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ORNL-4990

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Instrumentation and Controls Division

Annual Progress Report

FOR PERIOD ENDING SEPTEMBER 1, 1973

Non-LMFBR Programs

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy $5.50; Microfiche $2.25

ORNL-4980
UC-37 – Instruments

Contract No. W-7405-eng-26

INSTRUMENTATION AND CONTROLS DIVISION

ANNUAL PROGRESS REPORT

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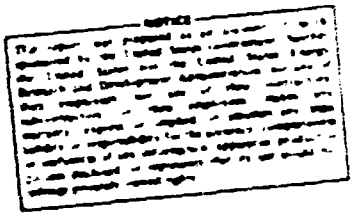

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C. A. Mossman, Head, Section B, Process Instruments

Compiled and Edited by G. S. Sadowski

AUGUST 1976

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Reports previously issued in this series are as follows

ORNL-714	Period Ending April 15, 1950
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ORNL-1021	Period Ending January 20, 1951
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ORNL-4620	Period Ending September 1, 1970
ORNL-4734	Period Ending September 1, 1971
ORNL-4822	Period Ending September 1, 1972

Foreword

The role of the Instrumentation and Controls Division in the activities of the Laboratory is one of wide diversification and covers many technical disciplines. A major function of the Division is to provide professional service for the design, development, procurement, fabrication, installation, testing, and repair of many kinds of instruments. Another effort of the Division deals with instrumentation systems that protect or control complex processes, such as chemical plants and nuclear reactors. This requires an understanding of the kinetic behavior of the processes during both normal and abnormal conditions. Thus, part of the work of the Division is directed toward the analysis and evaluation of the dynamic behavior of large plants and facilities. It is only natural that the Division is participating in the preparation of standards and criteria for instrumentation systems for the control and protection of nuclear reactors.

Our purpose in this report is to describe the work we did — not how we did it. Since instrument services are provided for almost all Laboratory divisions, we describe the scope of the work and its range of complexity from very simple components to complex, sophisticated systems. We hope that from this information our scientific readers at the Laboratory will have a better understanding of the technological level and capability of this Division and perhaps will obtain some ideas on how some application described herein might be beneficially applied to other experimental work. Another purpose of this report is to announce new or improved designs of instruments, new methods of measurement, accessories, etc., which represent a lower cost or improved performance over an existing unit or are noteworthy for some other reason, such as extending the range of application.

Most topics are reported briefly in only one or two paragraphs. If a report or a journal article has been published or submitted for publication or if a paper has been given or proposed, the abstract is included here. We hope that interested readers who desire more information on any topic will call or write any of the persons whose names are listed with each topic.

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8. PROCESS INSTRUMENTATION AND CONTROL

1. Pulse Counting and Analysis

1.1 APPLICATIONS OF POSITION-SENSITIVE PROPORTIONAL COUNTERS TO NEUTRON AND X-RAY SCATTERING EXPERIMENTS[1]

C. J. Borkowski M. K. Kopp

The authors review the characteristics of position-sensitive proportional counters (PSPC) with RC line signal encoder[2] and discuss some applications of one- and two-dimensional PSPCs to neutron and x-ray scattering experiments.

Compared to other methods, the RC line signal encoding method features relative simplicity in construction and operation and flexibility in design. Furthermore, these PSPCs show good spatial and energy resolutions, high data acquisition rates, and good detection efficiency for low-energy (<150 keV) gamma or x rays and thermal neutrons.

The spatial uncertainty with a 200-mm-long, one-dimensional PSPC is 0.15 mm (fwhm) for 6-keV x rays or 5-MeV alpha particles. For thermal neutrons, the spatial uncertainty is 0.4 mm (fwhm) with a 500-mm-long, one-dimensional PSPC. A two-dimensional PSPC with a sensitive area 200 by 200 mm^2 has 40,000 resolution elements, each 1 by 1 mm^2. The energy resolution is 760 eV (fwhm) for 6-keV x rays.

In recent work the authors have extended the data acquisition rate by reducing the signal processing time to 0.5 μsec/event while maintaining excellent spatial resolution.

---

1 Abstract of invited paper presented at Third International Congress on X-Ray and Neutron Small-Angle Scattering, Grenoble, France, Sept. 5–7, 1973.

2 C. J. Borkowski and M. K. Kopp, *Rev. Sci. Instrum.* 39(10), 1515 (1968).

1.2 RECENT DEVELOPMENTS AND NEW APPLICATIONS OF POSITION-SENSITIVE PROPORTIONAL COUNTERS USING RC LINE SIGNAL ENCODING[1]

C. J. Borkowski M. K. Kopp

The authors review position-sensitive proportional counters (PSPCs) using RC line signal encoding[2] and compare this method with other PSPC signal processing and construction methods.

In recent work the authors extended the practical limits on spatial uncertainty and count rate capability. For example, the signal processing time of one-dimensional PSPCs using RC line signal encoding was reduced to 0.5 μsec/event while maintaining excellent spatial resolution.

The advantages of RC line signal encoding were illustrated by applications of one- and two-dimensional PSPCs in various scientific fields.

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1 Abstract of invited paper presented at the *IEEE Nuclear Science Symposium, San Francisco, California, Nov. 14–16, 1973.*

2. C. J. Borkowski and M. K. Kopp, *Rev. Sci. Instrum.* 39(10), 1515 (1968).

1.3 SURGE CURRENT PROTECTION CIRCUIT FOR PROPORTIONAL COUNTERS

M. K. Kopp

A high-voltage filter for the anode bias in two-dimensional position-sensitive proportional counters with RC line signal encoder[1] was developed and tested. The filter provides the required low anode impedance (~100 Ω) for high-frequency signals and a high anode impedance (5 MΩ) for the bias supply voltage under normal operating conditions.

Under anode breakdown conditions, the diode (Fig. 1.3.1) disconnects the capacitor C_3 from the anode, thus limiting the surge current in the anode circuit and preventing destruction of the anode wires.

1. C. J. Borkowski and M. K. Kopp, *IEEE Trans. Nucl. Sci.* NS-19(3), 161 (1972).

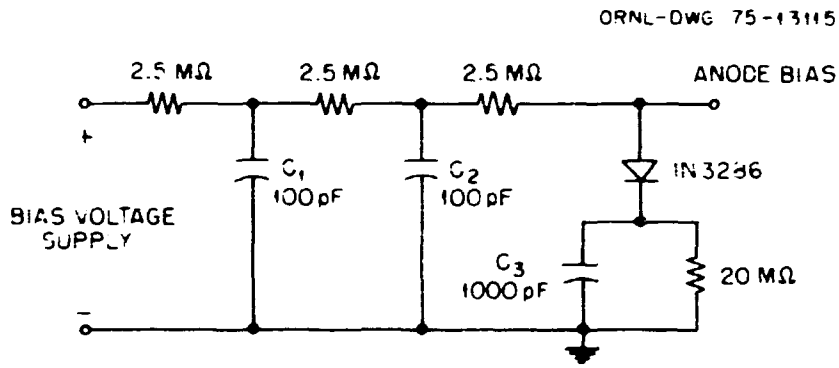

Fig. 1.3.1. Surge current protection circuit.

1.4 APPLICATION OF FLY'S EYE CAMERA TO DETERMINE THE EQUATION OF STATE OF XENON NEAR THE CRITICAL POINT

J. B. Davidson

A. L. Case S. H. Chen[1] T. A. Postal[1]

A new method proposed by Chen for determining the equation of state of xenon near the critical point requires measurement of the density gradient vs temperature along a vertical cell containing xenon near the critical point. If this measurement could be made to 0.1% accuracy, the equation of state could be determined with better accuracy than achieved with previously used thermodynamic methods.

Chen's method requires measurement of the neutron transmission along the cell with a position resolution of about 0.1 mm. A preliminary experiment was performed at the Oak Ridge Research Reactor (ORR) to determine the feasibility of this new method. The experimental apparatus was the ORNL Fly's Eye neutron camera and a cell and temperature controller designed at MIT.

Although the data obtained from this short experiment were rough, the liquid-gas interface was clearly seen, with sub-millimeter resolution. We concluded that the method is practicable and that a longer, more carefully executed experiment could yield the desired data. Such an experiment is being planned.

1. Nuclear Engineering Department, Massachusetts Institute of Technology, Cambridge.

1.5 NEUTRON MICROSCOPY OF SPIN DENSITY WAVE DOMAINS IN CHROMIUM[1]

J. B. Davidson S. A. Werner[2] A. S. Arrott[3]

The ORNL Fly's Eye neutron camera[4] has a resolution for images on the detector of about 150 μm (horizontal) and 500 μm (vertical). The system uses a scintillation screen of ^{6}LiF–ZnS, fiber optics, an image intensifier, a television camera, and a digital memory. In this study of the domain structure of two chromium crystals, the geometry of the incoming beam, crystal mosaic, and the required distance from sample to detector gave an overall resolution of 400 μm (horizontal) and 600 μm (vertical). This resolution provides clear images of the domains of a given **Q**-vector which are comparable to the crystal size (Fig. 1.5.1).

The polarization axis has been seen to vary continuously across the $\mathbf{Q}_2$ domain. This result is consistent with the neutron camera results given by Ando and Hosoya[5] and interpreted as large polarization domains.

1. Abstract of paper accepted for presentation at the 19th Conference on Magnetism and Magnetic Materials, Boston, Nov. 13–16, 1973.
2. Ford Motor Co., Dearborn, Michigan, and University of Michigan, Ann Arbor.
3. [illegible] University, Burnaby, B.C., Canada.
4. J. B. Davidson, *Acta Cryst.* A25, S66 (1969), and to be published.
5. M. Ando and S. Hosoya, *Phys. Rev. Lett.* 29, 281 (1972).

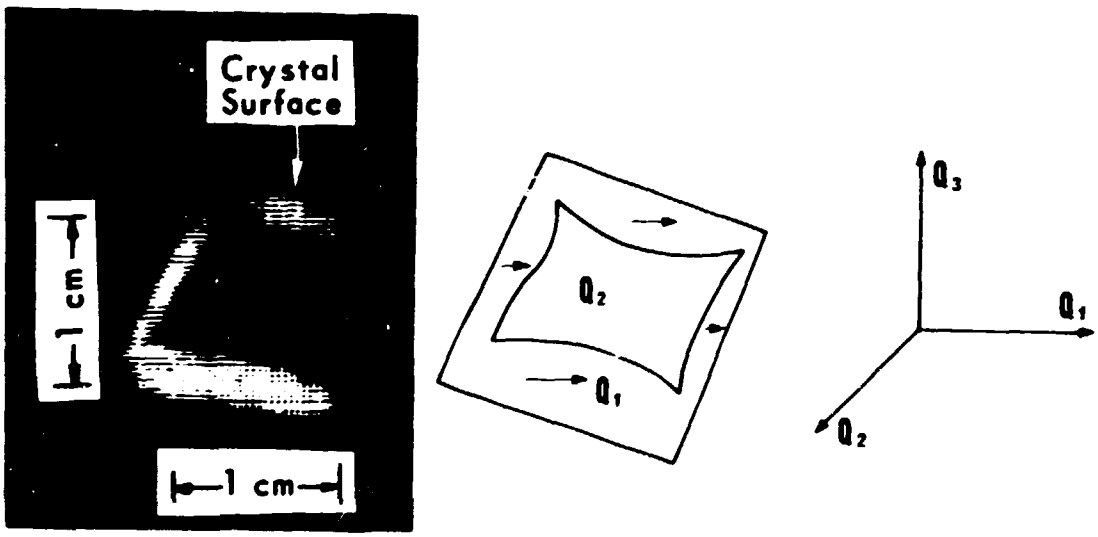

Fig. 1.5.1. Domain structure of chromium chrystal.

1.6 FLY'S EYE: A COUNTING CAMERA FOR THERMAL NEUTRONS[1]

J. B. Davidson

A two-dimensional position-sensing detector for thermal neutrons was developed to improve data collection in single-crystal neutron diffraction experiments, small-angle diffraction patterns from fibers and membranes, inelastic scattering measurements using the multiangle reflection crystal technique, nuclear and magnetic diffraction topography, and diffraction and transmission measurements on samples in which phase

changes are occurring. The detector is a unique tool for rapid inspection of crystal quality, isolating grains, and alignment of a number of small crystals so that they reflect together for intensity enhancement. Simple diffraction experiments were made to illustrate the range of application.

The detector is a camera that comprises a neutron phosphor screen, image intensifier, television pick-up tube, and digital storage. The detector is operated in a counting mode rather than in the more usual integrating mode; that is, the coordinates of single events derived from the television scan address a two-parameter pulse-height analyzer, and the events are summed in a digital memory. The stored information can be displayed in one- and two-dimensional formats and transferred to magnetic tape for computer analysis.

The camera resolution is 0.13 mm fwhm horizontal and 1.0 mm vertical, which will detect more than 80,000 detector elements over the useful area of the 150-mm-diam phosphor screen. The inherent capability is several times this number. The counting rate per detector element is 60 regularly occurring events per second. The counting efficiency, which depends on the phosphor thickness, is ~15% for a 0.5-mm phosphor.

---

1. Abstract of paper submitted for publication in the *Journal of Applied Crystallography*.

2. Support for the Thermonuclear Division ORMAK Project

2.1 MICROWAVE REFLECTOMETER FOR ORMAK[1]

D. D. Bates

A microwave reflectometer was designed and fabricated by equipping it with a pulsed radar unit from a previous experiment. Since above $10^{12}/cm^3$ density in the plasma the 40-GHz microwave signal is totally reflected, it is a source of data that enables researchers to follow the horizontal movement of the plasma. The reflected signal is mixed with the attenuated forward signal in a hybrid ring and then detected by a diode detector.

Although the prototype system worked well in an experimental setup, where a modulated metal speaker cone reflected the signal, there were not enough data points from the pulsed radar signal to allow researchers to follow the fast movements of the plasma during an ORMAK shot. Future experiments are planned for the reflectivity type measurements, using various frequencies and possibly swept frequencies of the microwave source.

---

1. G. G. Kelley et al., "The ORMAK Program," p 18 in *Thermonuclear Div. Annu. Progr. Rep. Dec. 31, 1971*, ORNL-4793.

2.2 ZEBRA-STRIPE MICROWAVE INTERFEROMETER FOR ORMAK

D. D. Bates J. F. Clarke[1]

With the interferometer system reported previously,[2] unambiguous line density measurements of the plasma were obtained for all ORMAK experimental shots. The basic 140-GHz system was expanded so that two measurements could be made simultaneously through the plasma.

Four channels of microwave plumbing were completed to the new ORMAK liner, including four sets of two horns that were electroformed and fabricated by the ORNL Fabrication Department. By switching the two available sets of electronics between the four sets of horns on two consecutive and identical shots, four channels of information were obtained to determine the density profile of the plasma. Also, data from the four channels were interpreted as a function of time to determine the horizontal movement of the plasma during a shot. Casters were designed and installed on the electronic cabinets so that they could be quickly switched to the desired channels between shots.

In the future, the interferometer system will be improved if it is possible to operate two sets of horns from one klystron rather than by duplicating each channel. If this is not feasible, then an attempt will be made to multiplex the channels by switching the output from the klystron among the sets of horns. As the complexity of the interferometer increases, data handling of the zebra-stripe system will become more cumbersome and better techniques for handling the data will be needed. One possible solution will be to

operate the klystron at a fixed frequency (the klystron is swept in the zebra-stripe system), determining the sine and cosine of the shifted signal and electronically counting the number of 2π shifts as the plasma increases or decreases.

1. Thermonuclear Division.
2. D. D. Bates, "Zebra-Stripe Microwave Interferometer for ORMAK," p. 13 in *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL 4822.

2.3 HIGH-ENERGY PULSER

D. D. Bates

A high-energy pulser was developed to operate a fast gas valve[1] to "puff" a given amount of gas into the liner of ORMAK. The pulser receives a timing pulse from the ORMAK control room and, through triggering circuits, fires an ignitron to discharge a 2400-μF capacitor through the valve coil. With 400 V on the capacitor, the valve operates in microseconds to allow a puff of gas to pass into the liner; the amount of gas is determined by the pressure to the valve. The charging circuits recharge the capacitor to a selected voltage between ORMAK shots.

1. Gas valve obtained from Lawrence Radiation Laboratory.

2.4 FAST ION GAGE

D. D. Bates

A VECO model RG-830 ionization gage control was purchased for the nude ionization gage in the liner of ORMAK. The gage control was modified so that it would be compatible with existing control circuits and respond to the fast pressure changes that occur during an experiment. The output was altered to respond to 1-msec changes that could be monitored with a commercial transient recorder.

2.5 SOLDERING UNIT CONTROLLER

D. D. Bates S. M. DeCamp[1]

In the past, when the copper liquid-N_2 cooling lines to ORMAK were soldered, the Kovar ceramic insulators were a major source of problems due to overheating (possibly cracking the ceramic insulator) or underheating (resulting in a poor solder joint). To achieve better control of the soldering temperature, an automatic controller for a 1-kW soldering unit was designed and fabricated. In this unit a thermopile infrared detector detects the temperature of the silver solder melt.

The detector is contained in stainless steel, thin-wall tubing and mounted in the soldering tongs in such a position that it monitors the solder melt. The output from the detector is fed through a coaxial cable to a battery-operated operational amplifier, one designed especially for this application. The output from the amplifier is connected to a set point controller which stops the power input to the soldering unit when the melted solder reaches a predetermined temperature.

1. Thermonuclear Division.

2.6 EQUIPMENT PROTECTION LOGIC SYSTEM

R. E. Wintenberg

A microwave equipment protection logic system was designed for the Thermonuclear Division ELMO Bumpy Torus Experiment.[1] The system, constructed largely of Digital Equipment Corporation logic cards, accepts low-level signals (50-mV trip levels) from 28 crystal detectors and drives combinations of five outputs. The outputs remove microwave drive power or cause crowbar action in the high-voltage power supplies. Bistable multivibrators with light-emitting diodes (LEDs) indicate which detector caused a shutdown.

1. R. A. Dandl et al., *The ELMO Bumpy Torus Experiment*, ORNL-TM-3694 (November 1971).

2.7 FERRITE SWITCH-ATTENUATOR DRIVER

R. E. Wintenberg

A microwave ferrite switch-attenuator driver was designed for the Thermonuclear Division ELMO Bumpy Torus Experiment. The driver is a high-gain, dc-coupled power amplifier with current feedback. The input is 0 to 10 V, and the output is 0 to ±2.5 A into a 20-mH, 1.3-Ω winding. The low-level circuit cards are packaged with six cards in four, three-unit-wide NIM modules, and the power stages are packaged with twelve on each of two water-cooled copper plates.

2.8 FERRITE SWITCH-ATTENUATOR TESTER

R. E. Wintenberg H. O. Eason[1]

A ferrite switch-attenuator tester, designed for the Thermonuclear Division ELMO Bumpy Torus Experiment, measures the switching speed and attenuation characteristics of a Raytheon SKuH8 ferrite switch. The tester has two power supplies and a combined mercury relay and SCR to open the coil current and to apply a large reverse potential. A crystal detector and a scope are used to measure the microwave time response.

1. Thermonuclear Division.

3. Miscellaneous Electronics Development

3.1 HYBRID MICROCIRCUIT ACTIVITIES

J. T. De Lorenzo C. H. Tucker
J. M. Rochelle E. J. Kennedy[1]
W. H. Houston H. N. Wilson

Further experience was obtained with hybrid microcircuit fabrication, and some construction practices and techniques were established. High-purity (99.5%), 2-in.-sq, 10-mil-thick alumina substrate material was purchased in a "Snapstrate" form cut to two different interior sizes. A 15,000-Å thin film of aluminum was applied to this material for conductor metallization. Artwork and etching capabilities were developed to achieve a line width resolution of 5 ± 1 mil. The registration resolution precision is ±2 mils across the 2-in. dimension of the substrate. Single- and two-component, silver-filled epoxies and electrical insulating epoxies are used for die and substrate attachment and for hermetic sealing.

An electrometer amplifier was constructed with a hybrid microcircuit and partially tested. One amplifier was installed in a new ORNL Cutie Pie instrument and is being field tested by the ORNL Health Physics Division. Another was installed in a CD V-715 survey meter for the Defense Civil Preparedness Agency. A modified electrometer amplifier with a higher open-loop gain was constructed; it is being tested as a possible replacement for the vibrating capacitor amplifier in the ORNL monitron.

Three units of each type were built to determine the relative cost and reliability of microcircuit construction. All failures of these units in service were caused by defective transistor chips. Only one defect, a damaged MOSFET, could be attributed to the assembly process. The cost (neglecting art and camera work) of constructing an amplifier with a microcircuit is comparable to that for construction from discrete components. Initial test results from both designs show that for an amplifier constructed with a microcircuit, (1) the offset current values are significantly less than those for one constructed with discrete components, (2) the peak-to-peak noise referred to the input is <2 mV, (3) there is a good uniformity of range of zero adjustment, (4) the short-term stability with a 10^{12}-Ω input resistor and a unity gain follower connection was <10 mV. Long-term stability tests were started.

Artwork for a four-transistor, wide-band pulse amplifier was completed for a thick-film circuit. The circuit design is identical to one constructed earlier with a microcircuit comprising chip resistors and a copper-clad, fiber-glass substrate. The pulse rise-times were <1 nsec with a stage having a gain of 10, and these values are anticipated after fabrication of prototypes intended for current pulse amplification of fission counters. The thick-film circuits will be constructed as a cooperative effort with the University of Tennessee, using equipment recently purchased by the University.

Additional electronic circuits utilizing the Silicon General IC breadboard were prepared for five ultrasonic fish tags[2] fabricated for the ORNL Environmental Sciences Division.

Experimental circuits containing the high impendance portion of current integrators were constructed and installed inside an ionization chamber for the Army Signal Corps.

1. Consultant, Department of Electrical Engineering, the University of Tennessee, Knoxville.
2. J. M. Rochelle, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734.

3.2 PCAP ADDITION TO ORNL 360 COMPUTER

J. T. De Lorenzo C. C. Webster[1]

The Princeton Circuit Analysis Program was added to the public disk of the ORNL 360 computer. The advantages of this program over the IBM Electronic Circuit Analysis Program[2] are that the PCAP has a more versatile output, including a printed graphic plot and an improved transient analysis algorithm that reduces execution time by allowing a longer time step for the desired accuracy. Portions of the program were tested, and the performance compares precisely with the ECAP performance.

1. Mathematics Division.
2. J. T. De Lorenzo, C. W. Nestor, and C. C. Webster, p. 43 in *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822.

3.3 GATED OSCILLATOR-AMPLIFIER FOR NEUTRON POLARIZATION

F. M. Glass J. L. Lovvorn

A variable-frequency (298 to 408 kHz) oscillator-amplifier that will deliver 1 A rms into a 370-μH inductor was designed and fabricated for the Solid State Division for experiments requiring neutron polarization. A modification of an earlier design,[1] this instrument has an automatic RF current control and a dual-range, linear, rf current output meter. An experimenter can set and maintain the output current much more accurately than possible with the older model.

1. J. L. Lovvorn, p. 26 in *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1967*, ORNL-4219.

3.4 ACOUSTIC TEMPERATURE TELEMETRY FROM SMALL AQUATIC ANIMALS[1]

J. M. Rochelle C. C. Coutant[2]

A small electronic transmitter that utilizes interval modulation of ultrasonic pulses was developed for temperature telemetry from free-ranging aquatic animals. The temperature sensor is a thermistor in the tip of a flexible appendage. The entire unit, including the thermistor, can be completely implanted in the animal's body, or the flexible appendage can be left outside the body cavity to enable internal or external temperature measurement respectively. The received signal is decoded using commercially available gear by interfacing the output of an ultrasonic receiver with a digital time intervalometer. The data can be stored on punched paper tape for later conversion to temperature by a computer.

The usable range of the transmitter extends to 500 m, and its calibration accuracy is within ±0.2°C over a range from 5 to 35°C. This calibration is maintained throughout the life of the battery. The air weight varies from 16.2 g for a transmitter with a life of 6 weeks to 37.0 g for one with a life of 60 weeks. Use of a breadboard integrated circuit enables production of a small number of units at a reasonable unit cost.

1. Abstract of paper submitted to *IEEE Transactions on Biomedical Engineering*.
2. Environmental Sciences Division.

3.5 A SIMPLE DIFFERENTIAL DISCRIMINATOR[1]

J. M. Rochelle

A circuit was designed to detect anticoincidence for single-channel analyzers that have differential comparator inputs. This circuit, with one two-input gate and three ancillary transistors, is useful where size or cost must be minimized.

1. Abstract of paper accepted for publication in *Nuclear Instruments and Methods*

3.6 MINIATURIZED LOGARITHMIC COUNT-RATE CIRCUIT[1]

J. M. Rochelle E. J. Kennedy[2]

A four-decade, logarithmic count-rate circuit with a log transistor as the feedback element in an electrometer amplifier was designed and constructed for measuring periodic or random inputs. This new design enables a much greater degree of miniaturization than possible with the conventional, parallel diode-pump configuration. Pulses of constant charge are supplied to the log electrometer by a common-base transistor current source that is driven by a stable univibrator. Frequency compensation of the electrometer is not required because of the stabilizing influence of a 0.1-μF feedback capacitor that maintains the output voltage ripple at <1 mV peak-to-peak for periodic inputs. The electrometer output changes 1 V per decade from +4 to 0 V as the average input rate increases from 10 to 10^5 counts/sec. From 0 to 50°C the total output voltage zero drift is <±10 mV, and the 1 V per decade calibration changes <±10 mV. The maximum error of the logarithmic conversion is <1% referred to the output voltage.

A figure of merit for the output response to a step change in input frequency is defined as the number of pulses required for the output to reach 90% of the difference between the initial and final output voltages. This response number is plotted as a function of the ratio of the initial and final input rates.

1. Abstract of paper submitted to *Review of Scientific Instruments*.
2. Consultant, Department of Electrical Engineering, University of Tennessee, Knoxville.

3.7 DESIGN OF GATEABLE TRANSMITTER FOR ACOUSTIC TELEMETERING TAGS[1]

J. M. Rochelle

A single-transistor class B oscillator was designed as a gateable transmitter stage for ultrasonic tags. The transmitting efficiency was analyzed by grouping the various losses into two categories: collector circuit losses to determine the collector efficiency, and load circuit losses to determine the load efficiency. The collector efficiency, 58.5% for this design, is a function of the internal battery resistance, collector saturation resistance, operating power level, and battery voltage. The load efficiency, 37% for this design, includes losses from the transformer, base circuit, and projector. The conditions for maximum power transfer were delineated, and a simple procedure for obtaining an approximate measure of projector efficiency was prepared.

1. Abstract of paper accepted for publication in *IEEE Transactions on Biomedical Engineering*.

3.8 INSTRUMENT FABRICATION

E. E. Waugh J. R. Jones C. H. Tucker

The Fabrication Shop fabricates electronic components, instruments, and assemblies, usually in small quantities, after such units are developed and a prototype is constructed by the Division Product Design

Group. The small quantities to be constructed along with the rigid construction specification are such that there is no outside commercial interest in building these units. The Fabrication Shop also assists development engineers in fabricating special new instruments. The following examples illustrate a cross section of instruments constructed:

1. Two orders were completed for construction of instrument assemblies for the Creep-Rupture Facility of the Metals and Ceramics Division. These assemblies consisted of NIM hardware modules and bins containing strain gage amplifiers, differential transformer amplifiers, and power supplies. Commercial manufacturers were unable to meet delivery dates on these assemblies.
2. New safety flux-signal conditioner modules, servo flux-signal conditioner modules, and wiring assemblies were constructed for installation at the High Flux Isotope Reactor.
3. A new ultrastable cyclic voltammeter (Q-5163) was constructed for the Analytical Chemistry Division.
4. Control amplifiers, signal conditioning units, power supplies, computer interfacing, sampling boxes, modifications to commercial instruments, and cables were fabricated, and commercial instruments were modified for a special experiment performed at ANL by the Reactor Controls Department of this Division.
5. Artwork for integrated circuits and photography for conductor printing were done for the Hybrid Integrated Circuit Facility of this Division. A prototype setup was assembled for cleaning, coating, printing, and etching substrates.

The Fabrication Shop also prepared master layouts and fabricated etched wiring boards, and printed and fabricated Metalphoto processed panels and identification tags. The layouts were made double scale, and the red and blue tape method was used to achieve absolute registrations when double-sided, etched wiring boards were prepared. Master negatives were made photographically by using colored filters and reducing the scale to full scale.

3.9 IMPROVED THERMOCOUPLE VACUUM GAGES

E. E. Waugh G. A. Holt J. W. Johnson

The thermocouple (TC) vacuum gage (Q-2254B) and TC vacuum gage and pump protector (Q-2173B) were improved by changing the hardware design so that a single unit or a combination of two units can be rack mounted by using NIM hardware. The TC vacuum gage and pump protector was also improved by replacing the old relay with a mercury relay to give a higher load capacity and longer life and by including thermal overload protection.

3.10 ALPHA OR BETA-GAMMA RADIATION MONITOR

E. E. Waugh C. C. Courtney G. A. Holt

An alpha or beta-gamma radiation monitor (Q-2277A) was developed by repackaging several NIM modules into a single, six-unit-wide, 5¼-in.-high NIM hardware module to contain a detector, high-voltage supply, count-rate meter, alarm circuit, audio circuit, and a self-contained NIM power supply. This module can be installed in a portable NIM cabinet or a NIM hardware bin. The instrument operates on 115 V ac power.

The instrument has six ranges that span 0 to 25,000 counts/min and three integrating times of 1, 11 and 21 sec. The new electronic circuit is not susceptible to maintenance problems that were associated with the optical meter relay used in the preceding model Q-2277A instrument.

3.11 AUDIOVISUAL PRESET COUNTDOWN TIMER

A. L. Case C. C. Hall

A presettable, countdown timer was developed for use at meetings at ORNL and offsite. Two displays, one for the meeting chairman and one for the speaker's podium, show the time remaining. The time can be preset from 1 to 99 min; 2 min before the end of the allotted time, a visible signal is given, and when no time remains an audible signal is sounded. The timer has TTL integrated circuits and incandescent, seven-segment numerical displays. Time data to the remote display are transmitted serially, at 60 times per second, on one wire instead of the sixteen required for parallel transmission of four BCD digits.

3.12 APPROVED WIRING DEVICES

G. A. Holt H. N. Wilson

The Division continued to assist the Laboratory program of upgrading wiring devices used in instrument construction for building wiring, and for portable tools. A pictorial ORNL Stores catalog supplement was issued in September 1972. This supplement, entitled "Standard Plugs and Receptacles for Use at Oak Ridge National Laboratory," lists approved product wiring devices that were carefully selected for usefulness and quality and that meet the ANSI-UAL and OSHA safety requirements.

This program is being checked regularly to ensure that only approved products are stocked in ORNL stores.

ANSI-UAL approved grounding outlets are being installed to enable mobile instrument vans to obtain electric power at the rear of the Instrument Laboratory Building 3500.

3.13 IMPROVEMENT OF STABILITY OF CURRENT-REGULATED SUPPLIES AT ORIC

W. E. Lingar

A study was made to determine the causes of instability in several current-regulated supplies at the Oak Ridge Isochronous Cyclotron and to propose a program for improving their performance. These supplies consist of 3 field-controlled motor generator sets (one 500 kW and two 1750 kW) and 19 series-transistor-regulated current sources. The output from the transistor-regulated supplies ranges from ~6 to 34 kW.

Measurements indicated that the supplies had not performed as desired; in particular, the long-term stability of the main field needed improvement more than a factor of 10. These measurements revealed other problems, such as electrical leakage paths to ground through the coolant hoses and oscillations in the feedback circuit of some of the regulators.

The supplies were analyzed to determine if the desired stability could be attained by using available devices and components. During the analytical tests, measurements of the inductance and resistance of many of the magnets (which are the loads for the supplies) showed that most of the larger magnets cannot be characterized by fixed values of inductance and resistance because their inductance is a function of excitation current and frequency and their resistance is a function of frequency and temperature.

The conclusion was that the supplies could be improved to achieve the desired stability, as follows: (1) replace the resistive shunt in the main-field magnet supply with a transductor to sample the output current, and (2) redesign the circuitry for the multiloop feedback systems. Stray magnetic fields in the probable location of the transductor were measured to determine how much magnetic shielding was required for the device. The other regulators, having less stringent stability requirements, can be improved by redesign of their circuits and by appropriate compensation of the feedback loops.

Since the greatest improvement of cyclotron beam stability can be achieved by improving the main-field stability, such work was begun. Design is ~90% complete, and fabrication will be started when sufficient material is received. Design and fabrication of the other regulators will begin as time, labor, and materials permit.

3.14 ION SOURCE MODIFICATIONS FOR THE TANDEM VAN de GRAAFF ACCELERATOR

J. W. Johnson G. S. Wells[1]

In response to an increased demand for heavy ions and a need for improved reliability and maintainability, the ion source of the EN Tandem Van de Graaff accelerator was modified.

