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INSTRUMENTATION AND CONTROLS DIVISION BIENNIAL PROGRESS REPORT For Period September 1, 1976, to September 1, 1978

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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 effort 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, which 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.

It is our purpose in this report to tell what 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, 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 desiring more information on any topic will call or write any of the persons whose names are listed with each topic.

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1976-1978: A PERIOD OF CHANGE AND ADAPTATION FOR THE INSTRUMENTATION AND CONTROLS DIVISION

H. N. Hill

During this report period, the Instrumentation and Controls Divisio experienced significant change. Foremost was the retirement of C. J. Borkowski, who was appointed Director of the newly created Division in 1954 and directed its work for 23 years. A prolific inventor and recognized by the scientific community for his pioneering in nuclear instrumentation and radiation detectors, he guided the growth of this Division to fill a broad and unique role within the UCC-ND and ORNL structures.

A second major change of the Division was the shift from mostly nuclear technology to the broader aspects of energy research and development — this change spurred by the merger in October 1977 of the Energy Research and Development Administration (ERDA) into the new U.S. Department of Energy (USDOE). The programmatic funded work now includes instrumentation for fossil and solar energy sources and energy conservation, in addition to instrumentation for fission and fusion energy sources and environmental and biomedical measurements.

During this report period, the number of Division employees was increased from 319 to 362 (includes 7 part-time), mostly in the professional staff (from 135 to 167). This increase indicates the expanded participation of this Division in ORNL programs. Commensurate with this expanded participation, the expenditures of the Division increased from $6.4 million to $15.2 million. In FY-1978 these expenditures were split almost equally three ways: R&D, $5.6 million, or 37%; engineering, $4.6 million, or 30%; and maintenance, $5.0 million, or 33%.

The organizational structure and staff assignments were altered to adapt to the changing and increased needs of the Division and the Laboratory. An advisory planning group was appointed early in 1978 to prepare a formal, Division long-range plan. The leader is J. B. Davidson, with J. L. Blankenship, W. R. Hamel, J. M. Rochelle, C. W. Ricker, and V. J. Zedler as members. (A statement that expresses their perception of the objective of the Division follows this introductory report.) The recommendations of this group will assist Division management in selecting

those areas where the Division manpower should be optimally allocated for R&D programs and support work, and where efforts are needed to facilitate personnel growth and to improve the Division organization.

To unify the maintenance support activities of the Division, these activities were administratively combined in mid-1978 under P. W. Hill as Head of a new Maintenance Management Department. The instrument foremen and technicians continue to report functionally to the engineering groups for technical support.

The Division responded to an increased need for documented quality assurance by planning and implementing a revitalized program under C. W. Ricker and D. G. Prater in early 1978. To date, the results of this program have been excellent.

Along with the organizational and administrative changes, the technical growth and achievements of this Division have continued apace. Division members organized an international meeting of reactor noise specialists in Gatlinburg, Tennessee, September 1977. R. S. Booth was chairman of the Second Specialists' Meeting on Reactor Noise, SMORN-II, and several members of the Division presented technical papers or assisted with meeting activities.

The outstanding technical achievements by members of this Division and others at ORNL were recognized by the *Industrial Research* magazine in September 1977, when its editors announced the IR-100 awards for the one hundred most-significant technical products of the year. Instrumentation and Controls Division personnel developed one of the honored products and were major contributors to the development of four of the products, which are listed below along with Division personnel who were contributors:

1. Johnson Noise Power Thermometer - C. J. Borkowski and T. V. Blalock (inventors) and R. J. Fox, J. A. Harter, and R. L. Shepard
2. Oak Ridge Small-Angle Scattering System - J. A. Ramsey, W. T. Clay, C. E. Fowler, M. K. Kopp, and R. G. Upton
3. One-Atom Detector - C. E. Fowler and R. E. Zedler
4. Portable Centrifugal Fast Analyzer - M. L. Bauer, W. F. Johnson, and D. G. Lakomy

We are proud of the broad range and value of the professional activities of the Division staff. It is our judgment that the professional activities, publications, papers, and patents listed at the back of this report indicate the technical competence of the staff. We hope that those readers especially interested in these matters will find an abundance of useful information in this document.

OVERALL OBJECTIVE OF THE INSTRUMENTATION AND CONTROLS DIVISION[1]

The objective of the Division is to provide and improve measurement and control technology in all the basic science and engineering research divisions within the Laboratory and within the federal national laboratory structure through the performance of two basic and equally important functions. These instrumentation functions are:

- Research and Development
- Project Team Support.

The Division will develop and maintain, on a continuing basis, a staff of highly trained and experienced engineers, scientists, and technicians equipped with the most advanced facilities for instrumentation research and development, design, and fabrication. An essential, integral part of this staff is a dynamic organization for maintaining all instruments, controls, and data systems throughout the Laboratory to the highest standards.

The Division will be continuously cognizant of the scientific and technological needs related to energy research and development for both the Laboratory and the Nation. Consequently, the Division responsibilities will encompass four technological areas:

- Detection and Measurement
- Signal Processing and Data Management
- Automatic Control
- Electrical Energy Conversion.

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1. This statement was prepared by the advisory planning group of the Instrumentation and Controls Division, J. B. Davidson, chairman.

1. RESEARCH AND DEVELOPMENT IN ELECTRONIC CIRCUITS

1.1 LOW-NOISE VOLTAGE-SENSITIVE PREAMPLIFIER WITH OUTPUT STABILIZATION BY POLE-ZERO CANCELLATION IN THE FEEDBACK CIRCUIT[1]

M. K. Kopp J. A. Williams

Low-noise, voltage-sensitive preamplifiers were designed with pole-zero cancellation in the feedback circuit to stabilize the output baseline against variations in the mean rate and amplitude of random signals. Compared to conventional feedback and subsequent pole-zero cancellation, this method of baseline stabilization increased the fraction of signals transmitted without distortion by preamplifier saturation from 50 to >99% for steplike input signals of 240 mV amplitude occurring randomly at a mean rate of 10^4 signals/sec.

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1. Abstract of published paper: *Rev. Sci. Instrum.* 48, 383 (1977).

1.2 DESCRIPTION AND CHARACTERISTICS OF A WIDE-BAND LINEAR CIRCUIT FOR PULSE AMPLIFICATION[1]

M. K. Kopp

A wide-band, linear, pulse amplifier stage was designed and tested. The closed-loop gain is ∿10, the gain-bandwidth product is 350 MHz, and the integral nonlinearity is <0.05%.

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1. Abstract of published paper: *Rev. Sci. Instrum.* 49, 273 (1978).

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1.3 DESIGN AND TEST OF COMPENSATED COUNT-RATE CIRCUIT FOR PORTABLE G-M SURVEY METERS

R. A. Todd F. M. Glass

A count-rate circuit for use in portable Geiger-Mueller survey meters was designed and tested that compensates for counting-loss errors in the G-M tube detector. Previous designs with some compensation indicated readings that were 8% high at midscale and 8% low at full scale for a 50% duty cycle count rate from the detector. By creating a transfer function analogous to the counting loss equation, the compensated count rate circuit indicates an output reading that is proportional to the true count within 1% up to duty cycles of 50%.

1.4 PERIOD MEASUREMENT COUNTER

J. M. Jansen, Jr. D. Friedman[1] D. L. Halperin[1]

The development of computer-based systems for measurement and control employing real-time multiprogramming software systems with high-level language applications software often requires measurement of the responsiveness and expandability of the system to improve or increase its performance. Various options to achieve one or both of these goals can be considered such as, for example, purchasing higher-throughput equipment, recoding critical algorithms and developing new assembly language routines to decrease execution times, recoding commonly used routines, or reallocating resources such as the separation of files among different disk drives. To quantitatively evaluate such options and to develop an understanding of the system's overhead in these real-time systems, a portable period measurement counter was developed to measure times between events. This device will measure time periods to 100 sec with a resolution of 1 μsec, and periods to 2.75 hr with a resolution of 100 μsec. It will measure the logically asserted period of a signal and the period between a logical start signal and a logical stop signal. The significant difference between this device and a period/frequency counter is that it can store the maximum and minimum periods determined since the last assertion of a logical reset signal. The operator can select the maximum, minimum, or previous period for display on a 10-digit readout device.

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1. ORAU student trainee, 1976 and 1977.

1.5 CONCEPTUAL DESIGN FOR MULTICHANNEL TELEMETRY OF STRAIN AND TEMPERATURE MEASUREMENTS FROM SHAFTS ROTATING AT HIGH SPEED

W. L. Bryan J. M. Rochelle R. A. Todd

Circuits for short-range telemetry of multiple strain and temperature measurements from the rotors of high speed machines were designed and breadboarded to verify their expected performance. The design permits a total of eight information channels (six of which are available for strain or temperature measurements) to be time-division multiplexed on a single, 1-MHz carrier which is capacitively coupled across a rotor-stator gap of about 0.5 in. The carrier is 100% AM modulated by a square-wave FM subcarrier, which is generated by processing the multiplexed and amplified data signals through a voltage-to-frequency converter.

The data channels are multiplexed at the data amplifier to minimize the amplifier count and the overall power of the rotor circuit. This low-level input multiplexing is made possible by utilizing stable current sources for sensor biasing. Also, the data amplifier gain can be switch selected concurrently with multiplexer switching to accommodate sensors with different sensitivities or scaling factors. The power requirement of the rotor circuit is about 500 mW, which is easily supplied by air-core inductive coupling at 20 kHz.

The rotor circuit is designed for production as four parts; each subcircuit part is fabricated as a 0.5-in. square hybrid microcircuit, using state-of-the-art monolithic circuit and resistor chips. Microcircuit construction is required to achieve both miniaturization and good reliability at high rotor speeds where gravitational forces may be centrifugally multiplied 50,000 times or more.

Strain measurement errors caused by a rise of the rotor temperature can be compensated automatically by utilizing one or more rotor temperature measurements to generate dynamic strain error correction factors in accordance with error-temperature functional relationships previously determined by static testing in a calibrated oven.

1.6 HIGH-GAIN FAST AMPLIFIER

K. Rush

A high-gain fast amplifier (Q-5617) was developed for use with radiation detectors. The amplifier has input and output impedances of 50 Ω, a gain of ∿1500, and a rise time of <3 nsec. The amplifier is packaged in an 8.4- by 3- by 1.3-cm solid aluminum case. It can be built at ORNL for a cost of about $400. The high performance, low cost, and small size are made possible by hybrid microcircuit techniques.

1.7 DEVELOPMENT OF FISSION COUNTER NOISE FILTERING

K. Rush

A technique was developed to determine optimum filter time constants for ionization type fission counters for the Physics Division.

The sensitivity of ionization type fission counters is reduced by the undesired detection of the alpha particles emitted by the fissionable material in the counter, as well as by noise originating in the electronic amplifiers. With the alpha particle signal considered as noise and combined with the amplifier noise, an optimum filter time constant was determined for the detection of fission signals in the presence of this combined noise. Then, based on this information, RLC filters were built and tested with signals from a fission chamber that had a total alpha background rate of 5.0×10^8 alpha counts/sec. During these tests, these filters enabled detection of fission fragments in the presence of higher alpha background count rates than any previously tested filters.

This filter optimization technique is being applied to a high-gamma-background fission counter.

1.8 DEVELOPMENT OF HIGH-FREQUENCY FILTERS

K. Rush

A technique was developed for realizing high-order RLC filters in the hundred mega-Hertz range. The technique employs hybrid microcircuits and leadless capacitors in solid, machined metal packages. Such filters were fabricated with bandwidths approaching 100 MHz.

1.9 USER MANUAL FOR THE Q-5485, 1.0-nsec FAST PREAMPLIFIER AND Q-5487, 1.0-nsec FAST AMPLIFIER[1]

K. Rush

An amplifier system (Q-5485 and Q-5487) with a rise time of 1.0 nsec was developed for service in nuclear event detectors that require a high timing resolution. Because of its lower cost, greater reliability, lower noise, and higher gain bandwidth, this system is expected to replace other amplifier systems commonly used in this service. Simplified circuitry, improved transistors, and hybrid microcircuit fabrication yield small, high-performance amplifiers that are compatible with existing 50-Ω

transmission components. Solid metal packaging eliminates RFI and ground-loop pickup; it also provides convenient handling and protection of the circuit.

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1. Abstract of published report: ORNL/TM-6239 (1978).

1.10 INSTRUMENT FOR MEASUREMENT OF JFET NOISE CHARACTERISTICS

R. A. Todd

A prototypic JFET noise measurement instrument was designed and built to measure the noise characteristics of unincapsulated n-channel JFET chips. The instrument is used to select the input devices of low-noise hybrid preamplifiers before the chips are epoxied and wire bonded in place, and has proved to be a useful tool for comparison of the noise characteristics of various device types. The instrument has also been used to measure the base-spreading resistance of NPN bipolar transistors.

1.11 DUAL-PEAK DETECTOR FOR ACCELEROMETER CALIBRATION

W. H. Andrews

A dual-peak detector was developed to compare the simultaneous output voltages from two piezoelectric accelerometers undergoing identical accelerations. To calibrate an accelerometer, it is rigidly fastened to a standard accelerometer, and the two accelerometers are mounted on an anvil which is struck by a falling metal ball. The instrument amplifies the output voltages from each accelerometer, and the voltage peaks are detected, preserved, and displayed on a digital meter. From the ratio of the two values and the sensitivity of the standard accelerometer, the sensitivity of the device under test can be determined.

The circuitry consists of two channels of analog peak detection and memory. Each channel contains a precision electronic switch/fast-charge integrator combination designed around high-input-impedance operational amplifiers. The digital voltmeter is based on the recent Intersil 7106 integrated circuit under evaluation by the Instrumentation and Controls Division at the time of fabrication.

1.12 REACTOR PERIOD MEASUREMENT MODULE

W. L. Bryan D. D. Walker

A circuit has been developed for the Operations Division for measurement of the reactor period at the DOSAR facility (building 7710). The circuit provides output signals related to the reactor period (i.e., the time in which the flux changes a factor of e) to a time interval counter from inputs proportional to the reactor flux.

1.13 HYBRID MICROCIRCUIT ACTIVITIES

J. T. De Lorenzo R. A. Todd E. J. Kennedy K. Rush
V. C. Miller R. E. Cooper C. H. Tucker H. N. Wilson

During the past two years, the thick-film, hybrid microcircuit program at ORNL entered a new phase. The cooperative contract between the Instrumentation and Controls Division of ORNL and the Electrical Engineering Department of the University of Tennessee-Knoxville (UTK) was concluded October 1, 1977, after three years of operation.

The contract originally involved the use of UTK thick-film laboratory equipment and personnel in the study of conductive and resistive inks and of fabrication techniques for thick-film, hybrid microcircuits. During the last two years of the contract, the major emphasis was to test and evaluate commercially available resistor inks to determine the excess noise properties of these inks at low frequencies[1] and to select inks suitable for use at ORNL. In subsequent tests, the effect of different conductive ink terminations on the excess noise characteristics was evaluated.

ORNL acquired thick-film equipment early in fiscal year 1977, shifting the fabrication work from UTK. In a new photographic facility of the Instrumentation and Controls Division, Mylar layouts were photographically reduced to glass plates and screens were fabricated. All screen printing, firing of substrates through a furnace, and air-brasive trimming of resistors was done at ORNL with the new equipment. As a result of the noise tests at UTK, a set of resistor inks was purchased, characterized for layout purposes, and used for fabricating new circuits. An evaluation of low-firing-temperature polymer inks that can be screen printed onto printed circuit boards was started to determine the feasibility of using the process at ORNL.

In addition to the preceding activities, the thick-film hybrid facility fabricated new designs, revised or updated earlier designs, and modified existing designs for special applications. Thick-film hybrid construction was used to fabricate a pulse amplifier for operation at 300°C, a 1-nsec current pulse amplifier for use with fission counters, RLC pulse-shaping filters, a thick-film hybrid personal radiation monitor

(PRM), and a wide-band differential voltage amplifier using either bipolar or matched dual JFET inputs. Some previous designs were revised because new devices had become available for incorporation in the design or because some monolithic circuit chips were no longer available. As examples, the common-base, input current pulse amplifier was revised to use 5-GHz transistors packaged in microminiature plastic packages, and the low-power electrometer was revised because the transistor array chips originally used were no longer readily available. Charge-sensitive and voltage-sensitive preamplifiers were adapted for use in photomultiplier tube bases, inside proportional counter housings, and at the end of long cables for use with BF_3 counters at the Tower Shielding Facility.

Specifications were prepared and a contract was awarded in March 1978 for 100, TF-12 voltage-sensitive preamplifiers for use with position-sensitive proportional counters. The amplifiers were inspected on delivery and made available for general ORNL use.

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1. E. J. Kennedy, J. P. Baker, and R. W. Tucker, Jr., "Low-Frequency Current Noise in Hybrid Thick-Film Resistors," *Int. J. Hybrid Microelectronics* 1(1), 16-22 (January 1978).

1.14 IMPROVED PHOTOGRAPHIC FACILITY FOR INSTRUMENTATION FABRICATION

C. H. Tucker

The product and design section improved its photographic facility to accommodate the increased work load from the Instrumentation and Controls Division and the Laboratory. The technicians work from master layouts to prepare high-resolution and high-contrast negatives to fabricate etched wiring boards, printed metalphoto processed panels, identification tags, and chemical milled plates.

The etched-circuit master layouts are double scale, and the red and blue tape method is used to achieve absolute registrations when double-sided etched wiring boards are prepared. The master negatives are made photographically by using color filters and reducing the scale to full size.

Reduced photographic glass plates and stainless steel photo screens were prepared for the hybrid integrated circuit facility of the Instrumentation and Controls Division. Microcircuits were printed from the screens.

2. INSTRUMENT DEVELOPMENT

Position-Sensitive Detection Systems

2.1 ELECTRONIC DISCRIMINATION OF THE EFFECTIVE THICKNESS OF PROPORTIONAL COUNTERS[1]

C. J. Borkowski M. K. Kopp

We developed and tested a new method of electronic discrimination of the effective thickness of proportional counters and applied this method in a proportional counter camera to adjust its effective aperture, i.e., the combination of counter efficiency and spatial resolution without changing the pinhole aperture, the collimator, or the distance between the subject and camera.

The discriminator virtually divides the thickness of the electron drift volume of the camera into two regions and separates the photons detected in each region. Thus, two sets of data are acquired and displayed simultaneously during an exposure: one with good spatial resolution (<2 mm fwhm) using photons detected in the drift volume close to the entrance window, and one with high detection efficiency (>50% for 60-keV photons) but poorer resolution (∿5 mm fwhm) using all detected photons.

Simultaneous acquisition of two sets of data with different apertures reduces the exposure time in applications, such as nuclear medicine, where a sequence of images often is required to select the optimum aperture for different portions of radioisotope distribution images.

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1. Abstract of published paper: *IEEE Trans. Nucl. Sci.* NS-24 (1), 287 (1977).

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2.2 RECENT IMPROVEMENTS TO RC-LINE ENCODED POSITION-SENSITIVE PROPORTIONAL COUNTERS[1]

C. J. Borkowski M. K. Kopp

Continuing research on the principles of position encoding with RC lines has advanced the design of position-sensitive proportional counters (PSPCs) to meet the requirements for high count rates ($>10^5$ counts/sec) and good spatial resolution ($>10^4$ spatial elements) in small-angle scattering experiments with x rays and neutrons. We developed (1) low-noise preamplifiers with pole-zero cancellation in the feedback circuit and modular linear amplifiers with passive RCL shaping to reduce output saturation at high count rates and to shorten the position signal processing time, (2) resistive self-heating and propylene decomposition to increase the conductance and film thickness of pyrolytic-carbon anodes and to reduce the effects of electron erosion at high count rates, (3) technology for large-area PSPCs ($>60 \times 60$ cm^2) for the measurement of small-angle scattering with neutrons, and (4) a method of electronic thickness discrimination to change the effective thickness of area PSPCs and to increase the signal-to-background ratio.

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1. Abstract of paper accepted for publication: *Journal of Applied Crystallography* (1978).

2.3 POSITION-SENSITIVE PROPORTIONAL COUNTER FOR ARGONNE NATIONAL LABORATORY

M. K. Kopp G. W. Allin
F. J. Lynch[1] R. Brenner[1]

A multiwire, position-sensitive proportional counter (PSPC) system was designed and fabrication was started for the ZING pulsed-neutron source at Argonne National Laboratory. This design is based on RC-line encoding and time difference decoding[2] of the spatial coordinates of the interaction loci of individual neutrons. The active area of the PSPC will be $\sim 20 \times 20$ cm^2. A matrix of 64×64 spatial elements (pixels) will be resolved. The count-rate capability for randomly incident neutrons will be $\sim 5 \times 10^4$ counts/sec, with a coincidence loss of <3%.

The PSPC container will be filled with ~50% ^{3}He, 35% Xe, and 15% CO_2 to an absolute pressure of 5×10^5 Pa (5 atm). The depth of the active volume will be ~5 cm. This counter depth and gas fill will result in a detection efficiency of ~60% for neutrons which will have a de Broglie wave length of 0.1 nm (1.0 Å).

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1. Argonne National Laboratory.
2. C. J. Borkowski and M. K. Kopp, *Rev. Sci. Instrum.* 46, 951 (1975).

2.4 CURVED, POSITION-SENSITIVE PROPORTIONAL COUNTER

M. K. Kopp A. H. Narten[1]

A curved, one-dimensional position-sensitive proportional counter (PSPC) was designed and construction was started for applications in large-angle neutron diffraction systems. The radius of curvature of this counter is 0.5 m, and the counter encircles 130°. The counter is 10 cm high, and the radial drift region is 5 cm thick. The PSPC container will be filled to an absolute pressure of 2×10^5 Pa (2 atm). This counter depth and gas fill will result in a detection efficiency of ∿80% for neutrons of interest, which will have a de Broglie wave length of 0.1 nm (1.0 Å).

Resistance-capacitance encoding and time-difference position decoding are used.[2] The expected angular resolution is 0.5°. The count-rate capability for randomly incident neutrons will be $\sim 2 \times 10^4$ counts/sec, with a coincidence loss of <3%.

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1. Chemistry Division.
2. C. J. Borkowski and M. K. Kopp, *Rev. Sci. Instrum.* 46, 951 (1975).

2.5 POSITION-SENSITIVE PROPORTIONAL COUNTER FOR THE NATIONAL SMALL-ANGLE NEUTRON SCATTERING FACILITY

M. K. Kopp G. W. Allin W. T. Clay

The design of a multiwire, position-sensitive proportional counter (PSPC) and its analog signal processing system was started for the National Small-Angle Neutron Scattering (SANS) Facility under construction at ORNL.[1] The counter is being constructed.

The PSPC design is based on RC-line encoding and time difference decoding[2] of the spatial coordinates of the interaction loci of individual neutrons. The active area of the PSPC will be $\sim 65 \times 65$ cm^2. A matrix of 128 × 128 spatial elements (pixels) will be resolved. The count rate capability for randomly incident neutrons will be $\sim 5 \times 10^4$ counts/sec, with a coincidence loss of <3%.

The PSPC container will be filled with ∿65% ^{3}He, 30% Xe, and 5% CO_2 to an absolute pressure of 3×10^5 Pa (3 atm) and will be used in a vacuum. The depth of the active volume will be ∿2.5 cm. This counter depth and gas fill will result in a detection efficiency of ∿80% for SANS facility neutrons which will have a de Broglie wave length of 0.474 nm (4.74 Å).

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1. A. L. Robinson, *Science* 199, 673 (February 10, 1978).
2. C. J. Borkowski and M. K. Kopp, *Rev. Sci. Instrum.* 46, 951 (1975).

2.6 DIGITAL TV-ECHELLE SPECTROGRAPH FOR SIMULTANEOUS MULTIELEMENTAL ANALYSIS

J. B. Davidson A. L. Case

An echelle cross-dispersion spectrograph covering 2000 - 8000 Å with ≅0.01 - 0.1 Å resolution in one exposure is being coupled to an image-intensifier, digital TV system based on the "fly's eye" neutron counter.[1] This system will make possible simultaneous analysis of ten or more elements in a single sample by atomic absorption or atomic emission. The wavelengths and intensities of selected elements will be digitized at TV rates and stored in a digital memory for rapid comparison with standard spectra. Because of 60-Hz rapid scanning of the wide spectral range, transient spectra can be studied to elucidate chemical intermediates. Since the SEC camera tube (secondary electron conducting) has a good integrating capability, single- or repetitive-flash spectra of extremely short duration can be recorded. This capability and the overall sensitivity of the system also may make possible operation at light fluxes in the intensity range normally covered by photon counting of a single spectral line with a photomultiplier tube.

