to the distance between heater and solution. Heavy container wall shields the solution from local disturbances in temperature at the cylinder surface.

For optimum performance, the controller should sense thermal conditions in the vicinity of the heater elements without time lag or loss of proportionality. This condition is approximately realized by using the heater winding itself as one arm of a Wheatstone bridge whose 60-cycle unbalance signal is the error signal actuating the controller. Platinum wire is used in the heater for good bridge sensitivity and stability.

Control is achieved by means of proportional and reset actions. The two amplifier stages, $T₁$ and $T₂$ in Fig. 7, provide a gain of about 6000 and apply the amplified error signal to the grid of $T₃$, a 684 power triode used as a phase-sensitive rectifier and power amplifier. Phase sensitivity is accomplished by connecting the 684 plate to a 220-v, 60-cycle source. When grid and plate voltages are in phase, the output of the stage increases with increasing grid signal. When an out-of-phase condition exists, the output decreases with increasing grid signal.

The rectified d-c voltage appearing between the 684 plate and ground is the input to the reset circuit (tubes $T₅$ and $T₆$). Filtering is achieved by the resistor-condenser combination in the grid circuit of $T₅$. This circuit also establishes the reset time constant.

The amplified signal at the grid of $T₃$ eventually appears as a bias change at the grid of $T₁$. The resulting current change through $T₁$ constitutes the controller reset signal. The final control element consists of a G-E type 6AG221 saturable reactor connected with the d-c winding in the 684 plate circuit and the a-c winding in the solution heater supply circuit. Reactor d-c bias level is dependent on the rectification of the 684 output and, in turn, establishes the impedance of the a-c windings. Change of this impedance controls heater current and consequently solution temperature.

A possible objection to this design arises from the following situation: The error signal supplied to the regulator should depend only upon the resistance of the heating element, which in turn depends on its temperature. However, if the bridge is unbalanced, a fraction of the bridge supply voltage appears at the input to the regulator and constitutes an undesirable feedback signal. A means for circumventing this effect is to use an error signal frequency different from the supply frequency.

In the case described here, separate control and signal frequencies were not found necessary.

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Fig. 7. Temperature Controller Proportional and Reset Circuits.
IN-LINE INSTRUMENTATION PROGRAM

M. J. Kelly

The In-line Instrumentation Program was established at the Laboratory in August 1955. The objective of the program is to provide data for chemical process control adjustments more rapidly than such data can be supplied from samples sent to an analytical laboratory. Immediate knowledge of a change in process conditions enables operating personnel to make adjustments to increase process efficiency and prevent loss of product. In-line instrumentation also eliminates time losses in feed preparation steps where laboratory analyses are now used to adjust feed batch to specifications. The use of in-line instruments will not replace data from laboratory analysis but will supply all necessary process information required for continuous plant operation.

The first project under this program is the development of satisfactory plant equipment for the concurrent determination of uranium and nitric acid in Purex feed solutions.

The method being investigated involves the relationships between density and conductance at constant temperature for solutions containing uranyl nitrate and nitric acid. A graph of these relations for various concentrations is shown in Fig. 8.

Conductance changes rapidly with acid concentration and slowly with uranium concentration. Similarly, density changes rapidly with uranium concentration and slowly with acid concentration. At constant temperature, measurement of conductance to ±5000 µmhos and density to 0.002 g/ml yields a precision of ±0.05 moles/liter for acid and ±3 g/liter for uranium.

Since density is temperature dependent (of the order of 0.0006 density units/°C) and since conductance is also temperature dependent (approximately 2%/°C), temperature effects must be corrected for or eliminated. The temperature of the solution in the feed tank may vary from ambient temperature to boiling. The environment within the tank is such that accessibility for sensing-element inspection or maintenance is impractical. These conditions make mandatory continuous withdrawal and return to the tank of a representative sample of its contents. This is accomplished by a side-stream sampler system shown in Fig. 9.