A semimodule type design (Fig. 3.14.1) was selected for the vacuum pumping, support structure, and

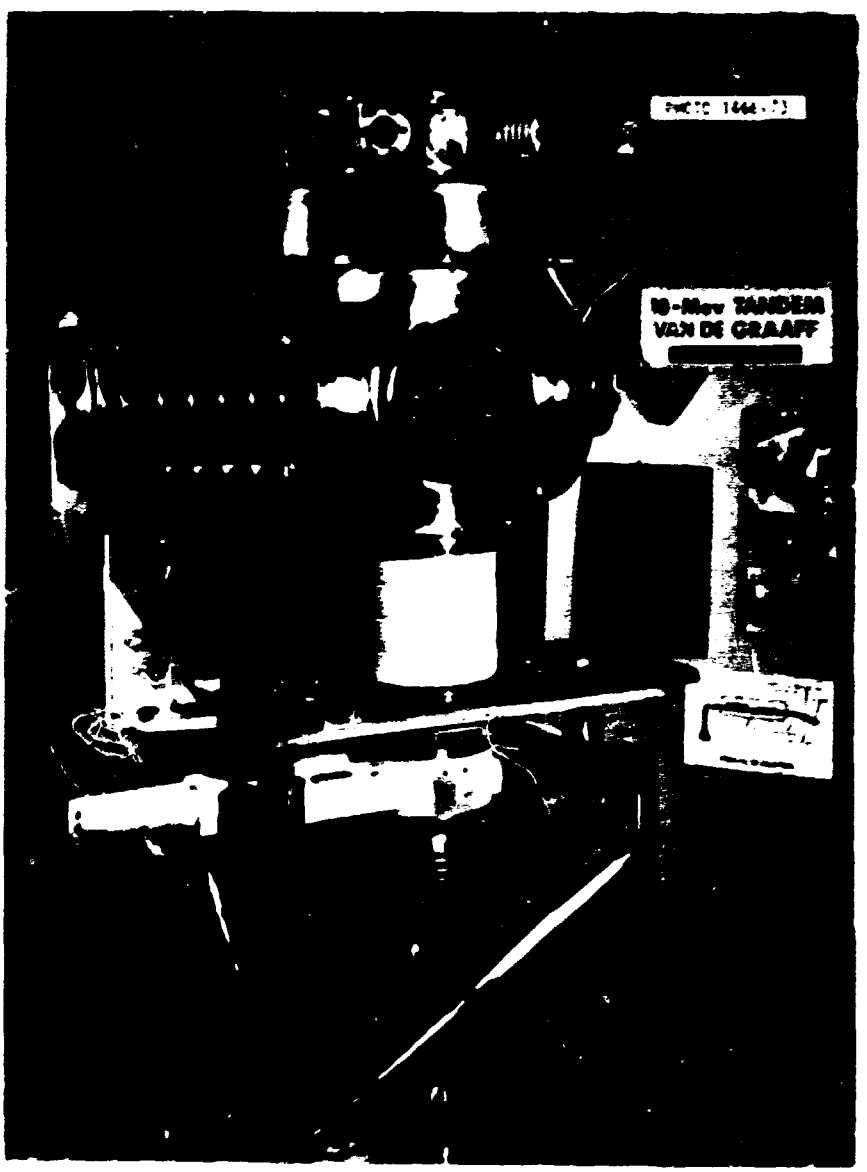

Fig. 3.14.1. Ion source module for tandem Van de Graaff.

ion-source vacuum housing so that different types of sources could be installed and maintained. Design features developed over years of use of the gas charge, exchange-type, negative-ion source were incorporated in a new lens-charge exchange structure. Commercial negative-ion sources of sputtering or discharge types were integrated into the system. A larger inflection magnet was designed and procured. The design will enable an increase of the injection energy to 100 to 125 kV for better transmission of the ion beam through the accelerator.

1. Physics Division.

3.15 HEAVY-ION SOURCE FOR THE CN VAN de GRAAFF ACCELERATOR

J. W. Johnson J. P. Judish[1] W. T. Newton[2]

To meet the needs of the CTR program for radiation damage studies using accelerated charged particles bombarding like target material, a heavy-ion source of the Nielsen[3] type was installed in the 5.5-MV CN Van de Graaff accelerator.

To make space for the ion source and related equipment, the pressure tank and high-voltage terminal were extended 6 ft. Thus, a crossed E-H field analyzer could be used to rapidly switch between two different ions from the source. The analyzer magnet was replaced with an $ME/q^2 = 36$ magnet mounted on a tracked carriage to allow room for the radiation damage target apparatus.

Radiation damage investigations using Al^+ ions and alpha particles on Al targets are in process. Other investigations using Li^+ beams were made.

1. Physics Division.
2. Former member of the Instrumentation and Controls Division.
3. K. O. Nielsen, *Nucl. Instrum. Meth.* 1(6), (1957).

3.16 REMOTE METERING ACROSS HIGH-VOLTAGE GAPS WITH LIGHTPIPES

R. P. Cumby W. T. Newton[1] G. F. Wells[2]

Voltages and currents several million volts above ground have been monitored many ways, i.e., optically with or without closed-circuit TV, rf, or radio link. Lightpipes are being used for such monitoring of the 5.5-MV Van de Graaff accelerator terminal and across a 100-kV gap in the Tandem Van de Graaff accelerator ion-source injector.

Light pulses are generated at a frequency proportional to the voltage or current being measured, the pulses are transmitted across the high-voltage gap through a lightpipe, and then they are converted to direct current which is read by a meter at ground. Linearities of the system are about ±2%.

1. Former member of the Instrumentation and Controls Division.
2. Physics Division.

3.17 IMPROVEMENTS TO TANDEM VAN de GRAAFF ACCELERATOR DRIVE MOTOR

J. W. Johnson G. F. Wells[1]

The short service life of the bearings in the drive motor and pulley generator for the charging belt of the EN Tandem Van de Graaff accelerator was analyzed. As a result, the design was changed to increase the life a factor of 5 to 10, as follows: (1) the minimum pressure of tank gas and the maximum concentration of SF_6 were preset; (2) the bearing type, seal, and lubrication were changed; (3) the fit of the bearing races in

their housings was changed; and (4) the bearing loading was changed so that there would be a thrust loading on all bearings.

The bearings now last more than 3000 hr, compared with the 200–1000 hr previous life.

[1] Physics Division

3.18 BEAM DEGRADER DRIVE

G. W. Allin B. C. Duggins H. J. Stripling, Jr.

A filter indexing drive was designed for the beam degrader assembly on the Heavy-Ion Bombardment Facility at the ORNL High Voltage Laboratory.

The drive has an eight-point Geneva indexing unit, with 2.5:1 reduction between the unit and the filter wheel so that there are 20 steps per revolution of the filter wheel. A synchronous motor drives a single-revolution, spring-wrapped clutch on the Geneva input shaft, which is set to declutch when the index drive is in the approximate center of the Geneva dwell period. A single, momentary-contact, normally open pushbutton switch is used to accurately step the filter wheel from one position to the next. A synchro-torque transmitter and receiver drive a pointer at the remote control console for position indication. This unit is operational and is performing satisfactorily.

4. Detectors of Ionizing Particles and Radiation

4.1 MULTIWIRE PROPORTIONAL COUNTERS

H. R. Brashear G. W. Allin H. O. Cohn[1]

Construction of 16 multiwire proportional counters,[2] amplifier receptacle boards, and 4 counter enclosures was completed for Physics Division participation in experiments at the 30-in. bubble chamber facility at the National Accelerator Laboratory. Design of the chamber enclosure mounting system was completed, and the system was fabricated by the University of Indiana and the University of Tennessee.

Each proportional counter has a sensitive area of 1 ft^2 that contains 156 anode wires spaced 0.0769 in. apart. Each anode wire is connected from an amplifier receptacle board to an individual amplifier and differential line driver. Signals from the amplifiers are stored in shift registers for eight beam extractions, and finally they are stored on magnetic tape.

The four enclosures are positioned in the particle beam path downstream from the bubble chamber. The first enclosure contains three proportional counters, the second and fourth enclosures contain four each, and the third enclosure contains five. Each enclosure is 46 by 54 in. and 8 in. thick; its assembled weight is 150 to 200 lb. Dowel pins in the enclosure mounting system allow removal and accurate repositioning of the enclosures for maintenance and other downstream experiments.

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1. Physics Division.
2. H. R. Brashear, G. W. Allin, and H. O. Cohn, "Multiwire Proportional Counters," p. 18 in *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822.

4.2 POSITION-SENSITIVE PROPORTIONAL COUNTERS FOR MAGNETIC SPECTROGRAPHS

R. E. Zedler

Three different Borkowski–Kopp types of position-sensitive proportional counters[1,2] were designed and built (Table 4.2.1) for the Physics Department for studies of light- and heavy-ion coulomb and nuclear excitation reactions[3–6] at the Tandem Van de Graaff accelerator and the Oak Ridge Isochronous Cyclotron. The detectors are operated in the magnetic spectrograph vacuum chambers. Since the detectors are used in the gas flow mode with a mixture of 90% Ar and 10% CH_4, the detector windows are thick enough to withstand the necessary differential pressure for particle energy absorption and proportional counting but also thin enough to allow particle entrance with minimal energy loss. The window material is Mylar film. For window widths of 1.2 cm and window thickness of 0.00015 in. and 0.00025 in., the pressure maintained in the detector is 0.33 and 0.5 atm respectively. For a 5-cm-wide and 0.0005-in.-thick window, the pressure is 0.33 atm. The Mylar windows can be changed to meet the needs of the experimenter or replaced if damaged. The detector spatial resolutions are <1 mm as used in the experiments.

Comprehensive descriptions of the principles of operation, fabrication details, use, and experimental results concerning these detectors are given in the references.

1. C. J. Borkowski and M. K. Kopp, *Rev. Sci. Instrum.* 39(10), 1515 (1968).
2. C. J. Borkowski and M. K. Kopp, *IEEE Trans. Nucl. Sci.* NS-17(3), 340 (1970).
3. J. L. C. Ford, Jr., et al., *Nucl. Instrum. Meth.* 98, 199 (1972).
4. J. L. C. Ford, Jr., et al., "States in ^{24}Mg Populated by the ^{10}B (^{16}O, *d*) and ^{12}C (^{16}O, *α*) Reactions," to be submitted for publication in *Nuclear Physics*.
5. J. Gomez del Campo et al., "Study of ^{10}B (^{16}O, α) ^{22}Na Reaction," to be submitted for publication in *The Physical Review*.
6. J. L. C. Ford, Jr., et al., "Interference Between Coulomb and Nuclear Excitation in the Inelastic Scattering of ^{11}B Ions from ^{208}Pb," to be submitted for publication in *The Physical Review*.

Table 4.2.1. Specifications of position-sensitive proportional counters

	Proportional counter types		
	1	2	3
Effective length, cm	20	60	60
Width, cm	1.1	1.2	5
Depth, cm	0.35	0.5	0.5
Anode diameter, in.[a]	0.001	0.003	0.003[b]
Window thickness, in.	0.00015	0.00015	0.005
Window thickness, in.	0.00025	0.00025	
Window thickness, in.	0.0005		

[a]Pyrolytic carbon coated quartz.
[b]Three are used.

4.3 GAS DISCHARGE RECYCLING IONIZATION CHAMBER

J. M. Rochelle

Research studies of a recycling ionization chamber, which uses a neon-argon glow discharge as its charge dumping mechanism, were continued for the Defense Civil Preparedness Agency.[1-4] The effects of gas mixture and pressure on the uniformity and magnitude of the charge dumped per cycle were investigated experimentally. The effects of external circuits, particularly the parallel capacitance and power supply ripple, were also studied.

1. J. M. Rochelle, "Evaluation of the Integrating Pulse Discharge Ionization Detector," p. 20 in *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1969*, ORNL-4459.
2. J. M. Rochelle and C. C. Courtney, "Rugged Low-Cost, Portable Digital Dosimeter," p. 19 in *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734.
3. J. T. De Lorenzo et al., *Radiological Instrument Design Investigation for OCD, January 1970 to October 1970. Annu. Rep.*, ORNL-TM-3370 (Mar. 31, 1971).
4. F. M. Glass, J. M. Rochelle, and H. N. Wilson, *Engineering Feasibility Study on Automated Attack-Effects Information Systems. Final Report*, ORNL-TM-4194 (Jan. 22, 1973).

4.4 SUPPORT FOR NEUTRON CROSS-SECTION MEASUREMENTS

F. E. Gillespie

A prototype fission chamber (Q-2851 model VIII) with 17 mg of ^{239}Pu was used to check the efficiency and pulse height of the design before a 20-plate chamber was constructed for the Neutron Physics Division. The prototype had two plates (each coated on one side) with 0.119 mg/cm^2 and 0.247 mg/cm^2 of ^{239}Pu as PuO_2. Three blank plates were interspaced to make a five-plate chamber. The plate spacing was $\frac{1}{8}$ in., and the filling gas was 10% CH_4-90% Ar at 1 atm. This combination was satisfactory for the 20-plate chamber, used with broadband current preamplifiers.

The 20 plutonium plates (82 mg) for the new chamber were prepared by vacuum evaporation.[1] The amount of ^{239}Pu on each plate was determined by low-geometry alpha counting. The chamber is being assembled.

1. H. Adair, Isotopes Division

4.5 HIGH-PRESSURE DETECTOR CHAMBER

G. W. Allin

A high-pressure (450 psig) detector chamber was designed for a single-wire proportional counter. The chamber is aluminum with a Van Stone-type ring flange of stainless steel and a Monel head. A helium-leak-tight, metal-to-metal seal was used to permit bakeout at assembly. The application required a compact design, thus excluding standard flanges. This chamber was fabricated, and it passed both hydrostatic and helium leak tests.

4.6 CARRIER-CONCENTRATION-DEPENDENT MOBILITY IN *n*-TYPE HIGH-PURITY GERMANIUM[1]

J. L. Blankenship

The Hall mobility of electrons in high-purity germanium was studied over a range from 7 to 200°K in a series of samples both before and after irradiation with ^{60}Co gamma rays. In several unirradiated samples the mobility was limited mainly by lattice scattering down to 7°K. The mobility at 35°K decreased with radiation dose for all samples, but the magnitude of the decrease was greater in samples having lower carrier concentrations (n_e). This decrease was well correlated with n_e. Measured mobilities at 35°K were significantly lower than values calculated from the Brooks-Herring impurity-scattering expression for $n_e < 10^{12}$ cm^{-3}. At $n_e = 10^{11}$ cm^{-3} the measured mobility was 0.01 times the calculated mobility. No satisfactory explanation has been found.

1. Abstract of a dissertation submitted to the University of Tennessee, Knoxville, in partial fulfillment of the requirements for the Ph.D. degree in physics and published in *Phys. Rev. B* 7(8), 3725–31 (April 15, 1973).

4.7 GAMMA-RAY DAMAGE AND ANNEALING IN ULTRA-HIGH-PURITY GERMANIUM[1]

J. L. Blankenship, Jr.

Defects introduced by ^{60}Co gamma rays at 0°C in *n*-type and *p*-type germanium were studied using Hall coefficient and electrical conductivity measurements. The material investigated had net impurity

concentrations in the range of 10^{11} to 10^{12} cm^{-3}; this allowed the detection of a lower range of radiation defect concentrations than was previously feasible. The properties of defects stable at room temperature are particularly interesting, because semiconductor radiation detectors have been made by irradiating lightly doped *n*-type germanium with ^{60}Co gamma rays. The lack of consistent results has prevented the commercial application of this process.

Two problems hamper Hall coefficient measurements on such very high-purity germanium: (1) the terminals of the specimen present a high source impedance at most temperatures, and (2) no information about the impurities or doping concentrations is available from the supplier. The first problem was solved by incorporating specially designed electrometer-type amplifiers in the measuring apparatus. The second problem of material characterization was partially solved by measuring the temperature dependence of carrier concentration well into the freeze-out region. The degree of compensation and activation energy of the dominant impurity dopant were determined from the freeze-out data. Material characterization by this method requires accurate temperature measurements and a stable temperature control system in the range of 6–15°K. Carrier concentrations as low as 2×10^{6} cm^{-3} were measured.

Raw data were collected on punched paper tape for later processing by computer. A hybrid computer program was developed which first reduced the raw data and then calculated the carrier concentration as a function of temperature from a theoretical model. The input parameters of the theoretical model were under control of the program operator, so that the experimental data points could be fitted in detail to the results of the model on a display oscilloscope. The input parameters were varied until agreement between theory and experiment was deemed adequate by the operator, and then the parameters were printed out.

The defects introduced by ^{60}Co irradiation exhibited three acceptor energy levels and caused an apparent change in net impurity concentration. The acceptor level observed at $E_c - 0.235$ eV was produced by the gamma rays with an efficiency of 8.58×10^{-5} cm^{-1}. This acceptor level annealed out readily at 100°C. An acceptor level at $E_v + 0.195$ eV was observed in *p*-type material. Anneals at 30 to 60°C appeared to convert this level to a level at $E_v + 0.09$ eV, with an apparent change in net impurity concentration.

The most stable electrical property of the radiation defects was the change in net impurity concentration, which was always toward more *p*-type. The carrier removal efficiency in *n*-type material was found to be 1.77×10^{-4} cm^{-1}. It appears possible to produce a stable change in net impurtiy concentration toward more *p*-type (or less *n*-type) without leaving an appreciable concentration of deep acceptor levels by using a sequence of ^{60}Co gamma irradiation and annealing. This observation is of interest to manufacturers of gamma-compensated germanium radiation detectors.

The temperature dependence of Hall mobility (μH) measured on germanium before irradiation agreed closely with theoretical mobility values limited only by lattice scattering. Reduction in μH produced by irradiation appeared to be correlated with the resulting carrier concentrations and not with the density of charged scattering centers. The magnitude of this mobility depression and the functional dependence on temperature were in disagreement with values calculated by assuming that only binary encounters contribute to the ionized-impurity scattering rate. Multiple encounter events were found to be predominant in some temperature regions, but the theory of this scattering mode is not amenable to comparison with experiment at this time.

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1. Abstract of a dissertation submitted to the Graduate Council of the University of Tennessee in partial fulfillment of the requirements for the degree of Doctor of Philosophy, published as report ORNL-TM-3998 (January 1973).

5. Radiation Monitoring

5.1 SOLID-STATE CUTIE PIE

E. E. Waugh G. A. Holt E. J. Kennedy[1]

To meet a continuing request for a portable beta-gamma radiation survey instrument (Cutie Pie, Q-2299), an improved unit (Fig. 5.1.1) was designed and constructed for evaluation. It is being field-tested by the ORNL Health Physics Division. Preliminary reports are that the instrument shows much promise.

In the new design the old electrometer tube and amplifier circuit were replaced with a new hybrid integrated circuit amplifier developed and produced in the Hybrid Integrated Circuit Facility of the Instrumentation and Controls Division. The instrument is powered by a potted dc-to-dc converter module and single D-cell battery, allowing >300 hr of operation.

The hybrid circuit amplifier, high-megohm resistors, and other circuit components are mounted on a plug-in epoxy fiberglass, etched wiring board. This assembly, covered with Dow Corning silicone compound 340 to keep the high-impedance circuitry clean and dry, is contained in an aluminum enclosure and guard-ring assembly connected electrically to the power supply common. The enclosure is packed full with the silicone 340.

The effective volume of the new high-impedance circuit enclosure was reduced to about 15% of the volume of the old design by reducing the physical volume of the aluminum enclosure and filling it with the silicone 340. This reduction in effective volume reduces the cameral effect that is common with ionization chamber instruments and that causes inaccurate meter readings.

The high-impedance circuit is switched by radially positioned reed switches in series with the high-megohm resistors. The switched are actuated by a small, permanent bar magnet mounted on an arm fixed to the bottom end of the shaft of the case-mounted rotary range switch that is placed outside the aluminum enclosure.

One of the problems with the old instrument was physical damage to the meter. The new unit has a flush-mounted meter face covered with a clear Mylar peel-off decal. The hand-fabricated instrument case of the older model was replaced with a modified deep-drawn aluminum can. Although the new instrument is only slightly smaller than the older model, the weight was reduced 40% (from 3.5 to 2.25 lb).

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1. Consultant, Department of Electrical Engineering, University of Tennessee, Knoxville.

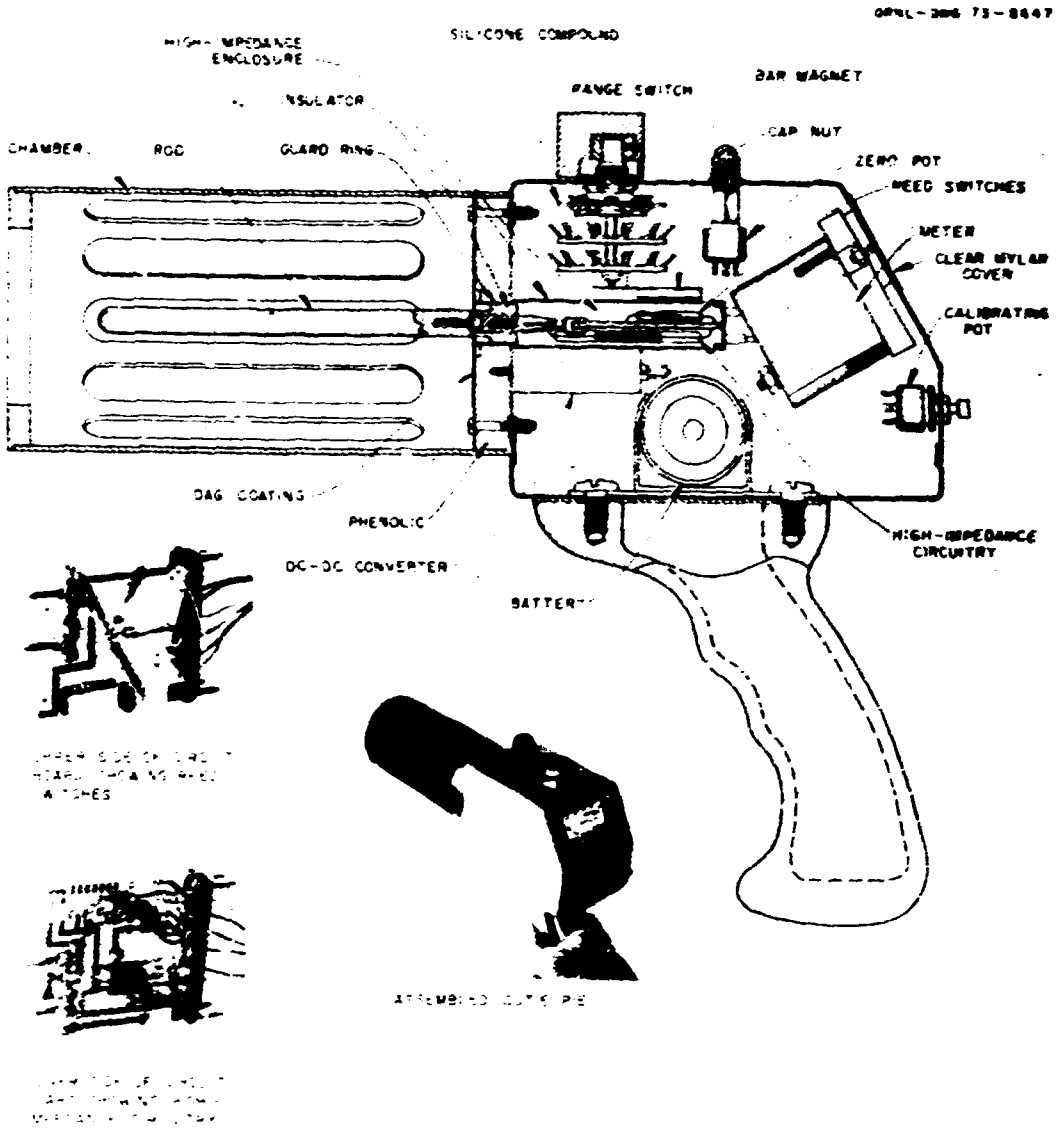

Fig. 5.1.1. Solid-state cutie pie.

5.2 DIGITAL NUCLEAR RADIATION DOSIMETER FOR FIELD PERSONNEL

H. R. Brashear F. M. Glass

A laboratory model of a digital nuclear radiation dosimeter was designed and fabricated for the U. S. Army Signal Corps. The dosimeter detector is a xenon-filled ionization chamber (17 cm^3 in volume).

A radiation dose is measured by storing the collected ionization charge on a capacitor until an amount of charge equivalent to 5 mR has been collected. The stored charge is removed from the capacitor through a diode switch. Each time the diode switch is actuated, a pulse that represents a nuclear radiation dose of 5 mR is stored in a register.

The high-impedance portion of the charge collection and removal circuit is a microcircuit mounted inside the ionization chamber. Connector terminals on the chamber are low-impedance points in the circuit.

The pulse storage circuit comprises complementary metal-oxide silicon field-effect transistor integrated circuits that consume little power. The accumulated dose is digitally displayed by pushing a switch that actuates a five-digit light-emitting diode array.

5.3 ENGINEERING ACTIVITIES CONCERNING RADIATION MONITORING

C. C. Hall J. L. Lovvorn P. P. Williams

Facility Radiation and Contamination Alarm Systems

Intermediate and High-Level Waste Evaporator Building (Building 2531)

A beta-gamma constant air monitor was added to the radiation monitoring system in Building 2531. The central alarm panel was rewired so that if a high-level or inoperative alarm is received at the central panel from any one of three beta-gamma constant air monitors, the building containment system is put into operation. A control module was added to the central alarm panel to operate a steam condensate valve when a high-level alarm is received at the panel from the steam condensate drain line monitor.

Metals and Ceramics Laboratory (Building 4508)

A remote alarm panel was installed at the south entrance of Building 4508. The remote panel provides visual alarms that duplicate any alarms received at the central alarm panel which cause building evacuation. The remote panel is located so that personnel can see the panel from outside the south entrance and can determine which instruments caused the evacuation alarm to sound without entering the building.

Other Radiation Monitoring Systems

Health Physics Research Reactor

As-built, schematic drawings of the Health Physics Research Reactor monitoring system were prepared and issued. A description of the facility radiation alarm system in the special materials machine shop, rolling mill, and source and special materials vault at ORNL was compiled and issued.

Effluent Waste Monitoring

A flow traverse of the Building 3039 off-gas stack was taken to determine the quantity of effluent gases.

A sampler was designed and installed to take small samples of water from the White Oak Creek flow; this sampler is an addition to one already installed.

Three Rustrak recorders and three range meters were added to the instrument panel in the Thorium-Uranium Recycle Facility (Building 7930) to show the local amount of radiation in the effluent water and off-gas from the building.

More than 32 drawings were revised and updated to show as-built and minor design changes of the monitoring systems.

Fallout Monitoring

A line noise rejection circuit was added to the No. 8 fallout monitoring transmission line to the Central Research and Administration Building 4500S.

5.4 DESCRIPTION OF FACILITY RADIATION ALARM SYSTEM IN SPECIAL MATERIALS MACHINE SHOP, ROLLING MILL, AND SOURCE AND SPECIAL MATERIALS VAULT AT ORNL[1]

P. P. Williams

A facility radiation alarm system was installed in the special materials machine shop (Building 3044), rolling mill (Building 3012), and source and special materials vault (Building 3027). Instruments continuously monitor both gamma and neutron radiations (burst and dose) in the first two buildings but only neutron radiation in the vault. The instruments and associated system components provide health physics information, sound local alarms when abnormal conditions occur, and indicate the abnormal condition on a central panel in Building 3044 and the Laboratory Emergency Control Center (Building 2500). The monitoring instruments also actuate building evacuation alarms in the machine shop and rolling mill when specific levels of radiation are reached.

1. Abstract of published report ORNL-TM-4064 (March 1973).

5.5 DESCRIPTION OF THE FACILITY RADIATION AND CONTAMINATION ALARM SYSTEM INSTALLED IN THE HIGH RADIATION LEVEL EXAMINATION LABORATORY[1]

C. C. Hall J. L. Lovvorn

A facility radiation and contamination alarm system was installed in the High Radiation Level Examination Laboratory, Building 3525, to continuously monitor beta and gamma radiation and airborne beta-gamma contamination. A monitor was installed in an exhaust duct to determine beta-gamma contamination carried in the exhaust duct. The radiation monitoring instruments and associated system components provide health physics information and sound local and remote alarms when abnormal conditions occur.

Radiation monitoring instruments actuate the building evacuation system when specific levels of radiation or contamination are reached.

1. Abstract of published report ORNL-TM-1251, Revision 1 (August 1973).

5.6 DESCRIPTION OF FACILITY RADIATION AND CONTAMINATION ALARM SYSTEMS INSTALLED IN THE INTERMEDIATE AND HIGH-LEVEL WASTE EVAPORATOR BUILDING[1]

C. C. Hall

A facility radiation and contamination monitoring system was installed in the Intermediate and High-Level Waste Evaporator Building (Building 2531) to continuously monitor airborne beta-gamma contamination, beta-gamma background radiation, and steam condensate beta-gamma and gamma radiation. The monitoring instruments and their associated system components provide health physics information, sound local alarms when abnormal conditions occur, and indicate the abnormal condition on a central panel in the operating area.

Beta-gamma air monitoring instruments actuate the building containment system when a predetermined level of airborne contamination is reached or when any one of the air monitors becomes inoperative.

1. Abstract of report ORNL-TM-4317 (to be published).

5.7 AIR FLOW MEASUREMENT IN THE 3039 STACK

G. W. Allin
D. J. Knowles H. J. Metz H. J. Stripling, Jr.

A propeller-type anemometer[1] was assembled for determining the velocity profile in the main off-gas stack.

A lightweight 9-in.-diam, two-bladed propeller made from expanded polystyrene beads drives a solid-state, incremental, low-torque shaft encoder. The encoder is mounted within a 3-in.-diam, thin wall, brass sphere and is bidirectional so that it will detect abnormal downdrafts as well as the normal updraft flow. The size of the entire anemometer is small so that it can be inserted into the stack through 6-in.-diam sleeve openings.

The manufacturer of the propeller claims that it will operate over a range from 0.5 to 90 mph when it is suitably mounted on a low-torque device. The anemometer assembly was tested operationally, but it was not calibrated or tested in the stack.

1. H. J. Metz et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 26.

5.8 ADVANCED AERIAL RADIAC STUDY

V. A. McKay R. L. Shipp

The study of possible techniques for high-speed, high-altitude measurement of ground-level nuclear radiation intensities associated with nuclear explosion fallout was continued.[1] The objective was to survey all (or almost all) of a fallout zone during a single pass with an aircraft flying at a ground speed of Mach 3 at 10,000 ft. Dose rates were to be measured at 500-ft-diam surface resolution from 1 to 10,000 rads/hr. This work was done for the U.S. Army Electronics Command.

Since geometric factors and air attenuation of gamma-ray radiation over a path of 10,000 ft or greater in air prevent direct aerial measurement of ground-level radiation distributions, most of the study was devoted to detection of radiation effects on the environment. Environmental effects considered in most detail were gamma-ray production in air of ozone, nitrous oxide, and fluorescence; and the effect of beta and gamma-ray heating at the earth's surface. Air fluorescence is the only one of these effects that has sufficient yield for possible development into an aerial radiac system. An ultraviolet line scanner system operating at a wavelength of 3371 Å, the wavelength of the most intense air fluorescence band, will meet the study requirements; however, survey operation is limited to clear nights when there is no interference from moonlight, aurora, or terrestrial light sources.

Interference from extraterrestrial light sources such as moonlight, aurora, airglow, and light from the sun at low angles of elevation can be eliminated by operation at a wavelength of 2977 Å where these light sources are strongly attenuated by ozone in the atmosphere. However, since the intensity of the 2977 Å band is about 10% of the band intensity at 3371 Å, the system requirements must be relaxed to compensate for this lower signal intensity. Since some of the data available for air fluorescence study is of questionable accuracy, we recommend further study of the air fluorescence technique. Further, since dosimetry by means of air fluorescence is limited to clear weather, additional development is recommended for the previously studied low-altitude direct gamma-ray measurement system.

1. R. L. Shipp and V. A. McKay, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 25.

5.9 LONG-TERM LUNAR MATERIAL STORAGE CONTAINERS

V. A. McKay T. F. Sliski

The Planetary and Earth Sciences Division of the Lyndon B. Johnson Space Center has selected certain lunar samples for long-term storage of at least 20 years. These samples are to be doubly contained in hermetically sealed stainless-steel containers. The inner containers will be 1200- and 5300-ml bolted top containers, which will be placed within a cubic storage container.

With reference to hermetic seals, the permeability and deformation characteristics of elastomeric seals make them useful only for short-term storage. Although metal seals are generally acceptable, indium and lead are unacceptable because of their high creep rates, and copper is marginally acceptable because it requires a high force to close the seal. High-purity aluminum (Alcoa 1199.0) has been used for lunar material containers for short-term storage.[1] since it has an acceptable creep rate and a satisfactory yield point, and seals can be effected with low seal loading in a circular lay.

The more stringent cleanliness needs for long storage periods require that the surfaces of all container material be free of inorganic and organic soils. A total absence of lubricants on the seal surfaces creates sufficient friction between the seal and flat sealing land that inhibits all seal surface flow, thus preventing a hermetic seal due to unfilled surface imperfections between the seal and the sealing land, such as pits and scratches.

A multiple groove sealing land was designed to segment the seal surface imperfections and induce seal surface flow without tearing. None of these units have failed during testing; they have been fabricated in sizes from 4 to 18 in. in diameter.

The design techniques learned while solving lunar material storage problems and the experience gained from the use of Alcoa 1199.0 aluminum have been applied to a variety of other sealing problems.

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1. V. A. McKay and T. F. Sliski, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734, pp. 88–89.