The system is being tested with limited digital storage and various sources, including a six-element hollow-cathode lamp. A direct comparison with film and photomultiplier readout is being made.

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1. J. B. Davidson, *J. Appl. Crystallogr.* 7(3), 356 (1974).

2.7 POSITION-SENSITIVE, DRIFT PROPORTIONAL CHAMBERS FOR HIGH-ENERGY PARTICLE TRAJECTORY DETERMINATION

H. R. Brashear

A drift proportional chamber with a 1-ft-diam sensitive area was constructed for use at the Fermi National Accelerator Laboratory to determine the trajectories of high-energy particles exiting from a bubble chamber. The chamber consists of three counters oriented 120° with respect to each other. This orientation allows spatial determination, with a minimum of ambiguity, of 150 μm in the plane perpendicular to the beam path of simultaneous particle trajectories.

Each counter consists of a sense plane sandwiched between electric-field-shaping cathode planes. The spacing between the cathode and sense planes is 3/16 in. Each sense plane contains six 0.0008-in.-diam, stainless steel anode wires spaced 2 in. apart and seven 0.004-in.-diam, beryllium-copper field-shaping wires at a separation of 2 in. to establish a 1-in. drift distance to the anode wires. The operating voltage of the anode wires is +1200 V dc, and the voltage on the field-shaping wires is -2000 V dc. Each inch of the cathode planes contains twenty 0.004-in.-diam,

beryllium-copper wires operated with an equal voltage division from -2000 V dc to ground potential directly opposite the anode wire. The overall configuration of the chamber is a hexagon with equal length wires. All three counters are in a common gas volume. The flow-through gas is contained with 0.003-in.-thick Mylar windows.

Proportional Counter Development

2.8 X-RAY PSPC FOR TOKAMAK

W. T. Clay

An x-ray, position-sensitive proportional counter (PSPC) assembly (Q-5483) was designed and fabricated for the Fusion Energy Division to obtain information concerning plasma impurities by analysis of the x rays from the tokamak machine.

The assembly contains five separate 3-5/8-in.-long, one-dimensional parallel counters. Each counter has a spatial resolution of 0.17 mm for 5.9-keV x rays. A hybrid preamplifier (Q-5451) is attached to each end of each counter's resistive center wire. The five counters and ten preamplifiers were required to obtain high count rates over a large area. The vacuum-tight, beryllium entrance window to the counters is 3 × 4-3/4 in. and 0.002 in. thick.

2.9 X-RAY POSITION-SENSITIVE PROPORTIONAL COUNTER FOR A KRATKY SMALL-ANGLE SCATTERING CAMERA

R. E. Zedler M. K. Kopp
R. W. Hendricks[1] T. P. Russell[2]

An x-ray, position-sensitive proportional counter was designed and fabricated for the Metals and Ceramics Division to meet the specific criteria required for determining extremely weak scattering patterns generated by a Kratky small-angle, x-ray scattering camera. These criteria were as follows: uniform x-ray absorption depth for a 1- by 10-cm slit; good absorption efficiency for 17-keV x rays; spatial resolution less than 0.05 mm; and uniform spatial resolution, energy resolution, and pulse height along the slit area.

Uniform x-ray absorption was obtained by using a flat beryllium window and a flat surface machined opposite the window in the interior surface of the 1-1/4-in.-ID cylindrical aluminum cathode. An absorption efficiency of ~50% for 17-keV x rays was obtained with a gas filling of 95% Xe - 5% CH_4 at 760 torr. In addition to a 0.003-in.-diam, pyrolytic-carbon-coated quartz anode, low capacity guard-ring structures were made to help

achieve a spatial resolution of less than 0.5 mm. Specially shaped and truncated conical counter ends were used, and anode capillary tubes[3] were inserted to an experimentally determined length through the guard ring structures to minimize detector end effects and to optimize the field uniformity for the slit area.

The detector performed as required. The x-ray data were accumulated in less than one-tenth the time and with greater accuracy than if a conventional detector had been used.

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1. Metals and Ceramics Division.
2. University of Massachusetts.
3. R. E. Zedler, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1969*, ORNL-4459, p. 18.

2.10 ADVANCED AND VERSATILE DETECTOR-CHAMBER FOR RESONANCE IONIZATION SPECTROSCOPY INVESTIGATIONS

R. E. Zedler C. E. Fowler G. S. Hurst[1]

A resonance ionization spectroscopy (RIS), single-atom detector-chamber, functionally more versatile than the proportional counter type,[2,3] was designed, developed, fabricated, and tested for the Health and Safety Research Division. This detector greatly increases the diversity of RIS experiments that can be performed and improves the selectivity and sensitivity of single-atom detection.

The detector-chamber has two sections. The chamber section is a parallel-plate unit with a field plate between the anode and cathode plates. The anode and field plates have 1- by 3-cm slots at their centers; there is a wire grid in the anode slot. The plate spacings may be changed easily. The detector section is a proportional counter that is mounted on the anode plate and centered over the slot. The electron drift velocity and direction are controlled by altering the voltage and polarity of the chamber plates, and the counter detects an electron allowed to enter it by the controlled chamber field.

For fission fragment studies, a surface barrier detector having a double-collimated ^{252}Cf source assembly attached to it is mounted on a rotatable arm at the periphery of and between the cathode and field plates. The arm may be externally rotated. The fission fragment-laser beam intercept angle, thus, can be altered easily.

The components are mounted in a vacuum-tight container. The housing has two laser-beam, quartz windows 180° apart; these windows are located so that the beam passes parallel to and between the cathode and field plates. A beryllium window in the same plane as the laser beam windows is used for x-ray experiments. In addition, solid samples to be vaporized can be introduced into the chamber through a port.

The detector-chamber is operated in the gas flow mode at a controlled pressure usually well below 760 torr after it is first pumped to a hard vacuum. A catalytic gas purifier is also used.

In the first of a series of experiments with the new detector-chamber, single, thermal, and neutral atoms of cesium from ^{252}Cf were measured. Investigations other than those of single-atom detection are also possible with the detector-chamber.[4]

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1. Health and Safety Research Division.
2. G. S. Hurst et al., *Phys. Rev. A* 15, 2283 (1977).
3. G. S. Hurst et al., *Springer Ser. Opt. Sci.* 7, 44 (1977).
4. G. S. Hurst et al., "Resonant Ionization Studies of the Fluctuations of Proportional Counters," *Nucl. Instrum. Methods* (to be published, 1978).

Research Instruments

2.11 GAMMA TRANSFER STANDARD

F. M. Glass R. A. Maples

A highly specialized electrometer was designed for the Defense Civil Preparedness Agency to be used with an ionization chamber for calibrating the ^{137}Cs calibrators used in repair shops. The ionization currents measured in this use are approximately 5×10^{-12}, 5×10^{-11}, 5×10^{-10}, and 5×10^{-9} A. When the 5×10^{-12} A current is measured with the 4.5 digit meter, the resolution is 10^{-15} A, obtained over a very long integrating time and with an extremely low-noise bias supply for the ionization chamber. The bias supply is a dc-to-dc converter, regulated at 200 V. The noise at the output of this supply is so low that the peak-to-peak noise from the supply within the bandpass of the electrometer is less than 10 μV at the electrometer input. A sequence timer prevents overvoltaging the electrometer and a subsequent long-term drift by energizing the input shorting relay when the instrument power is turned on. This relay (normally used while making zero adjustments) remains energized from the time the ac power is applied until the bias voltage reaches 99.65% of its final output voltage.

A timer that indicates when the meter should be read is automatically set and preset when the range selector switch is turned to a different range. The timer is preset for a time that is compatible with the range being used.

Since approximately ten of these instruments will have to serve all fifty states, the package construction has to be rugged and the high-impedance circuitry sealed for use in hostile environments.

2.12 NEUTRON DIFFRACTION TOMOGRAPHY: A UNIQUE, 3D INSPECTION TECHNIQUE FOR CRYSTALS USING AN INTENSIFIER TV SYSTEM[1]

J. B. Davidson A. L. Case

This paper describes the application of phosphor-intensifier-TV techniques to neutron topography and tomography of crystals. The older, analogous x-ray topography using wavelengths ≈1.5 Å is widely used for surface inspection. However, the crystal must actually be cut in order to see diffraction anomalies beneath the surface. Because 1.5-Å thermal neutrons are highly penetrating, much larger and thicker specimens can be used. Also, since neutrons have magnetic moments, they are diffracted by magnetic structures within crystals. In neutron volume topography, the entire crystal or a large part of it is irradiated, and the images obtained are superimposed reflections from the total volume. In neutron tomography (or section topography), a collimated beam irradiates a slice (0.5-10 mm) of the crystal. The diffracted image is a tomogram from this part only. A series of tomograms covering the crystal can be taken as the specimen is translated in steps across the narrow beam. Grains, voids, twinning, and other defects from regions down to 1 mm in size can be observed and isolated. Although, at present, poorer in resolution than the original film methods, the TV techniques are much faster and, in some cases, permit real-time viewing. Two camera systems are described: a counting camera having a 150-mm, ^{6}Li-ZnS screen for low-intensity reflections which are integrated in a digital memory, and a 300-mm system using analog image storage. Topographs and tomograms of several crystals ranging in size from 4 mm to 80 mm are shown.

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1. Abstract of paper presented at the Symposium on Real-Time Radiologic Imaging: Medical and Industrial Applications, May 8-10, 1978, National Bureau of Standards, Gaithersburg, Maryland.

2.13 FISSION COUNTERS FOR DECAY HEAT EXPERIMENT

F. E. Gillespie

Small, parallel-plate fission counters were developed for external neutron beam normalization used in the decay heat experiment[1] performed at the Oak Ridge Research Reactor by the Neutron Physics Division. These counters were used to calibrate a Ge(Li) detector which measured gammas from samples of ^{235}U, ^{239}Pu, and ^{241}Pu irradiated inside the reactor. To measure the absolute number of fissions that had occurred, two counters with different thicknesses of fissionable material were placed back-to-back in an aluminum housing and operated together. During a 24-hr run, the counter positions were switched. The counters and electronics operated from 20,000 to 80,000 fissions per second.

A counter consisted of two 5-cm-diam, 0.0127-cm-thick aluminum end windows separated by a Corning Macor machinable, glass-ceramic disk, 3 mm thick. A copper filling tube was inserted into the ceramic. All parts were epoxy bonded. A counter contained either a ^{235}U, ^{239}Pu, or ^{241}Pu foil, each with an area of 2 cm^2. They were filled with pure methane at 1 atm (10^5 Pa) pressure; their charge collection time was 60–80 nsec at 300–500 V.

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1. J. K. Dickens et al., *Fission Product Energy Release for Times Following Thermal Neutron Fission of ^{235}U, Between 2 and 1400 Seconds*, ORNL/NUREG-14 (October 1977).

2.14 HEAVY-ION FOCAL PLANE DETECTOR

R. E. Zedler V. C. Miller
J.L.C. Ford[1] D. Shapira[1]

A modified version of the Rochester heavy-ion detector[2] was designed and fabricated for the Physics Division. It will be used to determine the reaction angle, energy, atomic number, charge state, and mass of ions as heavy as A = 40 by the simultaneous measurement of the total energy, energy loss, residual energy, and the angle of incidence at the focal plane of each ion detected.[2] It will be used with the High Voltage Accelerator Laboratory EN tandem accelerator, the Oak Ridge Isochronous Cyclotron, and a new 25-MeV tandem facility now being constructed.

The detector consists of a Frisch grid chamber with two separate anodes in the same plane, and a Faraday cage cathode plus three proportional counters (two of which are position sensitive) located approximately in the anode plane and at different distances from the counter window. The detection area and volume are larger than the Rochester unit, and all preamplifiers are mounted inside the housing as was done in the Argonne focal plane detector.[3]

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1. ORNL Physics Division.
2. D. Shapira et al., *Nucl. Instrum. Methods* 129, 123 (1975).
3. J. R. Erskine and T. H. Braid, *Nucl. Instrum. Methods* 135, 67 (1976).

2.15 ELECTRONIC TELEMETRY INSTRUMENTATION FOR TRACKING FISH AND WILDLIFE

J. M. Rochelle

The improved, temperature-sensitive fish transmitters[1] (Q-5099) are performing reliably and successfully with various fish species in studies conducted by the ORNL Environmental Sciences Division and by the National Marine Fisheries Service (Hawaii) in studies with yellowfin tuna. For example, measurements of tuna body temperature versus swim speed using these transmitters have enabled researchers to demonstrate and model a thermoregulation mechanism for this fish species.[2] The circuit of this transmitter was uniquely suitable for these tests because the calibration accuracy is not affected by a transmitter-thermistor temperature differential.

The new technique for packaging transmitters, utilizing a metal foil wrapper with epoxy seals, proved more reliable than the original design (an epoxy casting covered with medical-grade silicone rubber tubing[3]). Transmitters returned after more than a year in the field showed no evidence of internal corrosion or moisture leakage. Battery reliability also improved significantly after silver oxide watch cells, instead of mercury cells, were installed in the 15-mm-OD tag.

The encapsulation of thermistor probes in 1/8 × 0.020 in. polyethylene tubing was adopted. This tubing is somewhat stiff, but it is exceptionally durable for underwater applications. The resistance of a test thermistor encapsulated with this tubing changed <0.3% after constant immersion in 0.9% saline solution at 20°C for 30 months (checked at 0°C; the resistance is 4.47 MΩ at 0°C).

In addition to the 15-mm-OD tags with watch cells, several 18-mm-OD tags were constructed with the new 3-V lithium cells, which are about 35 mm long and have 1000 mA-hr capacity. These larger tags are designed for greater transmitting range and longer battery life, and some have been equipped with two transducers oriented orthogonally for a more uniform ultrasound radiation pattern. Fish to which these transmitters are attached generally weigh 5 kg or more.

In other work, the ORNL Environmental Sciences Division was provided with support for other fish and terrestrial wildlife tracking projects, using commercially produced radio-frequency transmitters and receiving tuners. An rf antenna mount and rotator that incorporates a surveyor's compass was designed and fabricated to facilitate triangulation of transmitter locations in deer and bobcat studies.

A pulse detector circuit was designed and supplied that converts the rf tuner headphone signal (an audio-frequency tone burst) to a digital pulse; this pulse triggers the counter that measures the time interval of temperature-sensitive transmitters. The sensitivity of the detector circuit is similar to that of the human ear in terms of the recognition of a tone burst against a noisy background. The circuit uses two

micropower operational amplifiers and demands <1 mA total from the tuner's 12-V-dc battery pack.

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1. J. M. Rochelle, *Instmentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 13.
2. A. E. Dizon and R. W. Brill, "Physiological Thermoregulation in Yellowfin Tuna, *Thunnus Arbacares*," (to be published).
3. J. M. Rochelle and C. C. Coutant, *Temperature Sensitive Ultrasonic Fish Tag, Q-5033*, ORNL/TM-4438 (December 1973).

2.16 CAPACITANCE-VOLTAGE PROFILE COMPUTER

G. K. Schulze

An instrument to compute capacitance versus depth of a carrier depletion region was developed for the Solid State Division as a part of their project to develop and improve the efficiency of solar cells. The analog circuit solves for depth, $X \cong 1/C$, and the log of carrier concentration, $\ln N = Ky + 3 \ln C - \ln (dC/dV)$, and produces outputs which can be connected to an x-y plotter. The instrument works in conjunction with a lock-in amplifier and capacitance bridge.

2.17 MODULAR HIGH-CURRENT POTENTIOSTAT FOR AQUEOUS SEPARATION AND FIXATION OF ^3H FROM WASTE EFFLUENTS

G. K. Schulze

A system of modular, high-current potentiostats was designed and built for the Isotopes Division to test whether ^3H can be separated from waste effluents by an experimental cell membrane. The system, in operation for more than a year, potentiometrically controls each half of each cell independently to maximize the separation efficiency.

The system consists of a modified NIM bin and three module types: a three-unit-wide module provides metering; a one-unit-wide module provides timing signals for a forward and reverse application of potential across the cell membrane to clear off hydrogen gas bubbles; and four, two-unit-wide, dual-amplifier modules provide the direct potentiometric control. Each amplifier module has a high-impedance, differential instrumentation amplifier input that prevents loading on the cell, and each amplifier is capable of driving ≤ 5 A at ≤ 7 V through a cell. Each half of the dual-amplifier module is provided with a separate differential input instrument amplifier which can be used as a buffer for metering purposes. An experimentalist can connect cells in tandem to optimize the separation process.

2.18 VOLTAGE REGULATOR FOR AN UNINTERRUPTABLE POWER SOURCE

G. K. Schulze

A voltage-regulator and overvoltage circuit was designed and constructed for a Westinghouse, 400-Hz motor-generator set used as an uninterruptable power source. This unit, purchased several years ago, had never been in service due to an inadequate design and failure of the original regulator, which was a "one-of-a-kind" design. The original circuit design was modified to be functional, a regulator of better design was built to replace the original, and provision was made to allow quick change-over of the voltage-regulator and overvoltage detector cards from the new to the original cards retained as a back-up measure. Regulation of the new system is 0.25% at a line voltage of 208 V ac, and is 0.5% for the modified original design. The unit has been in service for over one year, which had allowed an alternative motor-generator set to be taken out of service for maintenance.

2.19 HIGH-RESOLUTION POWER REGULATOR FOR A CRYSTAL ZONING FURNACE

G. K. Schulze

A power regulating circuit was designed and constructed to provide high resolution in adjustment and control of an electron-beam furnace used by the Solid State Division to zone refine crystals. This furnace is in regular use for growing monocrystalline structures which are used in other experiments. Previously, control had been accomplished manually, and the zoned crystal had a widely varying diameter due to an uneven melt temperature caused by operator eye fatigue. This regulator circuit enables the total power delivered to the load to be set and regulated to an accuracy of 1 W at a power level ≤ 2 kW. The maximum power available is 10 kW. The circuit was tested with a small-diameter crystalline rod of a material type that is sensitive to the melting temperature; the results were gratifying. The system has been in use for six months, with excellent performance.

Power regulation is accomplished by sampling the high voltage and the beam current, finding the analog product which is compared to an adjustable reference, and phase controlling the power by gating back-to-back SCRs in the primary of the high voltage supply.

2.20 INSTRUMENT FOR AUTOMATIC MEASUREMENT OF SOLAR CELL VOLT-AMPERE CHARACTERISTICS

G. K. Schulze

An instrument was designed and constructed for the Solid State Division to rapidly determine cell performance by automatically varying the load on the cell from open circuit through short circuit and recording the important parameters. The outstanding feature of the instrument is its capability of determining the maximum power output, open-circuit voltage, short-circuit current, and efficiency in a single 300-msec scan. This rapidity reduces the effects of temperature changes and minimizes operator error. The accuracy of the system meets the design requirements and its ease and speed of use have enhanced the developmental work on solar cell technology. This new instrument replaces a Polaroid-oscillograph system.

The instrument consists of five circuit boards in a 7-in. relay rack chassis, and is operated in combination with a Digitec model 267 autorange dc voltmeter and a model 691 digital printer. The current-metering range can be set from milliamperes to 2.0 A maximum. It functions by sampling the voltage and current signals, computing the analog product, and detecting the peak power output. The important parameters are stored in sample- and hold-circuits and are multiplexed to the attached voltmeter and printer to record the data.

2.21 PERFORMANCE EVALUATION FACILITY FOR POSITION-SENSITIVE PROPORTIONAL COUNTERS

T. R. Barclay M. K. Kopp

A postconstruction performance evaluation facility was set up for the various position-sensitive proportional counters (PSPCs) at ORNL. It can handle one- and two-dimensional, flow-through, single- and double-chamber, and high- and low-pressure counters for detecting a variety of radiations, including x rays, gamma rays, protons, neutrons, alpha rays, and heavy ions. The facility is equipped with instrumentation for conducting position-resolution, energy-resolution, sensitivity, signal-to-noise ratio, efficiency, rise-time, and gas-amplification dynamic parameter measurements.

Field support includes assisting the experimentalists or the technical support personnel at the experiment site with PSPC instrumentation set up, observing malfunctions, and recommending corrective action. Sites at ORNL utilizing PSPCs include one- and two-dimensional units at the Oak Ridge Research Reactor; a one-dimensional unit at the High-Flux Isotope Reactor; a five-anode, one-dimensional unit at the tokamak facility; a two-chamber, one-dimensional unit at the High-Voltage Accelerator Laboratory; a two-chamber, one-dimensional unit at the Oak Ridge

Isochronous Cyclotron; and both one- and two-dimensional units at the Small-Angle X-ray Scattering Laboratory.

2.22 MULTIPLICITY DIGITIZER

C. R. Mitchell J. W. Woody

In many nuclear reactions the number of gamma rays emitted in each reaction must be known to determine the processes involved or, as in this case, to simplify the spectrum obtained when the reaction is viewed by high-resolution gamma detectors [Ge(Li)]. In one mode of operation the number of gamma rays detected by up to fourteen NaI detectors is stored with the digitized energy signal from a Ge(Li) detector, along with information that tells which of up to four Ge(Li) detectors actually detected the gamma rays. An alternative mode of operation requires a coincidence involving two, three, or four of the Ge(Li) detectors before the data are stored.

To accomplish this, a multiplicity digitizer was designed and built for the Chemistry Division. The digitizer accepts trigger pulses from as many as four detector systems and generates a variable-width gate signal which enables the inputs of up to sixteen multiplicity detectors. This information is stored in registers of four bits and sixteen bits, respectively. After suitable manipulation, this information is presented to the system computer's data bus.

The instrument is packaged in a three-unit-wide NIM module and is installed and operating.

2.23 IMPROVED FLUXATRON INSTRUMENT TO MEASURE EVAPOTRANSPIRATION

T. R. Barclay R. J. Luxmore[1]

An improved version of the fluxatron instrument similar to an Australian model[2] was developed for the Environmental Sciences Division. Two of these instruments are being built and field tested. These fluxatron instruments will provide field data to be correlated with simulated models of field water balances.

The fluxatron instrument measures vertical and horizontal wind speeds, temperature, and humidity, and calculates the fluxes of momentum, heat, and water vapor. The instrument directly measures evapotranspiration

from vegetation and electronically integrates over time periods to give short-term (minutes) and long-term (months) results.

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1. Environmental Sciences Division.
2. M. R. Raupach, *Atmospheric Flux Measurement by Eddy Correlation*, Flinders Institute for Atmospheric and Marine Sciences, Flinders University of South Australia, Bedford Park, S. A. 5042, Research Report No. 27 (July 1977).

2.24 PROGRAMMABLE CONTROL OF AN AUTOMATIC SMOKING MACHINE

R. W. Holmberg[1] M. T. Kelley[2] T. M. Gayle

Machines to automatically and continuously load, light, smoke, and eject cigarettes and to provide a continuous source of tobacco smoke for animal exposures have been evaluated and used by the Analytical Chemistry Division in their inhalation bioassay programs. The addition of a programmable controller for machine operation has considerably enhanced the performance of the smoking machine.

An SEM II, commercial smoking machine, was interfaced to a Texas Instruments, 5TI programmable controller to determine whether a programmable controller, rather than the machine's internal electromechanical timers, would contribute considerably to the reliability and versatility of control. This was successful because puff averaging, as well as many new exposure techniques, is possible due to the versatility of the controller.

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1. Analytical Chemistry Division.
2. Consultant, Analytical Chemistry Division.

2.25 GAMMA-RAY SPECTROMETER SYSTEM FOR ALTERNATE FUEL CYCLE TECHNOLOGY

W. T. Clay T. F. Sliski

A gamma-ray spectrometer system (Q-5627) was designed and fabricated for use by the Chemical Technology Division to study the solubility of ^{85}Kr gas in a 1-in.-diam column of liquid refrigerant.

There are three basic components of this system: a detector, a lead shield for the detector, and a motorized slide unit that positions the detector and its shield in relation to the column of liquid refrigerant. The slide unit is supported by a frame so that the collimator in

the shield allows the detector to "look" at a vertical increment of the column, and the motorized unit can position the detector and shield to scan the column vertically a distance of 10 in.

2.26 MULTICHANNEL, MULTICOMPONENT SMOKE ANALYSIS SYSTEMS

T. M. Gayle R. W. Holmberg[1]

Multicomponent smoke analysis systems were developed, and are now in use both at ORNL and other installations. These systems provide documentation of animal exposure levels and safety instrumentation, as well as a limited characterization of the gas phase of the smoke.