The sample stream is air-lifted to the sample cave. The air is separated from the sample stream, and the air-free stream is fed through a heat exchanger to the measuring elements and finally returned to the tank. The heat exchanger provides sufficient temperature control so that temperature compensation for density is not required. To allow compensation for errors in the conductance measurement caused by temperature changes, the temperature must be measured to ±0.1°C at the input to the conductance cell.

The first measurement problem investigated was that of density. The usual methods of precise density measurement involve moving elements that are sensitive to small load changes. Residue buildup and corrosion interfere with the long-term precision when moving elements are used. A method not requiring moving elements was therefore selected for critical evaluation.

The principles involved are shown in Fig. 10. The method as used in industrial practice is considered to have an accuracy of ±1%. It was felt that, by careful study of the parameters involved,
Fig. 9. Block Diagram of Side-Stream Sampler System.

the required accuracy of 0.2% could be obtained. Laboratory investigation showed that several factors affect the realizable precision. These are:
1. The accuracy is dependent on the regulation of the supply air to the over-all system.
2. Extremely viscous systems will not give good results because of viscous drag.
3. Unless separate air lines run from the bubbler tubes to the differential pressure cell, error is introduced by the pressure drop caused by the frictional losses in the purge lines.
4. Any agitation in the solution will cause erratic results due to bubbles that are broken off prematurely.
5. The conformation of the ends of the bubbler tubes does not materially affect the precision.
6. The most satisfactory bubble rates are from 20 to 40 bubbles/min.

7. The bubbler tube inner diameter should be at least \( \frac{3}{16} \) in. to minimize surface tension effects.
8. As great a vertical spacing as possible should be used since position errors in the bubbler tubes cause large discrepancies in calculated results.

To minimize some of these sources of error, a separate measuring catch pot was used. A sample flow rate of 200 to 300 ml/min passes through this cell. The velocity of this stream is small. The air rate through each bubbler tube is approximately 20 ml/min. When \( \frac{3}{8} \)-in. stainless steel tubing is used for the bubbler tubes, this air rate corresponds to a bubble rate of approximately 30 bubbles/min. A 10-in. spacing was chosen for the bubbler tubes in order to minimize error due to mechanical positioning. With this spacing, a position error of ±0.01 in., results in a density error of 0.1%. Initial positioning was within 0.002 in., but corrosion effects increase this figure with time.

Fairly extensive tests indicated that satisfactory results could be obtained with this equipment. Temperature changes of 40°F introduced no appreciable error due to equipment changes with temperature. With the recorder zero set at 1.000 g/ml and the span set to 0.300 g/ml, the over-all precision shown by these tests was ±0.0015 g/ml. Solutions with various viscosities and surface tensions were used, and no error due to change in these properties was observed unless the viscosity exceeded several hundred centipoises. Results were checked by hydrometer measurements and cathetometer readings upon a U-tube water manometer corrected for temperature.

Research was begun on the problem of satisfactory conductance measurement and will continue into the fiscal year of 1957. A restricted area cell of the general type shown in Fig. 11 is considered most suitable for this conductance measurement. Reasons for the selection of this type of cell are:
1. large electrode surfaces and therefore low current densities at the electrodes, thereby minimizing corrosion effects and keeping the metal-solution interface resistance low;
2. liquid flow over all cell surfaces to prevent sediment formation;
3. ease in obtaining the high cell constant required, since the solution to be measured will have a conductance as high as 500,000 \( \mu \)ohms/cm²;
LIQUID DENSITY = \( \rho \)
\[ \rho_2 - \rho_1 = \Delta \rho \]
\[ \rho = \rho_0 + \frac{\Delta \rho}{\rho_0} \]
\[ \rho_1 - \rho_2 = \frac{\Delta \rho}{\rho_0} \]
\[ \Delta \rho = (\rho_2 - \rho_1) \frac{\Delta \rho}{\rho_0} \]
\[ \sigma = \frac{\Delta \rho}{\rho_0} \]