6. Support for the Oak Ridge Electron Linear Accelerator

6.1 ENGINEERING DEVELOPMENT SUPPORT

J. H. Todd

General engineering support was given to developing and testing improved subsystems on the accelerator. Routine maintenance services were also furnished.

Design, construction, installation, and check-out of a new logic and timing system to increase the reliability and flexibility of operation of the accelerator were completed.

6.2 INSTRUMENTATION FOR $\bar{\nu}$ EXPERIMENT

R. W. Ingle

Assembly of a system for the measurement of $\bar{\nu}$ (the average number of neutrons per fission of fissile isotopes) was started at the Oak Ridge Electron Linear Accelerator (ORELA) facility for the Neutron Physics Division.

When completed, this instrumentation will detect and record fission events vs neutron energy that is produced when neutrons from the accelerator strike fissile material in the center of a detector; the resulting fission produces more neutrons.

The detector is a large spherical steel tank filled with 210 gal of Nuclear Enterprise type NE-224 liquid scintillator that contains dissolved gadolinium. Eight 5-in.-diam photomultiplier tubes scan the liquid. The fission neutrons are captured by the gadolinium, and gamma rays are emitted. The gamma rays cause scintillations in the liquid, which are detected and analyzed by the photomultiplier tubes and electronic instrumentation.

The electronic system consists of fast and slow channels for timing and energy analysis. The anode signals from the photomultipliers are summed together and fed to a fast discriminator for use as a timing signal. The dynode signals are mixed through a slow linear amplifier system for accurate bias setting and pulse height spectroscopy. The gains and timing signal must be matched equally for all tubes. The time-measuring device is an EG&G, model TDC-100 time-interval digitizer that receives parallel binary output data from a high-speed scaler and presents the binary time-of-flight information and scaler counts to the computer in dual parameter form. This scaler (ORTEC model 770) counts and records the number of neutrons from a fission event.

The electronic circuits and components have been acquired or fabricated, and the detector is being assembled.

6.3 NEUTRON MONITOR

J. H. Todd

A dual-channel neutron monitor with ^{235}U parallel-plate fission chambers was designed and constructed. A remotely operated system will insert the chambers to a monitor position near the accelerator target or retract them to a calibrate position. Calibration is an automatic procedure that is started by the machine operator.

6.4 EXPERIMENTAL ELECTRONIC ACTIVITIES

R. W. Ingle J. H. Todd

Continuing engineering assistance was given to the fissile isotope cross-section group of the Neutron Physics Division. These programs include measurement of the capture and fission cross sections of ^{233}U, ^{235}U, ^{236}U, ^{239}Pu, ^{240}Pu, and ^{241}Am.

An additional neutron time-of-flight station with instrumentation at 85 m was completed. With this station, measurements can be made at higher neutron energy ranges. We continued to develop and measure the parameters of neutron detectors, fission chambers, and photomultipliers with a goal of improving the detection efficiency, timing, and resolution of these devices.

Instrumentation is now being set up for the measurement of $\bar{\nu}$ at the 20-m station on flight path 4.

6.5 EIGHT-CHANNEL PRECISION PULSER

J. H. Todd

An eight-channel precision pulser was designed and constructed. Repetition rates are switch-selectable at 1 pulse/sec, 50 pulses/sec, and a variable rate up to 50 pulses/sec for each channel. The pulse outputs of the eight channels are equally spaced, and they occur sequentially. Timing pulses are available on each channel with a shift of <10 nsec for output pulse amplitudes from 10 V to 50 mV.

6.6 MULTIPARAMETER INTERFACING SYSTEM

R. W. Ingle

To improve the data acquisition and recording techniques of existing equipment, a multiparameter interfacing system was fabricated and installed at the ORELA facility to enable a Neutron Physics Division group to measure fission and capture cross sections as a function of neutron energy.

This interface simultaneously accepts parallel digital information from an EG&G model TDC-100 time-interval digitizer; a Nuclear Data 12-bit analog-to-digital converter; and a 20-nsec 12-bit time-interval counter. This instrument, built with TTL integrated circuits, simultaneously records time-of-flight of ORELA beam neutrons vs pulse height of fission capture gamma rays, and time-of-flight of beam neutrons vs time-of-flight of fission neutrons. This unit is the driving logic to the ORELA SEL computer system.

6.7 IMPROVEMENT PROGRAMS

T. A. Lewis

The on-going improvement programs continued to make significant progress in short-pulse acceleration and reliability. Recently developed electron guns and nonlinear pulse-shaping networks for pulsing these guns enabled achievement of higher peak current and greater reliability of ORELA performance.

Programs for further improvement, especially of short-pulse performance, will be continued.

7. Automatic Control and Data Acquisition

7.1 HIGH-SPEED READER-PUNCH INTERFACE FOR A PDP-8/E COMPUTER

J. L. Redford

An interface was designed and fabricated with TTL logic so that a Digitronics high-speed paper-tape reader and a BRPE (Teletype Corp.) high-speed paper-tape punch can be operated with a PDP-8/E digital computer. The interface card plugs directly into the omnibus of the computer, with logic level input from the reader and output to the punch. The interface will automatically turn on the high-speed punch and turn it off, after a delay. External drivers and power operate the punch coils of the high-speed punch.

7.2 REDESIGN OF INTERFACES FOR PDP-8/E COMPUTER

A. F. Johnson, Jr. J. L. Redford

Storage Display Interface

Because the Digital Equipment Corp. modified the PDP-8/E computer packaging, several interfaces previously used with a PDP-8/I computer had to be redesigned. The redesigned interfaces for the PDP-8/E computer contain the newest digital and linear integrated circuit modules, and they either connect directly to the computer mainframe (omnibus) or plug into one of the manufacturer's standard interface cards.

A new graphic display interface for a Tektronix 611 storage oscilloscope plots data with greater precision and can be fabricated at a lower cost than the previous interface for the PDP-8/I computer. The interface occupies a single mainframe (omnibus) slot, and its display resolution is 4096 by 4096 points. The display unit can be operated in a storage mode, a nonstorage (refresh) mode, or in a write-through (nonstored information displayed along with stored information) mode, and the screen can be erased by program control. Characters are generated by software; however, the new interface can be equipped with a hardware character generator.

The display unit and interface are being operated in two systems. In one application, the oscilloscope and a teletypewriter are located in a control bay 50 ft from the computer.

Watchdog Timer Interface

Data acquisition and process control systems that operate 24 hr/day require that hardware or software failures be detected by a time-out circuit called a watchdog timer. Previous on-line systems at ORNL consisted of relays, solid-state timers, and a makeshift bootstrap loader device. A bootstrap loader interface card was obtained from the Digital Equipment Corp., and a watchdog timer circuit was fabricated which plugs into the computer interface and communicates with the bootstrap loader card. The timer consists of a clock (free-running multivibrator) and count-down circuit, which is resettable with a computer instruction.

If the count-down circuit is not reset prior to rundown, the computer halts and the bootstrap loader sequence is initiated for a system reload. With this interface one can intervene by operating a console auxiliary switch.

Optical Isolator Buffer

By installing low-cost optical isolators (incorporating a light-emitting diode and a phototransistor in one package) one can protect process computer systems from external noise sources and from wiring errors by field technicians. Isolation of external signal wiring from the computer circuits is essential to achieve adequate reliability of an on-line system. An optically coupled buffer was designed to provide such isolation from the outside environment when a 12-contact input-output interface (DR8EA) is used in a PDP computer. The optical isolator circuits are interposed between the interface in the computer and a relay circuit board (previously designed for the PDP-8 and PDP-8/I computers) that contains terminal strips for all inputs and for utilization of the output relay contacts.

7.3 DATA ACQUISITION SYSTEM FOR CREEP-RUPTURE LABORATORY

J. T. Hutton C. D. Martin, Jr. R. W. Tucker

A modularized instrumentation system was designed to measure load and stress on metal specimens in creep-rupture machines and provide electrical analog signals for data acquisition. The creep-rupture laboratory of the ORNL Metals and Ceramics Division has about 150 creep-rupture machines that subject metal specimens to high stress loads at high temperatures for periods ranging from several days to several years. Load and strain data were previously acquired and recorded manually. The load was determined from the amount of weight attached to the lever arm of the individual machine, and the strain was read from mechanical dial gages that measured the physical displacement of the specimen. This information and temperature data were keypunched on tabulating cards and then analyzed by a computer program. The new system will ultimately acquire all data automatically and record them on magnetic tape for computer analysis, thus reducing human error and speeding up data acquisition and analysis.

The instrumentation system for a single creep-rupture machine is comprised of a strain-gage excitation supply and amplifier module for use with a load cell to measure the load applied to the specimen; a dual demodulator amplifier module to use with averaging linear variable differential transformer (LVDT) extensometers for measuring strain; and a dc power supply–power oscillator module that powers the other two modules and provides excitation for the LVDT extensometers. All modules are mounted in modified nuclear instrument module-type bins. To date, 44 creep-rupture machines have been equipped with the system. The data are recorded on analog strip-chart recorders. Performance of these systems (accuracy, drift vs temperature and time, maintainability, etc.) has been satisfactory.

A digital data acquisition system is being assembled to replace the strip-chart recorders. The part of the system that processes the analog signals is a commercial digital recorder that has a 100-channel analog multiplexer, analog-to-digital converter, printer for local data logging, and isolated data outputs for interfacing to external devices. The outputs from this instrument are dc voltage ranges of 10 mV and 10 V full scale and a linearized, Chromel-Alumel thermocouple range of −60 to +1370°C. The instrument will be interfaced to a PDP-8/E computer with a generalized binary coded decimal instrument hardware-software package; up to seven of the recorders and a digital clock-calendar can be accommodated by the interface package. The formatted data will be recorded on magnetic tape under computer control for further reduction and analysis on a larger computer at the ORNL computing center. Should the computer system

fail, the digital recorder printer will automatically continue logging data, which can be keypunched later and added to the data from the magnetic tapes.

[illegible] Hutton and J. M. Jansen, Jr., *Instrumentation and Controls Div. Ann. Prog. Rep. Sept. 1, 1972*, ORNL-4822, p. 33.

7.4 STATUS OF U.S. ARMY COASTAL ENGINEERING RESEARCH CENTER COMPUTER SYSTEM

J. M. Jansen Jr.
A. F. Johnson, Jr. R. L. Simpson H. R. Brashear

As a part of ORNL participation in the radioisotope sand tracer study,[1] design and fabrication of a minicomputer-based data acquisition system for the Coastal Engineering Research Center of the U.S. Army Corps of Engineers was completed, and the system was delivered to the U.S. Army at Ft. Belvoir, Virginia. The system is being utilized to study the movement of sand and other sediments along beaches and in harbors of the United States.

System software consists of the FOCAL[2] interpreter, extended for storage and retrieval of FOCAL programs on the magnetic tape transport, and assembly language routines that will read data stored on digital cassette tape by the auxiliary radiation detection and data collection system, and will verify, format, and write the data on ASCII compatible magnetic tape.

1. J. M. Jansen, Jr., et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 44.
2. FOCAL is an algebraic interactive programming language developed by the Digital Equipment Corp. We have extensively modified it to permit command of analog and digital input-output devices and to permit calculations based on time of day.

7.5 ANALOG INPUT SYSTEM FOR A PDP-8/E COMPUTER

A. F. Johnson, Jr. J. M. Jansen, Jr.

A general-purpose, low-cost, low-noise, 12-bit resolution analog input system was developed for the PDP-8/E computer. The main unit in the system is a commercial Xincom 3316 Computaverter module that contains a 16-channel multiplexer, a sample and hold amplifier, and a 12-bit successive approximation analog-to-digital converter-all in a 4.0- by 5.6- by 0.55-in. package. To minimize ground loops and their resulting noise, the analog system is optically isolated from the digital interface. The analog input system is controlled by a modified GeMSAEC interface[1] that occupies a single omnibus slot and provides such functions as channel selection, start conversion command, and converted data input. By using appropriate buffer cards, the system can accept either 0 to +10 V or 0 to −10 V input signals. Bipolar signals can also be handled. The typical system noise is ±1 least significant bit, and the maximum speed is 25 kHz.

The system was successfully implemented in the body fluids analyses data processing system (Sect. 7.13).

1. J. M. Jansen, Jr., "Miniature Computer System for the GeMSAEC Fast Analyzer," *Instrumentation and Controls Div. Ann. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 31.

7.6 TELETYPE INTERFACE FOR A BIOMATION TRANSIENT RECORDER

R. B. McFarland A. F. Johnson, Jr.

An interface was developed for the Biomation 802 transient recorder, which allows data stored in the recorder's memory to be punched on paper tape by a standard ASR 33 Teletype. The paper tape can be

sent to the ORNL computing center for processing or processed locally by the researcher's minicomputer. The interface formats each of the transient recorder's 1024 8-bit words into a three-digit octal number in ASCII representation. Each number is followed by a space, and each tenth number is followed by a carriage return and line feed character pair.

The interface is currently being used in thermocouple loop-current, step-response testing (Sect. 8.20).

7.7 COMPUTER-OPERATED DATA ACQUISITION SYSTEM PHASE III ADDITIONS

J. T. Hutton J. M. Jansen, Jr.

Several years ago we installed a computer-operated data acquisition system in the physical properties laboratory of the Metals and Ceramics Division.[1,2] Use of this system has expanded to where it is now in routine control of as many as six experimental systems. When greater system capacity was required, we decided that it would be better to install a new computer system rather than to add to the almost fully expanded existing computer.

The new computer will be a PDP-8 E with 8K words of core memory, a cartridge disk mass memory with 1.5M words of storage capacity, a real-time clock, a teletypewriter, a 12-bit analog-to-digital converter with a 16-channel analog signal multiplexer, and a contact input-output interface. The new interfaces will be controlled through FOCAL functions.

Additions to the new computer system, such as additional core memory and process control interfaces, will be called Phase IV. The system will control as many as four experiments simultaneously on an assigned priority basis by the new computer.

1. R. L. Simpson, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 36.
2. J. M. Jansen, Jr., and C. D. Martin, Jr., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1973*, ORNL-4734, p. 39.

7.8 AUTOMATED ELECTROCARDIOGRAM DATA ACQUISITION SYSTEM

R. L. Simpson

Continued support was given to the automated electrocardiogram data acquisition system.[1] This past year 3080 electrocardiograms from routine employee screening tests were processed. Analyses of electrocardiograms by a cardiologist were compared with analyses by the computer, and as a result, all routine electrocardiogram screening is done by the automated system.

This practice is much less expensive, since only abnormal electrocardiograms and every tenth normal electrocardiogram are sent to the cardiologist for analysis. In addition, electrocardiograms from all employees are now analyzed, whereas, previously, high costs limited routine analysis to employees more than 40 years of age.

The computer program was modified to reduce the processing time and computer costs. The total computer cost for the 3080 electrocardiograms processed was $1668, or 54¢ each.

1. R. L. Simpson, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 36.

7.9 EXPANSION OF DATA ACQUISITION SYSTEM FOR TURF DEVELOPMENT LABORATORY

J. M. Jansen, Jr. J. T. Hutton

The computer system previously reported[1] was expanded by the addition of 4K words of core memory, a Sykes tape cassette unit, a 2400 Baud send-receive asynchronous serial line interface, and 4K words of

dynamic MOS memory. The additional 4K words of core memory and the tape cassette unit are used for program storage and interchange (bypassing the loading of programs with the Teletype paper-tape reader). The tape cassette unit, the asynchronous serial line interface, and the MOS memory are used in conjunction with a pulse height analyser system for high-speed measurement of the diameter of coated fuel particles. Cumulative statistical data on particle characteristics are maintained on the cassette for use in production evaluation and control testing on fuel particle output.

1. J. M. Jansen, Jr., et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 31–32.

7.10 COMPUTER AIDED TEMPERATURE SENSOR CALIBRATION PROGRAM

R. L. Simpson

The computer program previously reported[1] for calibrating thermocouples and resistance thermometers was revised and expanded to include optical pyrometers as test elements, as well as standard references.

The new program includes the new IPTS-68[2] reference functions[3] for thermocouples and the new IPTS-68 functions for resistance thermometers and optical pyrometers. Tables for test or reference elements not in the above functions can be read from cards or magnetic tape.

1. R. L. Simpson et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1965*, ORNL-3875, p. 85.
2. "The International Practical Temperature Scale of 1968," *Metrologia* 5(2), (April 1969).
3. R. L. Powell et al., *Thermocouple Reference Data Based on the IPTS-68*, National Bureau of Standards Monograph 125.

7.11 ENGINEERING TEST AND CONTROL COMPUTERS[1]

R. K. Adams M. B. Herskovitz

Two minicomputer systems applied successively to a temperature sensor engineering test facility are described. The experience gained in 5 years of use of the first system for data acquisition and control was directed toward improvements in hardware and software design and application of the successor system.

1. Abstract of paper presented at Eighth Annual Conference on the Use of Digital Computers in Process Control, the University of Tennessee, Knoxville, April 16–18, 1973.

7.12 EVALUATION OF A LABORATORY UNIVERSAL DATA ACQUISITION CONCEPT

F. Ficke[1] R. K. Adams

Experimental apparatus designed to acquire more than a few dozen data readings needs a data acquisition system that will automatically record the information. Over the years we have tried a number of approaches for solving this problem; however, several basic shortcomings in the components available which have prevented our success are a large number of wires required to connect the laboratory instrument to the data acquisition system, the high cost of the data acquisition system, and the inflexibility of the data acquisition system to accommodate various types of laboratory instruments. Since new equipment recently announced by one manufacturer appears to solve several of these problems, we have renewed a study of universal data acquisition from laboratory instrumentation.

In the present system concept, either a Teletype unit or a computer could control data acquisition and record the information from the laboratory instrument. The system appears to solve the shortcomings of other systems, because only a relatively small number of wires is required to connect a laboratory instrument to the serial transmitter and only a twisted pair of wires up to 10,000 ft long is needed to

interconnect the various interface modules and the control multiplexer. Versatility is achieved by adhering to a common data language and by using ASCII code for data transmission.

A prototypic system using the commercial modules was fabricated and successfully interfaced to several laboratory instruments. Although the module, as supplied, accommodates eight characters of information from an instrument, we expanded it to handle 12 characters of information with an option of recording information in either binary coded decimal or 10-line decimal form to accommodate the instruments commonly found in ORNL laboratories.

1. Summer undergraduate student from the Oak Ridge Associated Universities.

7.13 BODY FLUIDS ANALYSES DATA ACQUISITION SYSTEMS

J. M. Jansen, Jr. A. F. Johnson D. D. Chilcote[1]

Three miniaturized computer-based data acquisition and analysis systems were developed and installed for on-line, real-time analysis of the chemical constituents of urine and other body fluids.[2] The computer systems, which are identical, are equipped with 12K words of memory, a dual-cassette tape transport, a real-time clock, a digital input-output interface, an automatic program loader, and an analog input subsystem. These interfaces enable the computer to be connected simultaneously to two chromatographic analyzers for data collection and processing.

Programming for the system is in FOCAL. The language was expanded to include commands to specify the data acquisition rate, to initiate or terminate data collection from either analyzer, to access data recorded for either analyzer, to write or read processed results onto or from cassette tape, and to access the real-time clock for program sequencing and timing.

Data from the liquid chromatographic columns are acquired by an automated foreground subprogram that is scheduled to operate periodically by the real time clock. The input data (two analog signals from photometers and associated digital control inputs) are double buffered into a block of the memory for each active analyzer by the foreground subprogram at the specified data rate. As the input data blocks are filled, they are written into a ring buffer on the data storage cassette for processing by a FOCAL program. FOCAL language programs written for an earlier computer system[3-5] were modified to operate the new systems.

1. Chemical Technology Division.

2. C. D. Scott, R. L. Jolley, W. W. Pitt, Jr., and W. F. Johnson, "Prototype Systems for the Automated, High-Resolution Analysis of UV-Absorbing Constituents and Carbohydrates in Body Fluids," *Amer. J. Clin. Pathol.* 53, 761 (1970).

3. R. F. Hyland and J. M. Jansen, Jr., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1969*, ORNL-4459, p. 41.

4. J. M. Jansen, Jr., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1970*, ORNL-4620, p. 54.

5. D. D. Chilcote and J. E. Mrochek, "Use of Automatic Digital Data Acquisition and On-Line Computer Analysis in High-Resolution Liquid Chromatography," *Clin. Chem.* 17, 751 (1971).

7.14 180° OAK RIDGE SECTOR ISOTOPE SEPARATOR COMPUTER SYSTEM

J. M. Jansen, Jr. W. K. Dagenhart[1]

The computer system[2] applied to the 180° Oak Ridge Sector Isotope Separator is being expanded for the third time. Greater versatility and faster processing speed will be attained through the use of a real-time, multiprogrammed system in which both assembly language tasks or subprograms as well as FOCAL language tasks will be supported.

Equipment was requisitioned to expand the memory to 32K words and the bulk memory to 1.6M words. A second teleprinter will be added to enable program development and changes in control programs

in a background mode, with the console teleprinter to serve as a logging device for periodic reporting of process conditions. An alphanumeric-graphics terminal will be installed at the operator console to quickly furnish status and alarm conditions and to plot trends of selected process parameters.

To ensure system operation during unmanned periods, a watchdog timer-bootstrap loader will be installed to enable automatic reload and restart of the system if either the power or software fails. The crossbar scanner controller was eliminated, and a direct-drive random access interface to the digital output controller was installed. The integrating digital voltmeter interface was improved to enable operation at a higher speed by eliminating a portion of the set-up time when program ranges are changed.

The real-time multiprogrammed system software will include device-independent input-output programming to the terminals and paper-tape equipment, sequential buffer data storage and input-output control (pooling) of all input-output devices, and actuation of tasks by clock interrupt, external event interrupt, or another task. A minimal linked file structure will be supported on a portion of the bulk storage devices, with the remainder used for conventional (contiguous) block structure storage.

1. Isotopes Division.
2. J. M. Jansen, Jr., and W. K. Dagenhart, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p 36.

7.15 MINICOMPUTER SYSTEM FOR THE ORNL STANDARDS LABORATORY

R. K. Adams

J. L. Horton M. H. Cooper R. F. Hyland

A minicomputer was adapted for the ORNL Standards Laboratory as a calculational tool. The FOCAL programming language was modified to achieve a calculational accuracy of ten decimal digits as well as to enable installation of the computer at a distance from a soundproofed teletypewriter terminal in the Standards Laboratory. Standards Laboratory personnel prepared several FOCAL programs to process instrument readings and ancillary correction factors for temperature, pressure, resistance, and voltage determinations.

7.16 FIBER-OPTIC FLOW FLUOROMETER

L. H. Thacker

A prototypic, bifurcated, fiber-optic flow fluorometer was developed for monitoring chromatograph eluents or for measuring the fluorescence of static solutions. Tests have shown that fluorescein is detectable at about 10^{-10} molar concentration (40 pg/ml).

The instrument consists of a bifurcated fiber optic lightpipe (of quartz, glass, or quartz-glass combination, depending on the excitation and emission wavelengths) with its distal end inserted into a flow cell through which the material to be analyzed passes. A light source-filter combination on one proximal branch of the lightpipe determines the excitation wavelength, and a filter-photomultiplier combination on the other proximal branch determines the acceptable fluorescent emission spectrum. Light from the source enters the liquid in the flow cell and excites the characteristic fluorescence of the sample material; this fluorescent emission is collected with high efficiency by the fibers returning to the photomultiplier and generates an appropriate output signal.

The electronic system, housed in a small cabinet, includes an adjustable high voltage supply for the photomultiplier and amplifiers for current-to-voltage conversion with zero and gain adjustment. The output signal is recorded on a strip-chart recorder.

7.17 MINIATURE FLOW FLUOROMETER FOR LIQUID CHROMATOGRAPHY

L. H. Thacker

Development of the miniature flow fluorometer previously reported[1] was continued. Two new instruments were built, each of which incorporates a miniature dc-to-dc high voltage converter photomultiplier power supply in place of the separate external supply previously used, and each is adapted for magnetic shielding of the photomultiplier tube. One of these new instruments was modified for a larger flow cell (possible because larger samples were available) to provide increased sensitivity to sample materials. Fabrication of this instrument was completed and is currently being tested.

1. L. H. Thacker, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 60.

7.18 MICRO-FAST ANALYZER SYSTEM

L. H. Thacker

Preliminary design of a micro-fast analyzer system similar in principle to to GeMSAEC[1] analyzers was completed and a unit is being fabricated. The new instrument will be approximately 4-3/4 in. square and 6-3/8 in. in height. The analyzer will accommodate both transmittance and fluorescence measurements from samples in a 2-1/4-in.-diam rotor that contains up to 16 cuvets. The source of light is a carefully regulated 12-W quartz-iodine lamp, and light is transmitted to the cuvets and the photomultiplier tube by both quartz and mirror optics. A desired wavelength can be selected by choosing an appropriate interference filter in two filter slides.

1. W. F. Johnson, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734, p. 131.

7.19 PARTICLE ANALYZER

L. H. Thacker W. R. Miller

An analyzer for counting and measuring the cross-sectional area of nuclear fuel microspheres was designed and fabricated. The new instrument uses a nuclear data analyzer (1024 channels) to analyze, accumulate, and display the number of particles as a function of particle cross section.

The particles are separated and passed, one at a time, at rates up to 10^5 per minute, between a light source and a silicon photovoltaic cell. The pulses resulting from quantitative shadowing of the photovoltaic cell are amplified, conditioned, and delivered to the input of the nuclear data analyzer.

A system prototype for recirculating a single particle at high speed for calibration of the analyzer was also developed and is being tested. A final model of the particle handling system and the optical detector head will be built when the tests are completed.

7.20 A RAPID SENSITIVE METHOD FOR THE DETERMINATION OF THE CHEMICAL OXYGEN DEMAND OF POLLUTED WATERS[1]

W. W. Pitt, Jr.[2] S. Katz[2] L. H. Thacker

A rapid, sensitive cerate oxidative method for measuring the chemical oxygen demand of waters is described. The pollutants are oxidized with perchlorato-cerate reagent and the resulting cerium(III) is determined fluorometrically. Analysis requires only a few minutes for determinations at levels as low as 100 μg oxygen demand per liter.

Results of tests on solutions of known organic compounds, various industrial waste streams, and natural waters show that the method compares favorably with the dichromate reflux procedure recommended by APHA. However, the new method is considerably faster and easier to use, and is a hundred times more sensitive. An analytical system, suitable for use as either a continuous chemical oxygen demand monitor or as an analyzer for multiple samples in series, is also described.

1. Abstract of paper in press, *AIChE Symposium Series, Water (1972)*.
2. Chemical Technology Division.

7.21 DYNAMIC MULTICUVETTE FLUOROMETER-SPECTROPHOTOMETER BASED ON THE GeMSAEC FAST ANALYZER PRINCIPLE[1]

T. O. Tiffany[2]

C. A. Burtis[2] J. C. Mailen[3] L. H. Thacker

A dynamic multicuvette fluorometer-spectrophotometer based on the GeMSAEC Fast Analyzer principle has been developed. Inherent in the establishment of a design criterion for such an analyzer is a consideration of the relationship between excitation intensity and point of observation of the emitted fluorescence signal within the cuvette. A discussion of the inner filter effect using as parameters the molar absorptivity of reduced nicotinamide adenine dinucleotide and fluorescein is presented as a practical demonstration of the advantage of using a frontal fluorescence detection optical configuration. A brief discussion of the instrument and a description of its current instrumental configuration are presented. The current detection limit of the fluorescent Fast Analyzer with respect to fluorescein was 0.8 ng/ml, with a useful analytical range above 10 ng/ml. A few examples of the many potential applications of fluorescence analysis to the Fast Analyzer are presented; these include calcium, cortisol, morphine, and an enzymic fixed-time analysis for glucose.

1. Abstract of journal article, *Anal. Chem.* **45**, 1716 (1973).
2. Molecular Anatomy Program.
3. Chemical Technology Division.

7.22 FLUOROMETRIC FAST ANALYZER: SOME APPLICATIONS TO FLUORESCENCE MEASUREMENTS IN CLINICAL CHEMISTRY[1]

T. O. Tiffany[2]

M. B. Watsky[2] C. A. Burtis[2] L. H. Thacker

A fluorometric Fast Analyzer has been developed, based on the GeMSAEC Fast Analyzer principle. Potential applications of a multiple-cuvet fluorometric analyzer are considered. A primary concern must be referencing enzyme activity assays and enzymic substrate analyses. Once adequate referencing techniques are developed, adaptation of analyses can proceed. The advantages of fluorescence procedures are sensitivity, availability of a variety of fluorogenic substrates, and potential perturbation of the excited state for direct physical measurements of interacting species. We describe the development of a direct kinetic assay, with use of 4-methylumbelliferyl phosphate, for human prostatic acid phosphatase; discuss assay of alkaline phosphatase activity with use of the same substrate; and consider the sensitivity of the analyzer as it relates to fluorescence tracer techniques and measurement of fluorescence polarization with the Fast Analyzer.

1. Abstract of paper presented at Fifth Annual Symposium in Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge National Laboratory, 1973; published in *Clin. Chem.* 19(8), 871 (1973).
2. Molecular Anatomy Program.

7.23 CONTINUING DEVELOPMENT OF THE MINIATURE FAST ANALYZER SYSTEM

W. F. Johnson

Two complete miniature fast analyzer systems were constructed for NASA. One system was delivered to the Manned Spacecraft Center at Houston for evaluation. The second system, which incorporates several improvements resulting from construction and operation of the first NASA system, is being used routinely in the clinical laboratory of the ORNL Health Division.

Each system comprises a miniature fast analyzer module, automatic sample-reagent loader, portable data processor (the basic principles of which were previously reported[1]), and a rotor cleaning station to automatically wash and dry the rotors for reuse. A second light source can be added to the analyzer to monitor the optical transmission of biochemical reactions at the 290-nm wave length. The second data processor is housed in a single cabinet that incorporates an improved printer carriage-drive mechanism. In the latest model of the rotor loading station, a washing station has programmed internal and external flushing of the sample and reagent dispensing tips just before each sample pick-up to eliminate problems due to a slight carry-over of sample material. Larger and faster positioning motors were installed to drive the rotor loading table through this additional loading step and still maintain a 4.25-min total loading time.

To meet the increasing requests for information from commercial sources, sets of drawings of the miniature fast analyzer can be obtained.[2]

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1. W. F. Johnston et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 58–59.
2. Designated as CAPE 2320; sold by the National Technical Information Service, U.S. Dept. of Commerce, 5285 Port Royal Road, Springfield, Virginia 22151.

7.24 SMOKE AND GAS MONITORS

W. R. Milier, L. H. Thacker

Recently, a newly developed and marketed gas and smoke sensor has become available. These units sell for about $2.25 each and are sensitive to smoke, natural gas, carbon monoxide, hydrogen, ammonia, and most hydrocarbon compounds, such as alcohol, benzene, ethanol, and acetone. Output signals as large as several volts are possible with smoke and gas concentrations of only 10 to 20 ppm.

Three instruments were developed at ORNL which utilize these sensors. The first (Fig. 7.24.1) is an inexpensive (less than $100) smoke and gas monitor for general environmental use. It has an adjustable alarm threshhold and audible tone warning device.

The second device (Fig. 7.24.2) is a portable gas and smoke monitor that operates by power from rechargeable Ni-Cd batteries and has a meter for quantitative readout. A small motor-driven fan draws the sample across the sensor. This unit is useful in testing for gas and hydrogen leaks from piping systems and gas transport trailers.

The third instrument (Fig. 7.24.3) is a hydrogen monitoring system. It has a water scrubber that absorbs most organic and smoke constituents from the sample stream and leaves the system sensitive almost exclusively to hydrogen. The instrument output consists of an analog signal for continuous recording, an adjustable alarm threshold, an audible tone alarm, and alarm contacts to actuate remote devices. Sensitivities of 8 ppm of hydrogen in ambient air are regularly achieved with this instrument.

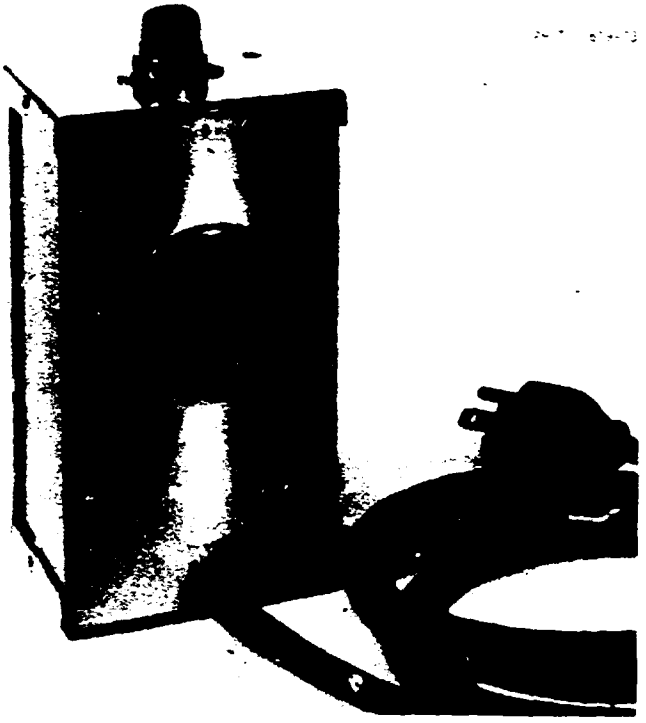

Fig. 7.24.1. Smoke and gas monitor.