The systems contain an ORNL developed, optical particulate sensor[2] as the primary concentration monitor, both for animal safety and for documentation of total exposure. A four-channel unit developed at ORNL is being used for studies of large-scale exposures at Microbiological Associates, Bethesda, Maryland. Additional features of this system include continuous measurement and integration of carbon monoxide and carbon dioxide levels, using infrared absorption. Other systems developed include these determinations as well as continuous measurement of oxides of nitrogen. Breathing-air measurement of animals has also been provided, and a heated laminar flowmeter for whole smoke is being evaluated for inclusion in future systems.

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1. Analytical Chemistry Division.
2. T. M. Gayle and C. E. Higgins, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5191, p. 17.

2.27 FILM TRANSPORT MECHANISM

G. W. Allin H. J. Stripling, Jr.

A film transport prototype was designed for use with a high-speed spiral reader used in processing film from bubble chamber studies in high-energy physics.

Three independent views of the bubble chamber, recorded simultaneously on a common piece of 70 mm film, are to be viewed side by side by the spiral reader operator in rapid succession, and the data from the visual form will be converted and recorded on magnetic tape for computer analysis.

The transport is being tested, and will be incorporated with the existing spiral reader, film handling system.

2.28 DIGITAL SCALE CONVERTER

R. G. Upton

A digital scale converter was developed for the Metals and Ceramics Division for experiments at the Oak Ridge Research Reactor. The converter, when connected to the binary coded decimal (BCD) output of any digital instrument, converts the original reading to a different scale and displays it. For example, when connected to a temperature indicator which displays degrees Farenheit, the converter displays the same reading in degrees Celsius. The value to be converted is set into a first BCD counter and counted down to zero while a second counter counts up from zero or an offset value at a different rate. The value present in the second counter at the time the first counter reaches zero is the equivalent value of the second scale.

Rate multipliers are used to generate pulses at selected rates for the proper conversion ratios. With the technique of using binary rate multipliers, changes in clock frequency have no effect on the operation, and no adjustments are necessary. In addition to converting temperature scales, the device is capable of converting any BCD variable. The possibilities include gallons to liters, inches to centimeters, and degrees to radians.

Biomedical Instruments

2.29 FABRICATION OF TWO, FOURTH-GENERATION MODELS OF PORTABLE FAST-ANALYZER SYSTEMS

M. L. Bauer

In conjunction with the Chemical Technology Division, portable fast-analyzers, fourth-generation analytical instruments based on the GeMSAEC centrifugal analyzer principle, were constructed and delivered to in-house and outside research agencies. The first production nit was delivered to the Environmental Sciences Division in the fall of 1977. Later units were delivered to the National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina; National Aeronautics and Space Administration, Houston, Texas; and the University of Michigan, Ann Arbor, Michigan. A final unit will be built for use in the Chemical Technology Division biotechnology programs.

Two different models were built. The first is a stand-alone unit, using an internal microcomputer which is based on an Intel 8080 chip. This unit has 11,000 bytes of program memory and 8000 bytes of data memory; it occupies only 2 ft^3 of volume and consumes 200 W of power. All the data acquisition and analysis is done by the microcomputer. In the second model, an LSI-11 based minicomputer, with dual diskette

drives and graphic scope, enhances the capabilities of the microcomputer-based system. The minicomputer system adds long-term data storage capabilities, as well as the graphic capabilities, to the system.

2.30 DEVELOPMENT OF AN AUTOMATED GEL ELECTROPHORESIS SYSTEM

M. L. Bauer

Development of a system for automation of gel electrophoresis chromatography was started in conjunction with the Chemical Technology Division. Gel electrophoresis is of special interest for separation of proteins and enzymes of clinical significance. For certain research, especially in a search for genetic effects, it would be useful to be able to run a large number of electrophoretic chromatograms.

The system under design attempts to make use of parallelism in order to increase the throughput of the total system. The steps to be automated include the casting of the acrylamid gel into a suitable carrier, the electrophoresis of a number of these carriers at the same time, the staining of this group of carriers, and, finally, the optical scanning of the gels, together with computer reduction of the data, possibly on-line (although some thought has been given to batch processing in off hours). The system will have twelve gels per carrier, six carriers per stack, and a daily throughput of four to six stacks. A prototype is being constructed and tested.

2.31 DEVELOPMENT OF A COMPUTER-BASED SYSTEM FOR ANALYZING SPECTROPHOTOMETRIC DATA FROM A PORTABLE FAST ANALYZER

J. M. Jansen, Jr. A. W. Peterson[1]

Two computer-based systems for the analysis of spectrophotometric data from a portable fast analyzer were developed under contract and delivered to the National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina, and the University of Michigan, Ann Arbor, Michigan. The systems, although identical in hardware and systems software design, utilize different applications software to study environmental pollutants and genetic mutation at the respective research centers.

A Digital Equipment Corp. (DEC) LSI-11 was specified to provide commonality with existing software developed for the miniature fast analyzer. The RT-11 operating system supports an ORNL-modified version of DEC's FOCAL to provide the interface with, and an analysis capability for, the portable fast analyzer. A dual, optical isolation interface

was developed to achieve noise immunity and ground isolation between the systems. A hardware and software "hand-shaking" protocol was employed to ensure acknowledgement and error checking of all transfers between the two systems. The systems were equipped with a bistable storage tube terminal for the presentation of graphics for operator presentation of analytical results.

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1. University of Tennessee, Knoxville.

2.32 DEVELOPMENT OF MINIATURE FAST-ANALYZER DATA SYSTEM

J. M. Jansen, Jr. J. L. Redford, Jr.

Two computer-based systems were developed to acquire and analyze data from the miniature fast analyzer.[1] This analyzer and computer system, which will provide a higher throughput and resolution than present methodologies, gives the biochemist a tool for development of clinical methods for analysis of body fluids.

The first system delivered to the Chemical Technology Division was expanded late this year to make it identical to the second system developed for the National Center for Toxicological Research at Pine Bluff, Arkansas.

FOCAL, the system language, was modified to include capabilities for acquisition of real-time data, outputting of results to a storage CRT, and storage and retrieval of analytical programs and data on a direct access cassette. The software package was developed to automatically determine the availability of additional memory and a storage CRT, and to adapt the software to provide access to the equipment if installed on the system.

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1. J. M. Jansen, Jr., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1972*, ORNL-4822, p. 31.

3. RADIATION MONITORING

3.1 LOW-RANGE BETA-GAMMA SURVEY METER

F. M. Glass H. R. Brashear R. A. Maples

A low-range beta-gamma survey meter that operates 400 hr on two Leclanche type, standard D cells was designed for the U.S. Navy. The new instrument has ten times the gamma range of the instrument in use, and its battery power requirement is 66% less. Two Geiger-Mueller (G-M) counter tubes having gamma sensitivities that differ by a factor of ~13 cover the full-scale ranges 0.1, 1.0, 10, 100, and 1000 mR/hr. The more sensitive of the two counter tubes has an end-window for beta counting. The less sensitive tube is used on all five ranges and is parallel with the end-window tube on the 1- and the 1.0-mR/hr ranges. Compensation for counting losses due to detector deadtime provides adequate linearity for a linear scale meter. Therefore, the scale numbers can be changed automatically by a mechanical linkage between the range switch and the meter, while retaining the same linear scale divisions on all ranges. Two separate, high efficiency, dc-to-dc converters provide regulated voltages at 6.3 and 715 V for the rate meter and counter tube bias, respectively.

3.2 ALPHA OR BETA-GAMMA RADIATION MONITOR

F. M. Glass R. A. Maples

A new radiation monitor (Q-5431) was designed to replace the Q-2277-A alpha or beta-gamma radiation monitor. The Q-2277-A monitors are used throughout ORNL and in some of the TVA nuclear power plants. Because of the availability of a large selection of low-cost integrated circuits, the cost of building the new monitor is much less than that of the old monitor, which was constructed entirely from discreet components. Like the earlier model, the Q-5431 monitor works equally well with Geiger-Mueller (G-M) counters or alpha scintillation probes. In addition to the features of the Q-2277-A monitor, the new unit has a detector bias supply that is variable over a range from 20 to 1200 V,

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a single calibration control that calibrates all ranges simultaneously, a more reliable test signal, and more reliable alarm circuits. The counting rate-meter ranges are 5×10^2, 1×10^3, 2.5×10^3, 5×10^3, 1×10^4, 2.5×10^4, 5×10^4, 1×10^5, and 2.5×10^5 counts/min.

3.3 G-M SURVEY METER

F. M. Glass A. A. Smith

A new Geiger-Mueller survey meter (Q-5218) was designed to replace a 14-year-old model in current use. Like the old model, this new instrument has full-scale ranges of 5×10^2, 5×10^3, 5×10^4, and 5×10^5 counts/min and is powered by a rechargeable nickel-cadmium battery. The power requirement is 7-9 V at 3.2 mA, or ~16% of the power required by the old instrument. The operating time between charges (150 hr) was increased a factor of three. The battery weight was reduced from 369 to 178 g.

The new instrument partially compensates for the 50% counting loss on the 5×10^5 range (a result of detector dead time); the maximum error on the linear scale is ~5.5% plus that due to nonlinearity of the 50 μA meter. (Most instruments require multiple nonlinear scales to approach this accuracy when detector counting losses are this high.)

The new instrument also has a keyed, 2500-Hz chirper that eliminates a need for a headset in all but extremely high noise level locations.

3.4 INSTRUMENTS FOR RADIATION SIMULATION EXERCISES

R. A. Todd R. A. Maples H. N. Wilson

Two instruments were developed for Defense Civil Preparedness Agency (DCPA) exercises. The first is a radiation simulator, a portable, battery-operated instrument. Its meter readings (simulated radiation dose rates) are generated by a circuit inside the instrument that steps through prerecorded data values stored in a programmable read only memory (PROM). The simulator generates meter readings over four ranges and has a circuit check switch and a zero adjustment control. In an exercise, several radiation simulators would be used at different monitoring locations within an area such as a county, several adjacent counties, or possibly a state. Radiological surveyors would be instructed to turn their instruments on at some prescribed time, causing the instrument to automatically step through the prerecorded readings to simulate exposure rates that might be caused by nuclear detonations in the vicinity.

The second instrument, a radiation simulator PROM programmer, is an ac-powered microprocessor-based instrument that is used in advance of an exercise to encode the PROMs with a sequence of data readings. Readings can be transferred into temporary storage in three different modes: (1) in manual, data values are entered one location at a time; (2) in auto, an entire curve is generated, for which the peak value and age are determined by front-panel settings; and (3) in copy, data stored in a previously recorded PROM placed in the front-panel socket are transferred to temporary memory. PROMs are programmed with the information stored in temporary memory when the instrument is actuated in the burn mode. The PROM is then plugged inside the radiation simulator, ready to generate the proper sequence of readings.

3.5 TRITIUM MONITORING EQUIPMENT

H. R. Brashear F. M. Glass R. A. Maples
R. L. Shipp W. L. Bryan G. W. Allin

A small liquid scintillation counter for measurement of tritium in water or urine and a tritium-in-air monitor which may be used in either fixed or portable service are being developed for the U.S. Navy.

The liquid scintillation counter requires a major redesign. Initial studies indicated that a single photomultiplier tube (PMT) system would be satisfactory and that a two-PMT coincident system would not be necessary. A single-PMT system was attractive from size, weight, and logistic considerations. However, as development of the single-PMT system approached the prototype stage, strong phosphorescence or chemoluminescence was encountered with some urine samples. Since such light is emitted as single photons which interfere strongly with single-PMT counting systems, but which have minimal interference with two-PMT coincident counting systems, the scintillation counting system is being redesigned as a two-PMT coincident system.

The tritium-in-air monitor, which is at the prototype stage of development, consists of a gamma-compensated, flow-through ionization chamber, an air pump, and associated electronics. The ionization chamber assembly is composed of four concentric, hemispherical shell electrodes which divide the volume into three ion-collection volumes. The filtered air sample from the pump flows first through a deionizer volume between the grounded outer shell and the outer bias electrode, then through a 2-liter flow-through ionization chamber volume between the outer bias and signal electrodes. The 2-liter gamma compensation chamber is between the signal electrode and the inner positive bias electrode. This concentric configuration of the gamma compensation chamber surrounded by the flow-through chamber produces gamma compensation which is nearly independent of the gamma field orientation.

The algebriac sum of the currents from the tritium chamber and the gamma compensating chamber is measured by a low-noise, low-drift electrometer located within the center electrode of the chamber. The electrometer output is read out on a 3.5 digit LCD display. The electrometer output signal is also processed to provide an external recorder signal, an external alarm signal, and a flashing light with an aural alarm signal at the instrument panel. The electrometer and all the signal processing circuitry can be checked by a single internal test signal. The +75 and -75 V chamber bias potentials are supplied by a regulated, low-noise dc-to-dc converter. The electrometer input is protected when the power is turned on by an automatic zero relay closure during the time the bias voltages are building up. The instrument will operate through a 7-hr power failure on power from internal nickel-cadmium batteries that normally are floating on trickle charge. This instrument also features self-diagnosis for some of the more common circuit malfunctions.

3.6 SOLID-STATE MULTIDECADE ANALOG DISPLAYS FOR AUTOMATIC RANGE CHANGING RADIATION SURVEY INSTRUMENTS

H. R. Brashear
T. V. Blalock[1] E. J. Kennedy[1]
R. G. Phillips[1] E. W. Walker, Jr.[1]

Two solid-state, analog displays were developed and incorporated in laboratory-model, nuclear radiation survey instruments. The goal of the development was to replace the conventional moving-vane analog meter with a display that is analog, linear, direct reading, and multidecade with automatic range switching. Both displays are four decades of bar graph, with ten positions per decade.

The first display is a liquid crystal (LCD) in which all segments up to the measured radiation field strength are energized. This is a very readable display.

The second display has ten light-emitting diodes (LED) per decade, and only the diode that corresponds to the measured radiation field strength is energized to serve as a pointer. The diode is energized for 0.1 sec, three times a second, to conserve power and to increase the readability. This display is as readable as the LCD in normal room lighting, is less readable in direct sunlight, and is more readable in the dark. Either display is more rugged than the analog meter, and should be cheaper to produce in quantity than the ruggedized, range-changing analog meter used on Navy radiac instruments.

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

3.7 MICROPROCESSOR DEVELOPMENT FOR U.S. NAVY RADIAC PROGRAM

W. L. Bryan A. A. Smith

A microprocessor development program was started for support of radiation instrument control and diagnostics within the U.S. Navy radiac development program. A hardware and software development system for an RCA CDP1802 microprocessor was procured. Development of a general purpose, low power, rugged, 1802-based microcomputer was started. After an initial phase of design and development, further work was deferred.

3.8 SAFETY SYSTEM CONTROL ELECTRONICS FOR RADIATION MONITORING

W. L. Bryan C. C. Hall H. N. Wilson

A personnel radiation monitoring control system was developed for the Physics Division for installation in the Holifield Heavy Ion Research Facility. This system will make controlled measurements of the gamma- and neutron-radiation rates and the integrated dose from twelve locations in the facility. The design, fabrication, and bench check were completed, and field installation was started.

The radiation safety requirements for the system require redundancy for greater safety. Two identical channels which measure the radiation rates and dose in occupied radiation zones will have equal control in shutting down the tandem operation in the facility. The system is an updated, dual version of a radiation monitoring system used at the ORNL High Voltage Accelerator Laboratory.

3.9 NEUTRON DETECTOR ASSEMBLY FOR COUNTING DELAYED NEUTRONS FROM ACTIVATED FISSILE MATERIAL

M. M. Chiles

A neutron detector assembly was designed, fabricated, and tested to count delayed neutrons emitted from a fissile uranium sample after it has been irradiated by thermal neutrons for a few seconds. This unit is being used to evaluate this technique for nondestructively assaying high-temperature gas-cooled reactor (HTGR) fuel. The assembly consists of an array of eight, 1-in.-diam proportional chambers filled with ^{3}He gas. The detectors are equally spaced in the polyethylene moderator surrounding a sample cavity in the center. Pulse amplitudes of all detectors are matched so that they can be operated in parallel at the same high voltage and connected to one pulse amplifier system. The pulse-height resolution of the assembly for the thermal neutron energy peak is 5.5% with no gamma radiation present.

3.10 GAS PROPORTIONAL CHAMBERS FOR DETECTING FAST NEUTRONS IN THE PRESENCE OF GAMMA RADIATION

M. M. Chiles J. E. Rushton[1]

The ^{233}U – ^{232}Th refabricated fuel for the high-temperature, gas-cooled reactor (HTGR) will contain small quantities of ^{232}U, from which the daughter products will contribute a high gamma background. An investigation was made to determine which neutron radiation detectors would operate best in fuel assay equipment when exposed to this gamma field. Also, electronic operating parameters, such as RC time constants in the main amplifier, and gas amplification in the proportional chamber were studied.

A test facility was installed inside a containment cell at the Thorium–Uranium Recycle Facility (TURF) to utilize ^{252}Cf as a neutron source and to vary the gamma intensity from a ^{60}Co source. The proportional chambers were 38.1 mm (1.5 in.) in diameter and had a sensitive length of 152.4 mm (6 in.). One was filled with ^{4}He to a pressure of 1520 cm Hg, and another was filled with methane to a pressure of 380 cm Hg. Both chambers had approximately the same fast-neutron efficiency when no gamma radiation was present.

A single-channel analyzer was used to accumulate data to plot integral bias curves when the detectors were exposed to three different radiations: (1) neutrons only, (2) neutrons plus gamma field, and (3) gamma radiation only. Each detector was tested with different RC time constants on the linear amplifier, at different anode voltages, and at several gamma intensities. From this information, the parameters which produced the highest neutron efficiency with best gamma discrimination can be selected.

A commercially available charge-sensitive preamplifier and an ORNL-designed current-pulse preamplifier[2] were evaluated. The current-pulse preamplifier performed best when operated with the methane chamber and amplifier time constants of 100 nsec. However, the charge-sensitive preamplifier performed almost as well when operated with the ^{4}He chamber and amplifier time constants of 0.25 usec.

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1. Metals and Ceramics Division.
2. J. T. De Lorenzo, M. M. Chiles, and V. C. Miller, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 6.

3.11 PARALLEL-PLATE IONIZATION CHAMBER FOR GAMMA DENSITOMETRY

R. L. Shipp

A parallel-plate ionization chamber was developed for Engineering Technology Division use in two-phase-flow gamma densitometry. This chamber was developed for small-diameter, gamma beam applications where the loss of gamma signal in the central electrode of coaxial ionization chambers is too high. These chambers and their associated electrometers, are interchangeable with the coaxial chambers used at the thermal hydraulic test facility, and will replace the scintillation detectors of the three-beam gamma densitometer.

This ionization chamber (Q-5638) including an electrometer amplifier I-10520-QC-398 is 2 in. OD and 12 in. long. The sensitive volume of the chamber is 5-1/8 in. long and is filled with xenon at a pressure of 20 atm. The chamber current is greater than 10^{-8} A for 10^{8} gamma counts/sec of ^{137}Cs in a 1-in.-diam beam incident to the end of the chamber.

3.12 HIGH-RESOLUTION GAMMA SPECTROMETER FOR ANALYSIS OF ACTINIDE ELEMENTS

M. M. Chiles R. T. Roseberry

A high-resolution gamma spectrometer was specified, procured, and tested for compliance with ORNL specifications. The spectrometer consists of a cryogenically cooled, high-purity (intrinsic) germanium detector and a computer-based, multichannel pulse height analyzer. The detector is a planar type, 10 mm diam by 10 mm deep. With a low-noise preamplifier, the pulse height resolution (fwhm is 500 eV at 122 keV energy) of the detector for gamma radiation is very good. A pulse pileup rejector/live-time corrector instrument was used because of the anticipated high count rate in its intended application. The detector was placed in position to observe the radiation being emitted from the actinide elements flowing through the process line in a cell at the Transuranium Processing Plant.

3.13 ENGINEERING ACTIVITIES CONCERNING RADIATION MONITORING

C. C. Hall

Facility Radiation and Contamination (FR&C) Alarm Systems

An evacuation alarm system was installed in building 3026. The system consists of three beta-gamma constant air monitors (CAMs), two evacuation horns, four manual evacuation switches, and two rotating

magenta beacons. The evacuation alarm is operated (a) when either of two CAMs in the radioisotope development laboratory-B (3026-C) is in a high-level alarm condition and one CAM in the dismantling and examination hot cells (3026-D) is in a high-level or an inoperative alarm condition, or (b) when one of the four manual evacuation switches is operated.

The FR&C alarm system in the radioisotope laboratory (building 3038) was modified to allow the facility operator to operate rotating magenta beacons and to stop the facility air conditioning fans manually from the central alarm panel.

The FR&C alarm system in the Thorium-Uranium Recycle Facility (building 7930) was modified to prevent inoperative alarms from CAMs on the second and third floors from operating the evacuation system.

Radiation Safety Systems

The design of a Radiation Safety System for the Holifield Heavy Ion Research Facility was completed. Fifty-four drawings and specifications were required for this system.

Conceptual Design Engineering and Cost Estimating

Conceptual designs and cost estimates were completed for radiation monitoring instruments and systems for the intermediate-level waste facility annex, the hot engineering test and refabrication facility, the solid waste handling and decontamination facility, the environmental monitoring upgrading project, and the special nuclear materials vault. The estimated cost for radiation monitoring instruments and systems for these projects is approximately $1,777,000.

3.14 ALPHA COUNTING FACILITY

R. T. Roseberry W. T. Clay L. D. Eyman[1]

Instrumentation was purchased for the Environmental Sciences Division for an alpha counting room. Four Si(Li) detectors were placed in vacuum chambers which are mounted on a manifold that utilizes a single vacuum pump. Data from each detector are fed to a gated analog router and then to a single analog-to-digital converter which is connected to a computer-based analyzer. Counting four samples simultaneously appears as one task to the analyzer, allowing its use for other experiments concurrently.

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1. Environmental Sciences Division.

3.15 GAMMA SPECTROSCOPY SYSTEM FOR THE WHOLE-BODY COUNTER

R. T. Roseberry R. Goans[1]

A computer-based multichannel analyzer was specified, purchased, and tested for use at the Whole-Body Counting Facility. The computer system, which replaces the older analyzers at the facility, establishes a new data base for the spectral data storage.

The spectroscopy system, which has multitask capability, is being used for other related measurements, as well as for all scheduled counting.

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1. Industrial Safety and Applied Health Physics Division.

3.16 RADIATION SAFETY FOR X-RAY GENERATING EQUIPMENT

C. C. Hall K. C. Knight T. F. Sliski

Safeguards for the protection of operators and other personnel at x-ray facilities were designed and installed in the Solid State Division laboratories building 3025, the Environmental Sciences Division annex-B (building 3504), and the central research and administration building 4500N and 4500S.

An actuator circuit for a fail-safe warning light was designed. The warning light will not be disabled unless two or more components fail simultaneously. Sixty-one of these units were fabricated and are being installed at x-ray facilities at ORNL.

4. PROCESS SYSTEMS AND INSTRUMENTATION DEVELOPMENT

4.1 DEVELOPMENT OF HIGH FLUID LEVEL DETECTOR AND CONTROLLER FOR MEMBRANE CELL

W. R. Miller

A four-stage level detector and controller was designed and built to maintain a constant level in a new tritium separations process. The instrument utilizes the voltages present in each of the four sections of the three-membrane cell to detect when a high-level condition exists. Normal level is restored by circuits which appropriately actuate four level-control solenoid valves in the fluid stream between sections of the cell.

4.2 DEVELOPMENT OF FLOW RATIO INSTRUMENT

W. H. Andrews

An instrument for monitoring two flow rates and calculating and recording the ratio of these flows was developed for use in the hydrofracture facility. A turbine meter measures the flow of the radioactive liquid waste that is mixed with a concrete slurry and pumped into the injection site. The output of a pump-stroke counter is used to calculate the slurry mixture flow rate. Analog flow-ratio computation is accomplished using an original frequency ratio circuit. Pulses from the turbine meter are shaped and integrated. The pump-stroke counter pulses, of a frequency that is more than an order of magnitude lower than that of the turbine meter pulses, are used to reset the integrator. The time-averaged output of the integrator is then proportional to the ratio of the liquid waste flow rate to the pump-injected slurry flow. The ratio is continuously displayed on a front panel meter and simultaneously recorded by a strip-chart recorder included in the instrument package.