THIS IgNORS
\[ \sum \Delta y = \text{sURFACE TENSION EFFECTS ON THE FORMING BUBBLE} \]
\[ \sum \Delta \rho = \text{BUBBLE DEPTH EFFECTS SINCE FOR EQUAL BUBBLE RATES THROUGH EACH TUBE THESE FACTORS CANCEL} \]

**Fig. 10. Dip Tubes — Theory and Error Contributions.**

4. Good dimensional stability of the liquid resistors formed by the nonconducting tubing; and
5. the ability to enclose such a cell completely in metal with the exception of one Teflon-coated lead wire through a Swagelok bushing.

Effectively, the process piping becomes one electrode of the cell which is held at ground potential. The two fluorothene tubes form liquid resistances connected to the center electrode. The conductance of this network is directly proportional to the sum of the weighted ionic concentrations in the solution.

Tests on salt and salt-acid solutions gave good reproducibility of results for this type of cell. Checks of the cell constant of the prototype during several weeks of tests gave 37.6 ± 0.2, indicating good electrical and mechanical stability.

An operating prototype of the complete sampling system was constructed and laboratory tested.

**Fig. 11. The Conductance Cell.**
A FACTOR AFFECTING THE COUNT RATE OF THE WINDOWLESS GAS-FLOW PROPORTIONAL COUNTER

R. E. Zedler

Many radioactive samples whose alpha and beta activities are measured in the Borkowski-type methane-gas-flow proportional counter$^1$ are deposited on a 2-in.-dia stainless steel plate to within $\frac{1}{8}$ in. of the edge of the plate. It is therefore important that the count rate be independent of the sample location over the $\frac{3}{4}$-in.-dia area on which it is likely to be deposited. This condition is normally achieved with less than 2% variation in count rate in newly assembled or reassembled counters. With continuous use, however, this independence disappears.

To check the count-rate dependence on sample position, a plutonium source uniformly plated over a $\frac{3}{4}$-in.-dia area centered on a 1-in.-dia platinum dish is used. With the voltage set at the operating point on the plateau, a count is taken with the dish at the center of the 2-in.-dia depression in the slide. Another count is taken with the dish $\frac{1}{2}$ in. to the left side of the center position (and wire). The counter is considered acceptable if the counting rate does not decrease by more than 2% when the sample is moved from the center position to the left side position.

It has been observed that after the counter has been operated for several months the counting rate difference between the two source positions will exceed 2% (often 5%), the center position absolute counting rate remaining unchanged.

It was found that this change can be simulated by applying a thin film of silicon grease to each end of the wire over a $\frac{1}{4}$-in. length. For this condition the center-position count rate is normal but the left-position count rate is low by 3.6%. When the grease film is applied to the full length of the wire, the center position count rate is 4.6% below normal and the left-position count rate is 3.4% below that at the center. By diligently cleaning the wire with alcohol, the counting rates can be restored to their proper values.

The results of the tests indicate that something accumulates on each end of the wire during counter operation. Because the wire passes diametrically through the cylindrical counter cathode, the potential gradient at each end of the wire is greater than at the center; precipitation preferentially occurs at the wire ends. The coating is a very thin film since its presence could not be observed, even with a microscope. Counters unusable because of low left-position count rates could be restored by vigorously cleaning the wire with alcohol. However, replacement of the center wire is preferred to cleaning.


DIFFERENTIAL-PULSE-HEIGHT DISTRIBUTION OF BF$_3$ NEUTRON COUNTERS

R. E. Zedler

The $^{10}\text{B}(\alpha,\alpha)^7\text{Li}$ reaction utilized in the detection of thermal neutrons proceeds either to the $^7\text{Li}$ ground state or excited state.$^1$ There is a $5.8 \pm 0.1\%$ probability that the reactions go to the ground state. In this event the sum of the particle energies is $2.793 \pm 0.027$ Mev. The remaining reactions are excited-state processes, the sum of the particle energies being $2.320 \pm 0.020$ Mev, plus the emission of a 0.48-Mev gamma ray.