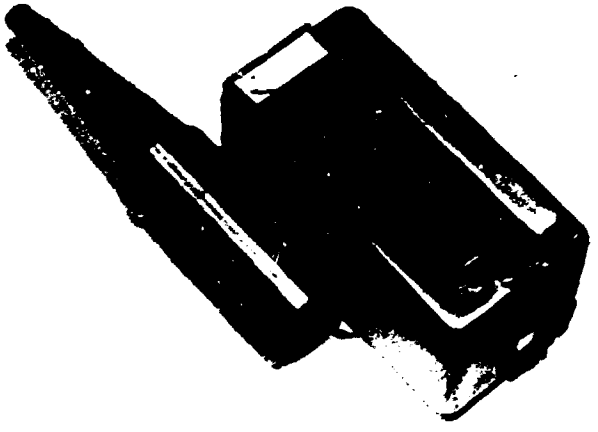

Fig. 7.24.2. Portable gas and smoke monitor.

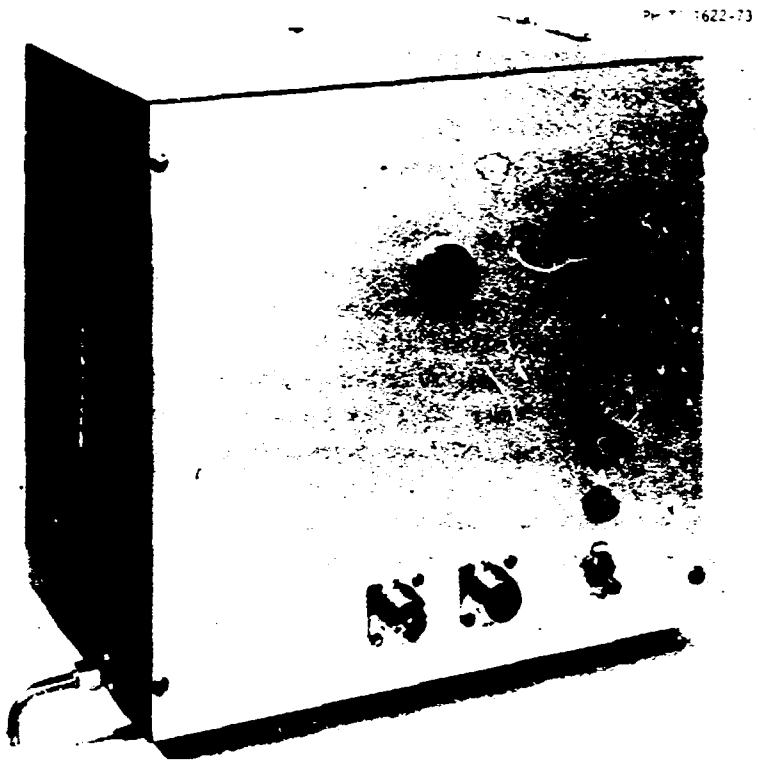

Fig. 7.24.3. Hydrogen monitoring system.

7.25 THERMOCOUPLE MATERIAL IDENTIFIER

W. R. Miller

Acceptance inspection of a large number of thermocouple assemblies has revealed that some contained the wrong connector alloy. Such an error is difficult to find by normal inspection methods and can cause calibration errors. A device was designed and built for inspecting thermocouples to accurately determine whether the thermocouple connectors contain the correct alloy.

Two copper alloy electrodes, one heated to 300°F and the other at ambient temperature, are pressed against the material to be tested. The microvolt signal from the electrodes is amplified and fed to several pairs of comparators. Each pair of comparators forms a voltage "window" that constitutes a go or no-go gage for a particular material. If the material is acceptable, that is, if the voltage signal is within the window, a pilot lamp is lit.

The device will test Chromel, Alumel, iron, and constantan connectors. Both electrodes are mounted in a probe that permits one-hand operation, and the other hand is free to hold the connector being tested. The unit is initially standardized (gain adjusted) by pressing the probe against a piece of constantan of known composition and adjusting for full-scale meter deflection.

7.26 INVESTIGATION OF A DIGITAL MICROPROCESSOR AS AN IDEALIZED BLACK BOX

R. K. Adams

The advent of electronic large-scale integration, by which thousands of transistor circuits can be placed on a 0.1-in. square silicon chip, has brought instrumentation technology closer to realization of a perfect black box as it might be implemented by a digital microprocessor.

The kinds of tasks we believe could be done to significant advantage by a digital microprocessor are those involving high accuracy, extreme signal transducer nonlinearities, mathematical function solving (e.g., integration, multiplication, division, and exponentiation), and control actions involving set points or limits. Preliminary surveys were made of available digital microprocessors, and one was purchased that has some potential for approaching the idealized black box concept. We are now learning how such a microprocessor could be used for one specific task at ORNL.

In becoming familiar with the digital microprocessor, we have learned that the instruction repertoire, the software support, and the input-output and interrupt hardware, by comparison with similar items for a digital minicomputer, are quite limited. These limitations restrict the application feasibility and the ease with which any specific problem can be solved by a digital microprocessor. We have started to develop support hardware and software with a goal of developing a microprocessor designed specifically for environmental stream flow sampling of the White Oak Creek; this microprocessor would ensure that radioactive contaminants released through ORNL area water discharge do not exceed the limits set by the Environmental Protection Agency.

The requirements for this system are as follows: accurate measurement of weir water level; solution of the nonlinear level vs flow rate equation; precise integration of the flow rate vs time (to determine total volume); and actuation of the sampling mechanism when the total volume of water held by the weir attains a specific value. When one sample has been drawn, the integration and sampling cycle is repeated.

Conventional (analog) instrumentation cannot be made sufficiently accurate or stable to achieve the desired overall accuracy. A special digital logic system could be designed to do the job, but cost of fabrication alone makes that approach unattractive; and the cost of a one-time custom digital design rules out the idea altogether. However, the cost of hardware for a programmable digital logic system, such as a digital microprocessor, appears to be competitive with a much less accurate conventional instrumentation system.

Once this device for White Oak Creek is completed, a general program of microprocessor development will be started to devise hardware and software needed to make an almost universal teachable process instrument for signal conditioning and limited control.

7.27 DEVELOPMENT OF A MINIATURE FAST ANALYTICAL SYSTEM[1]

C. A. Burtis W. F. Johnson J. C. Mailen
T. O. Tiffany J. B. Overton C. D. Scott

The development of a miniature fast analyzer has been previously reported.[2] Based on an improved version of this analyzer, a compact, potentially portable, analytical system has been developed. The system includes an automated and versatile sample-reagent loader, a miniature fast analyzer, several plastic rotors and their cleaning station, and a portable data system. The sample-reagent loader combines a unique turntable assembly and two Micromedic pipettes to quickly (i.e., 5 min per rotor), accurately, and precisely obtain, transfer, and dispense small volumes of sample (samples of 1 to 10 μl, diluents of 40 to 49 μl) and reagent (reagents of 20 μl, diluents of 50 μl) into their respective cavities in a 17-cuvet rotor. The loader utilizes separate sample and reagent carrousels, which allows one to operate the system in either the single-sample/multiple-chemistry, the multiple-sample/single-chemistry, or the multiple-sample/multiple-chemistry analytical mode. The miniature fast analyzer rotates a loaded 17-cuvet rotor through a stationary optical system at speeds up to 5000 rpm. The resulting centrifugal force is utilized to transfer and mix the discrete aliquots of sample(s) and reagent(s) into their respective cuvets. The ensuing reactions are monitored photometrically, and the data are processed in real time by either a portable data processor[3] or

an on-line computer. A major improvement to the analyzer has been the addition of a temperature control system that allows the temperature of the spinning rotor to be monitored and controlled to within ±0.2°C during an analytical run. After completion of an analytical run, the rotor is automatically washed and dried in the rotor cleaning station. Many of the standard clinical analyses, including most of the NADH-linked enzymatic analyses, have been adapted for use with the system. Special emphasis has been placed on operating the system in either the single-sample/multiple-chemistry or multiple-sample/multiple-chemistry analytical mode. The initial evaluation and preliminary results obtained with the system will be presented.

1. Abstract of paper presented at Fifth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge National Laboratory, 1973; published in *Clin. Chem.* 19, 895 (1973).
2. *Clin. Chem.* 18, 753 (1972).
3. Ref. 2, p. 762

7.28 X-Y OSCILLOSCOPE INTERFACE FOR A PDP-8/E BASED RECTILINEAR SCANNER DISPLAY

R. T. Roseberry P. R. Bell[1] W. J. McClain[1]

A display controller and computer interface was designed and built for the Molecular Anatomy Program to improve the display speed of rectilinear scans. The single-card interface to the PDP-8/E contains 10-bit digital-to-analog converters for both x and y axes and a 5-bit digital-to-analog converter for the z axis.

With few exceptions, the controller is program compatible with the computer manufacturer's x-y display control, yet it has several additional modes of operation. Interpolation of the z-axis and automatic incrementing or decrementing of the x-axis enhance the displayed image and plot data points in the exact order that the rectiliner scanner received them. In the interpolation mode, each data point is plotted as two points along the x axis. The first point is plotted with z equal to the average of the current data point and the previous data point values; the second point is plotted with z equal to that of the current data point. The x axis is automatically incremented or decremented by 1, 2, or 4 parts of 1024 for each point plotted. Single instructions for increasing or decreasing the y-axis value by 1, 2, or 4 parts of 1024 are also utilized.

The z-axis (or intensity) averaging is accomplished by using the high order 5 bits of a 6-bit digital-to-analog converter for displaying each actual data point. The value of each interpolated point is obtained by logically adding the value of the current and previous data points and by shifting right to take full advantage of the 6-bit accuracy of the digital-to-analog converter.

1. Molecular Anatomy Program.

7.29 PDP-9 COMPUTER – NEUTRON MULTIPLICITY COUNTER INTERFACE

E. Madden F. W. Snodgrass

An interface was designed and built for the Physics and Chemistry Divisions, jointly, to accumulate data from a neutron multiplicity counter[1] buffer memory and to process the data by a PDP-9 computer. This electronic system will be used to study neutron emission in spontaneous fission of heavy elements. Under interrupt control, 48-bit neutron multiplicity counter data words are transferred as four 12-bit bytes.

System electronic debugging was completed. Installation in the experimental environment must await completion of the system data acquisition, reduction, and display software.

1. R. T. Roseberry, J. Halperin, R. L. Macklin, and R. W. Stoughton, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734, p. 3.

7.30 OAK RIDGE ELECTRON LINEAR ACCELERATOR PHASE III[1] INSTALLATION AND ACCEPTANCE

J. W. Reynolds J. G. Craven[2] R. P. Rosenbaum

The third data acquistion computer (DAC 3) for ORELA was received April 6, 1973. Installation and acceptance testing of the SEL 810B computer were completed May 7, 1973. Oak Ridge National Laboratory modifications of the mainframe and ground isolation for the four-channel multiplexer and the scaler interface were completed May 18, 1973. The DAC 3 began routine service on July 16, 1973, after intermittent disk errors were traced to a heating problem in the 512-word buffer storage for the automatic update feature of the 1,048,576-word semi-random access disk. The maximum data rate, which is limited by central processor unit time, is 8500 events/sec, with 30 bits of data per event.

1. J. W. Reynolds and J. W. Woody, Jr., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 41.
2. Mathematics Division.

7.31 STATUS OF OAK RIDGE ELECTRON LINEAR ACCELERATOR DATA ACQUISITION SYSTEM[1]

J. W. Reynolds J. G. Craven[2]

The ORELA data acquisition system continued to give reliable service while five or six experimenters acquired data simultaneously on all three DACs. The number of channels required by each experiment continued to increase. The addition of DAC 3 with 10^6 channels completes the data acquisition system; the total capacity of the system is 2.1×10^6 (0.35, 0.75, and 1.0×10^6) channels distributed over three DACs. The maximum data rate of DAC 3, which is shared by a maximum of four experimenters is 8500 events/sec with the automatic update feature on the DAC 3 disk.

A peripheral equipment controller, a SEL 810B computer, was installed in November 1972 to shift the support functions, that is, card reading, line printing, x-y plotting, magnetic tape handling, and communications (transfer of data sets and programs), from DAC 2. Figure 7.31.1 shows the communications links between the computers at ORELA and the central computing facility. Communications programming is the responsibility of Mathematics Division personnel.

An engineering report of the ORELA data acquisition hardware was prepared; its eight sections include an Introduction, The Four-Channel Priority Multiplexers, The Scaler Interfaces, The Device Controllers, The SEL 810B/PDP-4/PDP-9 Intercomputer Link, Eight Stage Stacking Buffer Memory, Instruction Manual for the Multiplexer Channel and Scaler Interface Tester, and Instruction Manual for the Ground Isolation Driver and Receiver Cards on the Quiet Ground System at ORELA.

1. J. W. Reynolds, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 40.
2. Mathematics Division.

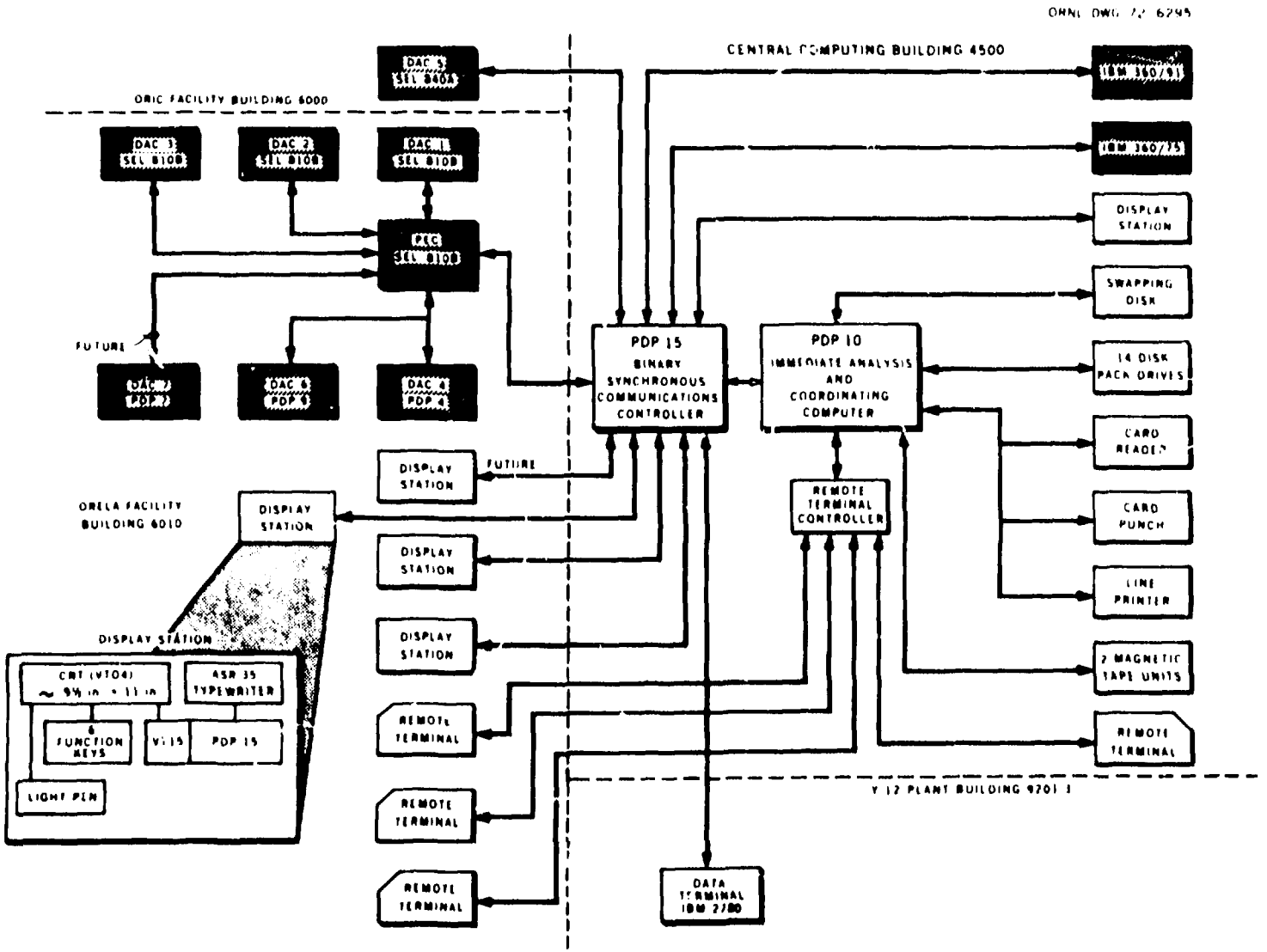

Fig. 7.31.1. ORELA data acquisition and handling system.

7.32 ELECTRON SPECTROMETER[1]

E. Madden

A PDP-8 E computer was purchased for data acquisition and experiment control of position-sensitive electron spectrometer experiments by the Physics Division. A control interface for a Fluke 3330B programmable high voltage power supply and a multiple-scaler data acquisition interface were designed.

1. E. Madden et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 41.

7.33 LIQUID, X-RAY DIFFRACTOMETER CONTROL

F. W. Snodgrass E. Madden

An x-ray diffractometer control interface (Q-5175) for a PDP-8/E computer was built and installed. To avoid the expense of development of new software, this system is program compatible with a previous neutron diffractometer system.[1] The interface has a 12-bit data scaler, an 8-bit neutron monitor prescaler with switch selectable scaling modulus, a 4-bit interrupt register, a 4-bit control register, a 300 pulse/sec clock for motor basic stepping rate, a stepping motor driver, and limit-of-travel protection circuits.

1. F. W. Snodgrass et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 42–43.

7.34 CASSETTE CONTROLLER[1]

E. Madden F. W. Snodgrass

A cassette magnetic-tape controller (Q-5139) to be used with a portable gamma spectrometer for Radioisotopic Sand Tracer studies by the Coastal Engineering Research Center, U. S. Corps of Engineers, was constructed. An Ampex, model TMC digital cassette tape unit/PDP-8/E, computer system interface was installed and checked out. Phase encode recording at 800 bits/in. and 6 in./sec will be used.

1. F. W. Snodgrass et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 45.

7.35 COMPUTER-BASED MULTICHANNEL PULSE-HEIGHT ANALYZER AND SAMPLE CHANGER FOR HIGH TEMPERATURE GAS-COOLED REACTOR BASE AND SAFETY PROGRAM STUDIES

E. McDaniel R. T. Roseberry J. H. Hargis[1]

A custom programming system was prepared for a gamma counting facility that is being used in the High Temperature Gas-Cooled Reactor surveillance program and in experiments to determine the effect of various parameters relative to fission-product release from coated particle fuels.

The fission product surveillance studies were conducted at the Peach Bottom Reactor.[2]

The number of samples being analyzed in the current work overloads the capacity of the analyzer on an 8-hr-day operation. When the interface for an automatic sample changer[3] is completed, 24-hr operation will be available.

1. Consultant, Graduate Student, University of Tennessee, Knoxville
2. Philadelphia Electric Company
3. G. W. Allin and R. T. Roseberry, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822

7.36 PROGRAM FOR COMPUTER-CONTROLLED SAMPLE CHANGER

E. McDaniel R. T. Roseberry

The programming system for the computer-based multi-channel pulse-height analyzer and sample changer for ecological studies[1] was modified. This system, in operation with results since March 1972, was changed as follows.

1. Information, such as intermediate calculational results, orginally considered unimportant by the experimenter was made available to him.

2. A desk calculator subroutine was implemented, with additional functions of exponentiation, natural log, and exponential.

3. Anomalous results were obtained when an isotope that was expected to be present in an ecological sample actually was not present, or when the experimenter used a program to test for the presence of two isotopes when only one isotope was possible. The modified program will recognize these anomalies and will print zeros for the disintegrations per minute and for Student's T test values to make either of these unexpected results apparent to the experimenter.

1. E. McDaniel, L. R. Gitgood, and R. T. Roseberry, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 45–46.

7.37 STUDY OF MULTIPLEXING TECHNIQUE FOR ULTRASONIC FISH TAGS

J. M. Rochelle T. G. Huemiller[1]

A study was made for the Environmental Sciences Division to determine how to simultaneously monitor the temperatures from several fish swimming unrestrained in a single reservoir. In practice, an electronic fish tag would be implanted in the body cavity of each fish, but in this study the data were simulated. A pulse code was devised to permit all tags to transmit a common carrier frequency (ultrasonic) so that only one receiving channel was required. The receiver output was a random mixture of the data pulses from all tags being monitored, and the output was stored on a single-channel magnetic tape for later analysis by a digital computer.

A computer program was prepared to reconstruct the pulse pattern of each tag in the mixture on the tape. To test the decoding software, sample data tapes were prepared by progressively mixing up to 11 simulated fish tag signals by using stereo and cassette tape recorders. These tapes were prepared to have appropriate detector dead times to reject echo pulses, which is required in low duty-cycle acoustical telemetry. Since each detected pulse is accompanied by a fixed dead time, a percentage of the total data is lost in a way similar to coincidence losses in a Geiger-Mueller counter. For a given fish tag system, the accuracy of the decoding software was satisfactory when the data losses due to dead time did not exceed about 10%.

1. Student from Albion College, Albion, Michigan.

7.38 AUTOMATED ATTACK-EFFECTS INFORMATION SYSTEMS

F. M. Glass

The Automated Attack-Effects Information Systems-1 proposed by Stanford Research Institute in April 1970 was studied to determine the practicability of such a system from an engineering viewpoint and to prepare preliminary circuit designs of two sensor stations. The sponsor is the Defense Civil Preparedness Agency. This work is a continuation and expansion of work previously reported.[1] The Defense Civil

Preparedness Agency has indicated a desire to have ORNL build a portable working model for test and evaluation. Some of the details for protection against electromagnetic pulses have not been worked out as of this date.

Both ORNL preliminary circuit designs will operate as dial-up systems with existing telephone networks and will derive power for operation directly from the telephone lines. Two tone telemetry will transmit overpressure and radiation level information, which when decoded will be recognizable as basic operating situations (BOS) that can be stored in a memory, recorded on tape, and displayed on a 3 × 3 matrix as single basic-operating-situation numbers. Low power consumption, good noise immunity, and memory during power outages are essential features that were achieved in the ORNL design.

1. F. M. Glass and C. C. Courtney, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 11.

7.39 ENGINEERING FEASIBILITY STUDY ON AUTOMATED ATTACK-EFFECTS INFORMATION SYSTEMS FINAL REPORT[1]

F. M. Glass J. M. Rochelle H. N. Wilson

The Automated-Effects Information Systems-I proposed by the Stanford Research Institute in April 1970 was studied to determine the practicability of such a system from an engineering viewpoint. At the request of the Defense Civil Preparedness Agency, ORNL prepared a preliminary design of two different models that are based on the original basic operating situation concept proposed before any work had been done on this system. Both ORNL designs will operate as dial-up systems with existing telephone networks and derive power necessary for operation directly from telephone lines. However, one is a digital system and the other is an analog system. From this study, a pressure-operated switch was developed that is automatically reset electrically and that requires only a few microcoulombs of stored energy to reset it after an interrogation. A recommendation from this study is that a test model be constructed to provide a means of checking for problems that could be encountered in a dial-up system when long distance is involved.

1. Abstract of published report ORNL-TM-4194 (January 1973).

7.40 INSTRUMENTATION AND CONTROLS DIVISION ACTIVITY WITH THE AEC REGION II MOBILE ASSAY VAN

V. A. McKay

E. McDaniel R. T. Roseberry T. F. Sliski

The Division activity with the Region II mobile assay van was concerned with maintenance, programming, analysis, and improvement.

The van was maintained by the Division's computer and analyzer group. The van came to the Division in a state of general disrepair due to overheating encountered in field and storage operations. The cause of overheating was corrected, and the electronic systems were repaired.

An assembly language program prepared for the ND-812 computer automatically determines the ^{235}U content in safeguard samples by nondestructive gamma-ray spectrometry. The programs were integrated into one package, all of which reside in the core memory, thereby eliminating the necessity and inconvenience of overlay programs.

The goal of the analytical program was to determine the optimum field sample and standard preparation parameters. For ease of preparation and minimum of measurement error under field conditions, samples with sectional densities of 1.0 g/cm^2 were determined as optimum.

The electronic circuit was updated by increasing the memory from 12 to 16K, by replacing the signal amplifier, by increasing the transport from two to three in the cassette tape system, and by purchasing a spare ASR 33 unit.

The assembly language program was enlarged by adding a real-time clock routine; an identification display with spectral data of title, date, time of day, and live time; a routine to read the data back into the computer; and additional routines that allow data analysis in the field.

Sample preparation techniques and equipment were demonstrated but not implemented. The detection equipment was replaced with two 3- by 3-in. NaI(Tl) high-resolution sensors and a portable 10-in.-OD "pickle barrel" shield with a 3-in.-thick lead wall.

7.41 RADIOISOTOPIC SAND TRACER STUDY SUPPORT

H. R. Brashear

F. N. Case[1] J. M Rochelle F. W. Snodgrass

Sand tracing equipment[2] used in a cooperative program of the U.S. Atomic Energy Commission, Division of Isotope Development, and the U.S. Army Corps of Engineers, Coastal Engineering Research Center, was transfered to the Corps of Engineers. ORNL personnel trained Coastal Engineering Research Center personnel at ORNL to handle radioisotope-tagged sand and to operate and maintain the equipment.

Technical personnel of ORNL assisted the Corps of Engineers during their February 1973 test at the Oceanside, California, harbor. Test results show that the radioisotopic sand tracer system is a capable tool to collect sand movement data in the coastal zone, and the results are being used to significantly reduce the cost of harbor maintenance at Oceanside.

1. Isotopes Division.

2. H. R. Brashear, F. H. Acree, and F. N. Case, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 43-44.

7.42 AUTOMATIC SAMPLE CHANGER

G. W. Allin R. T. Roseberry

Fabrication and installation of the hardware and shielding for the automatic sample changer previously reported[1] were completed. The computer software and interface will be completed soon.

1. G. W. Allin et al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1972*, ORNL-4822, p. 46.

7.43 ON-LINE COMPUTER DATA SYSTEM FOR THE ORANGE COUNTY WATER FACTORY 21

J. L. Redford S. J. Ball

A computerized data system was designed, assembled, and programmed for use at Water Factory 21, a vertical tube evaporator/multistage flash plant in Orange County, California. The system consists of a 12K-word core, PDP-8E computer with a 32K-word disk, a dual-cassette magnetic tape unit for program and data storage, and a Vidar 521 integrating digital voltmeter with reed-relay scanning capabilities for 100 resistance and 70 dc voltage inputs.

The programs written for the computer system utilize an expanded version of the FOCAL language which allows for data acquisition, disk and tape storage, and contact output control. The experiment programs aid preoperation instrument calibrations, perform detailed analyses of plant operation, and assist in running and analyzing several special experiments.

7.44 ON-LINE COMPUTER CONTROL OF BIAXIAL STRESS LOADINGS FOR LMFBR YIELD SURFACE STUDIES

S. J. Ball K. C. Liu[1]

Experimental studies were made to determine the elastic-plastic behavior of type 304 stainless steel (a prime candidate material for construction of LMFBR components) under simultaneous tension-torsion stress loading. To obtain valid results, the stress loading in both directions had to be controlled precisely. The first control device was a portable TR-10 analog computer. The stress trajectories in the tension-torsion coordinate system were controlled by integrator-generated ramp set-point voltages. The direction of the trajectory was controlled by manually setting the ramp rates. An on-line computation, using the measured strain signals, signaled when the elastic limit, or edge of the linear surface, was reached. At that point, the ramps would be stopped automatically and the trajectory would be reset for the next probing of the yield surface.

A better control scheme was devised which made the surface probing and many other tests fully automatic. A digital computer data-acquisition system, acquired from the U.S. Department of the Interior, was connected to the TR-10 computer and programmed by using an augmented version of the FOCAL language. With keyboard-entered instructions, an experimenter could request that a series of programs be run sequentially; such instructions could include, for example, (1) probe the yield surface from 16 equally spaced prespecified trajectories by beginning at the center of the surface and returning to the center point after each probing, and (2) aim at a target point in the stress space while varying the trajectory rate to keep the measured strain rates within the limits specified and checking to ensure that specified strain limits are not exceeded.

The digital computer calculates the strain-rate information, performs control algorithms, prints run status information, and punches data on paper tape for later processing.

1. Reactor Division.

7.45 CONTROLLED THERMONUCLEAR REACTOR PROGRAM CONTROLS ANALYSIS

J. E. Swander[1]

F. H. Clark R. S. Booth R. S. Stone

In anticipation of this Division's increasing involvement in controlled thermonuclear reactor research and development, the research group listed above was organized to become familiar with current controlled thermonuclear reactor experiments and proposed reactor configurations (chiefly Tokamak), to identify the types of activities that control-systems development will require, and to begin programs directed toward analysis of plasma-device dynamics from the control viewpoint. Thus far, the activities of the group have mainly been discussions with members of the Thermonuclear Division.

1. Subcontract with the University of Tennessee, Knoxville. (Deceased June 7, 1974.)

7.46 DATA ACQUISITION SYSTEM FOR ECOLOGICAL FIELD STUDIES[1]

C. D. Martin J. T. Hutton R. L. Simpson

A small computer-based data acquisition system was designed to acquire data remotely from rain gages and stream runoff (stage height) recorders. Commercially available telemetering modules that employ frequency-shift keying are used to transmit data and data acquisition commands over telephone lines. In addition to controlling the acquisition of data, the system software also diagnoses malfunctioning field sensors and it prints alarms at the computer site.

1. Abstract of paper presented at Eighth Annual Conference on Digital Computers in Process Control, the University of Tennessee, Knoxville, April 16–18, 1973.

8. Process Instrumentation and Control

8.1 GAMMA IRRADIATION CHAMBER PURGE CONTROL SYSTEM

W. R. Hamel B. C. Duggins

Rock salt that surrounds a container of high-level wastes in the federal waste repository will be exposed to high gamma-ray doses and intensities. A gamma irradiation facility was constructed at the High Flux Isotope Reactor (HFIR) to study the effects of radiation on rock salt. Specimens of rock salt can be lowered through a pipe into the center of spent HFIR fuel elements of various ages to simulate repository conditions. The pipe is closed and watertight, and it extends from the poolside to the spent fuel rack.

Because the pipe is immersed in water, there is a possibility that water could enter the pipe in some manner. If this should occur, some portion of the rock salt specimen would dissolve, including a Br impurity. The Br^- in solution would inhibit recombination of H_2 and O_2 produced from radiolysis of the entering water. With the recombination inhibited, explosive mixtures of these two gases could be formed.

To prevent an accumulation of an explosive mixture, the pipe is continuously purged with helium at a low flow rate; a back-up purge system was also installed. A hygrometer in the purge system determines whether water is present in the pipe.

8.2 HYBRID COMPUTER SIMULATION OF THE THERMAL HYDRAULIC TEST FACILITY HEAT REMOVAL SYSTEM

W. R. Hamel

Because of stringent control system performance requirements on the complex heat removal system of the Thermal Hydraulic Test Facility, a hybrid computer simulation is being developed to evaluate the system's design concepts and provide startup assistance.

A theoretical model of the heat removal system, including a model of a simplified rod-bundle test section, was developed, which comprises four lumped-parameter heat exchanger approximations; a simplified test section flow model; pressurized water pump characteristics; 13 control valves, including nonlinearities; and ten process controllers and associated process measurement devices.

We plan to implement the theoretical model on the Division's AD-4 PDP-10 hybrid computer; the amount of algebra implemented digitally will be maximized to conserve analog equipment. Process dynamics, such as heat exchanger response, will be programmed on the analog computer. Since the simulation will operate in real time, actual process controllers will be linked to the computer for the study.

8.3 AQUATIC LABORATORY STATUS

B. C. Duggins

The aquatic laboratory system was tested and is now operational with manual control of the blending valves. Funding of computer control was delayed to the extent that it will not be available until late FY 1974.

The analog controllers on the supply loops performed as expected except for the hot water

heater. Due to the light startup load, the rangeability of the bypass control on the steam-to-water exchanger was inadequate. The bypass control was replaced by throttling the steam supply, a method that gives greater rangeability but is somewhat less responsive.

One analog temperature program controller was assembled from reused components so that experiments that require programming could be conducted in one tank until the computer is received and installed.

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1. B. C. Duggins et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 53.

8.4 MEASUREMENT OF DYNAMIC STRAINS OF THE WELL-HEAD ASSEMBLY AT HYDRAULIC FRACTURING WASTE DISPOSAL FACILITY

W. R. Hamel B. C. Duggins

During the injection of radioactive wastes into underground shale formation at the hydraulic fracturing waste disposal facility, substantial vibrations of the well-head assembly were observed. Since such vibrations could greatly reduce the fatigue life (hence, operational life) of the components, we quantitatively evaluated the strain (or stress) amplitudes and frequencies at obvious high stress locations on the plug-head section of the well-head assembly. Twelve strain gages were mounted on the plug head by the Experimental Mechanics Section of the Reactor Division, and data were collected from these gages during two waste injections. Evaluation of these data indicated that the stress levels associated with the vibration were so far below the endurance limit of the plug-head material that any fatigue analysis would predict infinite life for the frequencies observed.