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4.3 STUDY OF DIFFERENTIAL ENTHALPY CONTROLLERS

W. H. Andrews

It is often more advantageous to use outside air in cooling a building than to recirculate the system return air, for example, when the total energy content (enthalpy) of the outside air is lower than that being returned to the heat pump from the living space. In this case, less energy would be consumed in cooling outside air to an enthalpy suitable for displacement of the warmer air inside. The outdoor enthalpy may be even less than the desired indoor air enthalpy, in which case the heat pump may be shut off entirely and outdoor air circulated through the building as needed.

It is desired to implement automatic control of this type in the Annual Cycle Energy System (ACES) experimental house. This would require a device which would make enthalpy measurements and, based on these measurements, would provide inputs to the programmable logic controller that will soon be operating the heating/cooling system for the ACES house.

A feasibility study was performed to determine if an economical controller can be developed that would be suitable for use at the ACES house, as well as in the homes of private citizens and in industrial and office buildings. With funding, this appears to be a realistic objective.

4.4 DEVELOPMENT OF A GAS FLOWMETER CALIBRATION SYSTEM

W. H. Andrews

A precision timer-controller was designed to allow, in conjunction with a lab-standard, piston displacement type volume meter, accurate determination of the gas flow rate in the metrology research and development laboratory. Infrared source-detector sensors were mounted at precise intervals on the volume meter to sense the altitude of the piston in the calibrated glass column. When flow is initiated, the lower sensor detects the rising piston and starts the crystal controlled timer. As the piston reaches the level of the upper sensor, the timing is stopped, and solenoid valves are operated to terminate gas flow and vent the collected gas to the atmosphere. Flow rates ranging from 0.001 to 1 liter/sec can be measured with better than 0.2% accuracy. Flow rates to 10 liters/sec can be measured with an accuracy of greater than 1%. A wide variety of flowmeters can be connected in series with the volume meter for calibration.

5. THERMOMETRY

5.1 POSITIONER FOR X-RAY EXAMINATION OF THERMOCOUPLES

G. W. Allin

A device was designed for positioning batches of sheathed thermocouples for x-ray examination. All sheathed thermocouples fabricated in accordance with reactor quality specifications are x rayed, individually rotated 90° about the longitudinal centerline of the sheath, and x rayed a second time. A device was needed to do this operation more rapidly and to ensure the proper rotation of each thermocouple.

This positioner will accommodate slight dimensional variations within a batch of thermocouples and will adjust to batches of different size thermocouples, 1/8 in. OD and smaller. A movement of one lever rotates a complete batch of ten thermocouples 90°.

One positioner was fabricated; it performed satisfactorily during preliminary bench testing. It is being field tested under actual operation conditions. Drawings of this device will be made available to thermocouple vendors to reduce the cost and to improve the quality of reactor-grade thermocouples.

5.2 ION MICROPROBE MASS ANALYSIS OF DECALIBRATED THERMOCOUPLES

R. L. Anderson

In a cooperative arrangement with personnel in the Analytical Chemistry Division at ORNL and the Y-12 Development Division, several types of thermocouples have been studied by ion microprobe mass analysis (IMMA) to determine the causes of decalibration. A type S thermocouple sheathed in tantalum dissolved 27 at.% Al after ∿2 hr at 1300°C by reduction of the aluminum oxide insulation. This thermocouple indicated a temperature in error by -152°C at 1300°C. A type S thermocouple sheathed in Inconel 600 with magnesium oxide insulation had ∿12 at.% Mg after high temperature exposure. This thermocouple indicated temperatures

in error by -47% at 400°C and -38% at 700°C. Evidence of contamination from sheath materials, notably Mn (also Ni, Cr, and Fe), was also found. These results were published in articles in the *Journal of the Less-Common Metals*.[1,2] Samples from small-diameter type S and type B thermocouples sheathed in four different materials were analyzed by IMMA after high-temperature exposure. A paper describing these results is in preparation.

In addition, type K thermocouples sheathed in type 304 stainless steel and in Inconel 600 were analyzed, and these results are also in preparation for publication.

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1. T. G. Kollie, W. H. Christie, and R. L. Anderson, *J. Less-Common Metals* 57, P9 (1978).
2. W. H. Christie, T. G. Kollie, R. E. Eby, and R. L. Anderson, *J. Less-Common Metals* 59, P17 (1978).

5.3 ION MICROPROBE INVESTIGATION OF LARGE DECALIBRATIONS IN INCONEL-SHEATHED MAGNESIA-INSULATED PLATINUM-RHODIUM/PLATINUM THERMOCOUPLE ASSEMBLIES DURING USE AT 1200°C[1]

W. H. Christie[2] T. G. Kollie[3]
R. E. Eby[2] R. L. Anderson

After 24-72 hr at 1200°C, Inconel-600-sheathed MgO-insulated, $Pt_{90}Rh_{10}$/Pt compacted thermocouple assemblies exhibited decalibrations of 5-47%. Metallographic and ion microprobe mass analysis showed that reactions had occurred within the thermocouple assemblies at the Pt-MgO and $Pt_{90}Rh_{10}$-MgO interfaces, resulting in solution of up to 12 at.% Mg in the thermocouple wires. Magnesium concentrations were less in the Pt-Rh wires than in the Pt wires. Aluminum, Ca, and Si in concentrations about 10-1000 times lower than Mg were also found in the wires. The origin of these impurities was the Al_2O_3, CaO, and SiO impurities in the MgO powder insulation. Manganese found in the wires was shown to come from the Inconel sheath. It was concluded that Pt/Rh thermocouples insulated with compacted MgO powder and sheathed in Inconel-600 are inherently unstable at temperatures of 1200°C because oxidation of the Inconel sheath produces a very low O_2 partial pressure inside the sheath that allows Pt and Pt/Rh to reduce MgO at the metal-oxide interface.

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1. Abstract of published article: *J. Less-Common Metals* 59, P17 (1978).
2. Analytical Chemistry Division.
3. Y-12 Development Division.

5.4 AUTOMATION OF THERMOCOUPLE CALIBRATIONS

R. L. Anderson D. W. McDonald

The calibration of thermocouples is performed more frequently than any other type of calibration in the metrology research and development laboratory (MRDL). Since digital voltmeters of sufficient sensitivity and accuracy are now available, thermocouple calibration was the most fruitful area in the MRDL for the application of automatic data acquisition. Two systems were placed in use: a Leeds and Northrup (L&N) model 2760 precision digital voltmeter (DVM) and associated low thermal scanner, and a Hewlett-Packard (H-P) 3455A DVM and scanner. The L&N unit is a 5-1/2 digit DVM with a sensitivity of 0.1 μV. The H-P unit is a 6-1/2 digit DVM with a sensitivity of 1 μV. By switching the input to the DVMs, emf readings are taken with both normal and reversed polarity. The average emf's are accurate to ±0.2 and 2 μV, respectively.

The L&N DVM and scanner can be controlled from the MRDL microcomputer or from the MRDL programmable calculator. The H-P DVM can be controlled only from the calculator. With the switching remotely programmed, the inputs can be reversed; and with grounded junction or bare wire thermocouples, each thermoelement can be measured against the platinum leg of the standard type S thermocouple, which provides a set of redundant measurements and increases calibration reliability. Both controllers can be programmed to read as many as 150 thermocouples in any order, to calculate temperatures and temperature differences, and to record these data on magnetic tape. Normally, the emf of each test thermocouple is bracketed by readings of the standard, which are then averaged to compensate for any small temperature drifts in the calibrating furnace or bath. In addition, the H-P DVM can be programmed to read two-wire resistance and thereby check each thermocouple circuit for continuity.

Automation has improved the overall accuracy of thermocouple calibrations by reducing transcription errors, by making redundant measurements, and by providing the operator with continuous checks on the quality of the measurements during the experiment.

5.5 LARGE DECALIBRATIONS IN Ta-SHEATHED, Al_2O_3-INSULATED Pt/Rh THERMOCOUPLE ASSEMBLIES DURING HEATING TO 1330°C[1]

T. G. Kollie[2] W. H. Christie[3] R. L. Anderson

Tantalum-sheathed, Al_2O_3-insulated $Pt_{90}Rh_{10}$/Pt (type S) and Pt_{70}-Rh_{30}/$Pt_{94}Rh_6$ (type B) thermocouple assemblies were unstable when heated to about 1100°C. Decalibrations of -152°C were measured when one lot of type S assemblies were heated to 1330°C. The type B assemblies were more stable and decalibrated only -11°C during heating to 1330°C. The total time at about 1100°C was 2.5 hr. After the assemblies had been heated

to 1330°C, measurements with a moving temperature gradient technique showed that the Seebeck coefficient, which produces the emf of a thermocouple, changed -86% and -4.5% in the type S and type B assemblies, respectively. Metallographic and ion microprobe mass analyses showed that reactions had occurred within the thermocouple assemblies at the Pt-Al_2O_3 and Pt/Rh-Al_2O_3 interfaces, resulting in solution of up to 27 at.% Al in the thermocouple wires. Aluminum concentrations were less in the Pt/Rh thermocouple wires than in the Pt thermocouple wires and were inversely related to the Rh content of the wires. Magnesium and Si, in concentrations about 1000 times lower than Al, were found in the thermocouple wires. The origin of these impurities was the MgO and SiO_2 impurities in the Al_2O_3 insulation. Aluminum was not found in the Ta sheath; however, an O concentration gradient did exist in the Ta sheath, with the higher O concentration at the Ta-Al_2O_3 interface. The work of others suggests that Pt can reduce Al_2O_3 in low O environments, forming the compound $AlPt_3$. The thermochemistry of the reaction

$$3Pt + \frac{1}{2} Al_2O_3 + \frac{6}{10} Ta \; AlPt_3 + \frac{3}{10} Ta_2O_5$$

is discussed to support the proposed reaction mechanism. It is concluded that type S and type B thermocouples insulated with Al_2O_3 and sheathed in Ta are inherently unstable at about 1100°C. References are cited to extend this conclusion to Pt/Rh thermocouples insulated with other oxides, such as MgO, and sheathed with other O-reactive metals, such as Nb.

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1. Abstract of published paper: *J. Less-Common Metals* 57, 9 (1978).
2. Y-12 Development Division.
3. Analytical Chemistry Division.

5.6 PULL TESTS ON SMALL-DIAMETER SHEATHED THERMOCOUPLE ASSEMBLIES

W. W. Johnston M. H. Cooper
J. D. Lyons J. L. Horton

A manufacturer of electrical heaters for the blowdown heat transfer (BDHT) program experienced an abnormally large number of failures in heater assemblies due to broken thermocouples. The manufacturer held that the cause was thermocouples supplied by ORNL under the large-scale procurement of temperature sensors (LSPTS) program.

During fabrication of the heaters, the ends of the thermocouple assemblies were spot welded to the inside diameter of the heater sheath. The thermocouples were held straight by applying up to ∿5 lb of tension while the heater element and insulation were added. During this process, the breakages occurred.

Twenty-nine thermocouple assemblies from three manufacturers were tested by subjecting the thermocouples to an increasing load until a break occurred, which was indicated by a sudden increase in the loop resistance. The load required for a break to occur varied from 11.3 to 21 lb. There was no obvious difference in the products from the three thermocouple manufacturers. It was concluded, therefore, that the thermocouples supplied by LSPTS were not faulty.

5.7 CALIBRATION OF INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AFTER 10,000 hr AT 650°C

W. W. Johnston R. L. Anderson M. H. Cooper

Thirty industrial-type platinum resistance thermometers were recalibrated in the metrology research and development laboratory after a long-term drift test at 650°C for 10,000 hr. The thermometers were calibrated at 0°C in an ice bath, and at 231, 419, and 550°C in a stirred salt bath. Attempts to calibrate these thermometers in metal-freeze-point cells showed that, with the relatively massive metal protection tubes, the immersion depths available in the freeze point cells were insufficient to provide reliable fixed points. Therefore, the thermometers were calibrated in the stirred salt bath by comparison with a standard platinum resistance thermometer. Before the calibrations were performed, the stability of the salt bath was evaluated, and a copper comparison block was immersed in the bath to eliminate short-term fluctuations and to provide temperatures stable to better than ±0.01°C.

The results of the calibrations showed that single-element thermometers from one manufacturer still matched the standard tables for industrial platinum resistance thermometers to about 0.1°C. In general, in dual-element thermometers one element was stable, but the second element drifted excessively and was very noisy. Again, as with the single-element thermometers, the dual-element thermometers of one manufacturer were more stable than those from others.

5.8 INSTALLATION OF A SENSOR FABRICATION FACILITY

R. L. Anderson J. D. Lyons

The development of advanced sensors, particularly temperature sensors, frequently requires in-house fabrication. Fabrication of thermocouples and other sensors which use MgO insulated, metal-sheathed cable for severe environments of temperature or radiation presents particular problems because of the hygroscopic nature of the MgO. To preserve the high insulation resistance and to prevent the intrusion of water vapor which can

promote corrosion of thermocouple elements at high temperatures, the manipulation, fabrication, and sealing of these sensors must be carried out in a dry, inert atmosphere.

A sensor fabrication facility was installed to contain the sensors during fabrication. It consists of a double-length glove box (7 ft), equipped with a recirculating inert-gas purifier and drying element, welding equipment for both spot welding and fusion welding, an oven for baking materials to 600°C under vacuum, a vacuum lock, and a stereo microscope. This facility was used to fabricate 0.5-mm-OD sheathed thermocouples from bulk material which had been processed under argon, without exposure of the MgO insulation to air or water vapor.

5.9 LARGE THERMOCOUPLE THERMOMETRY ERRORS CAUSED BY MAGNETIC FIELDS[1]

T. G. Kollie R. L. Anderson
J. L. Horton M. J. Roberts

Chromel/Alumel thermocouples used in a magnetic field indicated temperatures in error by about ±150% at 100°C. Diagnostic tests showed that the errors were caused by the Ettingshausen-Nernst (EN) effect. The EN effect produces an emf in a conductor, such as a thermocouple, placed in a magnetic field and temperature gradient which are both transverse to the length of the conductor. The heat transfer experiment at the Oak Ridge National Laboratory in which the temperature measurement errors were encountered is described, and the results of diagnostic tests performed in this experimental apparatus and in auxiliary lab-bench experiments to identify the EN effect are presented. Sources of error, other than the EN effect, for thermocouples used in a magnetic field are discussed.

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1. Abstract of published paper: *Rev. Sci. Instrum.* 48(5), 511 (1977).

5.10 MEASUREMENT OF B VERSUS H OF ALUMEL FROM 25 TO 180°C[1]

J. L. Horton T. G. Kollie L. G. Rubin[2]

The relationship between the magnetic induction B and the magnetic field H in Alumel was measured by the ring method for temperatures T between 25 and 180°C. These data were needed to correct for large temperature measurement errors that occurred when Chromel-vs-Alumel thermocouples were used in a magnetic field. Through application of the Weiss equation, the saturation value of the intrinsic magnetic

induction B_s was calculated as a function of T from the experimental B-vs-T data. Weiss's method was used to determine the Curie temperature of Alumel, $T_c \approx 152°C$, from a plot of B_s^2 versus T near T_c. The experimental values of B_s versus T were in good agreement with those obtained from the Brillouin function with quantum number $J=1/2$.

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1. Abstract of published paper: J. Appl. Phys. 48(11), 4666 (1977).
2. Francis Bitter National Magnet Laboratory, Massachusetts Institute of Technology.

5.11 TEST OF A FIBER OPTICS INFRARED THERMOMETER

M. H. Cooper

Use of optical fibers to measure temperatures in remote locations without the need for a line-of-sight optical path can be advantageous in many situations. Another advantage of the fiber optic system is that the field of view can be determined easily by back-illumination with a flashlight. A commercially produced optical fiber infrared thermometer was compared against a blackbody source to 600°C. The temperatures indicated by the fiber optics thermometer and the temperature of the blackbody as indicated by an imbedded type K thermocouple was ±1% from ~200 to 600°C.

5.12 MEASUREMENT OF PARAMETERS FOR A THERMOCOUPLE SHUNTING MODEL

J. D. Lyons R. L. Anderson

At high temperatures (above 1000°C), the exponential decrease of the insulation resistance of the mineral oxide insulation in metal-sheathed thermocouples can result in temperature measurement errors due to electrical shunting (the emf generated by the thermocouple is shunted by the lowered resistance of the insulation between the thermocouple wires) and electrical leakage (dc currents on the sheath can leak onto the thermocouple circuit).

An analytical model to estimate the effects of electrical shunting and electrical leakage in small diameter sheathed thermocouples was developed by Roberts and Kollie.[1] Application of the model requires that the parameters such as sheath resistance, wire resistance, and insulation resistance be known as functions of temperature. These parameters were measured in the metrology research and development laboratory (MRDL) for 1 m of 0.5-mm-OD, stainless steel sheathed, type K thermocouple material. Even though these parameters were observed to change with high temperature exposure during measurement, the calculated thermocouple output errors

agreed with the measured errors within 10% for electrical leakage and within 15% for electrical shunting.

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1. M. J. Roberts and T. G. Kollie, *Rev. Sci. Instrum.* 48(9), 1179-1191 (September 1977).

5.13 LOCATION OF WIRE BREAKS IN SHEATHED THERMOCOUPLES BY CAPACITANCE MEASUREMENTS

J. L. Horton

Wire breakage in 0.020-in. sheathed thermocouples in the blowdown heat transfer (BDHT) heater rod assemblies due to swaging or drawing in the fabrication of the assembly has been a problem. A nondestructive method of locating such breaks is desirable. The measurement of wire-to-wire and wire-to-sheath capacitance at the open end appears to be a usable technique.

With the small diameter and long lengths of such thermocouples, the wire resistances are high and the insulation leakage resistances are low, both of which are distributed along the length and make simple capacitance-length measurements difficult. A Boonton model 74, three-terminal, 100-kHz capacitance bridge with shunt resistance nulling was used because it allows the measurement of small capacitances when large common-mode capacitances are present, and the separation of the capacitance and resistive components.

A test was conducted with a 260-in.-long thermocouple assembly. A 1-in.-long section at 250, 220, 188, 152, 116, 80, and 40 in. from the open end was stretched until the Chromel wire broke. Wire-to-wire and broken wire-to-sheath capacitance was measured after each break. The curve of capacitance versus the length to a break for each break point was a smooth curve but nonlinear. We assume that this calibration curve would hold true for ascertaining break locations in other thermocouple assemblies of identical geometry and material. Use of this technique for different materials would require correction to this curve for each different material.

This was a preliminary test and the technique has not, at this time, been developed for routine testing.

5.14 ELECTRICAL SHUNTING AND LEAKAGE MODEL FOR SHEATHED THERMOCOUPLES

M. J. Roberts T. G. Kollie[1]

A three-wire transmission line model was derived to calculate temperature measurement errors caused by electrical shunting and leakage in metal-sheathed, oxide insulated, compacted thermocouple assemblies. The accuracy of the model was verified by experimental measurements on a 0.5 mm, stainless steel sheathed, MgO insulated, Chromel-Alumel thermocouple assembly. The three-wire transmission line equations were solved exactly for a uniform line and numerically for a nonuniform line.

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1. Y-12 Development Division.

6. INSTRUMENTATION FOR ENGINEERING EXPERIMENTS AND TEST LOOPS

General

6.1 MULTIROD BURST TESTS

K. R. Carr R. L. Anderson
F. R. Gibson J. H. Holladay

The design and installation of the instrumentation and controls were completed, and operational assistance was provided for the multirod burst test (MRBT) program.[1] Two facilities are now operational, a single-rod facility for testing of 1 fuel-rod simulator per experiment and a multirod facility for testing of as many as 64 fuel-rod simulators per experiment. Three multirod (4 × 4 rod array) experiments were run, and more than 70 single-rod experiments were completed.

The single-rod facility, in addition to its primary function of conveniently providing data for comparison and planning of multirod experiments, was also used to prove the accuracy of the instrumentation. For example, an experimental determination of thermal shunting by bare-wire thermocouples was included as part of a regular single-rod experiment. Thermocouples with various wire diameters were installed, and their responses in the temperature transient were compared. We concluded that thermal shunting by the bare-wire thermocouples is not an important source of temperature measurement error in this work.

The importance of the data and the cost of the multirod bundles (several hundred thousand dollars each) in these "one-shot" destructive tests place stringent requirements on the reliability and accuracy of the instrumentation and controls. Due to the several hundred data channels and the short (60 sec maximum) time duration of a multirod experiment, operation is by automatic control. The computer-controlled data acquisition system terminates the test automatically at specified end-of-test conditions, and associated relay circuits provide maximum protection against process conditions that might result in a loss or degradation of the data. The key process variables, pressure and temperature, are being provided by strain-gauge transducers and thermocouples, respectively. The instrumentation and controls functioned satisfactorily to date; we have experienced no failures or malfunctions resulting either in loss or degradation of data.

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An unusual requirement in the multirod experiments is the measurement of the temperature of a metal sheet inside the test vessel which has as much as 1000 A dc current flowing through it and with voltage potential to ground of as much as 200 V dc. This measurement is being accomplished satisfactorily using bare-wire, type S thermocouples with sensing junctions attached directly to the metal sheet. The thermocouple signals are routed through isolation amplifiers for ground isolation.

The total instrumentation effort to date in the MRBT program has amounted to approximately seven man-years, and this program is expected to continue for several more years.

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1. K. R. Carr et al., *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 92.

6.2 POTASSIUM VAPOR TOPPING CYCLE

J. W. Cunningham A. D. McNutt[1]
P. G. Herndon W. A. Bird

Design, procurement, installation, and checkout of instrumentation and controls for the potassium vapor system of this facility[2] were completed, and assistance was provided during startup and operational shakedown, which is currently underway. Performance of the instrumentation and controls to date was satisfactory; however, due to problems characteristic of liquid-metal systems, the facility is not yet fully operational and all of the controls have not been proved.

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1. UCC-ND Engineering.
2. P. G. Herndon, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 93.

6.3 POTASSIUM LEAK DETECTOR

W. R. Miller L. H. Thacker

A detector to sense the presence of potassium vapor in the effluent gases from the gas-fired boiler of the potassium topping cycle experiment was designed and built, and is now in service on that experiment. A sample stream of boiler exhaust gas is continuously injected into the burner of a flame photometer. Narrow-band interference filters selectively detect emissions from potassium vapor in the sample and, thus, detect leaks in the boiler tubes. The instrument provides both an annunciator warning and relays to actuate safety devices.

6.4 IN-PILE IRRADIATION TESTS

J. W. Cunningham

The design was completed for the modification of an experimental irradiation facility[1] at the High-Flux Isotope Reactor for first the HRB-13 experiment, which is a continuation of a series of irradiation tests of HTGR fuel materials, and later for HRB-14. Checkout of the instruments followed the field changes.

The design, procurement, and checkout of field work was also completed on the modification of the HTGR graphite creep irradiation facility[2] at the Oak Ridge Research Reactor (ORR) for experiment OC-2. A preoperational test of the heater controllers, operating through the ORR data acquisition and control system,[3] was performed while the experiment was "hanging" in the pool but before insertion in the reactor core.

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1. J. W. Cunningham and C. Brashear, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 93.
2. J. W. Cunningham, C. Brashear, and P. G. Herndon, ORNL-5196, p. 87.
3. J. M. Jansen et al., ORNL-5196, p. 42.

6.5 PREPARATION OF COST ESTIMATES FOR A LIGHT-WATER-REACTOR PRESSURE VESSEL IRRADIATION PROGRAM

J. W. Cunningham J. M. Jansen

Two estimates for instrumentation, data acquisition, and control of a facility for performing irradiation tests of heated specimens of pressure vessel steel were prepared. The estimates are based on the use of a computer-based, digital data acquisition system to control the specimen temperatures and to record the experimental data. The two estimates differ in the amount of control provided.

6.6 COAL EQUIPMENT TEST PROGRAM

J. W. Cunningham R. L. Moore

Instrumentation and control design criteria were added to preliminary process flow diagrams for a pilot coal conversion plant. These drawings were prepared to help other Department of Energy contractors (1) to select process instrumentation items which are critical to process operations and/or are subjected to environmental conditions which would result in questionable reliability, and (2) to propose a program for test

and evaluation of selected items to determine the adequacy of commercially available equipment and for development of new devices as required.

6.7 INTERMEDIATE VESSEL TESTS FOR THE HEAVY SECTION STEEL TECHNOLOGY PROGRAM

T. M. Cate J. L. Redford W. A. Bird

Support for this series of tests under the heavy section steel technology program was continued.