Both energy groups were observed during the course of studying the aging effects$^2$ in BF$_3$-filled, $\frac{1}{2}^2 \times 29$ in. aluminum counter tubes. When the differential-pulse-height distribution curves had resolutions for the 2.32-Mev peak of 10% or less, the 2.79-Mev peak was clearly defined. Assuming the major peak to be equivalent to 2.32 Mev, the average value of the high-energy peak


for seven determinations made on counters with resolutions for 6 to 9.5% was 2.82 Mev. The percentage of high-energy reactions was between 5 and 6% as determined from the areas under the peaks. Figure 12 shows a typical differential-pulse-height distribution curve for an aluminum 73-cm, B10F3 proportional counter having a 9.5% resolution, an inside diameter of 15/16 in., a wire diameter of 0.003 in., a length of 19 in., and a voltage of 2100. The electronic equipment included an A1A preamplifier, a Q-1151 A1-D differential and integral linear amplifier (gain = 24, beam width = 0.5 Mc, slit width = 1 v), a Q-1256 linear count rate meter, and a 10-mv Brown recorder with a chart drive potentiometer.

For counters having 1 to 15% resolutions the 2.79 peak is perceptible but not well defined. For resolutions greater than 15% the high-energy peak is indefinable, existing only as a "plateau" region.

The differential-pulse-height distribution curves were determined with a single-channel analyzer system, the count-rate information being continuously plotted on a 10-mv Brown recorder. Because of time lags and variations in statistical errors inherent in such a measuring system, the high-energy peak and reaction probability values are only approximate, but compare favorably with those measured by more precise methods.1

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**HIGH-VOLTAGE INSTRUMENTATION**

**MILLIMICROSECOND NEUTRON SPECTROMETRY**

R. F. King

An ion-source beam pulser was reported previously.1 This instrument used a sine wave of radio frequency at 0.5 Mc applied to deflector plates near the ion source to produce two short bursts of ions per cycle near the zero axis of the sweep voltage. It was found that the positions of these two bursts at the target were not precisely identical. This reduced the effectiveness of postacceleration clipping.

A device to correct this condition, the alternate pulse eliminator, was constructed and installed. In this system, a signal is taken from the main deflection oscillator and shifted in phase approximately 90 deg, then converted to a constant-amplitude 475-v square wave. The square wave is then applied to one of a pair of deflector plates that are placed below the main deflector plates and displaced 90 deg in the horizontal plane from them. When properly phased, the voltage on the lower plate is zero on one traverse of the beam across the aperture. This allows a burst of ions to enter the accelerator tube. On the next traverse the lower deflector plate potential is great enough to prevent the beam from entering the aperture. Since it is desirable to maintain the pulse rate at one per μsec, this now allows the oscillator frequency to be raised from 0.5 to 1.0 Mc/sec. This higher frequency makes production of shorter pulses possible, and, since all the pulses are now alike, they can be clipped to better advantage.

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The decade scaler has been continuously improved from the standpoint of mechanical construction and circuit design and is currently in a form that should make it useful for general laboratory use.

The basic design is similar to the decade scaler previously reported\(^1\) in that the scaler proper consists of a fast input decade, then two, three, or more slow decades. The first decade is the 6700 beam switching tube (previously known as the Burroughs MO-10) which has a resolving time of less than one \(\mu\)sec for paired pulses. The circuitry for this stage has been improved to allow two tubes to be eliminated with no loss of reliability or resolving time. The slow decades are Ericsson GC-10B glow-transfer tubes, each driven by a 1AG4 subminiature tube that is d-c coupled to the glow tube. This drive circuit is similar to one designed by F. M. Porter \textit{et al.} for use in a multichannel analyzer.\(^2\) The power consumed in this drive circuit is very low and the tube life is long, representing an improvement over the old a-c coupled univibrator-type driver.