8.5 ADDITIONS AND MODIFICATIONS TO THE ORNL STEAM PLANT CONTROL SYSTEMS

W. R. Hamel B. C. Duggins

Burner Control (Flame Safety) Systems

Boilers 1, 2, 3, and 4 of the ORNL Steam Plant were evaluated to determine their conformance with National Fire Protection Association Codes 85B and 85D, which define minimum requirements for safe operation of natural-gas and oil-fired multiple-burner boiler furnaces. Our conclusion was that the burner control systems were deficient. Codes 85B and 85D were studied in detail, and a suitable burner control was developed. Functional logic diagrams for the desired system capability were prepared and were used to communicate with vendors in obtaining budget estimates for the required hardware.

Combustion Control Systems

Because of the energy shortage, there has been a continual reduction in natural gas allotments for steam generation at ORNL. In the future, it will be necessary to burn fuel oil routinely to offset the reduction of natural gas. To achieve a safe and reliable steam generation capability with greater dependence on fuel oil, fuel oil burning in boilers 1, 2, 3, and 4 must be fully automated. In addition, much of the combustion control hardware must be replaced, because it is outdated and spare parts are scarce. To refurnish the combustion control systems, we will replace outdated equipment and install new fuel oil combustion automation equipment, feedwater control equipment, and boiler control panelboards.

A cost estimate for all phases of upgrading the burner controls and combustion controls was prepared cooperatively by the General Engineering Division and this Division. Preparation of a preliminary proposal to be sent to the AEC-ORO was started.

8.6 pH CONTROL OF STEAM PLANT EFFLUENTS TO WHITE OAK CREEK

W. R. Hamel

Possible methods of reducing the acidic effects of steam effluents on White Oak Creek were evaluated. From a study of various effluent sources, we concluded that the principal offender was effluent produced during regeneration of the boiler feedwater demineralization system. With the assistance of the Analytical Chemistry Division, we observed the daily and seasonal characteristics of these effluents and their effects on White Oak Creek. We found that if the effluents were accumulated, well mixed, and discharged slowly, their influence on the pH of White Oak Creek would be within acceptable limits even during periods of small rainfall. The result of this analysis of the total system was a simple, yet adequate, solution that eliminates the need for an active neutralization system.

8.7 PROTOTYPE GREENHOUSE FOR WASTE HEAT RESEARCH

B. Lieberman

Instrument engineering assistance was furnished to the Reactor Division of ORNL and the Tennessee Valley Authority (TVA) for construction of an experimental greenhouse by TVA at Muscle Shoals, Alabama. The purpose of this project is to determine the feasibility of the idea, originated and developed by the Reactor Division, that waste heat from power stations could be utilized to provide year-round controlled growing conditions for greenhouses. This Division has advised the Reactor Division and TVA whether the instrument components and systems proposed by the greenhouse contractor and his instrument subcontractor were suitable; prepared specifications for TVA to purchase instruments and controls for a water heater system that will simulate the waste heat source; and supplied test instruments to the Reactor Division personnel during their evaluation of the operation of the experimental greenhouse.

8.8 INSPECTION OF GLOVE BOX SYSTEMS

B. Lieberman B. C. Duggins

The Instrumentation and Controls Division has continued to assist the Laboratory Safety and Radiation Control Department in inspecting and testing glove box systems installed at ORNL.[1] Each system is inspected, and the control and safety instruments are evaluated. If the instrumentation is judged inadequate for safe operation, the inspectors recommend improvements. Ten systems were inspected, and six required improvements. Final testing for approval includes simulation of component failures in the control system to determine that the resulting pressure excursions will not exceed the safe limits for the glove box.

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1. B. C. Duggins and B. Lieberman, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 55.

8.9 PRESSURIZED AQUEOUS COMBUSTION EXPERIMENT

B. Lieberman A. H. Malone

Instrument systems were supplied to measure the flow of oxygen and to control the temperature and pressure in an autoclave for a laboratory scale batch-type process developed by the Chemical Technology Division for burning solid wastes. The solid waste materials are shredded, mixed with water, and oxygenated in an autoclave at 600 to 700°F and 700 to 1200 psig.

An instrument flow sheet was prepared for a larger continuously operating pilot plant.

8.10 INSTRUMENT DESIGN FOR A NEW HYDROFRACTURE FACILITY

R. E. Toucey

A conceptual design and a cost estimate were completed for a proposed new hydrofracture facility that will be constructed near an existing hydrofracture facility and will be operated for disposal of radioactive liquid wastes.

Measurement, control, and ratioing of the flows of concrete and radioactive waste solutions will be a major instrument task. Instruments will also monitor levels of dry solids in storage bins and levels of liquids in storage tanks. Liquid-level readings will be telemetered to the Waste Monitoring Control Center (Building 3105) for transfer of liquid waste from ORNL. Remotely operated valves will be controlled from a graphic control panel. A standard facility radiation system panel with alarms will be installed for protection of operating personnel.

8.11 HEAVY-ION BOMBARDMENT FACILITY

B. C. Duggins J. M. Googe[1] A. H. Malone

A control and data collection system was fabricated for the new Heavy-Ion Bombardment Facility, which utilizes the 6-MeV Van de Graaff accelerator. The facility will be used to study damage to metals expected in controlled thermonuclear reactors. The instrumentation system comprises vacuum pumping control, ion beam sweep, temperature control of specimens, and measurement of deposited power of the ion beam. The system is operational with good performance.

The most challenging instrument problem was that of measuring the deposited power of the ion beam. After assessing the features of various methods, we selected calorimetry and mechanically designed the specimen chamber (Fig. 8.11.1) to enhance the calorimetry and to overcome the deliberately poor heat transfer from the specimen. As a result, the temperature rise of the specimen per watt of deposited power is high. A precision temperature control loop controls the specimen heaters to set the experiment temperature at a selected value from ambient to 1000°C. Another loop, a precision temperature difference controller, controls the specimen auxiliary heater to set the specimen temperature significantly higher than that of its environment.

The temperature difference loop is set with the ion beam turned off. A requirement for setting this loop is that the power required by the specimen auxiliary heater must be greater than the power to be deposited by the ion beam. The electric power delivered to the specimen auxiliary heater is continuously measured and recorded. Then, when the ion beam is turned on, the temperature difference controller automatically reduces the electric power to the specimen auxiliary heater by the amount of the power deposited in the specimen by the ion beam.

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1. Consultant, Department of Electrical Engineering, University of Tennessee, Knoxville.

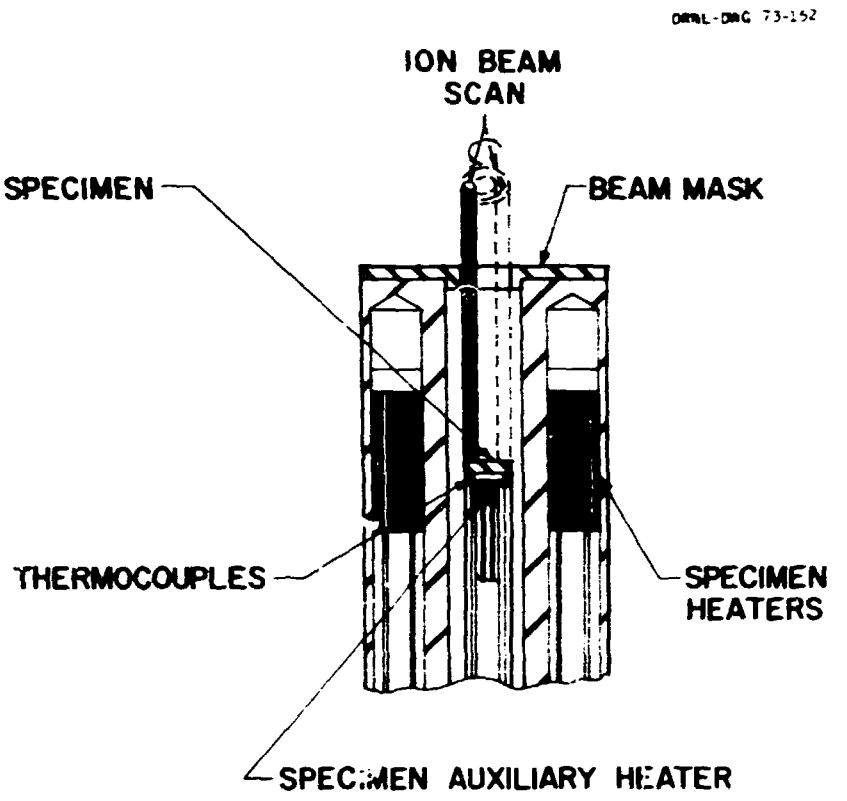

Fig. 8.11.1. Heavy ion bombardment facility specimen chamber.

8.12 TRANSURANIUM PROCESSING FACILITY STATUS

H. E. Cochran

The Transuranium Processing Facility, which is completing its seventh year of operation, is the only source of significant quantities of berkelium, californium, einsteinium, and fermium in the United States. During FY 1973 434 mg of ^{252}Cf was recovered for research and the commercial sales program.

No major changes were made in the plant or the instrumentation during the year, and only routine instrument maintenance and refinement of the control systems were required. The fast-neutron counting systems, previously reported,[1,2] continue to reproduce assay values within 1%.

Manpower for instrumentation was reduced to a minimum—one technician full-time and one engineer part-time during this past year.

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1. H. E. Cochran et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 51–52.
2. H. E. Cochran et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734, pp. 46–47.

8.13 INSTRUMENT CABINET FABRICATION FOR THE OAK RIDGE GASEOUS DIFFUSION PLANT

R. E. Toukey

The instrument panel fabrication shop of this Division was utilized to support the ORGDP cascade improvement program. Twenty relay-rack-type cabinet assemblies were fabricated to ORGDP designs, which required 220 man-days of craft labor.

8.14 FISSION GAS REMOVAL STUDIES

R. E. Toucey

Engineering services were furnished to design and fabricate an instrumentation system for an absorption-distillation system to study the removal of rare fission gases, primarily ^{85}Kr, from fuel processing off-gas. The system will use carbon dioxide or Freon in both liquid and gaseous states to absorb the fission gases. The instrument complement will include six capacitance level sensors, one turbine flowmeter, and seven thermal-type mass flowmeters for gases as well as conventional devices.

8.15 HTGR FUEL REFABRICATION DEVELOPMENT PROGRAM

H. E. Cochran A. J. Millet

Highlights of this Division's participation in the program[1] this year include expanded use of the fuel characterization data system (Sect. 7.3), development of a particle size sensor and purchase of an analyzer (Sect. 7.19), implementation of a multispectra neutron irradiation technique to determine the amount of fissionable material in fuel sticks, and development of a sequence controller for the fuel stick molding machine.

To assay fissionable material in the fuel sticks, fission is induced in the sticks and then the delayed neutrons emitted by the fuel are counted. A machine was devised to sequentially step the stick past a scanner-detector in lengthwise segments, to accumulate neutron data, and to log the data. Figure 8.15.1 shows the control panel and the machine with a stick being assayed.

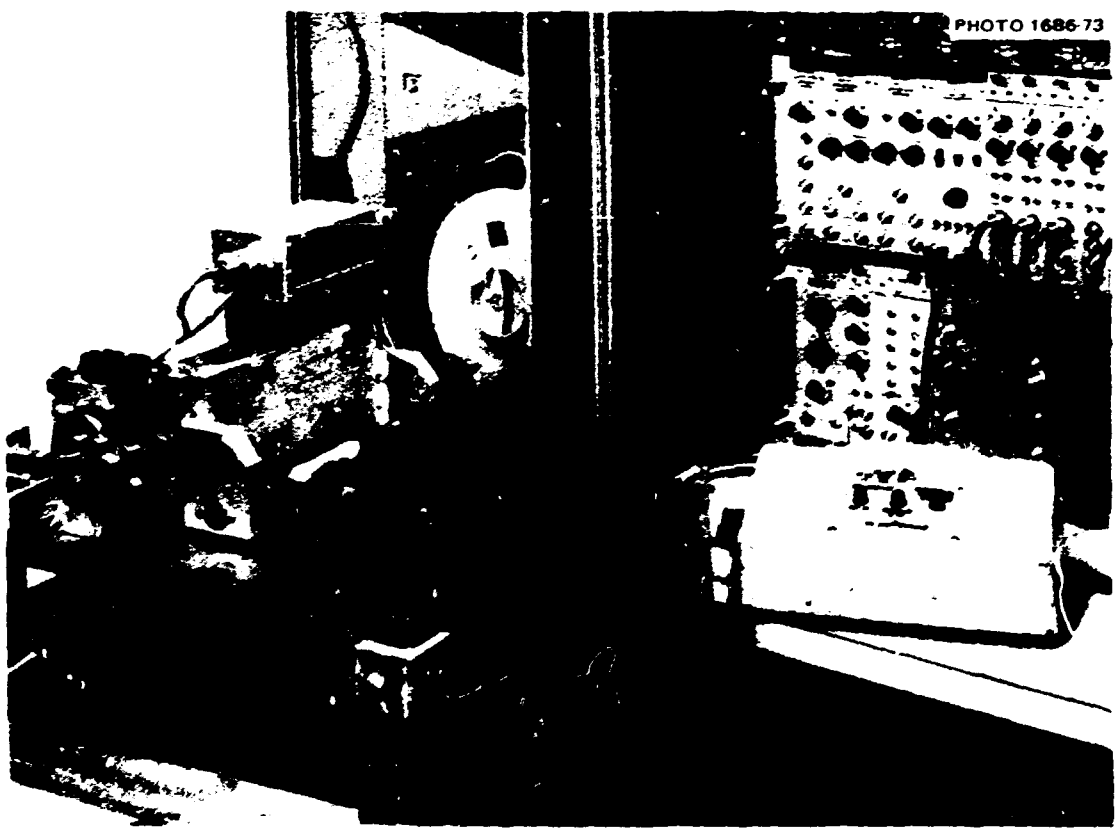


Fig. 8.15.1. HTGR fuel stick assay scanner.

The fuel stick molding machine has a 24-station circular index table that moves the mold through the steps required to produce a stick. Operations occur simultaneously at every station, including cleaning the mold; inserting the bottom punch, fuel particles, matrix slug, and top punch; heating; compressing; cooling; and ejecting. The sequence controller (Fig. 8.15.2) paces the machine through the steps and verifies that the operation at each station is completed before the table is indexed. This machine operates at a production rate of 200 sticks hr.

1. H. E. Cochran and B. Lieberman, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 52–53.

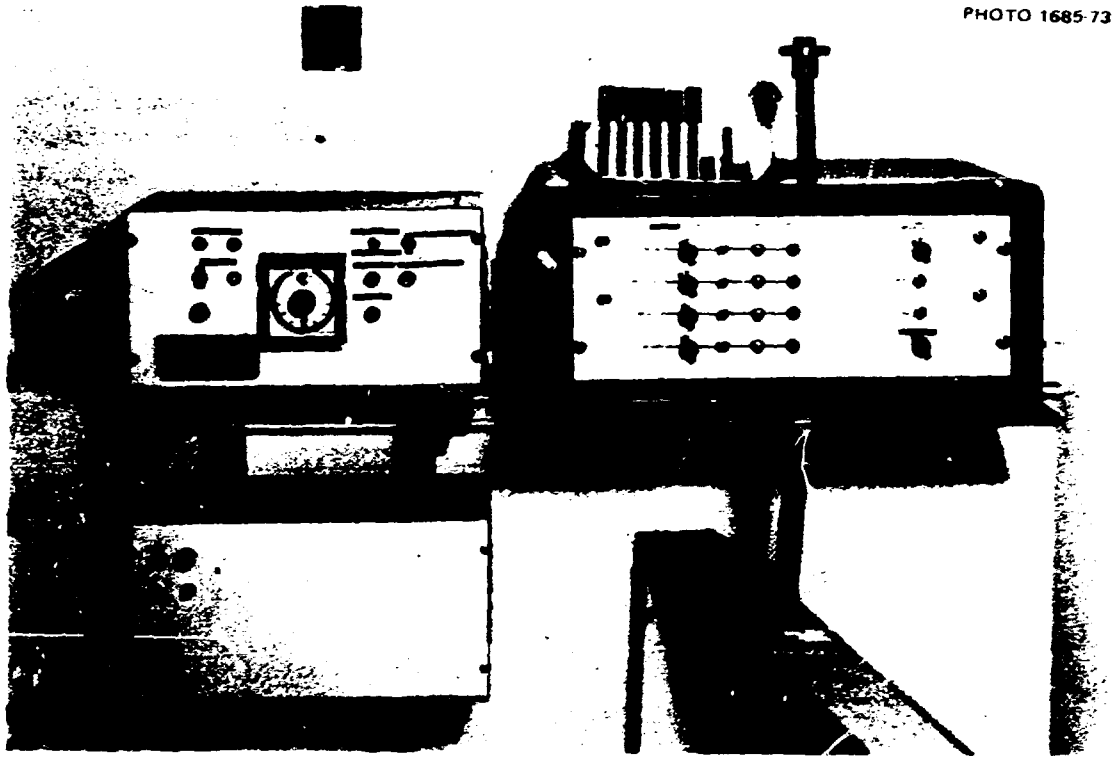


Fig. 8.15.2. HTGR fuel stick molding machine sequence controller.

8.16 ULTRASONIC THERMOMETERS FOR FUEL CENTER-LINE TEMPERATURE MEASUREMENTS IN HFIR IRRADIATION CAPSULES

R. L. Shepard R. M. Carroll

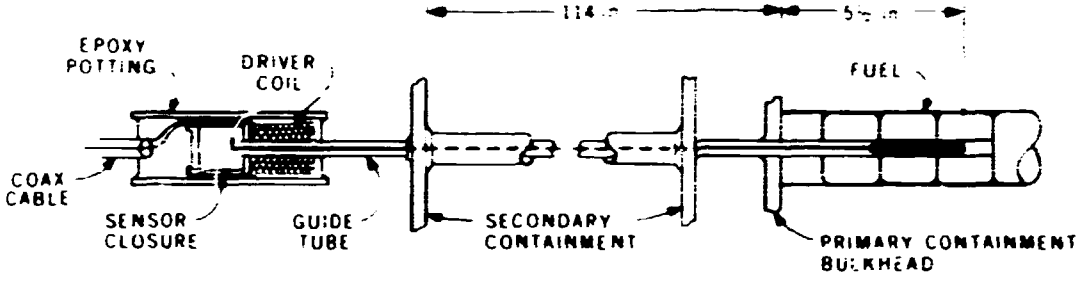
Rhenium ultrasonic thermometers were used to measure fuel center-line temperatures up to 1100°C in two HFIR irradiation capsules, HRB-5 (Fig. 8.16.1) and HRB-6.

In the 2500-hr HRB-5 irradiation, temperatures were continuously measured but were observed to drift with irradiation. A 7% shift in room temperature transit time was observed. At the completion of irradiation the thermometer was calibrated whole-capsule and in-pool in the HRB-X furnace to 800°C. The calibration data and transit times obtained between reactor cycles during isothermal shutdown conditions were used to correct for drift. These corrected temperatures agreed within 40°C of values obtained in a companion experiment using thermocouples. The drift was

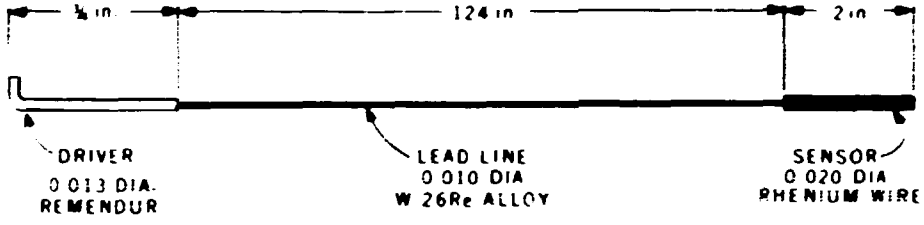
attributed largely to transmutation. Postirradiation examination of the pure rhenium sensor which received a thermal-neutron fluence of 1×10^{22} *nvt* and a fast-neutron fluence of 3×10^{21} *nvt*, showed the sensor material to have transmuted to 50% osmium-50% rhenium.

A duplicate ultrasonic thermometer in the HRB-6 capsule performed marginally during 3000 hr of irradiation and showed loss of sensitivity due to mechanical interference between the ultrasonic lead line and its guide tube.

Both thermometers were installed in a new way: the ultrasonic sensor, lead line, and magnetostrictive driver were contained in a ¼-in. guide tube, which was part of the fission gas primary containment, and the ultrasonic driver coil was wound outside the containment tube so that no hermetic electrical seal was needed.



FUEL PIN CENTERLINE INSTALLATION



SENSOR LINE

Fig. 8.16.1. Ultrasonic thermometer, model HRB-5.

8.17 LOOP RESISTANCE MONITORING OF TUNGSTEN-RHENIUM THERMOCOUPLES IN HFIR FUEL IRRADIATION CAPSULES

R. L. Shepard

The calibration of tungsten-rhenium thermocouples used in measuring fuel center-line temperatures is known to change with irradiation, thereby causing temperature errors of hundreds of degrees. Changes in the resistance of the thermocouple loop have been shown to accompany calibration changes.[1] Continuous monitoring of the loop resistance of W3Re W25Re thermocouples during two fuel irradiations (HRB-3 and -4) at the HFIR has provided a way of correcting for thermocouple calibration drift and of anticipating and diagnosing thermocouple failure.

In the 6000-hr 1100°C HRB-3 experiment, a calibration drift of −300°C was accompanied by an 11% increase in loop resistance. In the HRB-4 (Fig. 8.17.1) experiment, the thermocouple calibration drifted 75°C in 1,000 hr at 1100°C, accompanied by an 18% increase in loop resistance measured over only the 5-in. thermocouple loop actually within the fuel. These more sensitive measurements of loop resistance and thermal emf changes furnished a quantitative basis for correction of the thermocouple calibration during irradiation, after which the corrected temperatures agreed well with calculations based on heat production and conduction and with other determinations of thermocouple drift under similar reactor conditions.

In addition to enabling correction for calibration drift, the loop resistance measurements also gave an early warning of impending thermocouple failure. The process involved the rate of resistance increase, which continued to accelerate for 40 hr before the thermocouple failed because of an open circuit. Had the thermocouple been in a critical service, the reactor could have been shut down safely before the thermocouple had failed.

1. R. L. Shepard et al., "Thermocouple Surveillance of HRB-4 Experiment," *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 70.

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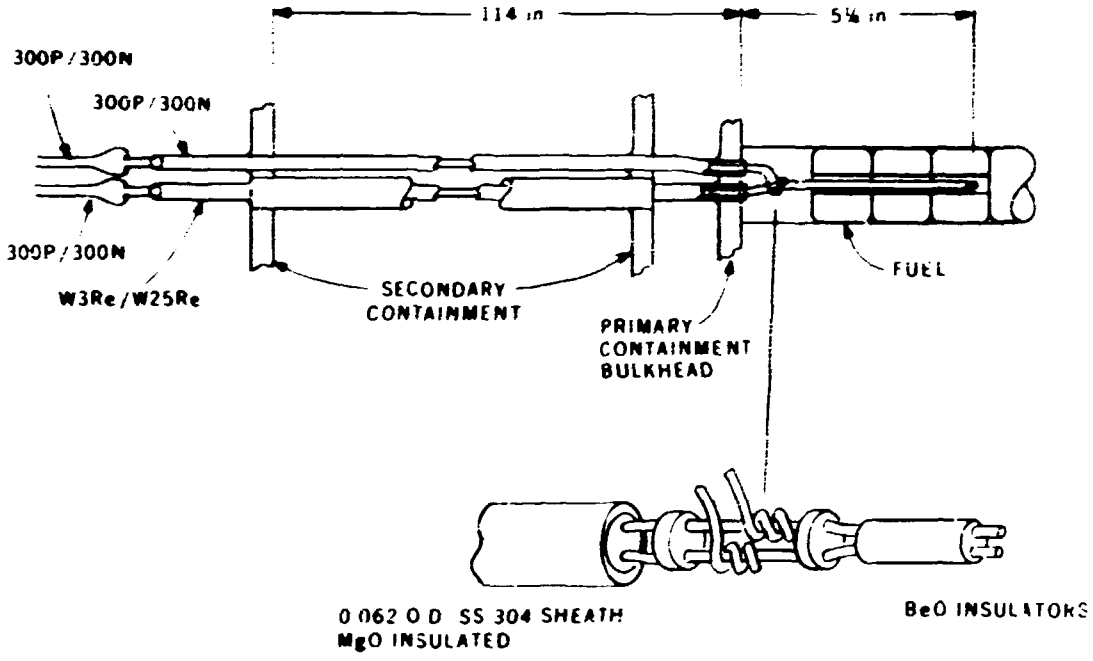

Fig. 8.17.1. Four-wire tungsten-rhenium thermocouples, model HRB-4.

8.18 IN-POOL CALIBRATION FURNACE HRB-X

R. L. Shepard W. A. Bird

A furnace facility (Fig. 8.18.1) was designed and constructed[1] to calibrate thermometers in instrumented HRB fuel irradiation cartridges. The facility was used for whole-capsule in-situ postirradiation calibration and for midterm calibration of the ultrasonic center-line thermometer in

the HRB-5 and HRB-6 cartridges, respectively. The latter cartridge was returned to its core position for further irradiation.

The entire irradiation capsule can be heated to 815°C in the furnace. HFIR pool water can be admitted or expelled for radiation shielding and for loading or unloading the capsule in-pool during a reactor shutdown. Failure of the cartridge containment during heating can be detected by observing the purge gas flow system. The normal gas-sweep flow through the cartridge and the internal temperature measuring system are continued during furnace heating. The temperature of the furnace can be controlled by observing the temperatures indicated by either the four sets of furnace thermocouples or the internal cartridge thermocouples. Four-zone heating, spanning 24 in., has controlled the axial temperature uniformity to ±11° at 590°C in the furnace and to ±7°C in the capsule within the furnace.

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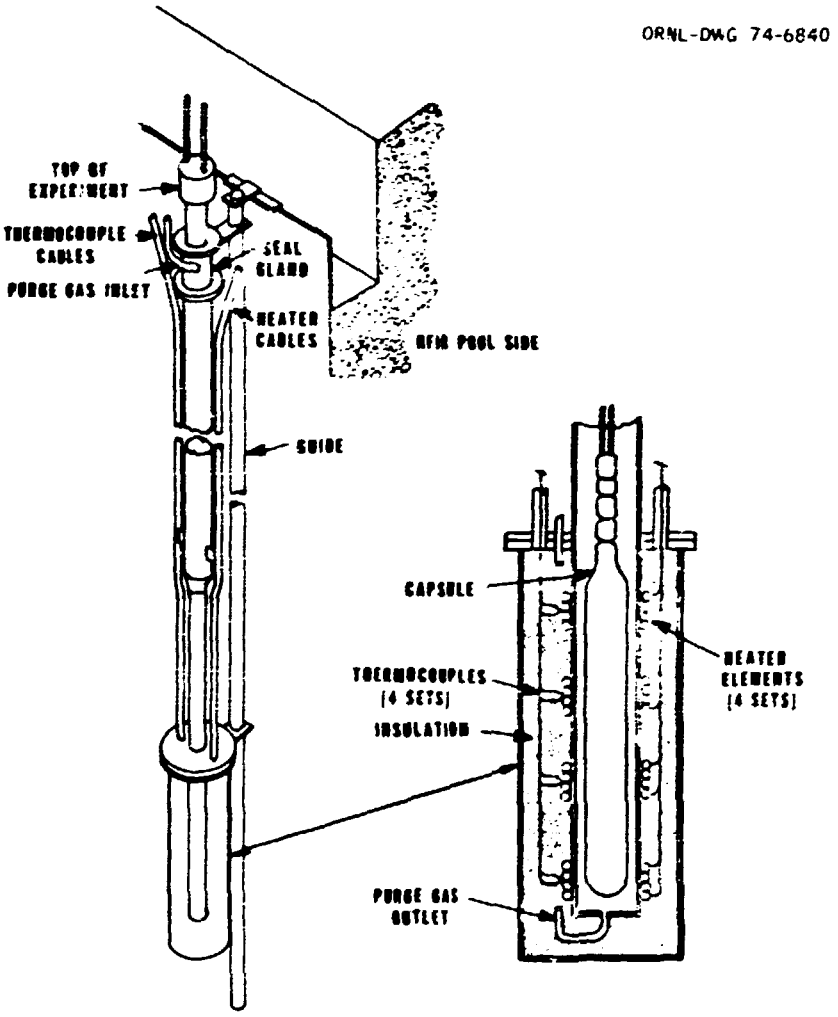
1. L. P. Pugh of the Reactor Division.



INPOOL CALIBRATION FURNACE HRB-X

Fig. 8.18.1. Inpool calibration furnace, model HRB-X.

8.19 IN-PLACE REWELDING OF FAILED SHEATHED THERMOCOUPLES

R. L. Shepard
W. A. Bird F. R. Gibson

A voltage-controlled, capacitor discharge welder was built which is similar to a device described by Babbe[1] for in-situ rewelding of open-circuited thermocouples in reactor experiments. A [illegible]-in.-OD, sheathed, type K thermocouple in the HRB-5 irradiation cartridge failed during irradiation, opening intermittently on heating and closing on cooling. The cartridge was transferred to the in-pool furnace HRB-X and heated to 425°C, that is, a temperature just above that at which the thermocouple opened. A breakdown test voltage was obtained for the failed thermocouple by using the Babbe device. The thermocouple was then rewelded by discharging a 40-mF capacitor charged to 110% of the breakdown voltage. The welding method was demonstrated twice more when the thermocouple failed during thermal cycling in the pool-side furnace.

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1. E. L. Babbe, *ZAPPER—A Device for Repairing Open-Circuited Thermocouples*, Report AI-AEC-TDR-12710, Atomics International (June 3, 1968).

8.20 LOOP-CURRENT STEP RESPONSE METHOD FOR MEASURING THERMOCOUPLE TIME CONSTANTS IN PLACE

R. M. Carroll R. L. Shepard

The time constant of a sheathed thermocouple in a nuclear reactor or in an industrial process is a measure of the thermocouple ability to follow rapid temperature changes. The time response is affected by the thermocouple's surroundings and may change with aging or irradiation. A method was developed to measure the time response of a thermocouple in place (Fig. 8.20.1). An electrical current is passed through the thermocouple loop, raising its temperature slightly. When the current is stopped abruptly, the thermocouple returns to ambient temperature. The thermal time constant of the thermocouple can be obtained by analysis of the output of the cooling thermocouple.

In the loop-current step response method, current is applied for a few seconds, then switched off, and the thermocouple output is stored in digital form during a few minutes of cooling. These digital data are processed numerically, using a smoothing and least-squares-fitting procedure, to provide a time-dependent equation that contains one or more time constants. These time constants can be obtained repeatedly for a given thermocouple within 3%, and they agree within 12% of the values of time constants obtained by another method where the thermocouple is plunged into a water bath.

The loop-current, step response method was used to measure time constants of six 0.0615-in.-diam, sheathed, type K insulated-junction thermocouples in the LMFBR Fuel Failure Mockup that was operated from 320 to 356°C with a rod power of 4.78 kW and immersed in flowing sodium. The measured time constants ranged from 102 to 287 msec and were reproducible to within 5%. In other applications, the method will detect improperly installed extension cables, moisture in thermocouple insulation, or changes in flow velocity in the fluid surrounding the thermocouple. With the loop-heating current, additional information can be obtained about the internal condition of the thermocouple by utilizing axial temperature gradients produced by the Peltier effect.

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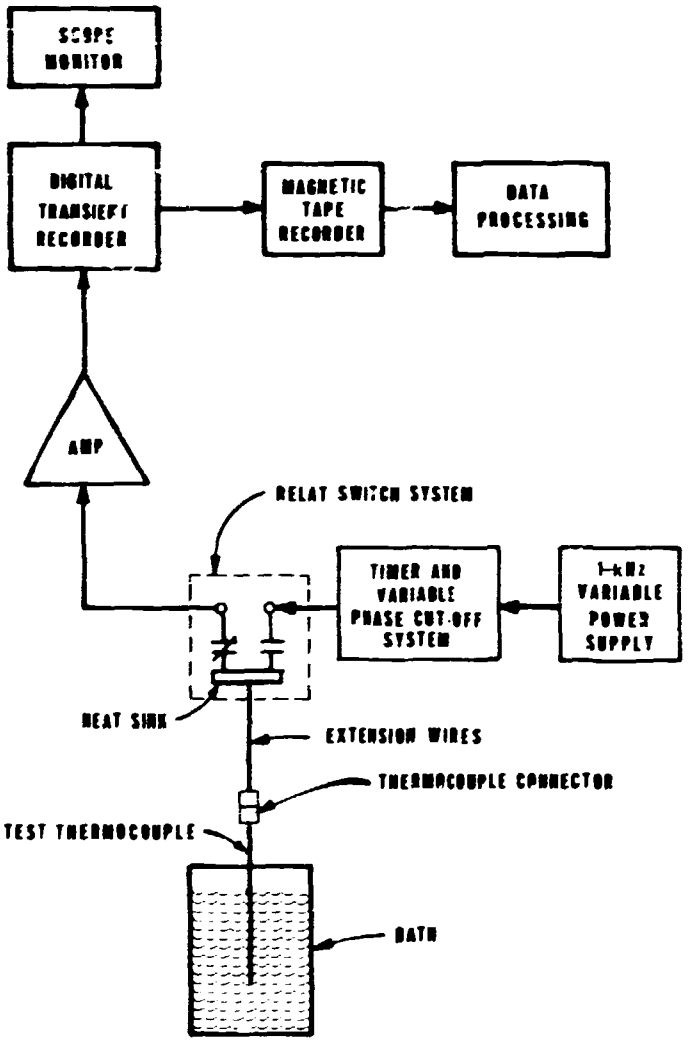

Fig. 8.20.1. Schematic of loop-current-step method of measuring thermocouple time response.