The instrumentation for the latest test in this series (V-7B) consisted of data acquisition instrumentation for recording steady-state and transient test data from 18 thermocouples, 3 pressure transducers, 3 displacement transducers, and 57 strain gauges. This test instrumentation was very nearly identical to that provided for test V-7A.[1]

Preparations were started for the next test in the series (V-8), which will be similar to other tests in the series except that the vessel test temperature will be much lower.

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1. R. H. Bryan et al., *Test of 6-in.-Thick Pressure Vessels Series 3: Intermediate Test Vessel V-7A Under Sustained Loading*, ORNL/NUREG-9 (February 1978), pp. 104, 110.

6.8 TESTS OF 1/15-SCALE STEAM GENERATOR CLOSURES

T. M. Cate

Instrumentation was provided for two 1/15-scale steam generator closure plug tests for the gas-cooled fast breeder reactor, prestressed concrete reactor vessel. In each test, the model was instrumented with 47 sensors (30 strain gauges, 6 beam gauges, 4 direct current differential transducers, 6 linear voltage displacement transducers, and 1 pressure transducer). The instrumentation provided for these tests included sensors, signal conditioners, data acquisition devices, and closed-circuit television viewing and recording equipment.

6.9 MODIFICATION OF FACILITY FOR THERMAL SHOCK TESTS

T. M. Cate

The originally planned series of tests for this facility was expanded and continued[1] until October 1977. After completion of the tests, the facility was extensively modified for a study to determine the feasibility of using liquid nitrogen to thermally shock test specimens in a future series of tests for observation of the temperature distribution in the specimens as a function of time. A specimen is instrumented with 50, 1/16-in.-OD mineral-insulated thermocouples. The thermocouples, as well as loop pressure, are recorded by means of a computer-controlled data acquisition system.

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1. J. W. Krewson and T. M. Cate, *Instrumentation and Controls Div. Semiann. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 88.

6.10 FISSION PRODUCTS TRANSPORT TEST

G. W. Greene R. L. Moore

Conceptual design drawings and a cost estimate were prepared for instrumentation of a test facility designed to simulate the release and transport of fission products that would occur in a pressurized water reactor following a loss-of-coolant accident.

6.11 STUDY OF HEAT EXCHANGER CHARACTERISTICS FOR CONVERSION OF OCEAN THERMAL ENERGY

J. W. Krewson

Design of instrumentation and controls for a small facility for studying the heat transfer characteristics of a medium-temperature heat exchanger, which will be used in a system for conversion of ocean thermal energy to electricity, was completed and revised. These revisions were made to incorporate additional instrumentation required for testing and evaluating condenser tubes and associated systems to determine the operating conditions and geometry necessary for maximum efficiency when using ammonia as the process fluid.

Procurement, installation, and checkout of instrumentation were completed, and the system is operational. This work was done for the ocean thermal energy conversion heat exchange project.

Test criteria required accurate measurement of system temperatures, process fluid flow, and heat input. Temperature measurement with high-resistance thermistors proved satisfactory, with the thermistors being both accurate and stable. A quartz thermometer was permanently installed in the system for calibrating the thermistors, which is done regularly with the system operating isothermally. The process fluid flow is measured with small turbine flowmeters, and this too proved satisfactory. Heat input is determined by measuring the voltage and current applied to the heaters for the ammonia boiler. Some thermocouples are used for maintaining operating conditions and for safety purposes.

The system is being modified and enlarged to accommodate an evaporator system in addition to the condenser system. The instruments and controls for this new system will be of the same quality as those for the condenser.

The two systems can be operated simultaneously, because they have equal and independent instrument and control systems.

6.12 GEOTHERMAL CONDENSER TEST FACILITY

J. W. Krewson

The instrument and control system for this facility is similar to that of the ocean thermal energy conversion heat exchange project, in that both systems require accurate measurement of temperatures and both programs are testing medium-temperature heat exchangers. The systems differ in that, in this program, the heat will be obtained from geothermal wells instead of the ocean and the process fluid will be ammonia instead of isobutane. Also, only the condenser inlet and exit temperatures of the process fluid and the cooling water are measured accurately. Thermistors are used for this purpose. The cooling water flows are measured with rotameters and orifice plates.

Two systems have been built, a 2-tube, and a 40-tube unit. Both will be tested at a geothermal test facility at East Mesa, California, in the Imperial Valley region.

Because of the very high ambient temperatures at this site -- 130°F is not unusual -- a small, mobile, air-conditioned office trailer was purchased and converted into an instrument trailer. Since this trailer will be used at remote sites where the ac voltage variations might be excessive, a voltage regulator was installed in the ac power lines to which instruments will be connected. Work benches, with regulated outlets, are provided for table mounted instruments.

The 2-tube unit has been tested for one three-week period at East Mesa and then returned to this area. The 40-tube unit is now being assembled and tested prior to being sent to East Mesa for operation.

Core Flow Test Loop

4.13 CORE FLOW TEST LOOP PROGRAM: OVERVIEW

P. G. Herndon A. D. McNutt R. E. Toucey

The advanced conceptual design of the instrumentation and control systems for the core flow test loop (CFTL) was completed during FY 1977. The Title I design will be completed and the Title II design will be initiated during FY 1978. The ORNL Engineering Technology Division, acting under directives from the Department of Energy, has the prime responsibility for the CFTL, which will be located in building 9201-3 in the Y-12 Plant.

The CFTL will provide a high-temperature, high-pressure helium circulating loop in which bundles of electrically heated rods will be operated to simulate portions of fuel- and control-rod elements or a full-sized blanket element of the gas-cooled fast breeder reactor (GCFBR) core. The test bundles will be subjected to power and helium-gas-flow conditions that will duplicate GCFBR operating conditions for the design of steady-state operations, normal-upset and emergency transients, and depressurization transients. The experimental results of the CFTL operations will be used to verify the analytical methods used to design the GCFBR core elements and to determine the capability of the elements to withstand the imposed conditions.

Operation of the CFTL in FY 1981 and 1982 is necessary to support the overall GCFBR program leading to demonstration plant operation in CY 1987. The total cost of the project when completed is estimated at $14.6 million, of which $3 million is for instrumentation and controls. Ten man-years of design effort over the next three years will be required for instrumentation.

The advanced conceptual design work was concerned primarily with defining the instrumentation and control systems, cost estimating, program planning, and providing some design support for component test facilities. Conceptual instrument application diagrams were completed for both the loop and test vessel. A tabulation and preliminary specifications for the instrument components were completed. A preliminary control room plan was completed. The plan establishes control room space, utility, and fire protection requirements. The conceptual design information served as the basis for estimating the cost of loop design and construction and for formulating work plans for design and construction activities. These plans included a work breakdown structure, an E-Z PERT planning chart, and manpower utilization schedules.

Duplicating the prescribed GCFBR operating conditions in the CFTL presents many difficult design problems. Instrumentation and controls performance requirements are pushed to the limits of capability by the extremely wide range of operating conditions. The operating pressure turndown is 60:1, extending from 9 MPa to 0.15 MPa at 350°C; the flow range turndown ratio for each of three, different-size, fuel-rod

inulator test bundles is more than 100:1 (the overall range for all three bundles extends from 3200 to 8 g/sec, a 400:1 turndown ratio); and during a simulated design basis depressurization accident, both pressure and mass flow rate decrease simultaneously from the maximum to the minimum values. Fast flow and fuel-rod simulator power transients that vary from 100 to 10% of maximum value for flow and to 1% for power must be measured and controlled in time spans that vary from a second to several minutes.

Investigations to date indicate that a venturi tube with multiple stacked pressure and differential pressure transmitters, or a vortex shedding type meter are the only commercially available instruments that individually come close to meeting these requirements. Perhaps a combination of both will be required. Venturis in combination with drag disks are also a possibility.

Valve sizing calculations have shown that a single-size valve body can be used for all tests, but a different size trim will be required for each size of the fuel-rod simulator test bundles.

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1. UCC-ND Engineering.

6.14 DATA ACQUISITION SYSTEM FOR THE CORE FLOW TEST LOOP

K. J. Cross A. F. Johnson

A data acquisition system was proposed to meet the requirements of the core flow test loop. The proposed system is based on the upgraded data acquisition for the thermal hydraulic test facility system, which is a PDP-11 based real-time system. The CFTL system will have a capacity of 640 analog channels which are to be limit-checked and recorded on magnetic tape. The system will also be capable of on-site analysis, using FORTRAN, to provide data conversions, and tabular and graphical output.

6.15 THERMOCOUPLE RESEARCH ON SMALL-DIAMETER SHEATHED THERMOCOUPLES FOR THE CORE FLOW TEST LOOP

R. L. Anderson J. D. Lyons

The CFTL is a simulation experiment designed to check the thermo-hydraulic performance and components for a high temperature, helium-cooled fast reactor. In this experiment, the cladding temperature of fuel-rod simulators will be measured with 0.5-mm-OD (0.020 in.) sheathed

thermocouples, which have become available only recently. Because these thermocouples must be more accurate and must operate over a greater temperature range in the CFTL than would be required for small-diameter thermocouples in other applications, a study was made to characterize these thermocouple materials.

The results of this project are: their insulation resistances were characterized to 1000°C; an analytical model was developed to predict electrical shunting and electrical leakage errors at high temperatures; their long-term drift characteristics were determined from 600 to 1150°C for type K wires in type 304 stainless steel and in Inconel 600 sheaths; and their reproducibility and causes of decalibration were determined for type S and type B thermocouples in 90% Pt-10% Rh, Type 304 stainless steel, and Inconel 600 sheaths.

6.16 ROTATION MONITOR AND SPEED READOUT DEVICE FOR GAS COMPRESSOR

W. R. Miller

A speed readout and rotation direction monitor instrument was designed and built for the core flow test loop facility The unit determines the direction of rotation of a 24,000 rpm gas compressor before 350 rpm is reached and shuts it down if the direction is incorrect. A digital readout that indicates the rpm under operating conditions was also provided.

6.17 TESTS TO DETERMINE THERMOCOUPLE ERRORS DUE TO ELECTRIC LEAKAGE OR SHUNTING AT HIGH TEMPERATURES

D. W. McDonald

Investigations by Kollie, Lyons, and Anderson[1] and the analytical work by Roberts and Kollie[2] on electrical shunting and leakage errors in sheathed thermocouples revealed a source of possibly large temperature measurement errors in the core flow test loop (CFTL). An experimental facility was constructed to subject individual fuel-rod simulators to the currents and temperatures expected in the CFTL and to determine if leakage currents onto the thermocouple sheaths would be of sufficient magnitude to generate significant temperature errors. An instrumentation system was developed to condition signals from various thermocouples, to read and display the voltage and current supplied to the simulators, to calculate and display the average power delivered to the simulators, and to interface all of these measurements to an available minicomputer. The results of the test indicated that errors believed to be due to leakage or shunting effects became evident at ~1100°C; unfortunately all the

simulators failed slightly above these temperatures, and further tests to higher temperatures are required to document the magnitude of errors that can be expected around 1200°C.

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1. T. G. Kollie, J. D. Lyons, and K. L. Anderson, "Small Diameter Thermocouples," *Gas Cooled Fast Reactor Program Semiannual Progress Report for Period Ending March 31, 1977*, ORNL-5294.
2. M. J. Roberts and T. G. Kollie, "Derivation and Testing of a Model to Calculate Electrical Shunting and Leakage Errors in Sheathed Thermocouples," *Rev. Sci. Instrum.* 48(9), 1179-1191 (September 1977).

6.18 RECOMMENDATION OF A FLOWMETER FOR CFTL GAS FLOW MEASUREMENT

S. P. Baker D. W. McDonald
F. M. Shofner[1] P. G. Herndon H. J. Metz

The Instrumentation and Controls Division was requested by the Department of Energy to evaluate the state of the art of gas flow measurement. This request was due in part to the severe flow measurement requirements in the core flow test loop (CFTL). These requirements include operation at 350°C (662°F) and 8.96 MPa (1300 psi), a mass flow rate rangeability of 400 to 1, a gas velocity rangeability of 592 to 1, accurate measurement during pressure transients, and an accuracy of 1% of the reading. Flow measurement techniques analyzed included hot wire anemometers, laser velocimeters, ultrasonic flowmeters, vortex-shedding flowmeters, and ion-displacement flowmeters. From the results, we concluded that the ion-displacement flowmeter held the greatest promise of meeting the CFTL flow measuring requirements.

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1. Shofner Engineering Assoc.

6.19 RECOMMENDATION FOR A CFTL POWER SUPPLY

D. W. McDonald

A final recommendation was made on a power supply concept for the core flow test loop (CFTL). The power supply must provide over 4 MW of power to 91 fuel-rod simulators, and must not introduce unmanageable interference on loop instrumentation, particularly thermocouples. Several configurations were investigated, including a commercially available three-phase, SCR phase fired, dc rectified system and two internally developed 60 Hz ac, zero phase fired systems.

The phase fired system was judged unacceptable because the electromagnetic interference would be too high and current leakage at high temperatures would introduce an error signal inseparable from the actual signal generated by the thermocouple.

The two remaining power supply concepts were evaluated with respect to performance, ease of implementation, reliability, and controllability. One was based on the addition and subtraction of transformer windings to give 40, discrete, linearly related voltage increments;[1] and the other was based on 15, discrete, linearly related power increments.[2] The latter system based on the 15 discrete power increments was chosen because of its superiority with respect to these parameters.

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1. M. J. Roberts, R. W. Rochelle, and D. W. McDonald, "SCR-Controlled Digitally Programmable AC Power Supply," *IEEE Trans. Ind. Electronics Control Instrumen.* IECI-25(1), 59-61 (February 1978).

2. T. L. Hudson and J. R. Stansberry, "AC Power and Control System," *Fast Flux Test Facility Program Prog. Rep. July 1, 1974, through September 30, 1974*, ORNL-5294.

6.20 CFTL POWER SUPPLY CONTROLLER

D. W. McDonald

The power supply controller for the 4-MW power supply for the core flow test loop (CFTL) has undergone evolutionary improvement as the power supply requirements have changed. A requirement was recently introduced that the controller operate in a closed-loop fashion and provide continuous manual adjustment capability. The device developed for this purpose can operate in both an open-loop and a closed-loop configuration. In the closed-loop mode it operates with either analog or digital feedback. In the digital closed-loop mode, a microcomputer compares the feedback signal with the required power profile and changes the code to the interface circuitry to maintain the power profile to that desired. In the analog closed-loop mode, the feedback signal is compared to an analog set point, and control is maintained in the usual fashion. The redundant analog and digital control are employed to evaluate the performance of each to the other. If the system will perform adequately under analog control, significant cost reductions will be realized by removing the microcomputer requirement. Although the saving is insignificant to CFTL, the carry-over of the technology into furnace controllers, machine drive controllers, welding equipment controllers, and other smaller ORNL projects will be more effective with the lower cost approach.

6.21 DYNAMIC ANALYSIS OF THE CORE FLOW TEST LOOP

L. J. Ball

The dynamic simulation code OPCIII for the Core Flow Test Loop (CFTL) was updated from its original, preliminary loop design version, and now it corresponds to the present advanced conceptual design. The CFTL is a high-pressure, high-temperature helium loop which will use electrically heated, fuel-rod simulator bundles to study the thermal-hydraulic and structural problems in gas-cooled fast breeder reactor (GCFBR) cores. The OPCIII code has been used in several analyses which helped to solve loop layout and component design problems.

Several approaches to controlling the main 4-MW heat exchanger (HX-1) flow over wide ranges were investigated. The path of the cooling air flow was revised to upflow so that there would be a smooth transition from forced to natural convection flow, and a simulation of the natural convection flow mode was developed. The results indicate that up to [illegible] kW of heat can be removed from the HX-1 by natural convection alone. The present plans for coolant control specify that the blower speeds and the inlet vane position will be varied for forced convection flow, and that the damper position will be varied for natural convection flow. For the zero and near-zero test bundle power cases, cooling air preheaters will be used.

The HX-1 control system utilizes a feedback signal from the heat exchanger, helium outlet temperature in conjunction with feed-forward signals from the helium inlet temperature and flow rate to vary the coolant air flow rate. The performance of the system has been satisfactory on runs made to date.

Control of the heat exchanger cooling capabilities, control valve manipulations, and the resulting temperature and flow transients during design-basis depressurization accident (DBDA) simulations were also investigated for a variety of cases. The results indicate that the predicted circulator and test section inlet temperature perturbations can be held to very small values during the transients. Also, the control scheme proposed for valve manipulations achieves the desired test section flow transients while keeping the circulator well within its desired operating range. Simulations to date also indicate that loop piping and heat exchanger temperatures can be maintained within design limits for all prescribed simulated accident conditions.

Blowdown Heat Transfer

6.22 BLOWDOWN HEAT TRANSFER PROGRAM: OVERVIEW

A. F. Johnson

The blowdown heat transfer (BDHT) program is an experimental separate-effects study of the principal variables involved in loss-of-coolant accident (LOCA) analysis for pressurized-water reactors. Primary test results are obtained from the thermal hydraulic test facility (THTF), which is a nonnuclear, pressurized-water loop incorporating a 49-rod electrically heated bundle. Supporting experiments are carried out in the forced convection test facility (FCTF), which is a single-rod, high-pressure facility used for heater rod evaluation and blowdown tests, and the air-water loop and transient instrument test facility which are used for evaluation of two-phase flow measuring instrumentation.

Instrumentation support for the BDHT program consisted primarily of operations support (including calibration and maintenance), design support for facility modifications, instrument development to improve existing instruments and to provide new instruments using advanced techniques, and error analysis to define the steady-state and transient error bands on the measurements. Approximately 8.5 instrument engineers are working in the areas of operations and design support, 0.5 in instrument development, and 1 in error analysis. As the BDHT program and its facilities progressed, the emphasis on instrumentation was shifted from design to development and error analysis, although a significant design effort will always be required to handle the modifications and additions which arise in any experimental environment.

6.23 THERMAL HYDRAULIC TEST FACILITY

A. F. Johnson

C. Branhcar	W. L. Bryan	M. E. Buchanan
K. R. Carr	W. S. Coleman	K. J. Cross
B. G. Eads	F. R. Gibson	R. L. Hansard
J. H. Holladay	E. C. Keith	E. L. Moore
R. C. Muller	W. Ragan	J. L. Redford
M. J. Roberts	E. R. Rohrer	R. L. Shipp
R. W. Tucker, Jr.	B. J. Veazie	

The thermal hydraulic test facility (THTF) has been in full operation since April 1976. Since that time, 27 blowdown tests have been run to simulate pressurized-water-reactor, loss-of-coolant accidents. Each test entailed the acquisition of over 6,000 transient data points from each of 500 instruments.

The primary effort through this report period has been operational support and facility additions. Several instruments were developed or significantly improved, principally the gamma densitometer, turbine meter electronics, power monitor, and power programmer. A more capable data acquisition system is being developed and is scheduled to be installed in the fourth quarter of FY 1978. Increased emphasis was placed on error-band analysis of the instrumentation system.

6.24 FORCED CONVECTION TEST FACILITY

C. Brashear J. L. Redford
A. F. Johnson B. J. Veazie

The forced convection test facility is used for single-rod blowdown testing in support of the thermal hydraulic test facility (THTF). Minimal instrumentation engineering was required above normal operational support, except for some special testing. Several blowdown tests were conducted to evaluate an in-bundle, liquid-level measurement rod procured from Idaho National Engineering Laboratory and destined for use in the THTF bundle 2. A computer-based data acquisition system was installed and placed in routine operation which greatly enhanced data handling and timely test evaluation.

6.25 AIR-WATER LOOP

J. W. Krewson

This loop is used for steady-state calibration and evaluation of two-phase flow measuring instrumentation in an ambient temperature and pressure environment.

The instrumentation effort during the past year has been in upgrading the instrument and control systems of the loop and providing for future expansion. These changes included improved organizations of wiring and instruments, connection of the instrumentation to the data acquisition system of the forced convection test facility, and assistance in obtaining instruments necessary to improve the quality of the instrument system.

6.26 TRANSIENT INSTRUMENT TEST FACILITY

J. W. Krewson

This facility is used for testing two-phase flow measuring instruments during a simulated blowdown transient from elevated temperature and pressure. The facility and its instrumentation was completed and checked out during this report period in preparation for the first design-basis blowdown test. One interesting problem was the continuous measurement of the rate of fluid flow during blowdown. The technique used is an ice-filled tank to condense the steam and a capacitance gauge to monitor the liquid-level change.

6.27 POWER MONITOR FOR THE THERMAL HYDRAULIC TEST FACILITY

K. R. Carr

An instrument was designed, constructed, and installed in the THTF to monitor the individual and total power (as much as ~12 MW) output by the four generators used to heat the test bundle. The primary function is to automatically terminate the experiment if the instrument senses a power rate-of-change that would be dangerous to the fuel rod simulator bundle, an assembly valued at several hundred thousand dollars. Also, several readouts and alarms concerning the generator power levels are provided for convenience of the facility operator.

The power rate-of-change detector is an operational amplifier stage with a tailored response that is followed by a time delay of 0.1 sec before an actual system trip. Various self-test features were included as an integral part of the instrument.

The power monitor was fully integrated into the routine operation of the THTF for 18 months, and has operated satisfactorily during that time.

6.28 POWER PROGRAMMER FOR THE THERMAL HYDRAULIC TEST FACILITY

K. R. Carr

Until June 1978, the scheduled THTF experiments used only a virtual step change in the bundle-heater input power at the start of the blowdown transient. Subsequent experiments, however, will require various profiles of bundle-heater input power during blowdown to achieve better

simulation of reactor conditions. To meet this requirement, a bundle power programmer was designed, constructed, and installed to automatically provide 1024 steps of generator voltage demand to each of the four generators, beginning at the start of blowdown. The time duration of each step may be easily varied over a wide range; the value being used initially is 50 msec.

An off-line microcomputer is used to convert a specified power program to digital form and to store the data in programmable read-only memories (PROMs). The PROMs are then installed in the power programmer to drive the ground-isolated, digital-to-analog converters at the outputs of the instrument.

Important advantages of the design are open-loop control to avoid noise interference, "bumpless" transfer from steady-state to programmed generator output, integral self-test features, and virtually no impact on operator procedures.

6.29 TURBINE FLOWMETER DATA PROCESSING TECHNIQUE

M. J. Roberts

The thermal hydraulic test facility uses turbine flowmeters to measure the volumetric flow of the coolant. The electrical signals from the turbine flowmeter have, until now, been processed by a vendor-supplied flow monitor, but this monitor is too slow to accurately indicate flow during a blowdown transient.

An algorithm was written and verified which corrects the output data from this flow monitor for the lag introduced by the monitor. The algorithm is accurate with artificially generated as well as with real-flow data from the monitor.

6.30 IMPROVED FLOW MONITOR ELECTRONICS

M. J. Roberts W. R. Miller

Because of an inadequate dynamic response in the vendor supplied flow monitors, a new electronic approach to turbine flowmeter data acquisition was designed and implemented. The new instrument detects the passage of each turbine blade and uses these individual blade passages to gate a crystal oscillator into a counter, thus providing an accurate flow measurement five times per revolution of the turbine, rather than averaging the blade passage rate over a much longer time period as commercial instruments do. The time response is improved by a factor of about 20.

The new instrument has computer interfacing and permits remote calibration and range changing. The unit can accommodate bidirectional flows, and readout is in engineering units.

6.31 STUDY OF LEAKAGE CURRENTS BETWEEN A HEATER TUBE AND CENTERLINE THERMOCOUPLES

J. L. Horton

In blowdown heat transfer tests using a 49-rod bundle, excessive leakage currents were encountered between the heater tube and the centerline thermocouples within the bundle. Several heaters had already failed; additional failures would severely limit the further usefulness of this bundle 1. It was postulated that leakage currents might have caused these failures. A study was made to determine whether this postulate may be true.

A large amount of data on leakage currents from 35 of the 49 heater rods in the bundle during BDHT test 151 were analyzed. The insulation resistance versus power plots resembled plots of insulation resistance versus temperature for MgO insulated thermocouples when the MgO had small quantities of absorbed moisture, including abrupt changes for moisture movement from one location to another. From this observation, a tentative conclusion was that the leakage currents were caused by water absorption and the bulk conductivity of the MgO. Also, even though 230 V maximum was applied across the insulation at full heater power and the leakage currents were much higher than desirable, the probability of heater failure was much less than anticipated. Data from test 152 showed leakages comparable to data from test 151, indicating that degradation from one test to the next was not appreciable.