In addition to the scaling stages, the basic instrument has a Schmitt trigger input to allow the input waveform requirements to be noncritical. The last glow-tube stage is followed by a pulse shaper, register driver, and a six-digit mechanical register. The instrument contains regulated power supplies.

Along with the circuit improvements, a great improvement has been made on the layout and mechanical design features of the instrument. These improvements are due primarily to the efforts of G. A. Holt and C. L. Haley of the Instrument Construction Section. The type of construction is semimodular in nature, permitting small variations in the basic circuit to be made easily. For example, an amplifier suitable for proportional counting may be used at the input instead of the Schmitt trigger. Or, when a suitable known pulse is to be used with the scaler, a simple input stage may be used. In addition, the number of glow-tube stages may be varied from two to six and a mechanical register may or may not be included, depending on the needs of the user. Other special features have already been incorporated into the basic scaler and additional variations are planned for the future.

As previously mentioned, the fast decade has a resolving time of less than 1 \(\mu\)sec and is capable of operating as fast as 1 Mc/sec on a uniform wave or series of pulses. The usual GC-10B stage has a practical upper limit of approximately 5 kc. The resolving time of the first GC-10B for random pulses presents a different problem. However, the problem is not serious because of the smoothing effect of the fast decade. When the scaler was tested with random input pulses from a proportional counter, with a counting rate of 10,000 counts/sec, no measurable loss was found that was due to the GC-10B. There was a loss of less than 0.2\% with a rate of 20,000 counts/sec.


ORNL APPLICATIONS OF MAGNETIC MEMORY CORES

T. L. Emmer  N. W. Hill

Present-day nuclear experiments require ever-increasing speed, accuracy, reliability, and capacity in the pulse-height and time-of-flight spectrometers used in the measuring systems.

A major part of a multichannel analyzer is the storage section, and the present trend is toward the use of small, ring-shaped ceramic cores of manganese-magnesium ferrite as the basic storage element. These cores, shown in Fig. 13, exhibit the following magnetic properties: square hysteresis loop, low coercive force ($H_c$), and high remanent flux density ($B_r$). As a result of these properties, the cores have the ability to store binary information. Their small size, combined with the speed and ease with which information can be transferred to and from the cores, makes them ideally suited for their intended purpose. The Laboratory has instituted a program involving the design, construction, and purchase of instruments using ferrite-core storage elements. The program is proceeding with the following schedule:

1. purchase of two 256-channel pulse-height analyzers of Argonne National Laboratory design for the Bulk Shielding Facility,
2. design of a 256-channel time-of-flight spectrometer for the LITR (A 256-channel magnetic

Fig. 13. 10,000 Ferrite Memory Cores.
core memory is being purchased for this instrument.),
3. design and construction of a core tester to automatically test and select good cores for memories,
4. design and construction of a 2048-channel time-of-flight spectrometer to be used at the ORR facility,
5. design and construction of punched tape output equipment for all these instruments in order that the Oracle can be used for automatic data reduction.

COINCIDENT CURRENT MEMORIES

A coincident current memory can be constructed from a core by inserting three wires through the core as shown in Fig. 14. Consider that the core has been previously saturated by a negative magnetizing force. The core then has a remanent flux density of $-B_r$ and is said to be in the "zero" state. If the core is pulsed by a current $+Im/2$ in magnitude on either the X or Y drive, the magnetizing force ($Hm/2$) produced will cause the remanent flux density in the core to change from $-B_r$ to $+B_r$, generating a small output voltage (zero) on the sense winding. But if both the X and Y drives are pulsed simultaneously with currents of $Im/2$, the total magnetizing force ($Hm$) is sufficient to switch the core from the $-B_r$ "zero" state to the $+B_r$ "one" state, and a large output voltage (one) is generated. Continued application of magnetizing forces of $Hm$ will generate a small output (zero) since the core is already in the "one" state. Thus a core can be sensed by coincidence currents to determine the state of the core.