8.21 TRANSIENT ELECTRICAL RESPONSE OF SHUNTED HIGH-TEMPERATURE THERMOCOUPLES

J. R. McDearman[1]
J. M. Googe[2] R. L. Shepard

At high temperatures above 2000°C, thermocouples give false, steady-state temperature indications due to insulator shunting. Shunting in the thermocouple insulator also affects the ability of the thermocouple to transmit electrical signals caused by rapid temperature changes at the hot end to external instruments at the cold end of the thermocouple. Quantitative limitations on the transient electrical response of a shunted thermocouple are needed to evaluate use of the thermocouple in safety circuits and in thermal noise analyses.

The equivalent circuit for a high temperature, metal-sheathed thermocouple with insulator shunting developed in previous studies[3] was expanded to include inductance and capacitance. The equations that describe the model were solved to predict the electrical transient behavior of a shunting thermocouple. The analysis was applied to cases (1) where the hot junction experiences a step change in temperature and (2) where a voltage step is applied to the cold junction and the reflected pulse is observed, as in a time domain reflectometer. The model predicts that the highly dissipative shunting thermocouple does not propagate the signal satisfactorily in most cases but shows a smeared-out delayed result at the cold end. The electrical delay time is of the order of microseconds, which is three or four orders of magnitude shorter than the thermal time constants of typical thermocouples.

1. Professor of Electrical Engineering, Tennessee Technological University, Cookeville, Tennessee.
2. Professor of Electrical Engineering, University of Tennessee, Knoxville.
3. J. R. McDearman, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 73.

8.22 ANALYSIS OF THE TRANSIENT RESPONSE OF MgO-INSULATED SHEATHED THERMOCOUPLES

J. E. Swander[1]
R. S. Booth N. E. Clapp F. H. Clark

The effects of heat transfer phenomena on the transient response of insulated junction thermocouples was investigated. Determination of the response as a function of structural parameters will be useful both in interpreting normal operating characteristics and in determining procedures[2] for detection of LMFBR thermocouple deterioration in situ.

An analysis to determine the effect of the MgO insulation indicated that the relatively high thermal resistivity of this material can account for experimentally observed lags in the response of thermocouples to step changes in the external temperature. More detailed analytic modeling of the thermocouple structure should permit quantitative correlation of experimentally measured time constants with physical parameters. This type of modeling is applicable to transient responses of the thermocouple to both external temperature changes and internal electrical heating.

1. Subcontract with the University of Tennessee, Knoxville.
2. R. M. Carroll, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 89.

8.23 EVALUATION OF TUNGSTEN-RHENIUM ALLOYS FOR HIGH TEMPERATURE THERMOMETRY

R. M. Carroll J. K. East R. L. Shepard

Tungsten-rhenium wires are the most refractory alloys known. These wires are used in thermocouples, and they can be used in other high temperature thermometers if the physical and electrical properties are known. Wires of various compositions from 3 to 26% rhenium were obtained, and their chemical and metallurgical characterization was started. These wires will be used to fabricate ultrasonic test lines for determining the velocity of sound vs temperature and the temperature dependence of the attenuation coefficient. In a joint study, the National Bureau of Standards (NBS) is examining the thermoelectric properties of wires from these same lots. Additional alloy compositions are being prepared, and further property measurements will be made in this joint ORNL-NBS program.

8.24 SHEATHED TUNGSTEN-RHENIUM THERMOCOUPLE SPECIFICATION AND PROCUREMENT INSPECTION

R. L. Shepard R. M. Carroll W. A. Bird

Stainless steel sheathed, magnesium oxide insulated, W-3Re vs W-25Re thermocouple swaged assemblies are used for measuring fuel temperature in ORNL reactor experiments. In typical designs, a 10-ft-long sheathed portion of the swaged assembly is brazed into the irradiation cartridge to contain fission gas and to be an integral extension cable for regions where the temperatures remain less than 1000° C. Then, about 1 ft of sheath and magnesia are removed from the hot end of the assembly and replaced with hard-fired beryllia insulation and rhenium foil to endure the high temperatures in the fuel.

Material for such applications was ordered to conform to a trial purchase specification based on RDT Standard C7-6T, "Thermocouple Material and Thermocouple Assembly, Chromel-P vs Alumel, Stainless Steel Sheathed, Magnesium Oxide Insulated," which was modified to make it appropriate for sheathed W-Re thermocouple material. Standard quality assurance procedures were invoked which required documented manufacturing procedures, materials certifications, and inspection tests both by the manufacturer and the purchaser to qualify this material for reactor experiment fabrication. New tests were devised, some based on testing[1] of thermocouple assemblies for earlier High Flux Isotope Reactor irradiations. These tests[2] included dimensions, calibration, homogeneity, thermal cycling, sheath integrity, bending ductility, x-ray, and scanning electron microscopic and metallographic examination.

A first batch of manufactured material was received and inspected. The material was rejected, because these tests showed that the W-3Re wires were necked down in random locations and were excessively brittle. A high degree of insulator compaction and other evidence indicated that the diameter of the sheathed assembly had been reduced excessively during fabrication. A second batch of manufactured material was inspected. Its quality was better with regard to the W-3Re wire and the degree of compaction, but defective W-25Re wire had been used. The assemblies often failed during thermal cycling tests. The mechanism of failure is being investigated.

An American Society for Testing Materials materials specification for W-Re thermocouple wire is being prepared to assist the assembly manufacturer to obtain suitable thermocouple material from the wire producer.

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1. R. M. Carroll and R. L. Shepard, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 71.

2. These tests were developed with the assistance of D. A. Canonico, B. C. Leslie, F. L. Long, and other members of the Metals and Ceramics Division.

8.25 HIGH-TEMPERATURE FURNACE FACILITY

H. J. Metz
W. A. Bird W. L. McCullough R. L. Shepard

A third, high-temperature furnace, capable of producing temperatures above 2400° C, was installed in the High-Temperature Furnace Facility (HTFF) in Building 3500 at ORNL. Other improvements made to the HTFF were (1) services to the facility were improved to accommodate the three furnaces; (2) additional transformer capacity was supplied to the facility; (3) an improved power distribution system was built for the previous two furnaces; (4) the cooling water distribution

and low-power interlock systems were improved and extended to supply the third furnace; (5) an argon gas distribution system was built to supply the three furnaces;[2] and (6) an oxygen monitor capable of detecting as little as 1 ppm O_2 in Ar was installed for checking the furnace supply and exhaust gas.

A traversing mechanism was designed and mounted on this third furnace so that a sample or sensor can be slowly inserted or retracted by a motor drive through the entire length of the furnace for profiling and homogeneity experiments. The unit can also be operated in a rapid, pneumatically driven insertion and retraction mode for temperature cycling of sensors. The sample and its connections are contained within the inert furnace atmosphere throughout the traverse. A water-cooled receiver section above the furnace produces quick cooling of the sample during cycling. This apparatus is used for studies of W-Re thermocouples and other high temperature thermometers.

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1. R. E. Toucey, B. C. Duggins, and J. M. Googe, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1969*, ORNL-4459, pp. 69–70.
2. H. J. Metz, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 51.

8.26 TEMPERATURE MEASUREMENTS OF DISPLACEMENT TRANSDUCERS IN MINT-I REACTOR EXPERIMENT

R. L. Shepard B. Fleischer[1]

Temperatures inside the MINT-I oxide fuel irradiation capsule were obtained by measuring the resistance of the center-tapped, transducer displacement-sensing coils. A three-wire method was used for measuring the resistance of the ceramic-coated silver wire coils to better than 0.1% at a distance of 60 ft, independent of the lead-wire resistance. The resistance temperature characteristics of the coils were determined in bench tests to 240°C on a spare transducer, and these data could be extrapolated to 350°C since these characteristics for silver are known. Internal temperatures in the capsule obtained this way were correlated with external thermocouple temperature indications as the power generation in the capsule was varied.[2] Measured values of coil temperature were used to correct the displacement calibration for effects of temperature and temperature gradients.[3] Resistance changes were also used to diagnose changes in the condition of the transducer with irradiation.

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1. Metals and Ceramics Division.
2. R. B. Fitts, B. Fleischer, and R. L. Senn, *Fuel Cladding Mechanical Interaction and Gas Pressure Build-up in a Shortened FTR-Type Fuel Pin*, ORNL-4875 (June 1973).
3. J. M. Googe, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 49–51.

8.27 QUALITY ASSURANCE IN INSTRUMENTATION

C. S. Lisser H. J. Metz

In continuing the program of quality assurance for the Instrumentation and Controls Division at Oak Ridge National Laboratory,[1] assistance was rendered to many ORNL divisions throughout the year. Within the Instrumentation and Controls Division, the writing of quality assurance procedures and related work procedures was continued. About 85 procedures were written, reviewed, and adopted; of these, 27 are part of the quality assurance-numbered series, and the others

provide a working-level base of detailed instructions. The ORNL quality assurance director, a management audit team, and the quality assurance coordinator for instrumentation and controls all conducted audits of various operations within the division. Audit team comments and recommendations showed an unsurprising number of suggestions for improvements.

One of the main quality assurance tasks this year was the work with ORNL instrumentation procurement for use by many USAEC installations. This included the large-scale procurement of temperature sensors program and the pilot procurement of current preamplifiers. In the temperature sensor program, two vendors contracted to manufacture thermocouples to the requirements of RDT Standard C 7-6T, under the guidance of ORNL staff. Both vendors produced generally acceptable thermocouples, although some deviations from good quality assurance practice occurred; five nonconformance reports were issued. The prototype preamplifiers, designed to RDT Standard C 15-3T, were fabricated within allowable tolerance limits.

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1. C. S. Lisser et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 74

8.28 RDT STANDARDS FOR INSTRUMENTATION

C. S. Lisser H. J. Metz J. A. Russell

In the continuing work for the RDT Standards Program,[1] instrumentation effort was expended at a rate of approximately 2 man-years during this report period. The production of new standards slowed in response to the AEC policy of having the first potential user write whatever standard may be needed. However, much work was done to keep ORNL-produced instrumentation standards updated through amendments, and to review standards produced at other installations.

This program also continues to render support to the standards efforts of national technical societies (specifically, the Instrument Society of America and the Institute of Electrical and Electronics Engineers) through the work of staff members with standards committees.

Table 8.28.1 shows the present status of instrumentation standards written at Oak Ridge National Laboratory.

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1. C. S. Lisser and J. A. Russell, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, pp. 73–74.

8.29 INSTRUMENTATION AND CONTROLS DIVISION MAINTENANCE INFORMATION COMMITTEE

K. W. West (chairman)

P. W. Hill	J. A. Keathley
D. J. Knowles (secretary)	J. L. Lovvorn
R. L. Simpson	R. E. Toucey

In May 1972, a committee consisting of W. P. Kinser (chairman), P. W. Hill, D. J. Knowles, E. McDaniel, R. L. Simpson, and K. W. West, was appointed to develop a division-wide inventory and maintenance information system. The main objectives of the program, which was designed to meet quality assurance, ORNL standard practices, and AEC directives were

1. automated storage and retrieval of instrument inventory information,
2. improvement of recall systems for routine maintenance and calibration,

Table 8.28.1. Status of RDT Standards for process instrumentation

Number	Title	Status[a]
C2-1T	Determination of Insulation Compaction in Ceramic-Insulated Conductors	A
	Amendment 1	S
C2-3T	Time Response Test for Sheathed, Mineral Insulated Thermocouple Assembly	A
C4-1T	Orifice Plate for Orifice Flange Union	C
C4-3	Orifice Flange Union Weld Neck, Stainless Steel, for 300-Pound Service	C
C6-2	Differential Pressure Transmitter, Pneumatic Output Signal	R
C7-1T	Thermocouple Material, Iron and Constantan, Solid Conductor (Bare, Fiberglass Insulated, and Sheathed over Fiberglass Insulation)	A
C7-2T	Thermocouple Material, Iron-Constantan, Magnesium-Oxide Insulated, Sheathed	A
	Amendment 1	A
C7-3T	Thermocouple Material, Copper and Constantan, Solid Conductor (Bare, Fiberglass Insulated, and Sheathed over Fiberglass Insulation)	A
C7-4T	Thermocouple Material, Copper-Constantan, Magnesium-Oxide Insulated, Sheathed	A
	Amendment 1	A
C7-5T	Thermocouple Material, Chromel-P and Alumel, Solid Conductor (Bare, Fiberglass Insulated, and Sheathed over Fiberglass Insulation)	A
C7-6T	Thermocouple Material and Thermocouple Assembly, Chromel-P vs Alumel, Stainless Steel Sheathed, Magnesium-Oxide Insulated	A
	Amendment 1	A
C7-7T	Thermocouple Materials, Platinum and Platinum-10% Rhodium Wires, Noninsulated Reference and Standard Grades	A
	Amendment 1	P
C7-15T	Thermocouple Connectors and Thermocouple Connector Panels	A
	Amendment 1	A
C7-16T	Thermocouple Assemblies, Magnesium-Oxide Insulated, Stainless Steel Sheathed	A
C7-17T	Platinum Resistance Thermometer	A
C9-1T	Single-Point Strip Chart Recording Potentiometer	A
C9-2T	Multipoint Strip Chart Recording Potentiometer	A
C11-2T	Pyrometer, High Sensitivity, Indicating Controlling	A
C13-1	General Purpose, Stored Program, Digital Computer	P
C15-3T	Current Pulse Preamplifiers for Use with Fission Counters	A
	Amendment 1	A
C16-1T	Supplementary Criteria and Requirements for RDT Reactor Plant	A
F3-11T	Mass Spectrometer Helium Leak Detection for Instruments and Small Components	A
M3-20T	Polyethylene Instrument Tubing	A

[a]Status: A, approved for issue; C, cancelled; R, being rewritten; P, in process; S, submitted for approval.

3. accumulation of maintenance and calibration histories for each instrument.

Although these objectives were met to a great extent, there are several smaller blocks of information applicable to a section or group that are not applicable at a division-wide level. An additional objective of the program is to retain the features of the older programs which have proved most useful.

The original committee designed a system and submitted drafts of two documents: a general description and an instruction manual. These documents are being prepared for distribution to division personnel in the near future.

The program has a number of callable printout options so that all available information on an estimated 20,000 items is not distributed routinely. Instead, the printout and recall information returned to the file points (which are usually the foremen of field shops) is limited to information of interest to that particular file point.

In May 1973, the committee was made permanent with the personnel listed above to implement the program, and the system is now in use on a trial basis. The committee serves as the central office to administer and modify the program as necessary. At least 3 man-days/month per member have been devoted to this effort since it started.

9. Reactor Instrumentation and Controls

9.1 NUCLEAR DESALINATION PLANT CONTROL STUDIES[1]

S. J. Ball N. E. Clapp, Jr. J. G. Delene[2]

The objective of the continuing studies of dual-purpose plant control is to ensure that satisfactory control and coupling schemes will be available for the prototype plants under development. While most of the past work has concentrated on multistage flash (MSF) plant technology, recent efforts have been aimed at substituting the more advanced combined vertical-tube evaporator (VTE) MSF plant technology. A digital simulator was developed to study the dynamics of "Water Factory 21," an experimental VTE MSF plant under construction in Orange County, California. This simulator is being used to plan experiments on the plant, which is due to begin operation in the fall of 1973. Data obtained from dynamics tests on the plant will be used to verify the models used in the simulation.

The full-scale dual-purpose plant simulator which was developed includes a pressurized-water reactor (PWR), a drum-type steam generator, and a large turbine generator plant coupled to the MSF evaporator. Extensive studies of parameter sensitivity, component failures, and alternative control schemes were made with the full back-pressure turbine plant (in which all exhaust steam drives the evaporators) and with the demonstration plant concept (in which only a small fraction of the total steam is utilized by the back-pressure turbine and evaporator).

Experimental work included several series of dynamics tests and parameter trend tests on an MSF plant at Wrightsville Beach, N.C. These tests were aided by an on-line computer data system that was engineered and programmed by ORNL (Sect. 7.43). A computer program was developed which generates pseudorandom binary sequence contact output signals for frequency response tests and also performs the required Fourier transforms on-line. Pseudorandom binary sequence tests were run on the evaporator over a full range of operating conditions. A dynamics test series was also run on an operating PWR, the H. B. Robinson Nuclear Power Plant (Carolina Power and Light Company). Results of these tests, made in joint effort with the University of Tennessee, led to improvements in the PWR part of the dual-purpose plant simulator.

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1. Summary of paper presented at *4th Int. Symp. Freshwater Sea*, Heidelberg, West Germany, Sept. 9–14, 1973.
2. Reactor Division.

9.2 HYBRID COMPUTER SIMULATION OF THE GAS-COOLED FAST BREEDER REACTOR STEAM GENERATOR

O. W. Burke

The hybrid computer simulation model of the Molten Salt Breeder Reactor (MSBR) supercritical once-through steam generator[1] previously reported was converted to a model of the subcritical, once-through steam generator for the gas-cooled fast breeder reactor (GCFBR, the proposed fast breeder reactor of Gulf General Atomic) by converting the MSBR steam generator model as required.

The most significant difference in the two steam generators, from a modeling standpoint, is that the GCFBR steam generator has three distinct regions, namely, the subcooled, boiling, and superheated regions, whereas the MSBR has only the supercritical region.

The simulation model is operable, and transient studies will be started in the near future.

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1. O. W. Burke, J. L. Anderson, and S. J. Ditto, *Instrumentation and Control Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 76.

9.3 TRANSPORT REACTOR KINETICS INVESTIGATIONS

J. E. Swander[1] R. S. Booth

Exploratory studies were performed in the area of reactor kinetics methods, including the need for development of efficient multidimensional transport methods as an alternative to finite-time-difference discrete ordinates or finite elements techniques; the suitability of various algorithms was considered for this purpose. Two techniques appeared to be attractive. Both make use of solutions to auxiliary static spatial problems, from which the time-dependent flux is calculated. In both cases, this approach should result in substantial savings in computation time, particularly for multidimensional transport calculations, with some corresponding limitation of the range of general applicability of each method.

The first technique, the quasistatic method,[2] has been applied considerably to fast reactor dynamics and safety work by using diffusion theory space algorithms. No difficulties in principle are foreseen in extending the method to transport theory by incorporating an existing static transport code. The quasistatic algorithm is appropriate primarily for reactor transient problems, but, in this context it is quite general; feedback effects and even fuel motion have been taken into account in existing quasistatic codes.[3]

The second algorithm, essentially a time moments flux reconstruction,[4] is much more restricted in scope and has received little attention. However, it may be attractive for transport problems where applicable because of its extreme economy in computation effort: it constructs the solution of an initial value problem at arbitrary times from the solutions of about 10 to 20 static problems. This method is under investigation to determine under what conditions it might be sufficiently accurate. Preliminary results indicate that this method might be useful for problems that require transport analysis, yet in which the shape of initial and asymptotic fluxes are not too different.

Other neutron transport kinetics projects also received attention. Work was performed on a multigroup, one-dimension transport kinetics code, SWAT,[5] to make it operational. A method was conceived to facilitate the Fourier inversion of frequency-domain transport calculations into the time domain. Finally, consideration was given to experiments in which neutron pulse propagation in

various fast reactor materials would be used to test cross-sectional data. Work is being continued in these areas.

1. Subcontract with the University of Tennessee, Knoxville.

2. K. O. Ott and D. A. Meneley, "Accuracy of the Quasistatic Treatment of Spatial Reactor Kinetics," *Nucl. Sci. Eng.* 36(3), 402–11 (1969).

3. A. T. Daly, D. R. Ferguson, and E. L. Fuller, "Improvement of and Calculations with the Two-Dimensional Space-Time Kinetics Code FX2," *Proc. Amer. Nucl. Soc. Top. Meet. Math. Models Comput. Tech. Anal. Nucl. Sys., April 1973* (to be published).

4. J. Devooght and C. Machgeels, "A New Synthesis Method for Pulsed-Neutron Experiments," *Nucl. Sci. Eng.* 32(1), 82–92 (1968).

5. J. H. Swanks, "Approximate Numerical Solutions to the Time-Dependent Neutron Transport Equations," Ph.D. dissertation, University of Tennessee, 1969.

9.4 ANALOG COMPUTER MODEL FOR ONE-DIMENSIONAL REACTOR DYNAMICS

J. E. Swander[1]
R. S. Stone R. S. Booth O. W. Burke

A two-group, one-space-dimension reactor dynamics program was implemented on the Controls Department analog computer. General interest in this area of computation was evidenced by a request for solutions to a one-dimensional benchmark problem involving a gas-cooled reactor as a program of the European-American Committee on Reactor Physics. Since this is an application wherein the analog machine has significant advantages, an analog solution for the benchmark problem was prepared.

The program provides for temperature feedback, with coolant flow in the axial direction; the reactor is currently described as being divided into core and reflector regions. Six delayed-neutron groups and two energy groups are used, and the control rod can be positioned.

The approach taken in the simulation was continuous time and discrete space. The customary first-order difference diffusion treatment is currently programmed, although higher order differencing could easily be substituted. Fourteen spatial nodes are provided: ten core nodes and two nodes for each of the reflectors.

In its present configuration the program occupies three interconnected analog computer consoles. Core neutronics are situated on the largest computer, while heat-transfers and reflector neutronics equations are programmed on the two smaller units. Delayed neutrons are simulated by a hard-wired network for each node of the core.

The program is now available for adaption to specific studies of reactor dynamics.

1. Subcontract with the University of Tennessee, Knoxville.

9.5 ENERGY-DEPENDENT TRANSPORT ANALYSIS OF FAST NEUTRON PULSE PROPAGATION

J. E. Swander[1]

Fast neutron pulse propagation experiments were shown to be sensitive to the energy dependence of the cross sections of the experimental medium,[2] so that these experiments are a potentially useful tool for evaluation of compiled cross-section sets for fast breeder reactor calculation. Numerical multigroup calculations performed in the frequency domain by using the code TASK[3] were

used successfully to correlate experimental results with cross-section data. However, the analytical study of propagation experiments is useful in furnishing a phenomenological bases for such numerical comparisons.

Neutron wave and pulse propagation in fast media was investigated by using a general form of the energy-dependent, Fourier time-transformed Boltzmann equation in slab geometry. The spectrum and forward and adjoint eigenfunctions of the wave Boltzmann operator were obtained in both multiplying and nonmultiplying cases. These results should prove helpful in interpreting fast neutron pulse propagation experiments and in describing other space-dependent kinetic phenomena.

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1. Subcontract with the University of Tennessee, Knoxville.

2. R. S. Booth, R. B. Perez, A. R. Buhl, J. C. Robinson, and E. Carroll, "Interpretation of 2.0–2.57 MeV Neutron Pulse Propagation in Iron," *Trans. Amer. Nucl. Soc.* 15(1), 530–31 (June 1972).

3. A. R. Buhl, R. A. Lillie, H. L. Dodds, Jr., O. W. Hermann, J. C. Robinson, and R. J. Hinton, *A User's Manual for TASK, A Generalized One-Dimensional Transport and Diffusion Kinetics Code*, ORNL-TM-3811 (December 1972).

9.6 MODEL FOR TWO-PHASE FLOW IN WATER[1]

F. H. Clark

A model for two-phase flow was developed to provide detailed dynamics of water flow in the core of a light-water reactor during blowdown. Further model development has been necessary to meet the enlarged problem scope resulting when nonequilibrium conditions are allowed between the two phases. Moreover, because of apparent disagreement in the textbook methods of representing some effects, a return to prior principles seems mandatory.

Nine thermodynamic regions are defined according to whether there are one or two phases present and also to the relation that the enthalpy of each phase bears to its equilibrium value. Three of these regions are discarded, because they have no bearing on problems of interest.

A complete set of equations appropriate to each region is developed different, in general, for each region. Appropriate region boundary conditions are devised (although there still remains a question about the correct enthalpy conditions at a boundary between a two-phase and a one-phase region).

Two kinds of interphase mass exchange are considered: that which is driven by heat or work input or pressure change, and that which arises from crossings of a phase boundary due to a statistical resolution of differences on the two sides. These are quite different effects, requiring different kinds of coefficients for their description.

The formal structure of the model is one dimensional. Transverse flows and interphase transfers are handled through the conventional strategy of nonhomogeneous terms. There is a wide difference of opinion in the literature concerning the treatment of pressure derivatives, the space derivative in the momentum equation, and the temporal derivative which appears when the energy equation is written in terms of enthalpy. One can find the temporal derivative. This study indicates that in the formulation chosen, the derivative should be partial.

In the separate phase formulation, a factor α or $(1 - \alpha)$ appears in each pressure derivative term, α being the local volume fraction of gas phase. This investigation indicates that the α and $(1 - \alpha)$ terms should fall within the differential operator, although a number of workers treat it as a coefficient to the operator.

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1. Abstract of published report ORNL-TM-4123 (June 1973).

9.7 LOCA MODELING ON THE HYBRID COMPUTER[1]

R. S. Stone

The hybrid computer is a working, symbiotic combination of an analog and a digital computer. The combination offers unique advantages in speed and stability when used for analysis of large space-time dependent systems. Application to the class of fuel-pin heatup problems addressed by the digital code THETA provides a fast running, flexible alternative for examination of LOCA-related problems.

1. Abstract of paper presented at the *Top. Meet. Water React. Saf.*, Salt Lake City, Utah, March 26-27, 1973.

9.8 MODERNIZATION OF PORTIONS OF THE HIGH FLUX ISOTOPE REACTOR PROTECTION AND CONTROL SYSTEMS

J. L. Anderson
C. C. Courtney O. C. Cole S. J. Ditto

Changes to modernize portions of the High Flux Isotope Reactor (HFIR) protection and control systems,[1] have now been completed. The objectives of the changes were to replace components that exhibited high trouble rates by noise or drift, to replace obsolete components that are no longer manufactured, and to enable later additions of functions to the plant protection system. Items involved in the change were as follows:

1. Operational amplifiers (Q-2605), which have mechanical choppers and which occasionally exhibited noise, oscillation, or erratic operation due to wear, were replaced with modern integrated-circuit amplifiers.
2. The flux reset module (Q-2603), with a motor-driven potentiometer that causes automatic gain change in the power measuring circuitry, was replaced with an all-electronic circuit that uses integrated-circuit multipliers. Worn contacts of the driving potentiometers were a frequent source of system noise, which sometimes caused false scrams.
3. Electrometer type amplifiers used for the flux amplifier (Q-2602) and the faulty fuel-element amplifier (Q-2637) were equipped with obsolete transistors that failed frequently or developed noise. These amplifiers were replaced with field-effect input, integrated-circuit, operational amplifiers that gave better performance and were more reliable.
4. Buffered inputs to the protection system were installed to make easier the measurement of safety rod release and travel time characteristics by using interchangeably either the on-line computer or other equipment.
5. Power supplies for a number of modules in the system were combined and rearranged, thereby eliminating some power modules.
6. Several signal-conditioning circuits, while retaining their original functions, were combined into a new module with the electronic flux reset function described above.

These rearrangements have freed considerable module space in the instrument bins to permit later additions if the need arises.

1. J. L. Anderson and C. C. Courtney, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 95.

9.9 POWER BURST FACILITY CONTROL AND SAFETY INSTRUMENTATION

J. L. Anderson S. J. Ditto

Fabrication of additional instruments for the control and protection systems of the Power Burst Facility at the National Reactor Testing Station was completed, and the instruments were shipped to the site.[1] The changes and additions to the protection system were made necessary by programmatic changes in the experiments planned for the facility, which required steady-state operation at higher powers than originally planned, as well as by modified burst operation.

A draft design-basis document for the complete modified protection system was prepared, and the system was reviewed for conformance with RDT Standard C 16-1T. These documents were completed and formalized by Aerojet Nuclear Company and submitted to the AEC.

Oak Ridge National Laboratory technical support for the Power Burst Facility is continuing as needed when requested by the Aerojet Nuclear Company.

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1. J. L. Anderson et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 94.

9.10 REVIEW OF DESIGN DOCUMENTS FOR THE ENGINEERING TEST REACTOR

J. L. Anderson S. J. Ditto

Our support of the staff of the Division of Reactor Research and Development (RRD) of AEC was expanded to include review of system design descriptions of the Engineering Test Reactor at the National Reactor Testing Station.

The plant protection system of the ETR is being modified to bring it into compliance with recent standards.

We reviewed the first half dozen of a series of preliminary documents that describe about 15 subsystems. Final system design descriptions will also be reviewed to make a total of about 30 separate documents ready for review. The objective of our review is to determine the degree of conformance of the documents to the format established in RDT standards, the extent to which the proposed changes will correct specific deficiencies in the existing plant protection system, and the compliance of the proposed system with ETR technical specifications.

Reports of our reviews are being sent to RRD in Washington, D.C., and to the Idaho Operations Office of the AEC. Following the completion of this group of reviews, we expect to perform similar reviews of modifications of the Advanced Test Reactor.

9.11 PROPOSED REVISION OF RDT STANDARD C 16-1T

J. L. Anderson S. J. Ditto

At the request of the Division of Reactor Research and Development (formerly Division of Reactor Development Technology), the experience with the use of RDT Standard C 16-1T, "Supplementary Criteria and Requirements for RDT Reactor Plant," was reviewed for guidance in revising that document. A draft copy of a proposed revision of Standard C 16-1 was prepared and distributed as directed to RRD sites and selected system vendors for comment. Subsequent to distribution of the draft, RRD decided that a revision was not needed at this time, and support for such revision was terminated. Future changes to the standard will be made through amendments rather than by revision.

9.12 REVIEW OF STATE-OF-THE-ART OF FAST SHUTDOWN SYSTEMS

E. P. Epler[1] J. L. Anderson S. J. Ditto

The review of the state-of-the-art of fast shutdown systems[2] was continued. A second draft report was prepared and was being scheduled for internal review when higher priority tasks were assigned by the RRD, leaving neither manpower nor support for this work. There is no plan in the foreseeable future for the continuation of this program.

1. Consultant to the Controls Department.
2. E. P. Epler et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 96.

9.13 HYBRID COMPUTATION OF FUEL PIN HEATUP IN A PWR LOSS-OF-COOLANT ACCIDENT

R. S. Stone F. H. Clark

The hybrid computer version of the THETA heatup code is now an available tool. During the past year several features were added to the model, including provision for metal-water reaction and the addition of thermal radiation and convection as heat transfer mechanisms between the fuel and the cladding. This latter extension of the program was added primarily to make possible the examination of heat transfer under swollen clad conditions, wherein radiation and convection become the dominant mechanisms for bridging the gas gap. An optional subroutine for such clad swelling was added, whereby one axial node can abruptly swell when specified conditions of clad temperature and differential pressure are achieved.

The model will be used as required for analysis of results from the experimental blowdown program.

9.14 NUCLEAR SAFETY INFORMATION CENTER

E. W. Hagen

The responsibility of collecting, evaluating, indexing, and disseminating information that pertains to instrumentation, controls, and electric power systems was continued for the Nuclear Safety Information Center (NSIC).[1] The NSIC at ORNL is in its tenth year as a national center for collecting, storing, evaluating, and disseminating nuclear safety information generated throughout the world.

The documents handled related to all phases of design and application for reactor instrumentation (component, modular, and system) and for the plant electrical system (supply, generation, and distribution). Approximately 1350 documents were reviewed and abstracted for the computerized retrieval system, and 35 direct requests for special information were processed for the national and international nuclear community during this year.

1. E. W. Hagen, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 90.

9.15 *NUCLEAR SAFETY* JOURNAL

E. W. Hagen

Publication of *Nuclear Safety* under the auspices of the Nuclear Safety Information Center was continued.[1] *Nuclear Safety* is now in its fourteenth year of publishing topical reviews and new

information that has a particular safety significance to members of the technical nuclear community. This publication places primary emphasis on safety in reactor design, construction, and operation. The preparation and editing of material relating to reactor controls and instrumentation was continued.[2] Seven members of the Instrumentation and Controls Division authored three[2] of the seven articles that appeared during the past year in the "Control and Instrumentation" section of *Nuclear Safety*.

1. E. W. Hagen, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 90.
2. E. W. Hagen (ed.), *Nucl. Saf.* 13(5), 366–72 (September–October 1972); 14(2), 95–104 (March–April 1973); 14(3), 206–19 (May–June 1973).

9.16 INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS: THE 26th ISA CONFERENCE AND EXHIBIT[1]

C. S. Lisser
B. G. Eads B. C. Duggins E. W. Hagen

The 26th Instrument Society of America Conference and Exhibit presented a review of the state of the technology of the industry and a suggestion of things to come. A broad range of topics concerning instrumentation theory and application was considered in the 92 technical sessions comprising the conference program; an innovation this year was a series of distinguished lectures on special areas of instrumentation. Concern about international standards highlighted the economic aspect, and more research and development were acknowledged to be needed in the environmental field. Some new work was reported on the study of vibration and its effects in and on nuclear plants. Selected papers of particular safety significance are reviewed.