6.32 DEVELOPMENT OF GAMMA DENSITOMETER

W. L. Bryan A. F. Johnson R. L. Shipp

Development of an ion-chamber-type gamma densitometer was started for density measurements of multiple phase flow at the thermal hydraulic test facility. This instrument must operate in an electrically hostile environment. Severe ground-isolation problems require development of common-mode transient tolerant circuits to enhance data acquisition. Component selection and testing was completed, and assembly development and field tests were started.

6.33 UPGRADED DATA ACQUISITION SYSTEM FOR THE THERMAL HYDRAULIC TEST FACILITY

K. J. Cross
R. W. Tucker, Jr.
A. F. Johnson, Jr.
W. S. Coleman

The requirements of the thermal hydraulic test facility expanded beyond the capabilities of the original PDP-8 based acquisition system.[1] A PDP-11 based system was developed to accommodate more analog channels and to facilitate more on-site data analysis.

The new system has a capacity of up to 1000 analog data signals, which are scanned at 20,000 channels per second and recorded on magnetic tape. While these data are being recorded, checks are made to ensure that no signals exceed predefined limits which could endanger the test bundle. The system can abort the test if any abnormality should occur.

At the conclusion of each test, an analysis of the results must be reported to the U.S. Nuclear Regulatory Commission within ten days. To help meet this requirement, the capability of the PDP-11 system for on-site data analysis was increased, including programming in FORTRAN, graphical (plotting), and execution of a number of different programs simultaneously.

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1. A. F. Johnson, J. L. Redford, and K. J. Cross, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 43.

6.34 PRESSURE TRANSIENT SIMULATION AND ANALYSIS

R. C. Muller

The pressure transients generated during blowdown of the thermal hydraulic test facility (THTF) system have shown marked oscillations which appear to have been artifacts generated by instrumentation. A study was made to determine the real shape of these transients and the cause of signal modification.

An experimental system was constructed to simulate the THTF hydraulic system to find the cause of the signal aberration. The system was shock excited, and pressure data were recorded. In addition, an investigation was made to find mathematical means to obtain system impulse response from input and output data.

The data showed that the primary cause of the signal aberration was vibration of the diaphragm of the d/p cell, probably in conjunction with the mass of water which moved with it. The impulse response of the d/p

cell was obtained from input and output data, and this is being used to obtain the actual differential pressure transients from various known output data.

6.35 GAMMA DENSITOMETER STATISTICAL ANALYSIS

R. C. Muller

At the thermal hydraulic test facility (THTF), four gamma densitometers were built and used to measure water-steam mixture densities under dynamic conditions. We analyzed the data from these densitometers to determine their accuracy and applied statistical methods and calibration checks to assign confidence limits to the data.

The method used was linear regression through the origin (there is sufficient reason to state that the point of origin was a valid assumption). There was a systematic error in the data as a result of low-angle gamma scattering. Such scattering affected the data because the diameter of the receiving aperture was appreciable compared with the path length of the gamma rays; thus the geometry was not point-to-point as the usual equations assume. The four densitometers averaged about 0.04 absolute specific gravity units within the 95% confidence limits.

6.36 PLATINUM RESISTANCE THERMOMETER VIBRATION DUE TO VORTEX SHEDDING IN THE THTF

K. R. Carr

Frequent failures of platinum resistance thermometers (PRTs) due to lead breakage internal to the sheath in one particular application in the thermal hydraulic test facility were investigated and found to be due to vortex shedding. Calculations indicated that the vortex shedding frequency and the experimentally determined natural frequency of the PRT, a 0.63-cm-OD (1/4-in.) cylinder with an unsupported length of 28.6 cm (11-1/4-in.), were sufficiently close to induce excessive vibration of the PRT in the liquid flow and cause lead breakage. The natural frequency of the PRT in air was measured by affixing a small coil on the end of the sensor in a weak magnetic field, plucking the end of the sensor by hand, and recording the voltage output of the coil.

The results indicated that a reduction of the unsupported length to 12.7 cm (5-in.) would increase the natural frequency a sufficient amount above the vortex shedding frequency to eliminate excessive vibration. The unsupported length of the PRT in this application was decreased to 12.7 cm, and no further PRT failures in this application have occurred during the past two years.

Advanced Instrumentation for Reflood Studies

6.37 ADVANCED INSTRUMENTATION FOR REFLOOD STUDIES PROGRAM: OVERVIEW

B. G. Eads

Work under the advanced instrumentation for reflood studies (AIRS) program was initiated at ORNL in late FY 1977 and has continued with the goal to develop and deliver measurement systems for application in several foreign reactor safety experimental facilities. The United States Nuclear Regulatory Commission has entered into a cooperative program with agencies in West Germany and Japan to conduct pressurized water reactor (PWR) safety studies. The purpose of these studies is to develop an improved understanding of the reflood portion of a loss-of-coolant-accident in a PWR. The role of ORNL in the three-party program is to develop instrumentation to measure two-phase flow parameters in the vessel of a reflood experimental facility. The program is managed by the Instrumentation and Controls Division and is supported by significant work in the Engineering Technology Division and Metals and Ceramics Division of ORNL and by UCC-ND Engineering.

Two basic types of instrumentation are being developed: (1) a film probe is to measure the thickness and velocity of liquid films on the internals of the reflood facilities, and (2) an impedance probe is to measure the velocity and void fraction of the two-phase fluid in the core and upper plenum of the test facilities. The instrumentation systems are to be loaned by the United States to German and Japanese test facilities. The development includes both hardware for measurement and software for processing and analyzing the results. When development is completed, instrumentation systems will be designed and procured to meet the specific requirements of each test facility. Where required, on-site consulting support will be provided during the installation and startup of the instrumentation systems.

Following initiation of this program, an assessment was completed of the state of the art of the technology of impedance probe and film probe development as applicable to PWR reflood studies. The on-going development at ORNL of impedance probes was accelerated. Communications were established with the film probe development program at Lehigh University, and the ORNL interaction in this effort was defined. In FY 1978, the impedance probe development was accelerated to the point where preliminary designs were sufficiently verified to enable their inclusion in the PKL Core II facility in Germany. These sensors represent a first generation for measuring void fraction and two-phase velocity in such an environment; thus, the accuracy of the sensors will be limited. Film probes with a film velocity measurement technique as developed at Lehigh University were adapted for the high-temperature, high-electromagnetic-field environments of the PKL. Following the development and design of instrumentation for the PKL, the development will be continued to optimize the measurement techniques and to apply them to other facilities.

The duration of the program is not clearly defined as yet, but it could extend through FY 1982. In FY 1978, approximately 9 man-years of I&C engineering was required, and in FY 1979, this is expected to increase to 11 man-years.

6.38 IMPEDANCE SENSOR DEVELOPMENT

M. B. Herskovitz P. A. Jallouk[1]
W. H. Leavell M. J. Roberts

Measurement systems are being developed to measure the velocity and void fraction of two-phase, steam-water flow in a reflood test facility. This task requires development of sensors, suitable electronics, and signal processing techniques for extracting velocity and void fraction information from the two-phase, fluid impedance measurements. The velocity measurement concept is based on a cross correlation of the signals from two spatially separated impedance sensors. The void fraction measurement depends on the existence of a functional relationship between void fraction and the measured impedance. Other investigators have developed void fraction techniques which show promise, and three different techniques are being tested to determine the one most suitable.

Development in four major areas is required to make this measurement technique applicable in a reflood experiment:

a. A stochastic analysis method of velocity estimation and signal processing techniques for obtaining void fraction information.
b. Electronic circuitry for impedance measurements in the presence of high-level electromagnetic interference while the cable and water properties change rapidly with the temperature transient.
c. Sensor configurations that give the best measurements and are mechanically simple.
d. Materials and fabrication methods for sensors that will survive the environment of a reflood test facility.

First-generation results have been obtained in all the areas. Sensor fabrication is the area needing the most development. Future plans include attempts to achieve optimization or, at least, improvements in these four areas. The first-generation impedance measurement systems will be applied in the PKL Facility in West Germany, and these systems will be essentially prototypes for application to other reflood facilities.

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1. Engineering Technology Division.

6.39 DEVELOPMENT OF WATER FILM THICKNESS AND VELOCITY SENSORS

J. O. Hylton C. J. Remenyik[1]

Sensors are being developed to measure the thickness and velocity of condensate films which occur on internal vessel surfaces during the reflood phase of a reactor loss-of-coolant accident. The basic concepts for the film thickness measurement and film velocity measurement were developed by Chen and coworkers at Lehigh University.[2] As a subtask of the advanced instrumentation for reflood studies program, these concepts are being developed into sensors and measurement systems which will be fabricated for application in the foreign reflood experiments.

The film thickness sensor is based on the measurement of the impedance between two electrodes mounted flush in the vessel surface containing the film. The principle of operation of the film velocity sensor is to measure the electrolysis current between two closely spaced wire electrodes mounted on the vessel surface. Both sensor types have been operated successfully in low-temperature, air and water experiments. A steam and water system was designed and constructed for continued probe development and testing under conditions more closely simulating those occurring in the reflood test facilities.

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1. Consultant, Engineering Science and Mechanics Dept., University of Tennessee, Knoxville.
2. M. R. Osgu and J. C. Chen, *Rev. Sci. Instrum.* 44(12), 1714-1716 (1973).

6.40 COMPUTER CROSS-CORRELATION ALGORITHM FOR TRACKING TRANSIENT TWO-PHASE FLOW VELOCITY

W. H. Leavell F. Shahrokhi C. O. McNew

A computer algorithm[1-2] that performs cross-correlation of in-core sensor signals was developed to track transient mass flow velocities that occur during a blowdown or reflood of a simulated pressurized water reactor (PWR) core. This initial development of the algorithm was performed for the Division of Reactor Safety Research of the U.S. Nuclear Regulatory Commission as a part of the advanced instrumentation for reflood studies program (AIRS). The development is continuing, and application was made to a transient typical of reflood under the AIRS program. The scope of this work has included the development, computer implementation, and testing (using simulated and real sensor data) of the algorithm based on the application of stochastic signal analysis to a transient system.

The algorithm was initially tested using computer-generated data that simulated signals from a pair of sensors in transient two-phase flow. The results show that the algorithm can track rapid changes in two-phase flow velocity. Results of further tests in steady-state air-water, two-phase flow, using impedance sensors, show that the algorithm's velocity estimates are in good agreement with velocity estimates calculated by standard, steady-state, statistical analysis techniques. A comparison of algorithm velocity estimates to those calculated by a two-velocity, fluid dynamic model shows that at a low void fraction (<30%) the algorithm estimates approach the calculated vapor velocity, but at a higher void fraction, the algorithm estimates are between the calculated liquid and vapor velocities. Analysis of two-phase flow transients in air-water covering a void fraction range from 80 to 0% similarly shows that the algorithm can track the changes in velocity, with the estimates lying initially between the calculated liquid and vapor velocities at high void fractions and then approaching the calculated vapor velocity as the void fraction approaches zero. We thus conclude that the algorithm should provide useful velocity information from reflood and blowdown tests, but that further work is needed to understand the relationship of the algorithm's velocity estimates to those calculated by standard two-velocity, fluid dynamic models.

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1. J. D. Sheppard et al., *Quarterly Progress Report on Advanced Two-Phase Instrumentation Program for November-December 1976*, ORNL/NUREG/TM-93.
2. J. D. Sheppard et al., *Quarterly Progress Report on Advanced Two-Phase Instrumentation Program for January-March 1977*, ORNL/NUREG/TM-119.

6.41 DEVELOPMENT OF ELECTRONIC CIRCUIT FOR THE AIRS PROGRAM

M. J. Roberts
W. H. Andrews
T. V. Blalock[1]
J. L. Horton
E. J. Kennedy[1]
W. E. Lingar
W. R. Miller
E. G. Phillips[2]
E. W. Walker[2]

Electronic circuitry was developed for measurement of the electric impedance between two electrodes in a two-phase (steam-water) flowing fluid. The sensors being developed for the advanced instrumentation for reflood studies program consist basically of two electrodes exposed to the two-phase mixture. As the character of the mixture changes, the impedance between the electrodes changes. The impedance can be modeled as a resistance and a capacitance in parallel. The capacitance range is typically from 1 to 100 pF and the resistance range is from 1 kΩ to 1 MΩ. Both quantities are functions of the temperature and ionic concentration of the water.

Of necessity, the sensors are at the end of long (3-10 m) cables. The circuitry that was developed measures the impedance and eliminates the capacitance (and conductance) effects of the cable. This is accomplished by using a triaxial cable with the sensor connected between the center conductor and the outer shield of the cable. The center conductor is driven at the same potential as the inner shield, thus eliminating the center conductor-to-inner shield capacitance in the measurement.

The resistive and capacitive (real and imaginary) components of the sensor current are separated by synchronously demodulating the signal with reference to the applied signal, both in-phase and quadrature. Since the ratio of water and steam conductivities and the ratio of water and steam permittivities are very different, and changes in water temperature and ionic concentration affect conductivity and permittivity differently, the separate measurement of both components of probe impedance yields more information about the nature of the two-phase mixture than would be obtained from a simple measurement of the impedance magnitude.

This circuitry was tested with sensors in an air-water, two-phase flow facility, and it worked well over a wide range of void fraction and velocity.

Other support work in the area of electronic circuitry consisted of the following tasks:

1. A conductivity, liquid-level probe designed by an outside vendor was evaluated.
2. The conductivity and pH of the water in air-water tests were measured.
3. Many sensor concepts were bench-tested to evaluate their sensitivity and response characteristics.
4. On-site assistance was provided for data-taking activities at the two-phase flow facility.
5. Several channels of the driven-shield-concept electronic circuitry were fabricated.

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

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6.42 MEASUREMENT OF ELECTROMAGNETIC INTERFERENCE AT THE PKL FACILITY

M. J. Roberts J. L. Horton M. B. Herskovitz

Electromagnetic interference measurements were made and analyzed at the PKL reflood facility in West Germany. In this facility, a

phase-fired SCR ac power supply controls the power applied to fuel-rod simulators used for reflood experiments. In other, previous work, phase-fired SCRs have produced a very stong interference with low-level electrical measurements, such as those made with the film and impedance sensors to be supplied to the PKL facility by the AIRS program. This interference was due to electrical and magnetic fields of high intensity and a wide spectrum of frequencies. Also, in some cases, the ac power line voltage was distorted by short intense spikes or bursts of noise which corrupted the low-level measurements by coupling through their ac power supply.

In December 1977, measurements were made at the PKL to determine the severity of the electromagnetic interference at that facility.

Engineering and craft personnel of the Instrumentation and Controls Division designed and fabricated several sensors capable of measuring electric and magnetic fields both inside and outside the PKL rod bundle. The sensors and associated test and recording equipment were shipped to the facility, and 130 measurements were made of the following: (1) the electric field inside the bundle in the water and in air; (2) the magnetic field at various locations in the bundle, in the upper plenum, and outside the pressure vessel; and (3) the voltage and current applied to the bundle. Also, some measurements were made with a spectrum analyzer to determine the frequency content of the interference.

Since the measurements were made, an analysis was performed to determine the effects of the electric and magnetic fields on the performance of the electrical impedance measurement systems and to devise a way of filtering to optimally attenuate the effect of the interference.

6.43 DEVELOPMENT OF HIGH-TEMPERATURE METAL-TO-CERAMIC SEALS

M. B. Herskovitz J. O. Hylton
A. J. Moorhead[1] C. S. Morgan[1]

Metal-to-ceramic seals for impedance sensor electrodes were developed for application in the high temperature environment of a reflood experiment. The film and impedance sensors which are installed in the core bundle of a reflood experiment must be able to withstand steam temperatures of 950°C and the severe thermal shock which results from the sudden quenching due to injection of the emergency core cooling water. An aluminum oxide based cermet containing platinum was developed as an electrical insulator. This cermet can withstand all of the specified environmental conditions without cracking or leaking. No commercially available ceramics could meet these requirements.

The remaining essential part of a sensor assembly is a suitable ceramic-to-metal seal which will survive the above conditions. The combination of corrosive environment, high temperatures, thermal shock, and

severe thermal expansion mismatch between the metal and the ceramic makes this a formidable problem. A number of concepts involving various experimental braze alloys and seal designs using metals of low thermal expansion were investigated, and several viable concepts were identified. Development is continuing, and the most promising concept will be used in the first sensor assemblies to be delivered to the reflood facility.

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1. Metals and Ceramics Division.

6.44 INSTRUMENTATION OF STEAM-WATER TEST STAND

G. W. Greene R. L. Moore

Instrumentation for a steam-water test facility was designed, procured, and installed. The purpose of the facility is to provide an environment in which a wide range of known steam-water, two-phase flow conditions can be established in which to test developmental instrumentation for the advanced instrumentation for reflood studies program.

The instrumentation was designed to enable the experimentalists to make wide-range flow measurements in the steam and water systems, as well as measurements from which mass flow, velocity, quality, and density in the two-phase system can be determined. Additionally, this instrumentation will measure electrolytic conductivity and various system pressures and temperatures.

6.45 IMPEDANCE SENSOR TESTING

W. H. Leavell
W. H. Andrews J. E. Hardy[1]
P. A. Jallouk[1] C. O. McNew

Steady-state, air-water tests were performed to evaluate the two-phase velocity and void fraction measurement capabilities of various impedance sensor designs. This work is being done as part of the advanced instrumentation for reflood studies (AIRS) program. The scope of this work includes the development of testing plans and procedures, execution of tests in an air-water test facility, final data reduction and statistical analysis of the sensor signals, and data interpretation. The results of these tests are being used to identify optimum sensor designs and dimensions to provide in-vessel velocity and void fraction measurements during simulated, PWR-core, reflood tests.

Preliminary results of the air-water testing of the various sensors designs show the following:

1. Pure conductivity measurements in void fractions above 80% do not provide adequate, correlatable signals;
2. The measurement of complex admittance seems to give better results (higher signal levels and coherence) than simple conductivity measurements for void fractions greater than 80%;
3. The RMS signal level of the sensors for a given void fraction appears to be a direct function of flow volume sampled by each sensor;
4. Adequate correlations of sensor signals for velocity measurement have been obtained when the two sensors are separated 1 in. or less.

Future work will include steam-water testing of prototype sensors whose designs were established based on the air-water results.

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1. Engineering Technology Division.

6.46 ADVANCED TWO-PHASE FLOW INSTRUMENTATION SYSTEMS FOR REFLOOD FACILITIES

B. G. Eads
M. B. Herskovitz
J. O. Hylton
H. R. Payne[1]
M. J. Roberts
J. D. Stout[1]

Two-phase flow measurement systems are to be designed, fabricated, tested, and delivered to large scale reflood test facilities as a part of the advanced instrumentation for reflood studies program. Each system includes (as a package) the sensors, signal conditioning electronics, interconnecting cables, spare parts, complete documentation (drawings), instructions and procedures, on-site installation and start-up assistance, and signal processing and analysis software.

The first systems will be supplied for the PKL facility in West Germany. They will consist of ∿40 impedance sensors mounted in guide tubes for measurement of in-core velocities and void fractions, ∿10 film-thickness sensors, and ∿10 film-velocity sensors to be mounted in the core shroud wall. During the early test runs, the recorded data from these sensors will be processed at ORNL. As the analysis technique becomes routine, it will be transferred to West Germany.

ORNL plans to deliver such measurement systems to at least three additional foreign test facilities, one in West Germany, and two in Japan. The delivery schedule for these facilities extends from FY 1979 into FY 1981.

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1. *UCC-ND Engineering.*

7. HTGR FUEL RECYCLE DEVELOPMENT

7.1 SUPPORT FOR THE HIGH TEMPERATURE GAS COOLED REACTOR FUEL RECYCLE DEVELOPMENT PROGRAM

B. J. Bolfing

Instrumentation for the HTGR fuel recycle development program included support for engineering-scale as well as laboratory-scale projects. Instrumentation for many operating systems was developed and installed to demonstrate and test process operation. Conceptual designs were prepared for future systems, using criteria developed in laboratory-scale processes.

7.2 INSTRUMENTATION DESIGN CRITERIA AND COST ESTIMATES FOR A COLD PROTOTYPE TEST FACILITY

S. P. Baker
B. O. Barringer
H. E. Cochran
B. J. Bolfing
D. Gray[1]
R. C. Muller

This division developed instrumentation design criteria and provided system cost estimates that were included in a feasibility study for the cold prototype test facility. This test facility is being designed for testing full-scale, high temperature, gas-cooled reactor fuel recycle equipment and components that will be used in the remotely operated, hot engineering test facility.

Design criteria for the cold prototype, fuel rod fabrication machine were prepared. The primary control system components are a programmable logic controller for mechanical sequencing and interlocking and a microprocessor-based system to implement the algorithm for fuel rod length control. The contractor design is being reviewed.

A study and estimate report was prepared for the cold prototype, 24-cm coating furnace.

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Instrumentation design was started for the cold prototype, fuel assembly, "cure-in-place" furnace. These activities included preparation of specifications for all instrumentation components. A programmable logic controller was specified for overall control of the process.

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1. UCC-ND Engineering.

7.3 CONCEPTUAL DESIGN REPORT FOR A HOT ENGINEERING TEST FACILITY

S. P. Baker B. O. Barringer
B. J. Bolfing H. E. Cochran
C. C. Hall W. P. Murray

A conceptual design report was prepared for the hot engineering test facility. This remotely operated facility will be designed to evaluate the effects of radioactive, recycled high temperature, gas-cooled reactor fuels on the performance of fuel reprocessing and refabrication operations. The Instrumentation and Controls Division supplied the cost estimate, system flowsheets, and a written description of the process systems within the facility.

7.4 CONTROL UNIT AND SAMPLING SYSTEM FOR A MICROSPHERE COATER-UNLOADER LOOP

B. J. Bolfing R. E. Toucey R. Suchomel[1]

The control unit for unloading and inspection equipment for the 5-in.-diameter microsphere coating system was developed and installed. The system involves remote control of the unloading sequence, particle pneumatic transfer, and precise weighing of the microspheres. A multipoint sampling system was designed for monitoring oxygen to maintain a <10 ppm concentration within the system. The overall process sequence and interlocking is controlled by a programmable logic controller.

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1. Metals and Ceramics Division.

7.5 SYSTEM FOR DETERMINING THE HOMOGENEITY OF FUEL RODS

S. P. Baker B. O. Barringer
M. M. Chiles P. Angelini[1]

The homogeneity of uranium-thorium fuel rods was determined using the selective K edge absorption technique. An automated high resolution gamma spectrometer consisting of an intrinsic germanium detector and a multichannel pulse height analyzer was used to collect the data which was then stored in a computer. Radiation sources were selected which emit gamma photons appropriate for the experiment. A programmable logic controller was used to control the fuel rod translator and analyzer. Analysis programs were written for data acquisition, reduction, and computation of fuel rod homogeneity.

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1. Metals and Ceramics Division.

7.6 DEVELOPMENT OF CONTROL SYSTEM FOR FUEL-ROD MAGAZINE, LOADER-UNLOADER SYSTEM

M. Defenderfer B. O. Barringer

A microprocessor-based control system was developed to replace the minicomputer control system used to control the fuel rod. The microprocessor system, which provides a stand-alone capability from the time-shared minicomputer system, independently controls a three-axis positioning of the fuel rod storage magazine and the magazine loading-unloading mechanism. The minicomputer system now provides high-speed loading of programs to the microprocessor.

7.7 INSTRUMENTATION AND CONTROL FLOWSHEETS FOR FUEL-BLOCK LOADER AND STACK COLUMN ASSEMBLY

B. J. Bolfing R. F. Wolny[1]

Instrumentation and control flowsheets were developed for the HTGR stack column assembly machine and the HTGR fuel block loader system.

Stack column assembly is primarily a sequential process of assembling an HTGR fuel column consisting of fifteen fuel rods and four spacers. This process will be controlled by a programmable logic controller.

The fuel block loader consists of a three-axis positioning table for properly locating the high temperature, gas-cooled reactor fuel block and a fuel column loading mechanism. A microprocessor-based control

system will supervise positioning of the fuel block and load the fuel column into the fuel block.

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1. UCC-ND Engineering.

7.8 CONTROL SYSTEM FOR PROMPT-NEUTRON ASSAY OF HTGR FUEL RODS

D. D. McCue

A control system for automation of the nondestructive prompt-neutron assay of high temperature gas-cooled reactor fuel rods was developed and installed. A programmable logic controller was used to control assay mechanical sequences and interlocks and also to control data acquisition from the prompt-neutron detector.