A plane of cores can be constructed by threading the X and Y drive and sense winding through a square array of cores. Such a plane is shown in Fig. 15. The planes can be stacked to produce a cubic matrix such that the X and Y drive will sense the outputs of a $x$ column of cores. A memory system composed of a cubic matrix of this type is capable of storing a large volume of information reliably and has a short access time to any part of the information.

Not every core supplied by the manufacturer has acceptable electrical characteristics. In order to grade the cores, a core handler and tester was designed and is now under construction. This device operates at a rate of three cores per second, automatically sorting them into three bins according to electrical performance. The logic for the electronic portion of this tester is shown in Fig. 16. The assembly is shown in Fig. 17.

256-CHANNEL TIME-OF-FLIGHT SPECTROMETER

The controls for a 256-channel time-of-flight spectrometer have been designed and are now

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Fig. 14. Coincidence Current Core Circuit.
Fig. 15. 32 by 32 Magnetic Core Memory Frame.
under construction. A 256-channel magnetic core memory for this spectrometer was purchased, and the entire unit will be installed at the LITR before January 1957.

The control features of this instrument are:
1. 256 channels with a storage capacity of about 65,000 counts per channel,
2. a selection of 1/2, 1, 2, 4, or 8-μsec time channels,
3. a range of 0 to 1023 channels divided into 8 blocks of 128 channels each (Data can be analyzed in any 2 of these 8 blocks at one time.),
4. two detectors that can be used simultaneously – each detector commanding 128 channels,
5. a linear oscilloscope display that monitors the information in the memory,
6. the information in the memory can be recorded by an analogue printout accurate to 1%, a decimal printout, or a punched-tape printout.
The model Q-1212 mercury relay pulse generator was redesigned to increase its usefulness. One of the attractive features of the original instrument was its small size of 5 x 6 x 9 in. These dimensions were retained in the new model. A front view of the instrument is shown in Fig. 18. The circuit diagram is shown in Fig. 19. The electrical specifications are as follows:

- **Pulse shape** — A fast rise of less than 7 μsec, followed by an exponential decay. If both output terminals are terminated with 100-ohm resistors, the decay has a time constant of 300 μsec. If only one is terminated, the decay has a time constant of 600 μsec.

- **Pulse polarity** — Either positive or negative.

- **Repetition rate** — 60 PPS.

- **Termination** — At least one of the output terminals must be terminated with a 100-ohm load.

- **Output voltage** — A maximum of 5.0 v ± 2% can be obtained from the attenuated output terminal when it is terminated with a 100 ± 1 ohm resistor. A maximum of 10.0 v ± 2% can be obtained from the direct output terminal under open circuit conditions. If terminated with a 100 ± 1 ohm resistor, this voltage is divided in half. Loading one terminal has no effect on the output voltage of the other.

- **Internal impedance** — 100 ± 1 ohm at either output terminal.

- **Controls** — The relay switch turns the relay off without turning the power supply off. The pulse height control adjusts the output level. This control has a linear calibration, the linearity being accurate to ±0.1% of the full scale value. The attenuation factor switches attenuate the signal appearing at the attenuated output terminal. The normalize control varies the output from the pulse height control over a 3:1 range. This control has a nonlinear calibration.