1. Abstract of published article, *Nucl. Saf.* 13(5), 366–72 (September–October 1972).

9.17 OBSTACLES TO COMPLETE AUTOMATION OF REACTOR CONTROL[1]

E. P. Epler L. C. Oakes

Anomalous reactivity changes resulting from conditions other than anticipated control-rod motion occurred in early experimental reactors and led to local melting. Doubt has been expressed, however, that such changes could occur in commercial power reactors. Defenses against the reactivity anomaly have since been developed for test and production reactors which have permitted an increased degree of automation to be safely applied. The principles so developed, which rely on digital techniques, are equally applicable to power reactors. Accepted criteria for the application of digital techniques to control and protection systems have not yet been developed; however, an extension of existing practices and precedents should be adequate until such criteria are available.

1. Abstract of published article, *Nucl. Saf.* 14(2), 95–104 (March–April 1973).

9.18 STANDBY EMERGENCY POWER SYSTEMS[1]

E. W. Hagen

Availability of reliable standby or emergency power systems has always been a prime consideration in station design, beginning with the early nuclear reactor power plants. The documented operating experiences were reviewed for the station off-site and on-site standby,

emergency ac power sources and battery systems. Part 1 discusses these systems for the generating reactors commissioned circa 1959–1967. The ability of these systems to perform satisfactorily when needed nas been very good for the early plants, but the ability to perform satisfactorily at any given time was something less. However, with the advancement of regulatory design guides and industry standards, the reliability is expected to continue to be good and the availability to be improved. In the later plants, to be discussed in Part 2, with standardized and modularized designs, these efforts and effects will become apparent through better use, testing, and documentation.

1. Abstract of published article, "Part 1. The Early Plants," *Nucl. Saf.* 14(3), 206–19 (May–June 1973).

9.19 REACTOR PROTECTION SYSTEM: PHILOSOPHIES AND INSTRUMENTATION[1]

E. W. Hagen

Prominent aspects of the design philosophies for the reactor protection system are summarized. This review develops a rationale of the doctrines and philosophies governing the design of the reactor trip systems. It is a composite of the ideas previously expressed by many authors and of those promulgated by the industry standards. These separate views and proposed tenets are set into a single composition which has attempted to collate the significant concepts. The article is an overview. It proposes to show that there are many routes to a protection system design, and that it is not necessary that all designs be identical to perform their missions satisfactorily. The report consists of a subject introduction, 26 reprinted articles from *Nuclear Safety*, and a 9-section appendix containing 1 federal regulation, 2 AEC safety guides, 5 industry standards, and 3 abstracted references to AEC standard and NSIC reports.

1. Abstract of published report, ORNL-NSIC-111 (June 1973).

9.20 ISA POWER SUPPLY STANDARDS

E. W. Hagen

The ISA Standards Committee SP54, "Emergency Power Supplies," completed the following seven proposed standards:

1. S54.1 Emergency Power Supplies,
2. S54.2 Emergency Electrical Power Supply Engine-Generator Units,
3. S54.3 Lead-Acid and Pocket Nickel Cadmium Storage Batteries for Stationary Services,
4. S54.4 Battery Chargers,
5. S54.5 Fixed Frequency, Self-Commutated Semiconductor Inverters,
6. S54.6 Electromagnetic Automatic Transfer Switches,
7. S54.7 Static Automatic Transfer Switches.

These standards were reviewed for comment and balloting.

9.21 RELIABILITY AND SAFETY ANALYSES OF HIGH-TEMPERATURE GAS-COOLED REACTOR SYSTEM

Paul Rubel

Participation in the High-Temperature Gas-Cooled Reactor (HTGR) Safety Program at ORNL was continued[1] mainly in matters of system reliability and accident risk analysis. The immediate

purpose of such analysis is to assess objectively the various means for preventing accidents or mitigating their consequences. In view of the program's expanding concern with the support safety technology for commercial plants, the perspective conferred by analysis should be of value in identifying program technical objectives and in allocating resources.

A central role for analysis is proposed in the national HTGR Safety Program plan draft that is currently being reviewed by the AEC. In essence, the plan calls for continual evaluation of plant safety prospects with regard to current support technology. The evaluations are to consist of individual system fault tree and plant transient studies, organized about logical models of the potential accident sequences. Interpretation of such analysis sets should then yield the following kinds of information needed for methodical planning of the basic program activities: (1) system or component limitations that most strongly affect potential accident courses, (2) situation outcomes that have the more serious consequences, (3) opportunities for blocking undesirable event sequences, (4) conditions under which likelihood of accident sequences cannot be assessed adequately due to uncertainties in plant or component response or in operation of damage mechanisms, and (5) plant parameter value ranges associated with accident conditions.

The basic program activity proposals were organized in the plan, first, by task areas that correspond to the principal technologies involved, such as the prestressed concrete reactor vessel and fission product chemistry and transport. Within areas, tasks were arranged by groups according to broad technical objectives and ordered in a natural progression from limited to broad objectives. Beginning each sequence are the source tasks, which include laboratory or fundamental research. These are followed by synthesis tasks, which typically involve application of fundamentals from several sources to develop a practical component specification or analysis procedure. Validation tasks conclude each sequence with proof of adequacy of a method or component, either by planned observation or test in reactor service, or by large-scale tests outside a reactor.

Further development and organization of analysis methods suitable for program application proceeded through case studies of the coolant flow interruption accident. We are attempting to summarize the principal event and condition sequences of this entire class of accidents on a single decision tree logic diagram, which depends on separate subsidiary analyses to develop the detailed considerations that enter each decision. Some modifications of the classical decision tree format are necessary, therefore, to permit representation of loosely defined event groups rather than very specific (and often trivial) individual events. Other modifications are being devised to compress the logic and to convey pertinent information, such as degree of damage sustained during a sequence.

In support of the above trial accident analysis, elementary heat transfer and heat balance studies were performed to examine core heatup effects on the coolant temperatures that ensue from delayed start of auxiliary circulators. Core exit gas temperature is a major factor in the prospects for continuation of emergency cooling after delayed initiation, since high temperatures could either damage the auxiliary loop heat exchanger or cause duct wall failures that would impede subsequent flow. More extensive investigations of coolant interruption effects were reviewed by Gulf General Atomic.

1. P. Rubel, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 92.

9.22 RELIABILITY DATA PROGRAM

Paul Rubel

The AEC Office of Operations Analysis (OOA) developed and proposed for trial use a program to gather, compile, store, and retrieve data concerning deficiencies of nuclear power plant safeguard

systems and their components. At the request of the OOA staff, this program, designated Reactor Experience Information System (REXIS), was reviewed with regard to scope, content, and operational aspects. The resulting principal recommendations to the OOA were (1) to emphasize, via reporting detail, components of design or subject to service conditions peculiar to their reactor plant applications; (2) to identify and respond to system user needs, for example, those of the accident risk analysis groups; (3) to monitor equipment reliability trends and signal appropriate actions; and (4) to compare the derived information with statistics available from the United Kingdom Authority for corresponding equipment in England. The REXIS program was later abandoned in favor of participation by the AEC in the similar industry-supported program managed by the Edison Electric Institute. Most of the recommendations for enhancing REXIS apply also to the Edison Electric Institute program.

10. Instrumentation for Reactor Division Experiments and Test Loops

10.1 THERMAL HYDRAULIC TEST FACILITY

R. L. Moore
B. G. Eads D. G. Davis
A. H. Malone C. D. Martin, Jr.

Design of instrumentation and controls for the Thermal Hydraulic Test Facility (THTF)[1] was continued. When completed, this facility will be used to study the blowdown heat transfer effects on electrically heated, 49-rod arrays that will simulate fuel rods in a section of a pressurized water reactor (PWR) core. Information from these tests will be appraised to evaluate the effects on the fuel cladding of a loss-of-coolant depressurization accident in a PWR system.

The design basis of the THTF was changed from the original plan of enlarging and modifying the existing Rod Burnout Test Facility (RBTF). The new plan is to construct a new system separate from the RBTF, leaving the RBTF intact, and to use indirectly instead of directly heated rods during initial tests, while deferring tests with directly heated rods until later. Although these changes offer significant advantage in cost and scheduling of the overall project, they also make redesign of some completed portions of the instrumentation and controls necessary or desirable.

The basic design of instrumentation and controls for the system with indirectly heated rods is nearly complete, and the detailed design is under way in some areas. The instrument applications diagrams and tabulations are essentially complete. Design of control circuits and layout of control panels is under way. Requirements for control valves were determined, valve specifications were prepared, and procurement of the valves was started. Except for some minor details, the requirements for data acquisition and most of the process instrumentation components were determined. Procurement of these items will be started when the necessary funding approvals are obtained.

The authors assisted in the project with preparation of schedules, cost estimates, and planning documents such as the systems design description and the measurements requirements document. They also helped to determine the quality levels and procedures needed to satisfy the requirements of the project and of the ORNL and AEC quality assurance programs.

One of the most challenging instrument problems is the measurement of two-phase (steam-water) flow during the short (about 30 sec) blowdown interval. Various methods of making this measurement were studied, and a method was selected for initial test. Mass flux (ρv) will be computed from data supplied by a combination of gamma densitometers (ρ) and either drag disks (ρv) or turbine meters (v). Two-phase flow instrumentation being installed in the forced convection test facility will provide advanced experience with techniques and equipment (Sect. 10.3).

In FY 1973 the Instrumentation and Controls Division supplied about 2.5 man-years of engineering and drafting manpower; it is expected to supply about 6 man-years in FY 1974. The total cost for design, procurement, and installation of instrumentation, including the data acquisition systems, is estimated to be $750,000. The schedule calls for completion of construction and start of an operational shakedown of the process portion of the facility in the last quarter of FY 1974, and completion of the test section and related instrumentation during the first quarter of FY 1975.

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1. R. L. Moore et al., *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 99.

10.2 INSTRUMENTATION FOR CAPSULES IN THE HIGH TEMPERATURE GAS-COOLED REACTOR FUEL DEVELOPMENT PROGRAM

J. W. Cunningham

Instrument drawings were prepared for four capsules to be irradiated in the Oak Ridge Research Reactor (ORR) and three in the HFIR. Design of a second experimental facility for irradiating capsules in the HFIR, which was started a year ago, was completed. This work and procurement of instrument equipment and checkout of the field installation required about 1.5 man-years.

From a safety analysis standpoint, the portions of each capsule which contain fuel are similar regardless of the reactor in which they will be irradiated. A primary containment holds the fuel, and a secondary containment encloses the primary. There is gas in the space between the two containment shells whose pressure is higher than the gas pressure in the primary containment or the reactor water pressure that surrounds the capsule. A leak in either containment would cause a drop in the gas pressure between the two containments. Therefore, this pressure is monitored as a safety parameter. The temperature of the fuel is sometimes monitored as a safety parameter as well.

For a typical experiment, two new drawings and four to six revised facility drawings are required. The facility drawings are the gas supply systems instrument application diagrams, wiring tables for the detailed wiring of the instrument cabinets, and a schematic drawing. These electrical drawings describe the safety circuits as well as miscellaneous power circuits needed for an experiment. The two new drawings, an instrument application diagram and a signal cable drawing, are related more directly to each experiment.

The signal cable drawing shows all thermocouple lead-wire connections and how each thermocouple is connected to a recorder and to the Dextir data collection system. The number of thermocouples per capsule varies from 10 to 35. Chromel-Alumel thermocouples are used except where temperatures at the measuring junction exceed 1000°C. Then W - 3% Re W - 24% Re are used.

Cables used on the pressure measuring parameters and on radiation measurements are shown on the signal drawing also.

10.3 FORCED CONVECTION TEST FACILITY

C. Brashear J. W. Krewson
B. G. Eads R. L. Moore

Modifications of the Forced Convection Test Facility (FCTF)[1] for use in blowdown (depressurization) testing of single rods were completed. In these tests, loss-of-coolant and pressure

accidents will be simulated for light-water reactors with various lengths of fuel rods to obtain data for reactor safety analysis and to determine the similarity between electrical rods that experience blowdown transients and nuclear fuel rods under similar environmental conditions.

Tests were performed early in the year on two 5'-ft heater rods by utilizing the Zircaloy cladding failure test facility[1] that had been reactivated and modified for performing the blowdown test. Major modifications were later made to the facility and its instrumentation and control systems for testing 12-ft rods.

A new, saturable reactor-controlled power supply capable of delivering 100% power (150 kW–800 A) to the 12-ft heater rods was installed. The characteristics of the ground fault detectors in the rod and decay heat electrical power circuits were studied, and the detectors were modified so that their sensitivities can be set from about 1 mA to hundreds of milliamperes for protection of the individual rods during tests.

The tests to be performed in the FCTF will complement the blowdown tests of multirod arrays to be performed in the Thermal Hydraulic Test Facility (THTF) (Sect. 10.1). Density (gamma densitometer) and flow (drag disks) instrumentation to measure two-phase (steam-water) flow during depressurization is being installed to obtain mass flux data during the blowdown experiments at the FCTF and to become familiar with making measurements for the design of the THTF. (The two-phase flow measurement is reported in detail in Sect. 10.1.) A new instrument panel for the two-phase flow instruments was completed and installed at the FCTF. The panel includes instrumentation for the densitometer, drag disks, fast transient response pressure transducers, and controls for the densitometer gamma source positioner.

New pressure taps designed by the Aerojet Nuclear Company were installed in the loop to compare pressure measurements made with them to measurements made with taps designed by ORNL. Also, exposed junction thermocouples of the type used by Aerojet Nuclear were installed for comparison with temperature measurements made by using ribbon-type exposed junction thermocouples.

During initial operations with the 12-ft heater rod, 60-Hz series-mode noise on the signal inputs from the 20 fast-response, heater-rod thermocouples and from several loop thermocouples to the high-speed data acquisition system caused the quality of the data to be unacceptable. Simple and inexpensive RC filters installed on each of the thermocouples decreased the noise to a negligible level without unduly affecting the response time.

Routine assistance was also supplied in response to continuing requests for advice and assistance with instrumentation problems, such as evaluation and improvement of equipment performance; assistance with operations during the tests; analysis of data; and selection, location, and procurement of instruments and equipment.

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1. R. L. Moore and J. W. Krewson, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 100.
2. R. L. Moore and J. M. Cate, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1971*, ORNL-4734, p. 116.

10.4 GAS SYSTEMS TECHNOLOGY FACILITY

P. G. Herndon

The Gas Systems Technology Facility, a facility for circulating about 1000 gpm of molten salt at temperatures from 1050 to 1300°F, was originally constructed to develop a way to remove gaseous fission-product poisons from molten-salt reactors. The circulating stream was to be utilized to

evaluate gas system components and gas recycle techniques. As the installation of the facility neared completion, the Molten-Salt Reactor Program was terminated and all work was stopped. The facility was placed in a standby condition, and all components were catalogued and stored for use on future projects.

10.5 INSTRUMENTATION FOR MSBR COOLANT-SALT TECHNOLOGY FACILITY

C. Brashear R. I. Durall A. H. Anderson

Termination of the MSR Program this year resulted in a stoppage of all work on the Coolant-Salt Technology Facility. The design, installation, and checkout of instrumentation and controls were completed, and the facility was operational before the program was canceled. All instrumentation and control systems performed satisfactorily during startup and at design conditions.

Termination of the operation required an orderly shutdown and the disabling of all electrical systems after the molten salt was drained and frozen in the drain tank. All other systems, such as cooling water, salt pump lube oil, off-gas, and cover gas, were disabled and placed in a safe state. All instrumentation systems were shut down.

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1. C. Brashear, R. I. Durall, and A. H. Anderson, *Instrumentation and Controls for the Coolant-Salt Technology Facility*, ORNL-4822, p. 102.

10.6 POTASSIUM-STEAM BINARY VAPOR CYCLE TEST FACILITY

P. G. Herndon

The Oak Ridge National Laboratory has proposed to the National Science Foundation that a potassium-vapor, Rankine topping cycle be developed as a means of raising the peak temperature of steam power plants to 1600°F, thereby increasing their thermodynamic efficiency. The cycle would be superimposed on a conventional steam cycle with a turbine inlet temperature of 1000 to 1050°F. The overall thermal efficiency would be raised from about 39% to greater than 50%, thereby decreasing the waste heat rejection to almost half and the fuel consumption to 75% of that for a conventional supercritical pressure steam plant.[1]

The initial task is to design, construct, and operate a test facility that contains a full-scale potassium boiler tube bundle and burner module with a design output of 20,000,000 Btu/hr. About 100 of these modules would constitute the boiler-furnace for a full-scale power plant of 400 MW(e). The test facility would have two major parts: the potassium circulating system, which includes the boiler tube bundle, vapor condenser, drain tank, and cover gas system; and the furnace, which includes the natural gas burner with fuel and air supply systems.

Preliminary design studies of the instrumentation and controls requirements have been under way since March 1973, and the process flow diagrams that define the system and reveal the scope of these requirements were completed. The design of the instrumentation and controls system was started.

Primary elements for measuring potassium temperatures, pressures, flows, and levels at high temperatures (1540°F) are required, and existing devices, such as the electromagnetic flowmeter, resistance-type, liquid-level probes, and high-quality, stainless steel sheathed, magnesium oxide insulated thermocouple assemblies—all developed for use on previous facilities that make use of boiling potassium and liquid metals—are available for these applications.[2]

About 100 thermocouple assemblies will be required on the potassium circulating system. Of these, 50 will be attached to the piping outside the furnace, but 40 (15 to 40 ft long) will be attached to the outside wall of the boiler tubes inside the combustion chamber where they will be exposed to high temperature (1200 to 2700°F) combustion gases. A purchase order for these thermocouple assemblies has been placed in accordance with the requirements of the RRD Large-Scale Procurement of Temperature Sensor Program, with modifications tailored to the requirements of this facility.

The furnace is a natural gas-fired single burner that is enclosed in a supercharged combustion chamber designed to operate at pressures to 6 atm. Combustion air flow requirements for operation at 1–6 atm range from 30 to 1800 scfm, and the fuel flow requirements are about 10% of these values. Standard process-type industrial instrument components are suitable for the combustion control system, but the measurement and control of fuel and air flow rates into a variable pressure combustion chamber over such a wide range (60:1) is more difficult than experienced with conventional boiler furnaces. Instrumentation is also required to analyze the flue gases and to measure the combustion chamber pressures and the gas pressure drop across the burner.

In addition to the operating controls just described, a separate system of safety controls that will protect against fuel explosion hazards must be provided as required by the National Fire Protection Association standard 86B, 1973.

Initial operations will be at low firing rates with atmospheric pressure in the furnace.

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1. Potassium-Steam Binary Vapor Cycle Research proposal submitted to the National Science Foundation, Research Applied to National Needs (RANN), Oak Ridge National Laboratory, ANL-AG-302 (January 1973).
2. A. P. Fraas, *Preliminary Assessment of a Potassium-Steam-Gas Vapor Cycle for Better Fuel Economy and Reduced Thermal Pollution*, ORNL-NSF-EP-6 (August 1971).
3. H. J. Metz and M. M. Yarosh, "Experiences and Developments in Instrumentation for Liquid Metal Experiments," *Proc. 6th High Temp. Liq. Met. Heat Transfer Technol. Conf.*, Sept. 28–29, 1965, Vol. 2, ANL-7100.
4. M. M. Yarosh and P. A. Gnadt, *The Intermediate Potassium System—A Rankine-Cycle Test Facility*, ORNL-4025 (October 1966).

10.7 SUPPORT FOR THE SOLID MECHANICS DEPARTMENT OF THE EXPERIMENTAL MECHANICS SECTION

R. L. Moore
W. A. Bird, T. M. Cate
R. L. Durall, W. A. Johnston, Jr.

The Instrumentation and Controls Division furnished about 1.5 man-years of labor for design, application, and maintenance of instruments and instrument systems for a variety of experimental programs of the Solid Mechanics Department. This support was shared by four major programs: heavy section steel technology, liquid-metal fast breeder reactor (LMFBR) structural design methods, ORNL piping, and prestressed concrete reactor vessel.

For the intermediate vessel test series under the heavy section steel technology program, Division personnel checked, calibrated, and operated all remote viewing systems, data acquisition systems, and instrument systems in preparation for and during tests of three test specimens, IVT-2, IVT-3, and IVT-4.

Construction and checkout of the circular plate test facility for the structural design methods program was completed. Assistance was provided to set up, calibrate, and operate this facility during three tests lasting from 300 to 1000 hr. Operation of an elevated temperature beam test was

continued and Division personnel assisted in the operation of this facility during three beam tests, which operated from 300 to 1000 hr each. Design of a new instrument system was started for the elevated temperature beam test.

Division personnel also continued to assist structures tests being performed under the ORNL piping program.

A thermal cylinder test under the prestressed concrete reactor vessel program was successfully completed, and this test facility was dismantled.

10.8 DATA ACQUISITION AND ANALYSIS FOR THE FORCED CONVECTION DEPRESSURIZATION LOOP EXPERIMENTS

N. E. Clapp, Jr.

As part of the blowdown heat transfer program, the Zircaloy cladding failure test loop was used to investigate the heat transfer during blowdown (depressurization) of a loop containing a single heater rod. Data (millivolts on magnetic tape) were recorded by an Anscan data acquisition system. Computer codes were written to convert the millivolt signals to engineering units and to plot time response curves of various signals.

11. Maintenance and Service

11.1 ENGINEERING ACTIVITIES OF THE SPECIAL ELECTRONIC SERVICES GROUP

J. L. Lowvorn
D. D. Bates A. L. Case
C. C. Hall J. A. Russell, Jr.

Engineering assistance was provided on a wide variety of projects as requested or required by ORNL operations.

For the Thermonuclear Division, the group assisted in the design, fabrication, installation, and operation of the microwave diagnostics system for plasma research.

A complete TV sync generator, with EIA standards, was built using a single commercial integrated circuit chip.

A commercial, 1-in. videotape recorder was modified for use as a wide-band instrument recorder. A useful frequency range of 30 Hz to over 3.0 MHz was demonstrated after the modification.

Consulting assistance was furnished to an ORNL project for the Defense Civil Preparedness Agency with the goal of developing a concept that would help to protect two-way radio communications receivers from damage as a result of electromagnetic pulses.

An estimate of instrument needs for a proposed environmental sciences laboratory was prepared.

A review of all x-ray machine installations at ORNL was started to determine if the safety interlock and warning systems are adequate. A lamp failure alarm was designed, and an alarm unit will be installed at most x-ray diffraction machine installations where warning lights are now installed.

Four cameras with remote monitors were specified, procured, and installed for surveillance at the Radio Chemical Processing Pilot Plant (Building 3019).

Finally, 0.5 man-year was spent in preparing RDT Standards for instrumentation and for assistance in the evaluation of other specifications and standards.

11.2 ORNL RADIO COMMUNICATIONS SYSTEM

J. A. Russell, Jr.

Minor changes were made to the ORNL radio communications systems. One mobile unit was installed for the Environmental Sciences Division. Two mobile units and one portable unit were purchased and placed in service for the electrical line maintenance crew. An auxiliary main-base repeater station was installed for the Plant and Equipment Division radio network.

From an audit of radio system maintenance in June 1972, the auditors recommended that studies be made to determine whether new field test equipment should be purchased and whether older radio units should be replaced. Subsequent recommendations were made, but because sufficient funds were not available, no purchases were made.

A 5-year communications plan which covers long-range additions and improvements to the ORNL radio system to keep it in a sufficient state of readiness and to continue to provide essential communications, was submitted to the AEC, along with similar plans from the other Oak Ridge facilities. Again, there were not enough funds to implement the ORNL plan.

A continuing search is under way for a suitable low-cost method of recording communications on the Plant and Equipment net.

11.3 ACTIVITIES OF THE COMPUTER AND ANALYZER GROUP

J. A. Keathley E. McDaniel

With the increased use of visual terminals and other high-speed computer communication systems, the activities of this group were expanded to maintain these devices.

New computers and multichannel analyzers were acquired by the Laboratory while all the older units were continued in service. The number of Teletypes was increased by 30 to a total of 190 units. The number of acoustic couplers to connect these and other input-output devices by telephone lines to the computers was also increased.

Two factory schools on computers were attended by group personnel to expand the maintenance capabilities of the group. In-house training programs were also taught a portion of the year and will be expanded as the work load permits.

Maintenance assistance was furnished away from ORNL, including California, North Carolina, and Virginia.

The older analog computer in the Controls Department of this Division was replaced with a larger unit acquired from the U.S. Air Force. The older unit was installed in Building 2001 for use by the Environmental Sciences Division. Both units are operational.

11.4 ACTIVITIES OF THE RADIATION MONITORING SYSTEMS MAINTENANCE GROUP

J. D. Blanton J. L. Lovvorn P. P. Williams

The maintenance organization of the monitoring system section consists of nine instrument technicians and one foreman. Activities of this group remained approximately as previously reported.

A total of 1154 stationary health-physics instrument systems are installed throughout the Laboratory. Four technicians performed 1523 services on these instruments in this reporting period. These technicians performed bimonthly performance checks of fixed instruments installed in 13 facility radiation and contamination alarm systems, in three facility alarm and containment systems, and in five remote radiation alarm systems. These systems were in 21 buildings and consisted of 295 radiation monitoring stations. Twenty-two local air monitor and fallout monitor stations were checked semimonthly for proper operation, and their condition was logged and corrected as required.

Three technicians maintained and calibrated 1289 portable health physics instruments at the health physics calibration laboratory. These same three technicians serviced 4280 portable instruments.

Two technicians assigned to the Operations Division serviced and maintained approximately 30 gas and 31 liquid-waste effluent monitors that telemeter alarms and other information to the waste disposal control center (Building 3105). The conditions were logged, and malfunctions were corrected. Three water-quality monitoring stations (located along the streams into which plant waste water flows) and the instruments in the control center were serviced and maintained by these two technicians. These systems were checked biweekly for performance.

Of the 597 personal radiation monitors in service, about 150 units were serviced by a technician.

11.5 MAINTENANCE ACTIVITIES OF THE SPECIAL ELECTRONIC SERVICES SHOPS

J. L. Lovvorn R. L. McKinney

The maintenance section of the Special Electronic Services Group consisted of one foreman and four technicians, with shops in the Instrument Laboratory (Building 3500) and in Buildings 4500N and 4500S.

The shop in Building 3500 maintained all oscilloscopes in the Laboratory, the electronic instrumentation for this Division, and serviced instruments for the Isotopes Division and that part of the Analytical Chemistry Division located in the west end of the Laboratory. This shop also repaired digital voltmeters, pulse amplifiers, nuclear scalers, electrometers, power supplies, and similar equipment for all divisions on a call-in basis.

The shop in Room E-1, Building 4500N, maintained many types of electronic instruments, including all Laboratory spectrophotometers, for the Chemistry, Analytical Chemistry, Chemical Technology, and Physics Divisions and for the Research Group of the Health Physics Division.

The shop in Building 4500S maintained instruments only for the nondestructive testing group of the Metals and Ceramics Division.

11.6 MAINTENANCE ACTIVITIES FOR ENVIRONMENTAL SCIENCES, SOLID STATE, AND INSPECTION ENGINEERING DIVISIONS

J. L. Lovvorn W. Ragan

The group that furnishes instrument service for Environmental Sciences, Solid State, and Inspection Engineering Divisions is staffed with a foreman and four technicians. Two repair shops are maintained, one in the Graphite Reactor Building 3001 and the other in the Solid State Laboratory Annex Building 2000. The services of this group include routine maintenance, fabrication, modification, troubleshooting and repair of complex electronic systems. The members of this group serve as a liaison between the experimenter and the various engineering groups of this Division to solve special design problems.

Most of the work for the Solid State Division was routine maintenance and repairs. No major jobs were initiated.

Other than routine maintenance and repair, the major jobs accomplished by the group were as follows.

1. Installed oxygen analyzers, Brown recorders, thermocouples, and associated wiring at the Walker watershed site for sediment studies.

2. Installed new equipment and modified a pH system for alkaline and caustic studies in the Environmental Sciences Division Building 2001.
3. Installed instrumentation and wiring in a trailer and associated field equipment for study of forest animals.
4. Completed overhaul and modification of instruments and associated equipment in a trailer for an oil disposal experiment.

In addition to maintenance and repair for the Inspection Engineering Department, the scheduled checkout and calibration of immerscopes and reflectoscopes were completed.

11.7 ACTIVITIES OF THE RADIO, TELEVISION, PAGING, AND INTERCOM MAINTENANCE GROUP

J. D. Blanton J. L. Lovvorn

There were 299 pieces of two-way radio equipment in service at the Laboratory. An instrument technician was assigned full time to service and maintain this equipment. The computerized program continued to perform semiannually power, frequency, deviation, and sensitivity performance checks on two-way radio units. Approximately 624 two-way radio units were serviced during this period.

One technician serviced and maintained closed-circuit television, a microwave TV system, video recorders, audiopaging, and intercom systems at the Laboratory.

There were 269 radiopaging receivers in service. About 102 receivers were serviced and maintained by an instrument technician working part-time during this period.

11.8 ACTIVITIES OF THE AUDIOVISUAL SERVICE GROUP

C. C. Hall J. L. Lovvorn J. Miniard

Public address systems, visual-aid projection, and audio and videotape recording were furnished for 396 in-Laboratory meetings and 14 offsite meetings (eleven in Oak Ridge and three in Gatlinburg). Three technicians and a foreman worked full time at these meetings. Other personnel assisted during peak loads and at offsite meetings. The group also maintained audiovisual equipment of this Division and similar equipment for other groups.

Both audio and videotapes were duplicated on request. Audiovisual equipment was inventoried, and inventory records were updated.

Assistance was provided to the ORNL Motion Picture Group and the Personnel Development and Systems Department in making films and videotape production.

11.9 ACTIVITIES OF THE OAK RIDGE ISOCHRONOUS CYCLOTRON INSTRUMENT MAINTENANCE GROUP

J. L. Lovvorn E. W. Sparks

Electronic components, power supplies, and control circuits at the Oak Ridge Isochronous Cyclotron were maintained most of the year during 11 shifts per week and for one month of the year during 16 shifts per week by one foreman and four technicians.

Fabrication and modification services were provided for interfacing the ORIC and the modular systems computer. Another project of the group was to assist with design changes to replace the

RCA6949 triode power amplifier with an RCA 4648 tetrode power amplifier, since the latter tube is more readily available and its cost is about one third that of the first tube.

In other activities, this group assisted in troubleshooting and modifying an X-Y machine table, controlled by a Hughes NC200 machine controller, which was started for use as a probe positioner for a 0.15 scale magnetic model of the National Heavy Ion Laboratory Cyclotron. A power pulser capable of 6 kV at 8 A was constructed for heavy-ion beam switching. It has a 4CX25000A power tube, and its pulse width can be varied from a few microseconds to several milliseconds.

11.10 MAINTENANCE ACTIVITIES OF THE OPERATING REACTORS GROUP

K. W. West

Some major changes in the organization and responsibilities of this group were made in the past year to unify similar services to all reactors. The instrument technicians (2 : men) assigned to the Neutron Physics Division reactors, the Health Physics Research Reactor (HPRR), and the Tower Shielding Facility (TSF) now report to the Operating Reactors Group rather than to the Services for Neutron Physics Division Group. The group of four technicians assigned to the Operations Division reactors (HFIR, ORR, Bulk Shielding Facility, and Pool Critical Assembly), was reduced to three because of funding. The Oak Ridge Research Reactor (ORR) experimental staff was reduced to one technician because of a reduction in the number of experiments. These technicians report to a single foreman.

To supplement the knowledge and experience of the instrument technicians who maintain the reactor control systems, a training program was started which covers instrumentation and controls of the operating reactors. Three technicians who are not assigned to the Operating Reactors Group also attend the training sessions to assist the group if required.

A foreman was assigned to implement the inventory and maintenance control program (Sect. 8.29) for all reactors and experiment instruments, and to prepare and update existing reactor controls and instrument test and calibration procedures.

Another foreman was designated field engineer for the ORR and Bulk Shielding Facility (BSF), in addition to maintaining his staff responsibility for the HPRR and TSF nuclear electronics.

Reactor controls change memoranda remain a responsibility of the group, and additional formal documents for design request, design change description, and design review are being prepared in accordance with quality assurance document QA-IC-11. An engineer, with assistance from the field engineers and the Reactor Projects Group, is responsible for the change memoranda and associated design.

11.11 MAINTENANCE OF THE HEALTH PHYSICS RESEARCH REACTOR

J. B. Puble D. D. Walker K. W. West

During the last 12 months the Health Physics Research Reactor (HPRR) had only one unscheduled shutdown due to instrumentation, caused by noise from a faulty chamber in the log N channel. The chamber was replaced with a spare chamber.

Occasional intermittent malfunction of the No. 1 counting channel was attributed to a loose connection within the fission chamber; this chamber was replaced with a spare unit.

Reactor control circuit changes included (1) removal of the motor drive and wiring of the No. 1 fission counting channel to make it a fixed position channel similar to the No. 2 channel, and (2) replacement of vacuum tube rectifiers in safety power supplies with solid-state plug-in components.

ORNL-HPER 73-2 incident report described a malfunction of the reactor pickup mechanism and interference with the storage pit door, which dislodged the reactor from the support mechanism. This Division supplied support personnel to analyze the malfunction and restore the reactor to normal operation. One of the two thermocouples that measure the reactor core temperature had been damaged, and a replacement was fabricated and installed. Both thermocouples were compared with a standard to determine their accuracy. The reactor was returned to its normal operating schedule.

11.12 MAINTENANCE OF NEUTRON PHYSICS REACTORS

J. B. Ruble D. D. Walker K. W. West

The reactor controls and instrumentation systems of the TSR-II reactor at the Tower Shielding Facility (TSF) operated satisfactorily. Minor changes were made to the controls system to improve operation of the reactor. We are continuing to improve the regulating plate operation at low power levels.