7.9 INSTRUMENTATION FOR SAMPLE INSPECTION PARTICLE SIZE ANALYSIS AND PARTICLE SHAPE RATIO DETERMINATION

F. M. Schofner[1] G. Kreikebaum[1]
B. J. Bolfing J. T. Hutton

Microsphere fuel particle size distribution is determined for a flowing stream of particles by an analyzer and minicomputer data acquisition system. The stability of the system was improved by providing a dc feedback loop to control the particle size analyzer light source intensity and improving the signal to noise ratio of the detector/amplifier instrumentation.

A particle shape ratio instrument was developed to provide a two-dimensional orthogonal view of the high temperature, gas-cooled reactor fuel particle. Data from this system was fed to a minicomputer based data acquisition system for calculation of particle size and shape standard deviations.

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1. Private consultant.

7.10 INSTRUMENTATION FOR DETERMINATION OF THE OPTAF OF MICROSPHERE COATINGS

B. O. Barringer J. T. Hutton

The automatic determination of the optical anisothropy factor of microsphere coatings has been accomplished with equipment and software purchased from an Austrian company. The equipment was connected to a minicomputer for control and data analysis.

A more sophisticated device, a synchronous micro polarimeter (SMP), developed by the General Atomic Co. was investigated for this purpose. The automation of a manual version of this device was designed to have a phase-locked-loop controlled lock-in-amplifier to resolve the pertinent components from the composite microspectrophotometer signal. The SMP will be equipped with a microcomputer for on-line control, and complex data analysis will be done by a development computer system.

8. REACTOR MEASUREMENTS AND ANALYSIS

Measurements

8.1 IDENTIFICATION OF NEUTRON NOISE SOURCES IN A BOILING WATER REACTOR[1]

W. R. Sides, Jr. M. V. Mathis[2] C. M. Smith

Measurements were made of the noise signals from selected neutron and process sensors during full-power operation of two, 1067-MWe boiling water reactors (BWRs). The measurements were made to characterize the noise signatures from these sensors and to determine the usefulness of such signatures for anomaly detection in BWR-4s. This work is part of a five-part program to develop a complete and systematic analysis and representation of BWR neutron and process noise. The program includes (1) recording as many neutron detector and process sensor noise signals as are available in a BWR-4, (2) reducing these data to perform an empirical analysis of spatial and time relationships between signals, (3) developing useful mathematical models to aid interpretation of the data, (4) comparing empirical measurements with the results from the models, and (5) using the models to predict the usefulness of noise monitoring to detect in-core anomalies. The work reported here was accomplished under parts (1) and (2) of the program.

Approximately 70 hr of signals from 169 individual tests were recorded from units 2 and 3 of the Browns Ferry Nuclear Plant. The signals were analyzed in the frequency range from 0.01 to 1 Hz. The principal descriptor used in the analysis was the coherence function between selected pairs of signals. (This function is a measure of the significance of the effect of one signal on another.)

The results of the analysis indicate that the sources of neutron noise within the core in the frequency range from 0.01 to 0.1 Hz were more localized than those in the range from 0.1 to 1 Hz. Also, a peak in the coherence function at 0.5 Hz is evident in every pair of neutron signals tested (and in several process signals as well). The results also indicate that the coherence is sufficiently high to provide surveillance for some anomalies involving reactor pressure, total core flow, and total steam flow by monitoring the neutron signals from the average

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power range monitor system. However, the core driver flow, individual jet pump flow, feedwater flow, and reactor water level signals are not sufficiently correlated with the neutron signals to allow monitoring of these variables with the neutron signals.

The quality of most of the signals, obtained from the existing plant sensors and signal conditioning equipment, indicate that under normal full-power operation these signals are suitable for use with noise analysis surveillance and monitoring techniques to a frequency of ~1-2 Hz. Future efforts will be directed to the model development proposed in the latter three parts of the program. The preceding results indicate that the peaking observed in the coherence function at 0.5 Hz could be investigated by modeling only the core region.

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1. Abstract of paper presented at the Second Specialists' Meeting on Reactor Noise (SMORN-II), Gatlinburg, Tennessee, September 19-23, 1977, and published in *Prog. Nucl. Energy* 1(2-4), 119-135 (1977); also published in *Trans. Amer. Nucl. Soc.* 27, 678-679 (November 1977).
2. Technology for Energy, Inc., Knoxville, Tennessee.

8.2 CHARACTERIZATION STUDIES OF BWR-4 NEUTRON NOISE ANALYSIS SPECTRA[1]

M. V. Mathis[2] C. M. Smith
D. N. Fry M. L. Dailey[3]

Neutron noise analysis measurements were made in three BWR-4 reactors under full-power conditions to determine the noise characterization spectra of the reactors with two different instrument-tube cooling configurations. Both configurations were designed to prevent flow-induced vibration of the instrument tubes and subsequent damage of fuel channel boxes caused by impacts of the tubes with the boxes. Noise spectra from these three reactors were compared with spectra previously obtained prior to changing the instrument-tube cooling configuration, and no evidence of impacting was found.

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1. Abstract of paper presented at the Second Specialists' Meeting on Reactor Noise (SMORN-II), Gatlinburg, Tennessee, September 19-23, 1977, and published in *Prog. Nucl. Energy* 1, 667-672 (1977).
2. Technology for Energy, Inc., Knoxville, Tennessee.
3. Tennessee Valley Authority, Chattanooga, Tennessee.

8.3 DETERMINATION OF VOID FRACTION PROFILE IN A BOILING WATER REACTOR CHANNEL USING NEUTRON NOISE ANALYSIS[1]

M. Ashraf Atta[2] D. N. Fry
J. E. Mott[3] W. T. King[4]

Fluctuations in the neutron flux caused by steam bubbles were analyzed to infer the average void fraction in the four fuel bundles that surround an in-core detector string in a boiling water reactor. The velocity of steam bubbles was inferred from the phase lag between axially displaced in-core fission detectors. This velocity, together with the measured power distribution and mass flow rate, was used to obtain the void fraction as a function of axial position. The results are in agreement with the predictions based on the Zuber et al. model, except near the top of the fuel channel.

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1. Abstract of published technical note: *Nucl. Sci. Eng.* 66(2), 264-268 (1978).
2. IAEA Fellow from the Pakistan Institute of Nuclear Science and Technology, Nilore, Rawalpindi, Pakistan.
3. Consultant, Nuclear Engineering Dept., University of Tennessee, Knoxville.
4. Graduate Student, Nuclear Engineering Dept., University of Tennessee, Knoxville.

8.4 SUMMARY OF ORNL INVESTIGATION OF IN-CORE VIBRATIONS IN BWR-4s[1]

D. N. Fry
R. C. Kryter M. V. Mathis[2]
J. E. Mott[3] J. C. Robinson[3]

This report describes the use of noise analysis to investigate in-core instrument tube vibrations in BWR-4 reactors. Neutron noise signals from in-core fission chambers and acoustic noise signals from externally mounted accelerometers were used in these studies. The results show that neutron noise can be used to detect vibration and, more importantly, impacting of instrument tubes against adjacent fuel channel boxes. Externally mounted accelerometers detect impacting, but not rubbing, of instrument tubes against fuel channel boxes. Accelerometers can monitor impacting only on the particular instrument tube where the accelerometer is mounted.

Surveillance for instrument tube impacts can be accomplished using standard BWR-4 in-core power range neutron flux detectors at all instrument tube locations containing these detectors. Ex-vessel accelerometers can then be used to monitor instrument tubes that lack power range neutron flux detectors. However, noise on axial flux profiles obtained with

movable in-core detectors is not a reliable indicator of impacting, because the recorder used to plot the flux profiles does not respond adequately to the noise frequency generated by impacting.

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1. Abstract of published report: ORNL/NUREG/TM-101 (May 1977).
2. Consultant.
3. Consultant, Nuclear Engineering Dept., University of Tennessee, Knoxville.

Modeling

8.5 MODELING ACTIVITIES FOR SURVEILLANCE SUCCESS PREDICTION

F. J. Sweeney[1]

For the past year and a half we have been developing mathematical models and computational methods by which one may determine, without recourse to reactor measurements, the degree to which the nature of in-vessel noise sources (arising, for example, from structural vibrations, localized boiling or similar hydraulic disturbances, and other operational anomalies) may be ascertained using noise analysis of signals from installed plant sensors. As a first application, a noise-equivalent source for void formation and destruction in a boiling water reactor (BWR) fuel channel was formulated and, by means of a suitable time-dependent neutron flux computer code combined with a variational algorithm, the fluctuations in neutron density that would be expected to be "seen" by in-core detectors were constructed.

Although not nearly complete, the work to date has shown, for example, that axially separated sources of void noise must be statistically uncorrelated to produce the phase relationships that have been observed among in-core neutron detectors in operating BWRs.

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1. Graduate student, Nuclear Engineering Dept., University of Tennessee, Knoxville.

8.6 HTGR SAFETY ANALYSIS RESEARCH

S. J. Ball
J. C. Cleveland[1] J. C. Conklin[1]
M. Hatta[2] J. P. Sanders[1]

The purpose of high-temperature gas-cooled reactor safety analysis research for the U.S. Nuclear Regulatory Commission is to obtain

independent evaluations of analytical methods and accident studies. This confirmatory program, which has concentrated on current licensing questions for the Fort St. Vrain (FSV) reactor, consists of three major parts: code development, accident analysis, and code verification.

Our systems analysis capability consists of a family of computer codes, including an overall plant nuclear steam supply system (NSSS) simulation (ORTAP), and detailed component codes for investigating (a) core neutronic accidents (CORTAP), (b) shutdown emergency-cooling accidents via a three-dimensional core model (ORECA), and (c) once-through steam generator transients (BLAST). The component codes can be run either independently or in the overall NSSS code.

Several postulated accident sequences have been analyzed, including rod pair withdrawal accidents, design basis depressurization accidents, loss of forced-convection cooling accidents, and slow depressurization accidents. Sensitivity studies are run in conjunction with each accident to determine the importance of both model and parameter uncertainties.

Code verification efforts to date have consisted of using existing FSV dynamics data to compare against predictions. Comparisons made for a reactor scram from 28% power showed good agreement using ORECA. An optimization code was used to rationalize differences between the predicted and measured core regional outlet temperatures, and excellent agreement was attained by adjustment of parameters well within their uncertainty ranges.

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1. Engineering Technology Division.
2. Guest researcher from IHI, Japan.

8.7 EVALUATION OF THE GENERAL ATOMIC CODES "TAP" AND "RECA" FOR HTGR ACCIDENT ANALYSES

S. J. Ball J. C. Cleveland[1] J. P. Sanders[1]

The General Atomic codes TAP (transient analysis program) and RECA (reactor emergency cooling analysis) are evaluated with respect to their capability for predicting the dynamic behavior of high-temperature gas-cooled reactors (HTGRs) for postulated accident conditions. Several apparent modeling problems are noted, and the susceptibility of the codes to misuse and input errors is discussed. A critique of code verification plans is also included. The several cases where direct comparisons could be made between TAP/RECA calculations and those based on other independently developed codes indicated generally good agreement, thus contributing to the credibility of the codes.

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1. Engineering Technology Division.

8.8 ORTAP: A NUCLEAR STEAM SUPPLY SYSTEM SIMULATION FOR THE DYNAMIC ANALYSIS OF HIGH TEMPERATURE GAS COOLED REACTOR TRANSIENTS[1]

J. C. Cleveland[2] R. A. Hedrick[2]
S. J. Ball J. G. Delene[2]

ORTAP was developed to predict the dynamic behavior of the high-temperature gas-cooled reactor (HTGR) nuclear steam supply system for normal operational transients and postulated accident conditions. It was developed for the U.S. Nuclear Regulatory Commission (USNRC) as an independent means of obtaining conservative predictions of the transient response of HTGRs over a wide range of conditions. The approach has been to build sufficient detail into the component models so that the coupling between the primary and secondary systems can be accurately represented and so that transients which cover a wide range of conditions can be simulated.

System components which are modeled in ORTAP include the reactor core, a typical reheater and steam generator module, a typical helium circulator and circulator turbine and the turbine generator plant. The major plant control systems are also modeled.

Normal operational transients which can be analyzed with ORTAP include reactor start-up and shutdown, and normal and rapid load changes. Upset transients which can be analyzed with ORTAP include reactor trip, turbine trip, and sudden reduction in feedwater flow. ORTAP has also been used to predict plant response to emergency or faulted conditions such as primary system depressurization, loss of primary coolant flow, and uncontrolled removal of control poison from the reactor core.

ORTAP predictions will be compared with dynamic test results obtained from the Fort St. Vrain reactor owned by Public Service of Colorado, and based on these comparisons, appropriate improvements will be made in the code.

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1. Abstract of published report ORNL/NUREG/TM-78 (September 1977) and of paper "ORTAP: A Simulator of High Temperature Gas-Cooled Reactor Nuclear Steam Supply System Dynamics," pp. 359-369 in *Proc. Summer Computer Simulation Conference, Chicago, July 18-20, 1977.*
2. Engineering Technology Division.

8.9 SIMULATION OF THE RESPONSE OF THE FORT ST. VRAIN HIGH TEMPERATURE GAS COOLED REACTOR SYSTEM TO A POSTULATED ROD WITHDRAWAL ACCIDENT[1]

J. C. Cleveland[2]
S. J. Ball R. A. Hedrick[2]
J. G. Delene[2] J. C. Conklin[2]

Transients resulting from postulated accidental withdrawal of a control rod pair from the Fort St. Vrain HTGR core have been analyzed with a nuclear steam supply system simulation. Various cases have been investigated to determine what conditions and assumptions lead to the most severe core temperature transients. Results indicate that the most severe temperature transient occurs if the accident initiates from full power at beginning of equilibrium cycle conditions.

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1. Abstract of paper presented at the Amer. Nucl. Soc. Thermal Reactor Safety Meeting, Sun Valley, Idaho, July 31-August 4, 1977; pp. 318-336 in *Proc. Amer. Nucl. Soc. Meet. Therm. Reactor Saf.: Vol. 2*, CONF-770708 (1977).
2. Engineering Technology Division.

Studies and Evaluations

8.10 U.S. EXPERIENCE WITH IN-SERVICE MONITORING OF CORE BARREL MOTION IN PWRs USING EX-CORE NEUTRON DETECTORS[1]

R. C. Kryter J. C. Robinson[2] J. A. Thie[3]

Coolant flow forces and pressure pulsations in a PWR combine to cause pendular (and other more complicated) motions of the reactor core support barrel within its surrounding pressure vessel. The displacements are normally quite small (a few thousandths of an inch) and constitute no safety or operational problem, but in view of one past occurrence where movement increased with plant operating time to much larger values and some internal structural damage resulted, the U.S. Nuclear Regulatory Commission is considering developing recommended procedures for in-service monitoring for excessive core barrel motion. The experience of many workers suggests that such in-service monitoring can be performed nonperturbatively and quantitatively by decomposing and interpreting the signals

from the ex-core, power-range neutron monitors that are already a part of the usual PWR instrumentation.

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1. Abstract of paper presented at the International Conference on Vibration in Nuclear Plants, Keswick, England, May 9-12, 1978, and to be published in the proceedings of this conference.
2. Consultant, Nuclear Engineering Dept., University of Tennessee, Knoxville.
3. Consultant, P.O. Box 517, Barrington, Illinois.

8.11 INFERENCE OF CORE BARREL MOTION FROM NEUTRON NOISE SPECTRAL DENSITY[1]

J. C. Robinson[2] F. Shahrokhi[3] R. C. Kryter

A method was developed for inference of core barrel motion from the fluctuating component of ex-core neutron sensors using the following statistical descriptors: cross-power spectral density, auto-power spectral density, and amplitude probability density. To quantify the core barrel motion in a typical pressurized water reactor (PWR), a scale factor relating mills of motion to these descriptors was calculated in both one- and two-dimensional geometries using forward, variational, and perturbation methods of discrete ordinates neutron transport. A procedure for selection of the proper frequency band limits for the statistical descriptors was developed.

We found that although perturbation theory is adequate for the calculation of the scale factor, two-dimensional geometric effects are important enough to rule out the use of a one-dimensional approximation for all but the crudest calculations. We also found that contributions of gamma rays can be ignored and that the results are relatively insensitive to the cross-section set employed.

The proper frequency band for the statistical descriptors is conveniently determined from the coherence and phase information from two ex-core power range neutron monitors positioned diametrically across the reactor vessel. Core barrel motion can then be quantified from the integral of the band-limited cross-power spectral density of two diametrically opposed ex-core monitors or, if the coherence between the pair is ≥ 0.7, from a properly band-limited amplitude probability density

function. Wide-band amplitude probability density functions were demonstrated to yield erroneous estimates for the magnitude of core barrel motion.

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1. Abstract of published report: ORNL/NUREG/TM-100 (April 1977).
2. Consultant, Nuclear Engineering Dept., University of Tennessee, Knoxville.
3. Student Research Assistant, Nuclear Engineering Dept., University of Tennessee, Knoxville.

8.12 BANDWIDTH-RELATED ERRORS IN THE INFERENCE OF PWR BARREL MOTION FROM EX-CORE NEUTRON DETECTOR SIGNALS[1]

J. C. Robinson[2] R. C. Kryter

To quantify the effects of signal bandwidth on estimates of PWR core support barrel (CSB) motion inferred from ex-core neutron detector signals, we measured the amplitude probability density (APD) and root-mean-square (RMS) of signals from two sister PWR plants over several frequency ranges. The major conclusions from our study were: (1) inferred CSB displacements can be too large by a factor of at least ten if the neutron signal bandwidth is not limited to that frequency region where CSB motion constitutes the dominant source of signal fluctuations; (2) auto- and cross-power spectral density estimation methods yield approximately the same results, although the latter statistical descriptor has a greater capability for minimizing contributions from corrupting noise sources; and (3) APD and RMS methods yield consistent motion estimates when applied over the same frequency bandwidth and when a crest factor (ratio of peak to RMS) appropriate to random motion is assumed.

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1. Abstract of published paper: *Trans. Amer. Nucl. Soc.* 24, 413-15 (November 1976).
2. Consultant, Nuclear Engineering Dept., University of Tennessee, Knoxville.

8.13 ASSESSMENT OF A SIMPLIFIED METHOD FOR VIBRATIONAL QUALIFICATION OF NUCLEAR PLANT PIPING

J. E. Stoneking[1] R. C. Kryter

A subcommittee of the American Society of Mechanical Engineers (ASME) is attempting to develop a simplified qualification method by which nuclear plant piping systems undergoing vibrations can be assured safe, thus meeting the requirements set forth in the U.S. Nuclear Regulatory

Commission (USNRC) standard review plan and similar documents. Keeping the qualification methods both simple and applicable to a wide variety of piping configurations has necessitated the incorporation of many simplifying assumptions and approximations, all of which cast doubt on the accuracy of the results and the suitability of the acceptance criteria based on them. Accordingly, the USNRC requested that we critically assess the methodology currently proposed by the ASME subcommittee.

Since extensive experimental verification would be prohibitively expensive, we turned to finite element modeling and numerical analysis for initial guidance. Three realistic piping subsystems have been studied to date, ranging from two liquified natural gas applications (comprising a single pipe size and lacking concentrated masses) to a much more complicated nuclear plant auxiliary feedwater system (comprising main and branch pipes, heavy valves, one-, two-, and three-dimensional restraints, and similar complexities).

Our assessment is not complete but initial results indicate that the ASME simplified qualification method is quite conservative in that it *over*predicts the maximum pipe bending stresses by factors of 5-30, depending on the subsystem geometry, material properties, and mechanical restraints employed in the design. We believe that it will be necessary to analyze several more piping systems before the universality and general magnitude of this apparent conservatism can be confirmed.

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1. Consultant, Engineering Science and Mechanics Dept., University of Tennessee, Knoxville.

8.14 LOOSE-PARTS MONITORING: PRESENT STATUS OF THE TECHNOLOGY, ITS IMPLEMENTATION IN U.S. REACTORS, AND SOME RECOMMENDATIONS FOR ACHIEVING IMPROVED PERFORMANCE[1]

R. C. Kryter C. W. Ricker J. E. Jones[2]

At the request of the U.S. Nuclear Regulatory Commission (USNRC), an assessment of the technical development status of loose-parts monitoring systems (LPMS) and their performance record to date in commercial light-water-cooled nuclear reactor plants was made during the spring of 1977, using an on-site personal interview and equipment demonstration approach. Our study revealed that while presently demonstrated LPMS technology does indeed provide a capability for detecting the *presence* of those relatively massive loose parts that would likely constitute a serious operational or safety hazard to the plant, it unfortunately affords little information useful to the determination of the parts' safety significance and has not yet attained the levels of sophistication and reliability ordinarily associated with safety systems. We also found a need for specification of the functional requirements for LPMS, in the form of a statement of NRC policy regarding the formulation and implementation of safety-oriented,

yet operationally practicable, loose-parts monitoring *programs* for both existing and future nuclear generating stations so that overall objectives of both the utilities and the regulatory agency might be satisfied simultaneously.

While it is our best technical judgment that loose-parts monitoring programs providing reliable *detection* (but not *characterization*) capabilities could be implemented with today's technology, the path on which the nuclear utility industry should proceed in order to meet USNRC expectations is not completely clear. A Regulatory Guide entitled "Loose Part Detection Program for the Primary System of Light-Water-Cooled Reactors," soon to be issued for public comment, constitutes a first step towards satisfying this need for guidance and goal establishment.

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1. Abstract of paper presented at the Second Specialists' Meeting on Reactor Noise (SMORN-II), Gatlinburg, Tennessee, September 19-23, 1977, and published in *Prog. Nucl. Energy* 1, 667-672 (1977).
2. Student Research Assistant, Nuclear Engineering Dept., University of Tennessee, Knoxville.

8.15 AN INVESTIGATION OF THE EFFECTS OF SOME SAFETY SYSTEM MODIFICATIONS ON THE SAFETY OF THE HFIR[1]

R. S. Stone O. W. Burke

A need for noise reduction in the High-Flux Isotope Reactor has led to proposals to modify modes 2 and 3 by adding smoothing capacitors to signal amplifiers and by removing the rate trip to lessen the effects of noise. Since both proposals can slow the safety system response, it must be demonstrated that the modified system still gives satisfactory protection against design basis accidents. Analog simulation was used to determine the effect of the proposed changes on the overall safety system response. In addition, many previously run transient simulations were repeated using up-to-date values for system parameters. Safety system response with the proposed changes was found to give adequate protection against the most challenging combination of mishaps which are even marginally possible.

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1. Abstract of published report: ORNL/TM-5738 (June 1977).

8.16 MODIFICATION OF THE HFIR SAFETY SYSTEM

J. L. Anderson D. S. Asquith
R. E. Battle O. W. Burke

The safety system in the High-Flux Isotope Reactor was modified to allow reactor operation in modes 2 and 3. Prior to this modification, the reactor would trip on flux level or flux rate whenever modes 2 or 3 were selected, even though the reactor would be in the shutdown condition.

It was shown that 60-Hz noise was causing the trip when the safety flux amplifier gain was increased by a factor of 60 to mode 2 and 1500 to mode 3. Feedback capacitors were added to the flux amplifier to prevent level trip caused by the noise. This change was not sufficient to prevent a rate trip in modes 2 or 3, but since the rate trip was not originally designed to provide protection in these two modes, it was eliminated for them. In the original installation the rate trip did not interfere with operation in modes 2 or 3, but subsequent modifications made the rate trip more susceptible to noise. It was demonstrated on an analog computer facility that the additional time delay in the response of the flux level trip and the removal of the rate trip would not result in unacceptable fuel temperatures. The safety system has been modified, and the reactor can now operate in modes 2 and 3.

8.17 MODIFICATION OF THE HPRR POSITION INDICATION SYSTEM

G. W. Allin R. E. Battle

The existing synchro drive arrangement for the position indication system of the Health Physics Research Reactor was modified to improve its read-out accuracy.

All gears in the instrument gear case were pinned to their shafts, and the existing universal joint connection to the reactor drive shaft was replaced with a pair of zero-backlash, wafer-type, clamp hub couplings. (This also simplifies zeroing the read-out system.)

A synchro-to-digital, shaft-angle-position, read-out device which operates off a synchro transmitter signal and therefore uses the existing transmitter and signal cables was incorporated into the system. Because the digital panel meter has a high impedance and requires very little signal power, it enables the use of a remote display (~1/4 mile) without amplification, as was required with the synchro receiver. This device has improved the accuracy of the position indication system.