- **Stability** — One of the major goals of the design was to obtain an extremely stable instrument. The circuit that was chosen results in a minimum of heat dissipation. The measured temperature rise above room temperature at the pulse height control is only 13°C. Low-temperature-coefficient wire-wound resistors were used at all points in the power supply where the noise and stability of the resistors are of importance. The attenuator in the signal line uses metallized film resistors. With a regulated power line in a temperature-controlled laboratory, a 100-hr stability test was performed on the generator power supply. A continuous recording of the output voltage showed two components — a long-period variation which will be called “drift,” and a short-period variation which will be called “noise.” The peak-to-peak drift measured 0.022% with a mean drift of 0.01%. At no time did the drift rate exceed 0.005% per hour. The peak-to-peak noise observed during a 2-hr portion of the test was less than 0.005%. It should be pointed out that the pulse height control is wound with 4000 turns of wire, resulting in an ultimate resolution of 0.025%. The peak-to-peak variation in the generator supply during the test was less than the resolution of the output control. A typical 2-hr portion of the test recording is
Fig. 19. Circuit Diagram of Mercury Relay Pulse Generator.
shown in Fig. 20. The ordinate refers to an output level of 5 v.

An attempt was made to determine the noise introduced by the relay and the output attenuator under actual operating conditions. To do this, the generator was used as the signal source in a high-resolution alpha energy analyzer. With the pulse height and normalize dials set for maximum output and with the attenuator switches set for maximum attenuation (these settings correspond to the condition of maximum possible generator noise), the pulse-height distribution curve was observed to be approximately Gaussian with a full width at half maximum of 0.1%. The test was repeated with the attenuator switches set for no attenuation and with the pulse height control set near minimum output (corresponding to the least noisy settings). No detectable change was observed in the pulse-height spectrum. A separate set of measurements on the spectrometer indicated that the measured pulse-height distribution was due to noise in the spectrometer and not to generator noise.

Since the generator was designed to be operated from a regulated power line, a simple, medium-gain voltage regulator circuit was used in the power supply. A sudden change in line voltage of 10% produces a sudden change in generator output level of approximately 0.25%. Within a few seconds, the change in cathode temperature of the Z729 tube reduces this value to less than 0.05%.

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**Fig. 20. Short-Time Stability of Model Q-1212C Pulse Generator.**

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**MOBILE AIR MONITOR Q-1740**

J. V. Francis  
W. S. McBee

The mobile air monitor Q-1740 is a revision of the Q-847. The instrument is used for air-contamination monitoring in critical locations where long-period continuous operation is required.

This instrument includes a logarithmic-count-rate meter, model Q-1454B, to replace the linear-count-rate meter used in previous models. This revision eliminates the range-changing mechanism with its attendant maintenance difficulties. By using this system, any background level that is within the range of the instrument can be suppressed, and from one to five decades may be selected for display on the strip-chart recorder. This scale arrangement allows the instrument to accumulate air-contamination data while operating in areas where the background count is high.

A model H Leeds & Northrup Speedomax recorder provided with upscale, downscale, and setpoint alarms is used to replace the previously used Esterline-Angus graphic milliammeter. The alarms indicate high radiation, instrument failure, and above-tolerance radiation, respectively.

Air flow to the detector is furnished by a Roots-Connersville positive-displacement pump controlled by a bypass valve in the vacuum line, replacing the pump-speed-changing mechanism in previous models.

The alarm circuit is so arranged that an instrument failure or very high radiation conditions, an alarm bell and a red annunciation light are
actuated simultaneously. If the air contamination increases to a point above the setpoint, a yellow annunciator light, indicating tolerance level, is actuated. The annunciator lights are mounted on top of the instrument cabinet so that operation of the monitor can be observed from any position in the immediate area.

The cabinet is constructed in two sections to facilitate the removal of the electronic portion of the instrument without the burden of the lead detector shield or air pumping equipment. Lugs for attaching a lifting chain or hooks to the dolly are located inside the frame so that the dolly may be crane-handled only after the instrument cabinet has been lifted off its base.

The large rubber-tired wheels permit the moving of the equipment with greater ease and safety than with the casters provided on the original model.

Figure 21 is a view of the mobile air monitor showing the cabinet and control arrangement.

Fig. 21. Mobile Air Monitor, Q-1740.