Control of access to the area by reactor operators was improved by installing a unit at the control console that indicates the status of the main access gate.

Following mechanical failure of the control ball of TSR-II in May 1972, personnel from this Division assisted in installing the spare control ball and restoring reactor operation.

The TSF SNAP-10 reactor was removed from service during May and June 1973. The control system and its components were removed in such a way as to permit future use of this reactor, if desirable.

Technical assistance and service were furnished for the instrumentation in the experimental data collecting systems at the TSF. After adjustment and calibration, new transistorized preamplifiers for the hydrogen counters were placed in service.

11.13 MAINTENANCE OF THE OAK RIDGE RESEARCH REACTOR

J. M. Farmer J. B. Ruble K. W. West

There were eight unscheduled shutdowns at the ORR during the last 12 months which were caused by control power wiring, instrumentation, and relay failure. Four shutdowns occurred during a three-day period, but each was definitely of a momentary nature. Troubleshooting revealed two loose connections in the neutral wiring loop in the control power circuitry. The troubleshooting technique was to use a 1-kW dummy load and observe the voltage drop throughout the many terminal points in the neutral leg of the control power wiring.

Two instruments failed: a recorder in the north gamma channel, and an electrometer in the ^{16}N channel which caused the recorder to drive upscale.

One experiment (GB10) was shut down when a faulty potentiometer wiper in a strain gage power supply was jarred by the closing of an adjacent recorder door.

The relay failure occurred when a regulating-rod control relay became stuck in the withdraw mode, causing a power excursion to the reverse point (120%). The defective relay was replaced.

The following changes were made to the reactor control circuit:

1. A relay was added in pH recorder contacts to interlock and limit the dead band for pH control.
2. A 5×10^{5} Ω resistor was added to the log-N amplifier input circuit to supply a small positive

current and thus eliminate a false overcompensated output signal from the ionization chamber during a reactor startup.

3. A capacitor in the preamplifier of the fission counting channel was changed to stabilize its gain.

11.14 MAINTENANCE OF THE BULK SHIELDING REACTOR AND POOL CRITICAL ASSEMBLY

J. M. Farmer J. B. Ruble K. W. West

The Bulk Shielding Reactor (BSR) underwent an unscheduled shut down only once during the last 12 months owing to an instrument failure. The cause of this shutdown was a momentary failure of a manual slow-scram (drop out scram) relay. As a corrective step, the relay contacts were cleaned and adjusted.

The BSR control circuit was changed to eliminate duplication of the slow-scram functions by removing raise-clutch switch and key switch contacts from the slow-scram relay circuits. An interlock was installed in the primary coolant circulating pump to prevent the pump from being started when the flapper valve is fully open and mode 1 operation is selected.

A new built-in test facility for the Δt channel was installed for use during quarterly instrument checkout periods.

One dual PCP III ionization chamber was replaced, because an annual routine check of its saturation characteristics revealed it to be unacceptable.

The Pool Critical Assembly was continued as an experimental facility for intermittent use by the Universities of Tennessee, Kentucky, Oklahoma, and Mississippi State for student training and by the Tennessee Valley Authority for operator training. With minor maintenance and quarterly checkout, it has performed satisfactorily.

11.15 MAINTENANCE OF THE HIGH FLUX ISOTOPE REACTOR

D. S. Asquith C. T. Carney K. W. West

Experience continued at about the same level as that of the previous year. Most routine maintenance was performed on-line with the reactor in operation. Through proper scheduling, less than 10% of the programmed maintenance required that the reactor be shut down.

Various maintenance programs were reviewed and updated. New procedures were prepared when additional information was needed by the technicians. When this review is completed, a single HFIR Maintenance Manual will be prepared, which will comprise all individual maintenance programs and procedures into a single volume.

All HFIR reactor instruments were included in the Instrument Inventory and Maintenance Control Program. Assignment of inventory numbers and a catalog of the approximate 1000 instruments assigned to this reactor were started.

A newly designed operational amplifier was accepted for the HFIR to replace older chopper-stabilized types that were approaching the end of their design life. The new amplifiers performed satisfactorily, with no failures attributed to them.

The flux measuring circuits were redesigned. The flux amplifier, the mechanically driven flux reset module, and several operational amplifiers were incorporated into a single flux-conditioner module, which is all solid state and has an electronic flux reset circuit. Because of circuit differences, separate versions of this module were required for the safety and servo channels. All channels were converted to this new system.

During this report period, an unscheduled shutdown (trip) occurred eight times during routine testing of the safety channels when the second of three channels in the two-of-three coincidence system was tripped. These shutdowns accounted for 0.968 hr of a total 59.985 hr of unscheduled reactor downtime. All of these trips occurred after the installation of the new safety flux conditioner modules and were a result of the susceptibility of these modules to electrical noise. After the circuit was modified slightly, no further malfunctions were recorded.

As reported previously[1] the primary responsibility for rod time-of-flight measurements was assigned to the HFIR computer. To provide some degree of buffering between the measurement system and the protective system, the OR gate modules were modified, and the start time-of-flight signal is now coupled to the OR gate modules through opto-isolators. This panel will accept four individual experiment alarm inputs, and only minor wiring need be installed from the experiment to a centrally located panel in the experiment room to complete the monitoring connection.

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1. D. S. Asquith, C. T. Carney, and K. W. West, *Instrumentation and Controls Div. Annu. Progr. Rep. Sept. 1, 1972*, ORNL-4822, p. 112.

11.16 COMPUTER PROGRAM FOR INSTRUMENT INVENTORY AND PROGRAMMED MAINTENANCE

R. L. Simpson

A manageable instrument inventory and maintenance record system is essential to the overall design of the record format, data storage, and file system to take advantage of computer processing and storage methods. A system was devised and computer programs were written to match the computer processing to the record processing needs. The system procedure is as follows.

Inventory cards are filled out for each instrument, and the information is read into the computer. These data are stored on disk in records identified by instrument identification number.

When an instrument is maintained, a maintenance card is filled out, which records the time spent on the instrument. The card lists nine activities for which work can be categorized along with the date the work was done. The information on these cards is read into the computer and stored with the instrument inventory data. The result is a recorded description of each instrument, along with pertinent calibration and maintenance information.

Each month when the program is run, the computer prints a card that gives notice that programmed maintenance or calibration (or both) is due, if a schedule for these services was indicated on the inventory card. A list of all maintenance and calibration cards is printed for use by Division supervisors. If the instrument is not maintained or calibrated during the month when notice is given, an overdue notice is printed the following month and each succeeding month until the scheduled service is completed.

The listings given on request are (1) complete inventory, (2) inventory by file point, and (3) inventory of property items in numerical order of property number.

11.17 MAINTENANCE ACTIVITIES OF VAN DE GRAAFF ACCELERATOR GROUP

R. P. Cumby J. W. Johnson

The service group from this Division assigned to the Van de Graaff Accelerator Laboratory maintained and modified instruments used by the Physics Division for their nuclear and atomic

physics programs. There were three Van de Graaff accelerators in Building 5500, the largest of which was a HVEC, EN Tandem. All electronic power supplies for these accelerators were maintained by this group. Other instruments maintained were eight highly regulated magnet supplies; 264 NIM modules and 29 NIM bin-power supplies; 84 vacuum measuring instruments, including four mass spectrometer helium leak detectors; and two area radiation monitoring systems.

12. Ecological Science Studies

12.1 METHODS OF ESTIMATING DOSE TO MAN FROM REGIONAL GROWTH OF NUCLEAR POWER[1]

K. E. Cowser[2]
R. S. Booth B. R. Fish[3] G. R. Siegel[4]
W. S. Snyder[5] W. H. Wilkie[5] J. P. Witherspoon[6]

A joint study of the potential radiological impact of an expanding nuclear power economy on the Tennessee Valley region was started by ORNL, the Tennessee Valley Authority, the Atmospheric Turbulence and Diffusion Laboratory–National Oceanic and Atmospheric Administration, and the Hanford Engineering Development Laboratory (HEDL) in cooperation with USAEC.

The Tennessee Valley region study involves an appraisal of the generation, management, and control of radioactive effluents from nuclear facilities in the region through the year 2000. It considers nuclear power requirements to the year 2000, siting for nuclear facilities, radionuclide release and transport in air and water, radionuclide concentration in terrestrial and aquatic systems, and estimation and interpretation of the potential dose to man.

This is the second such regional study initiated by the USAEC in the continental United States; the first considered the region defined as the Upper Mississippi River Basin. A computer model, HERMES (Hanford Engineering Regional Mode for Environmental Studies), was developed by HEDL and applied in the Upper Mississippi River Basin study. The model permits estimates, on a regional basis, of the potential radiation dose that might be received by individuals and population groups as a result of radioactive materials estimated to be released from reactors and fuel reprocessing plants.

Modifications in HERMES are discussed within the context of the uniqueness of the Tennessee Valley region, and additions or improvements are based on the initial application of HERMES. This paper, one of three companion reports, includes information on the data requirements and the components of HERMES concerned with the estimation of dose to man from internal and external modes of exposure.

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1. For presentation at IAEA Symposium on Environmental Behavior of Radionuclides Released in the Nuclear Industry, Aix-en-Provence, France, May 14–18, 1973.
2. Special Assistant to J. R. Totter.
3. Health Physics Division.
4. Tennessee Valley Authority, Chattanooga, Tennessee.
5. Tennessee Valley Authority, Muscle Shoals, Alabama.
6. Environmental Sciences Division.

12.2 A COMPENDIUM OF RADIONUCLIDES FOUND IN LIQUID EFFLUENTS OF NUCLEAR POWER STATIONS[1]

R. S. Booth

Radionuclides released in liquid effluents from power reactors in quantities high enough to require an environmental impact assessment were tabulated and their expected annual releases were determined from published measurements and operating experience with 24 light-water reactors. This standard list of 63 radionuclides was the one used for preparation of environmental impact statements for nuclear power stations. Use of this list helped ensure completeness in estimating the consequences of radionuclide releases from each reactor without having to consider repeatedly the several hundred radionuclides that could be released. The expected releases and their variations tabulated here were used to verify theoretical releases included in the impact statements for specific reactors.

Operating experience shows that the quantities of radionuclides released from similar reactors during any year and from the same reactor for subsequent years can differ by orders of magnitude. However, analysis of measured releases indicates that the probability of a given release decreases inversely with the magnitude of that release.

The average amount of ^{3}H released per year was ~900 Ci for pressurized water reactors (PWR) and ~25 Ci for boiling water reactors (BWR). The average amount of gross beta and gamma releases (in addition to ^{3}H) was ~5 Ci/year for PWRs and ~10 Ci/year from BWRs. Average releases of individual radionuclides considered here varied from ~10^{-4} to ~2 Ci/year.

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1. Abstract of report ORNL-TM-3801 (to be published).

12.3 IMPLEMENTATION OF A PREDATOR-PREY BIOMASS MODEL FOR FISHES[1]

J. F. Kitchell[2] J. F. Koonce[2] R. V. O'Neill[3]
H. H. Shugart, Jr.[3] J. J. Magnuson[4] R. S. Booth[2]

A predator-prey biomass model is developed for fishes based on a series of equations that describe the processes of feeding, growth, egestion, respiration, excretion, gamete production, and predatory and nonpredatory mortalities. Terms are presented to account for rate dependences on thermal conditions, size structure of the population, and density-dependent interactions. All terms of the model were implemented empirically, based on previous work at Lake Wingra and those data available from literature sources.

Simulations were performed to assess the response pattern and relative stability of the model and to compare predicted results with those derived from independent observations under both laboratory and field conditions.

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1. Abstract of International Biological Program Eastern Deciduous Forest Biome Memo Report 72-11.
2. Institute of Environmental Studies, University of Wisconsin, Madison.
3. Environmental Sciences Division.
4. Department of Zoology, University of Wisconsin, Madison.

12.4 DEVELOPMENT OF A ZOOPLANKTON-PHYTOPLANKTON MODEL

O. L. Smith R. V. O'Neill[1]
H. H. Shugart[1] R. S. Booth

In 1972 the central modeling group of the International Biological Program initiated development of a general model for mass or carbon transfer in an aquatic ecosystem. During this report period, a submodel that describes planktonic behavior was completed. The submodel equations were derived from basic first principles with precise definitions of species parameters. From the equations, ecological principles were analytically deduced which described in general terms the behavior of a community of several zooplankton species competing for phytoplankton. A commonly used definition was proposed. In addition to the analytical studies that used somewhat simplified systems equations, a computer program was developed to handle the most complex forms of the model equations. A report of the work was prepared and submitted for publication in the open literature.

1. Environmental Sciences Division.

12.5 PRODUCTION MODEL FOR *Myriophyllum spicatum* L.[1]

J. E. Titus[2]
M. S. Adams[2] P. R. Weiler[2] R. V. O'Neill[4]
H. H. Shugart[4] R. S. Booth R. A. Goldstein[4]

The growth of *Myriophyllum spicatum*, a submergent macrophyte species, was mathematically described, considering photosynthesis, respiration, acclimation, excretion, sloughing of leaves, shoot mortality, and growth form. Variation in these growth-related processes and associated environmental parameters with water depth was included.

Comparison of model predictions with field observations verified that many of the features of *M. spicatum* growth were successfully formulated. However, limitations of the model are still evident. The model is currently used in guiding experimental work with *M. spicatum*, and we hope that it will be of general application to other submergent macrophytes in the biome.

1. Abstract of International Biological Program Eastern Forest Biome Memo Report 72-108.
2. Department of Botany, University of Wisconsin, Madison.
3. Institute for Environmental Studies, University of Wisconsin, Madison.
4. Environmental Sciences Division.

12.6 A MODEL FOR AQUATIC MICROBIAL DECOMPOSITION[1]

L. S. Clesceri[2]
J. A. Bloomfield[2] R. V. O'Neill[3]
H. H. Shugart[3] R. S. Booth

A 22-compartment decomposition process model was developed to represent the carbon transfers that result from heterotrophic microbiological activity in freshwater ecosystems. The model accommodates anaerobic and aerobic interactions for the water column and surface sediments and

only anaerobic interactions in the deep sediments. Thermal stratification is accounted for by distinguishing between transfers that occur only in the epilimnion, in the hypolimnion, or both.

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1 Abstract of International Biological Program Eastern Deciduous Forest Biome Memo Report 72-40

2 Rensselaer Polytechnic Institute, Troy, New York

3 Environmental Sciences Division

12.7 HERMES DOSE FACTORS

R. S. Booth

Dose commitments as calculated from the HERMES expression were compared with dose commitments as calculated from the ORNL expression,[1] assuming that identical parameters were used in the two expressions. The intake of radioactivity by man was assumed to follow the equation

$$I(t) = Ioe^{At}, \qquad 0 \leqslant t \leqslant n,$$

where $I(t)$ is the intake rate that occurs during the time range from $t = 0$ to $t = n$ years, Io is a constant, and A is a parameter that can have any value. At $t = 0$, the concentration of radioactivity in the organ of interest was assumed to be zero. The two dose commitments were calculated for the time range from $t = 0$ to $t = \tau$ years, where $\tau \geqslant n$.

The two expressions were determined to be identical if the intake rate is an impulse. However, the HERMES dose commitment exceeds the ORNL dose commitment for any other intake function. This conservatism results completely from the form of the HERMES expression and is, therefore, artificial. The HERMES annual dose commitment ($n = 1$ and $\tau = 1$) was too high by about a factor of 2 for radionuclides whose half-lives exceed 1 year.

These conclusions were incorporated into an overall critique of the HERMES document.

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1 J. F. Fletcher and W. L. Dotson (compilers), *HERMES - A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry*, HEDL-TME-71-168 (December 1971), Eq. (44), p. 159

2 P. S. Rohwer, K. E. Cowser, W. S. Snyder, and E. G. Struxness, "An Approach for Assessing Potential Population Exposures," *Health Physics Society Symposium on Environmental Surveillance in the Vicinity of Nuclear Facilities*, William C. Reinig (ed.), Charles C. Thomas (publisher), 1970

12.8 CRITIQUE OF THE FOOD PATHWAYS MODEL IN THE HERMES COMPUTER CODE

O. L. Smith R. S. Booth

The HERMES food pathways model developed for the Year 2000 Study by the Hanford Engineering Development Laboratory (HEDL)[1] was evaluated by comparing it with a revised model devised by the authors who started from basically the same farm management scheme as that used by HEDL. In this revised model, several approximations used by HEDL were removed and only one new constant was added. A computer code was developed to compare the models quantitatively. The results show that some HEDL assumptions and mathematical approximations can cause significant conservatism (answers that are too large) in the concentration of radionuclides in farm animal products calculated by their model. In addition, nonconservatism can be introduced into the HEDL model for radionuclides with short half-lives compared to HEDL's time-mesh of one point per month. The HEDL model calculational error ranged from −100 to +1400% (relative to the revised

model), depending on the radioactive and biological half-lives of the particular radionuclide being considered. However, for radionuclides with radioactive half-lives greater than ≈8 days and biological half-lives between ≈1 day and ≈30 years, differences were 40 to +100% for milk and −15 to +200% for beef.

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1. J. F. Fletcher and W. L. Dotson (compilers), *HERMES—A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry*, HEDL-TME-71-168 (December 1971).

12.9 LINEAR ECOLOGICAL MODEL INVESTIGATION

F. H. Clark[1] H. A. Vanderploeg[1] R. S. Booth[1]

To make meaningful selections of the type of ecological model to be applied to a given physical system, an understanding of the options is required. To furnish such understanding, linear ecological systems were investigated. This work will be reported later.

In this investigation, the relative merits of describing an ecological system in terms of a linear reactivity model and a linear specific activity model were evaluated. The relationship between the two models and the principal features and advantages of each model were determined. An investigation was also made of which parameters of one environment may be generalized and cataloged for use in other environments. The uses of bounding solutions and of almost equivalent systems to reduce data requirements were assessed.

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1. Environmental Sciences Division

12.10 USER'S MANUAL FOR MODSOV, A TERMINAL-OPERATED PROGRAM FOR SOLVING THE LINEAR MATRIX EQUATION $\dot{x} = Ax + k$[1]

F. H. Clark[2] R. S. Booth[2] H. A. Vanderploeg[2]

To meet day-to-day calculation requirements of ecological systems, the linear matrix equation $\dot{x} = Ax + k$ was programmed for terminal operation. The existing program MATEXP, which deals with this problem class, was adapted to the task. A simple conversational structure was created to enable use of the program with only a few minutes of training. The user can designate a specific activity or a radioactivity model, thereby causing the program to undertake some of the coefficient processing from minimal input. Or, he may choose to solve a more general problem and supply all coefficients explicitly.

A unique feature of the program is an option that permits the user to suppress short-time characteristics after they have no more appreciable effect on the solutions. This option enables avoidance of the most often encountered form of mathematical instability for this class of problems.

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1. Abstract of report ORNL-TM-4404 (to be published).
2. Environmental Sciences Division

12.11 INTERNATIONAL BIOLOGICAL PROGRAM WOODLANDS WORKSHOP

R. S. Booth

The Eastern Deciduous Forest Biome of the International Biological Program (IBP) hosted a modeling workshop, August 14–26, 1973, at ORNL. Scientists from IBP sites representing 14 countries brought data sets from their respective sites. They worked with environmental modelers (eleven from ORNL and six from four U.S. universities) to develop linear biomass and nutrient models of their forest system, and time-varying seasonal models for four different forest types. The models developed, with intercomparisons, and a series of contributed papers will be printed as a progress report of the conference.

Professional Awards, Achievements, Offices, and Memberships in Professional Groups Held by Instrumentation and Controls Division Personnel

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

H. J. Metz: Member

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

W. W. Johnston, Jr.: Member of Committee C-96, Thermocouples

D. J. Knowles: Alternate Member with F. W. Manning of Committee N-42, Nuclear Instrumentation

J. W. Krewson: Member of Subcommittee, Liquid Level; under Committee B-88, Calibration of Instruments

F. W. Manning: Member of Committee N-42, Nuclear Instrumentation

H. A. Todd and F. W. Manning: Who's Who in the South and Southwest

F. W. Manning: Who's Who in Finance and Commerce

AMERICAN NUCLEAR SOCIETY (ANS)

J. L. Anderson: Member of Subcommittee ANS-4, Reactor Dynamics and Control, Standards Committee

C. J. Borkowski: Fellow

E. P. Epler: Fellow

J. B. Bullock: Chairman of Digital Computer Control Planning Group, Subcommittee ANS-4

F. W. Manning: Member of Committee ANS-16, Nuclear Instrument Standards

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

W. W. Johnston, Jr.: Member of Committee E-20, Temperature Measurement; Chairman of Subcommittee, Resistance Thermometers, Member of other Subcommittees and Sections under Committee E20.04, Thermocouples

R. L. Shepard: Chairman of Subcommittee, Acoustical Thermometry, under Committee E-20, Temperature Measurement, Member of other Subcommittees and Sections under Committee E20.04, Thermocouples

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

S. J. Ditto: Member of Subcommittee SC-6, Nuclear Power Engineering Committee, of the Power Engineering Society

J. H. Holladay: Chairman, Oak Ridge Section

C. F. Holloway: Member of Subcommittee SC-4, Auxiliary Power Systems, under Joint Committee on Nuclear Power Standards of Nuclear Science Group and Power Group. Chairman of Fellowship and Attendance Committee, Oak Ridge Section

P. Rubel: Director and Chairman of the Publicity Committee, Oak Ridge Section

INSTRUMENT SOCIETY OF AMERICA (ISA)

R. K. Adams: Fellow

A. H. Anderson: Business Manager (Recorder), Oak Ridge Section

C. S. Lisser: Member of U.S. Technical Advisory Group

J. A. Russell: Chairman, Awards Committee, Oak Ridge Section

R. L. Shepard: Editor, "Omnibus Thermometry," *Temp. Meas. Control Sci. Ind.* 4(1), (1972).

INSTRUMENTATION AND CONTROLS DIVISION COMMITTEES

J. A. Russell: Design and Drafting, Standards Committee

J. L. Lovvorn: Division Maintenance, Information Committee; Semiconductor, ORNL Stores Stock Advisory Committee; Operational Amplifier, ORNL Stores Stock Advisory Committee

C. C. Hall: Vacuum Tubes, ORNL Stores Stock Advisory Committee

J. A. Russell: Batteries, ORNL Stores Stock Advisory Committee

INTERNATIONAL ELECTROTECHNICAL COMMISSION TECHNICAL COMMITTEE 65

C. S. Lisser: Member of U.S. Technical Advisory Group

NATIONAL COUNCIL ON RADIATION PROTECTION AND UNITS

F. H. Clark: Consultant

ORNL REVIEW COMMITTEES

J. L. Anderson: Neutron Physics Division Safety Review Committee

B. G. Eads: Accelerator and Source Safety

B. C. Duggins: Reactor Operations

B. Lieberman: Radioactive Operations

L. C. Oakes: Reactor Review

J. A. Russell: Accelerator and Source Safety

SCIENTIFIC RESEARCH SOCIETY OF AMERICA

J. B. Davidson: Secretary, Oak Ridge Branch

SOCIETY FOR NUCLEAR MEDICINE

F. H. Clark: Chairman, Computer Standards Committee

J. W. Woody: Member, Computer Standards Committee

TENNESSEE SOCIETY OF PROFESSIONAL ENGINEERS

Tom M. Gayle: Professional Engineer

H. J. Metz: Professional Engineer

J. A. Russell: Professional Engineer and Member of Engineer of the Year Committee

U.S. ATOMIC ENERGY COMMISSION NIM-CAMAC COMMITTEE

N. W. Hill: Member, Subcommittee on Analog Signals

G. A. Holt: Member, Executive Committee

J. W. Woody: Member, NIM Committee

U.S. NAVY

H. E. Cochran, Commander: Executive Officer of Research Company 6-3 of the U.S. Naval Reserve

Publications

Some of the publications listed below were prepared jointly with members of other divisions and with consultants and other nonemployees. Their affiliations are footnoted.

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Buhl, A. R.,[a] H. L. Dobbs, Jr., J. C. Robinson, R. A. Lillie,[a] O. W. Hermann,[a] and R. J. Hinton,[a] *A User's Manual for TASK, A Generalized One Dimensional Transport and Diffusion Kinetics Code*, ORNL-TM-3811 (December 1972).

Buhl, A. R.,[a] and R. L. Childs,[a] *An Evaluation of the ^{252}Cf Method for Source Level Flux Monitoring in the FTR*, ORNL-TM-3883 (August 1972).

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Chiles, M. M., "Low-Level Detector for Alpha Contamination Monitor in Continuously Flowing Process Waste Water," *Nucl. Instrum. Methods* 109(3), 541–46 (June 15, 1973).

Clark, F. H., *Model for Two-Phase Flow in Water*, ORNL-TM-4123 (April 1973).

Cleseri, L. S.,[a] J. A. Bloomfield,[a] R. V. O'Neil,[a] H. H. Shugart,[a] and R. S. Booth, *A Model for Aquatic Microbial Decomposition*, IBP Eastern Deciduous Forest Biome Report 72-40 (June 1972).

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1. University of Tennessee, Knoxville.
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10. Metals and Ceramics Division.
11. University of Washington, Seattle.
12. Reactor Chemistry Division.
13. Albion College, Albion, Michigan.
14. University of Illinois, Chicago.
15. Chemical Technology Division.

Papers Presented at Professional Meetings

Some of the papers listed below were prepared jointly with members of other divisions and with consultants and other nonemployees. Their affiliations are footnoted.

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Cowser, K. E.,[1] R. S. Booth, B. R. Fish,[2] G. R. Siegel,[2] W. S. Snyder,[3] W. H. Wilkie,[2] and J. P. Witherspoon.[1] "Methods of Estimating Dose to Man from Regional Growth of Nuclear Power."

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Theses Completed

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1. Reactor Division.
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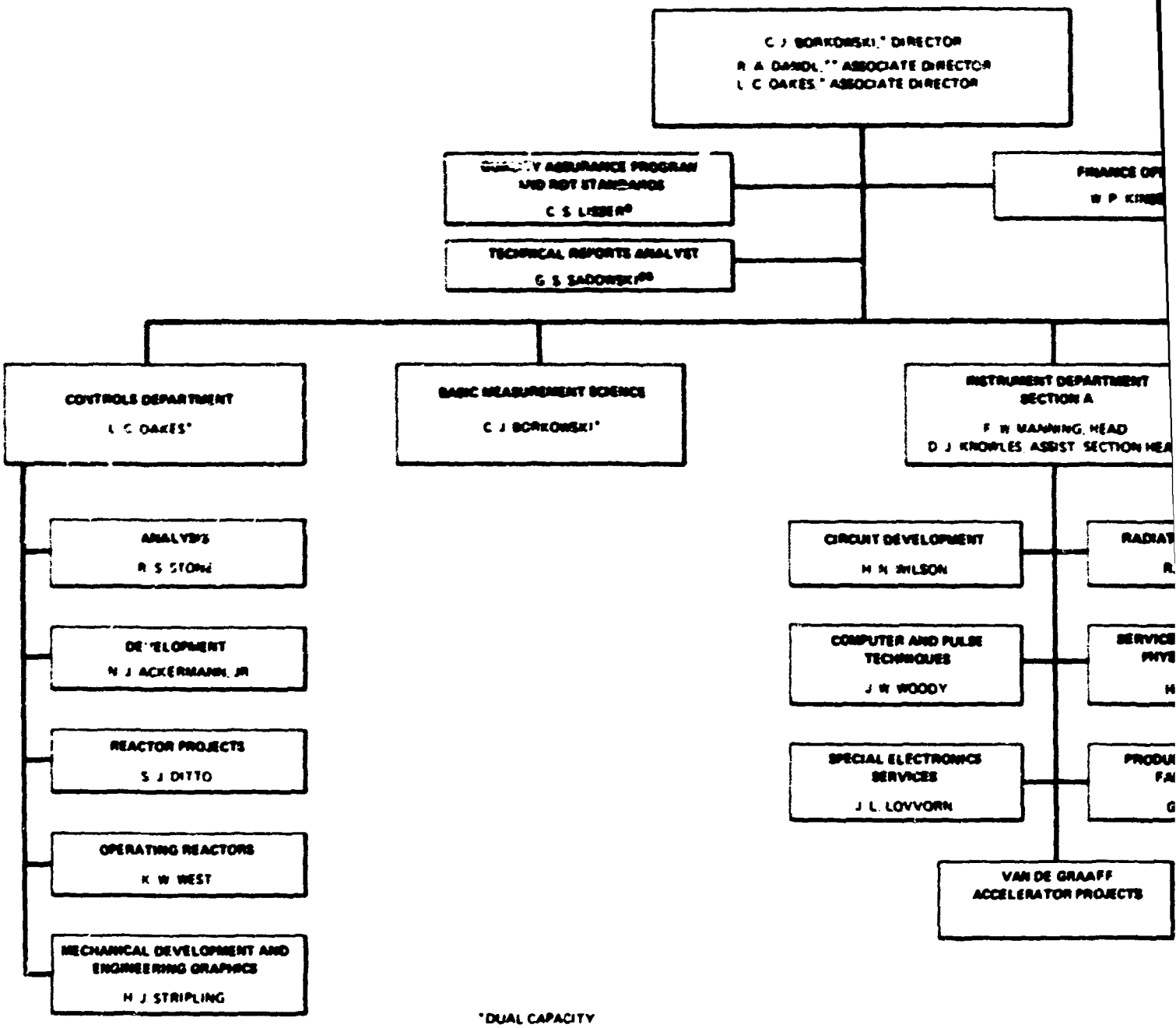
INSTRUMENTATION AND CONTROLS



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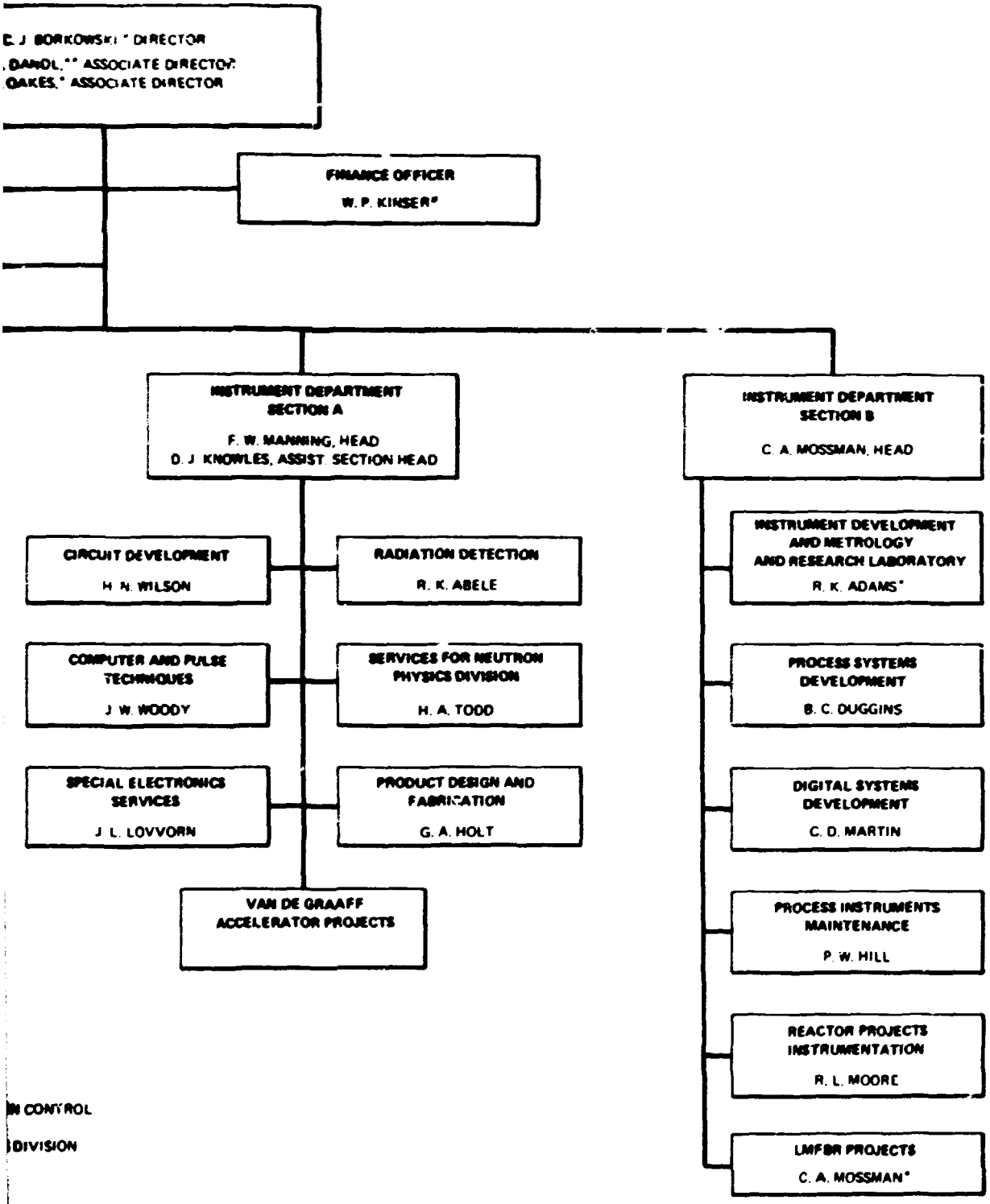

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