8.18 ANALYSIS OF REACTIVITY CONTROL SYSTEMS

S. J. Ditto

The purpose of this task is to aid the Division of Systems Safety (DSS) of the Office of Nuclear Reactor Regulation (NRR) of the U.S. Nuclear Regulatory Commission (USNRC) to evaluate the potential for and consequences of failures within the reactivity control systems of nuclear power plants. The specific activities include evaluation of systems used by the four U.S. light-water reactor manufacturers, with emphasis on their conformance with existing regulatory criteria.

The work included a review of a Westinghouse report, WCAP-8976, *Failure Mode and Effects Analysis of the Solid State Full Length Rod Control System.* A letter report of the review was submitted to the DSS and was followed by a list of proposed questions to be submitted to the manufacturer as a part of the review of a Westinghouse standard plant.

Future work will include obtaining detailed information on each system under review by the USNRC, reviewing these systems, and responding to specific requests from the USNRC on an ad hoc basis.

8.19 STUDIES OF AUXILIARY CONTROL AND PROTECTION SYSTEM INTERACTION

J. L. Anderson E. B. Johnson

This task is to evaluate the potential for auxiliary control system and protection system interaction in commercial nuclear power plants. Specifically, the task is intended to identify mechanisms whereby a failure within the auxiliary control systems could lead to unacceptable consequences owing to adverse control-safety interaction or to conditions for which protection is inadequate. As part of this task, a detailed study was made of the Babcock and Wilcox designed, integrated control system (ICS) as applied to the Oconee and North Anna plants. No direct or potential interactions between the control and protection systems were identified that, in the opinion of the reviewers, could significantly reduce their protective capability or increase the challenge rate. In general, it is believed that well-designed control systems tend to reduce the challenge to protection systems which result from control or load anomalies.

Similar evaluations are continuing for boiling-water reactor plants and pressurized-water reactor plants manufactured by other vendors.

8.20 NONSAFETY LOADS ON CLASS 1E POWER SOURCES

J. Lewin

The practice of supplying nonsafety loads from Class 1E power trains has been sanctioned by IEEE Standard 384-1977 and by U.S. Nuclear Regulatory Commission (USNRC) Guide 1.75. A survey was conducted for the Division of Systems Safety (DSS) of the USNRC Office of Nuclear Reactor Regulation among architect-engineering firms to determine current application of this practice. The existence, in practice, of non-Class 1E loads that are essential to the orderly shut down of a plant and that require reliable power supplies is the principal motivating reason for thus supplying nonsafety loads through an isolation system. The requirements that the isolation system be actuated by a signal derived from a plant accident condition, as well as by either fault current or remote manual switching, has necessitated complexity in the control circuitry of isolation systems that has been questioned because of the addition of potential for random failures.

Although earlier plants tended to supply relatively greater quantities and capacities of non-Class 1E circuits from Class 1E trains, the trend in later plant designs is to reduce such connections, thereby minimizing the risk of degrading the Class 1E systems.

8.21 ACCEPTANCE CRITERIA FOR BREAKERS AND FUSES AS ISOLATION DEVICES

J. Lewin

This task provides assistance to the Division of Systems Safety (DSS) of the U.S. Nuclear Regulatory Commission in the development of acceptance criteria for breakers and fuses as devices to isolate nonsafety loads from Class 1E power sources during upset conditions.

An attempt was made to obtain failure rate and reliability data from manufacturers for overcurrent protective devices (circuit breakers and fuses) in order to have a basis for evaluating the effect of accident signal actuation on the reliability of isolation systems. Such data proved to be essentially unavailable outside the framework of compliance with IEEE Standard 323-1974 and the "qualified life" projections made therefrom. Only one company responded with specific assumptions of the number of challenges per year for testing prototypes to demonstrate qualified life.

An attempt was made to obtain approaches of reactor plant operators to reliability and qualified life of equipment. Considerable differences in approach were found, but not enough reactor operating time has been accumulated to provide reliable statistics for comparison of the net effects.

Thus, an explicit relationship between design details, manufacturing and testing practices, qualified life projections, and statistical reliability data appears very difficult to establish.

8.22 STANDARDS FOR ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT BUILDINGS

G. E. Heberlein[1] F. H. Clark

Oak Ridge National Laboratory has been assigned the task of evaluating the U.S. Nuclear Regulatory Commission standards for electrical penetration of reactor containment buildings. The work is in progress and is being coordinated with related work in UCC-ND General Engineering.

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1. Consultant, Philadelphia, Pennsylvania.

8.23 APPLICATION OF DIGITAL COMPUTERS IN REACTOR PROTECTION SYSTEMS

J. B. Bullock

Technical assistance was provided to the U.S. Nuclear Regulatory Commission in evaluating the digital computer portion of the core protection system for the Arkansas One Unit-2 plant. This activity required numerous site audits, ranging from computer systems manufacturers to plant startup data assessment, and participation in several advisory committee on reactor safeguards (ACRS) review meetings. Inputs to the final safety analysis report were provided. Similar assistance was started for the review of a microprocessor-based protection system to be used on future Westinghouse reactors.

8.24 REMOTE MULTIPLEXING IN PLANT PROTECTION SYSTEMS

W. H. Sides, Jr.

As a part of the program of technical assistance to the Division of Systems Safety, U.S. Nuclear Regulatory Commission (USNRC), a review was made of the available remote multiplexing equipment and techniques to establish the acceptability of such techniques and systems in nuclear power plant protection systems. Discussions were held with remote

multiplexing system (RMS) vendors and users, including reactor manufacturers, architect-engineers, and the aerospace industry. The operational characteristics and design features of RMSs were reviewed, together with applicable industry standards, regulations, and regulatory guides. A report was written and transmitted to the USNRC which contained conclusions and recommendations in four principal areas: (1) the limitations imposed by the use of a discrete-data system, (2) the qualification of RMS equipment for use in the expected environments in field locations in a power plant, (3) the assurance of the separation and independence of redundant channels in the protection system, and (4) the assurance of reliability and availability through system design and testing. The report is currently being reviewed by the USNRC.

8.25 REVIEW OF TECHNIQUES FOR TESTING SENSOR RESPONSE TIME

W. H. Sides, Jr.

As a part of the program of technical assistance to the Division of Systems Safety, U.S. Nuclear Regulatory Commission (USNRC), a review was made of the techniques available for the measurement and surveillance testing of the response time of protection system sensors. A method is needed to ensure, on a continuing basis, that the response time of pressure, differential pressure, temperature, flow, level, and neutron flux sensors in the plant protection system is equal to or better than that assumed in the safety analysis of the plant. Discussions were held with the Electric Power and Research Institute (EPRI), reactor manufacturers, utilities, nuclear service companies, and sensor manufacturers to determine the advantages and disadvantages of the methods available or under development from both a theoretical and a practical point of view.

8.26 GENERATOR CIRCUIT BREAKER TEST EVALUATION

G. E. Heberlein[1] F. H. Clark

Nuclear power plant system design has come to the point where it appears desirable in some systems to place a circuit breaker between the generator and the low-voltage windings of the main transformer (permitting breaker action which isolates only the generator from this tie point). Several plants now under design or construction incorporate this feature. A circuit breaker so placed, however, operates at very high current, higher than any contemplated when test standards were formulated.

Special test requirements were therefore set up to apply to these circuit breakers. We have reviewed these procedures for the Division of Operating Reactors (DOR) of the U.S. Nuclear Regulatory Commission and found them to be reasonable extensions of existing requirements, and, in our judgment, adequate tests of the components.

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1. Consultant, Philadelphia, Pennsylvania.

8.27 STUDIES OF THE ELECTRIC POWER GRID

R. E. Battle
T. W. Reddoch[1] T. Inyai[2]
M. Ahmed[2] F. H. Clark

A number of tasks were undertaken in a power grid analysis program for the U.S. Nuclear Regulatory Commission (USNRC). In some studies we used load flow and transient stability programs supplied by Philadelphia Electric, and we are now making operable the long-term dynamics program developed by the Electric Power and Research Institute (EPRI).

Studies were made to determine under what conditions a power grid might provide degraded voltages over extended time periods. We sought cooperation of the Tennessee Valley Authority, the Mid-Atlantic Area Council, and the National Electric Reliability Council.

A sensitivity matrix was developed to help identify buses that have the most effect on some designated bus. This permits the development of more meaningful requirements in safety analysis reports. This work is being carried forward to try to identify indices which might signal in advance a possible instability and to develop criteria that can be used to determine when one condition of a grid can be said to bound another with respect to stability.

We studied the New York City power outage of July 13, 1977, and the Miami power outage of May 16, 1977, and reported on these with recommendations for corrective measures.

We assessed the maximum anticipated rate of frequency decay on a power grid in connection with a possible reactor safeguard problem.

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1. Consultant, Electrical Engineering Dept., University of Tennessee, Knoxville.
2. Graduate student, Electrical Engineering Dept., University of Tennessee, Knoxville.

8.28 STUDIES OF BWR CORE STABILITY

F. H. Clark P. J. Otaduy[1]

The computer code LAPUR-3 was brought to an intermediate state of completion, which permits the analysis of hydraulic and power stability of boiling-water reactor cores. Extensive spatial representation of the thermohydrodynamics of the core is used to determine the reactivity feedback to the neutron dynamics represented by the fundamental mode neutronic equations. The frequency response of the power of the reactor core to perturbations of reactivity, coolant flow rate, and coolant inlet temperature can be calculated.

A user's manual was prepared for the present state of the code.

The code has been applied to the study of the stability of the Hatch-1 BWR at the end of core-life and natural circulation operating conditions. The results obtained showed good agreement with those presented by the General Electric Co. to the U.S. Nuclear Regulatory Commission.

Work is continuing to implement in the code the three-dimensional representation of the core neutronics.

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1. Graduate student, University of Florida, Gainesville.

8.29 STUDY OF NEUTRON NOISE IN BWRs

F. C. Difilippo[1] P. J. Otaduy[2]

A study of the coupling between the global and the local components of the neutron noise was performed using the computer code LAPUR-3 with certain modifications to permit treatment of stochastic processes.

Preliminary calculations appear to confirm the rough spectral separation of local and global effects predicted by simpler models.

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1. Research staff, Nuclear Engineering Dept., University of Tennessee, Knoxville.
2. Graduate student, University of Florida, Gainesville.

8.30 INSTRUMENTATION FOR CONTROL AND SAFETY OF THE POWER BURST FACILITY

J. L. Anderson S. J. Ditto

Engineering assistance and consultation for the power burst facility at the Idaho National Engineering Laboratory were continued. Activities included a number of design changes to the protection system to accommodate "natural burst" operation, wherein power transients are terminated only by the fuel Doppler characteristics. A time-level safety circuit was adapted to provide "windows" of allowable operating characteristics and to initiate safety action if either the peak power or the allotted time at a particular power was exceeded. Special power measurement circuitry was necessary because acceptable operating conditions ranged from 20 MW steady-state to brief bursts reaching 3×10^5 MW. The instruments were designed and fabricated at ORNL.

8.31 NUCLEAR SAFETY INFORMATION CENTER

E. W. Hagen

The responsibility for collecting, evaluating, indexing, and disseminating information pertaining to nuclear control, instrumentation, and power plant electrical systems was continued for the Nuclear Safety Information Center. This center is in its fifteenth 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, application, installation, and operations for reactor instrumentation (component, modular, and system) and for the plant electrical system (supply, generation, and distribution). Approximately 2940 of these documents were reviewed, as were another 6896 pertaining to the licensing process, and were abstracted for the computerized information retrieval system. A total of 62 direct requests for specific information were received from the national and international nuclear communities.

8.32 NUCLEAR SAFETY JOURNAL

E. W. Hagen

Publication of *Nuclear Safety* under the auspices of the Nuclear Safety Information Center was continued. This journal is in its nineteenth year of publishing topical reviews and new information that have a particular significance for safety to members of the technical

nuclear community. Its primary emphasis is safety in reactor design licensing, construction, and operation; however, safety considerations in reactor fuel fabrication, spent-fuel processing, nuclear waste disposal, mining, handling radioisotopes, and environmental effects of these operations are also treated. Responsibility was continued for the acquisition, preparation, and editing of material related to reactor controls and instrumentation. Seven of the fourteen articles published in the Control and Instrumentation Section of *Nuclear Safety* during this period were authored by personnel of this division.

9. AUTOMATIC CONTROL AND DATA ACQUISITION

Computer-Based Systems

9.1 ACTIVITIES OF THE DIGITAL SYSTEMS DEVELOPMENT GROUP

R. R. Bentz J. M. Jansen, Jr. K. J. Cross

The development of computer-based data acquisition and control systems for laboratory research and engineering projects was continued. A PDP-11/34 minicomputer system was purchased for assembling, compiling, debugging, and documenting software codes and for developing and testing hardware interfaces. Use of this PDP-11 system will aid in the development of a new PDP-11 system or in the expansion of an existing PDP-11 system by reducing the risks associated with field testing, excessive downtime due to equipment nonconformance, or damage to the existing equipment due to the installation of faulty equipment.

The PDP-11/34 system consists of 32K words of MOS memory, a serial interface, and a dual, floppy disk drive with 512K words of bulk storage. An electrostatic printer/plotter was installed on the system. A second serial interface, an additional 32K words of MOS memory, and a high-speed, paper-tape reader/punch were installed to increase the system capabilities. An operator can communicate with the system through a hard-copy terminal operating at 30 characters per second. The system operates under a real-time system, residing on floppy diskettes, that supports high-level programming languages as well as assembly language program task development.

9.2 DATA SYSTEM SUPPORT FOR THE ENGINEERING TECHNOLOGY DIVISION

J. L. Redford

Computer-based data acquisition systems were installed at the forced convection test facility and fuel aerosol simulant test. Each system has a large removable disk, magnetic tape, and a 10,000 channel/sec analog

signal multiplexer. All software in the systems is based on FOCAL, with the data format on magnetic tape such that programs and data can be interchanged on all systems at ORNL that are equipped with a DATUM, Inc., high-speed analog scanner.

The data acquisition system for the thermal hydraulic, out-of-reactor safety[1] (formerly the fuel failure mockup) facility was expanded from 256 to 512 analog channels, and a second magnetic-tape unit was installed.

The data acquisition system for the multiaxial strain[2] test facility was updated to utilize a magnetic-tape unit for data storage. The software for this system was modified: FOCAL is now a background system, and eight real-time data collection tasks operate in the foreground. Each task can acquire data from up to eleven analog channels at repetition rates of from one set of data per second to one set of data per month. All data are retained on magnetic tape. All real-time tasks are set up and modified via FOCAL commands.

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1. J. L. Redford, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 45.
2. J. L. Redford and K. Liu, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1974*, ORNL-5032, p. 54.

9.3 CHEMICAL ENGINEERING RESEARCH COMPUTER SUPPORT

B. O. Barringer

A computer-based data acquisition and scientific analysis system was installed in the unit operations building 4503 for the Chemical Technology Division. The system is a medium size PDP-11/40 with disk storage, magnetic tape, analog and digital input/output capability, and several terminals. The RSX-11M real-time multitasking software system is being used.

On- and off-line data analysis support was provided for the fusion reactor cryosorption vacuum pumping studies. Devices interfaced to the computer include a mass spectrometer, several low-level temperature indicators, ion gauges, a liquid-helium level indicator, and a heater power indicator. Prior to the computer, data had been transcribed and analyzed manually, but now with the computer, the efficiency and utility of this data acquisition and analysis are greatly increased.

The computer system is being similarly used in support of the block pyrolysis studies for the in situ coal gasification program. Devices interfaced to the computer include a gas chromatograph, several thermocouples, and a wet test flow meter.

FORTRAN scientific data analysis support is being provided for the anaerobic upflow (ANFLOW), bioreactor development, and three-phase fluidized bed programs. A Tektronix plotting package and an Elographics graphic data digitizer are being utilized by these programs as data analysis aids.

9.4 UPGRADED COMPUTER SYSTEM FOR SNM ACCOUNTABILITY IN THE RADIOCHEMICAL SEPARATIONS PILOT PLANT

J. A. McEvers W. P. Murray A. M. Krichinsky[1]
R. M. Tuft L. R. Layman[2] T. H. Dunigan[2]
R. F. Wolny[3] W. R. Hamel J. M. Jansen, Jr.

Upgrading of the facility safeguards at the Radiochemical Processing Pilot Plant (building 3019) was started in 1976,[4] including ways to improve the accounting of special nuclear materials (SNM) within the pilot plant. The accountability methods and plant operations were analyzed to determine areas where the SNM accounting could be improved.

From this study it was determined that timely and accurate information could be obtained with an on-site computer that would receive direct, on-line inputs from pilot-plant-operations, accountability, and analytical personnel and from direct process monitors by means of electronic, differential-pressure transmitters. A proposal for such a computer system was submitted and funded. Detailed design of the hardware components was started, and functional requirements for the software were defined and reviewed by project personnel and the pilot plant staff.

A PDP-11/70 computer system was purchased. Development of software to obtain plant inventories, to monitor material transfers, and to acquire process data in real time was started. The software will maintain records of all transfers of SNMs into and out of the pilot plant and between logically defined control areas within the pilot plant. Electronic differential-pressure transmitters will be installed in the process vessels to transmit real-time measurements of liquid level and specific gravity to the computer for calculation of the in-process distribution of SNMs.

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1. Chemical Technology Division.
2. Computer Sciences Division.
3. UCC-ND Engineering.
4. W. R. Hamel, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 71.

9.5 CENTRAL SECURITY MONITORING AND ACCESS CONTROL SYSTEM

E. Madden J. A. Russell F. E. Wetzel[1]

A central, computer-based, alarm monitoring and card-key access control system was specified and ordered for installation at ORNL. It will monitor multiple alarm points located in safeguard security sensitive areas throughout the ORNL plant area, in addition to providing automatic card-key access control of many security areas at ORNL. The system will provide automatic logging of all alarm activity, interactive operator displays, and printouts of summary information upon operator request. An alphanumeric graphics CRT display terminal will display a running account of alarm activity, operator responses, and selected maps and information displays to aid the dispatchers in determining the proper response to individual alarm conditions. A separate backup alarm monitoring system will operate from signals derived from remote interface boxes during any downtime of the central computer system. In addition, a separate volumetric alarm monitoring system will monitor a large number of additional security areas. All electronic equipment in the system will have battery-powered, power-fail, automatic-switched power supplies. The system will provide audible alarms, lighted annunciators, access/secure operation, and multiple and redundant data transmission channels. The system is scheduled for delivery in October 1978.

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1. UCC-ND Engineering.

9.6 AUTOMATED CALIBRATION AND VERIFICATION SYSTEM

W. S. Coleman
A. F. Johnson, Jr. K. J. Cross
J. T. Hutton J. M. Jansen, Jr.

Data acquisition systems require a high degree of measurement assurance, i.e., proof that the data acquired are accurate within normal instrumentation limits. When such systems have a large number of instruments, manual calibration of the analog input subsystem and verification of the operation of the instruments are tedious and time consuming operations. Design of a system was started to perform these operations automatically under computer control.

The system will switch a selected instrument or group of instruments onto a verification bus, thus isolating the instrument from the data acquisition system; it will also switch single or multiple channels of the data acquisition system onto a calibration bus. The system will be controlled by the host computer through a standard IEEE 488 bus interface and expandable to 2048 channels. A failure detection circuit will ensure

that all field instruments are connected to the data acquisition system during normal operation.

The system will be initially implemented in the thermal hydraulic test facility and the core flow test loop.

9.7 COMPUTER-BASED DATA ACQUISITION AND CONTROL SYSTEM FOR IRRADIATION TESTING

J. M. Jansen, Jr. W. W. Manges J. A. McEvers

The Oak Ridge Research Reactor (ORR) data acquisition and control system previously reported[1] was expanded. Two magnetic-tape drives and a line printer were added to the system to enlarge the archival storage of experimental data for both computer and visual analysis. Additional analog signal multiplexing equipment and digital input/output equipment were purchased to handle the OC-2, OC-3, and OG-4 irradiation capsules. A user-oriented plotting software package was developed so that parametric studies of operational procedures could be made more easily for control of the capsules. Further expansion was started to make the software system capable of handling multiple control experiments.

Estimates were prepared and a request for funds was issued to instrument a heavy section steel test facility at the ORR poolside. Approximately 90 thermocouples will be monitored to obtain feedback for direct digital control of 24 electrically heated zones in two capsules. Other signals from support instrumentation will be monitored, limit-checked, alarmed, and logged.

An estimate and a request for funds were prepared to construct a remote monitoring facility at the ORR for irradiation experiments at the High-Flux Isotope Reactor (HFIR). In addition, a remote, operator access station will be placed at Y-12 to allow remote monitoring, set-point adjustment, and graphic display to eliminate travel to the reactor sites. These capabilities will allow one operator, with backup support by the operations engineer at Y-12, to service two experiments at the HFIR and three at the ORR from the ORR site during normal operational periods.

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1. J. M. Jansen et al., *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 42.

9.8 ELECTROCHEMICAL DATA ACQUISITION SYSTEM

E. Madden E. McDaniel

A Data General Nova 3-12 computer system was specified, purchased, and installed to implement the automatic data acquisition and control of molten salt electrochemical experiments of the thermodynamics and transport behavior group of the Chemistry Division. The existing experimental equipment (Q-2943, controlled-potential and controlled-current cyclic voltammeter[1]) was interfaced to the computer via a Data General, 12-bit analog-to-digital converter and four-channel input multiplexer with sample and hold on all channels. The computer is also used to compare experimental results with theoretical models. Additional computer equipment is being purchased to allow cross-compiling and interactive data reduction with an ECLIPSE computer used by the structural chemistry group of the Chemistry Division.

A system control program was written to control the data acquisition by specifying parameters such as experiment identification number, initial potential, value of current, maximum elapsed time between data points, and signal voltage or current increment that will cause a data point to be measured regardless of elapsed time.

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1. T. R. Mueller and H. C. Jones, Analytical Chemistry Division.

9.9 HIGH-SPEED ANALOG SIGNAL MULTIPLEXER CONTROLLER FOR A PDP-11 COMPUTER

K. J. Cross
J. M. Jansen, Jr. A. F. Johnson, Jr.
J. L. Redford R. M. Tate

The acquisition and recording of a large number of analog channels at high speed on a PDP-11 computer was required by the data acquisition systems of several currently active programs, including the thermal hydraulic test facility, the advanced fuel reprocessing program, and the core flow test loop. A controller capable of the required continuous operation of up to 2048 analog channels converted to digital data at a rate of up to 20,000 conversions per second was not commercially available. The controller was designed by the Instrumentation and Controls Division; the implementation and fabrication of the design was commercially contracted.

The analog signals can range from 5 mV to 10 V full scale. Double-buffering is used to provide continuous operation at 20,000 conversions per second to permit the data to be recorded on magnetic tape by computer software control.

Nuclear Spectrometer Systems

9.10 UPGRADE OF TWO-DIMENSIONAL POSITION-SENSITIVE DETECTOR SYSTEM

E. Madden

An upgrade was started of the Hewlett-Packard 21MX computer instrumentation for a small-angle neutron scattering spectrometer[1] located at the experimental hole HB-3 at the Oak Ridge Research Reactor (ORR). This facility will serve as one of three members of the National Small-Angle Neutron Scattering (SANS) Facility at ORNL. The other two members will be a 10-m, facility in Room 119 of the High Voltage Accelerator Laboratory (building 5500) and a facility sponsored by the National Science Foundation to be installed at the High-Flux Isotope Reactor.

The HP 21MX system will be expanded to 96K bytes of memory, with a 50M byte disk, and a Tektronix 4014-1 graphics CRT terminal. The user operation hardware and software will be the same, as closely as possible, in all three facilities. Both a synchronous and an asynchronous communication channel will be provided to the ORNL PDP-10 computer facility to enable interactive data file manipulation for the graphics display terminal. All applications programs will be written in FORTRAN. The system will continue to use the existing front-end interfacing to a Borkowski-Kopp position-sensitive gas-filled proportional detector.

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1. E. Madden, E. McDaniel, S. Spooner, and R. Childs, *Instrumentation and Controls Division Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 38.

9.11 EXPANSION OF COMPUTER CONTROL SYSTEM FOR AN AUTOCORRELATION NEUTRON TIME-OF-FLIGHT SPECTROMETER[1]

C. R. Mitchell

A computer-based system for the control and acquisition of data from a neutron time-of-flight spectrometer had been installed at the HB-4 beam hole at the High-Flux Isotope Reactor (HFIR).[1] After several years of continuous and reliable operation, the capability of the system was improved by expanding the time-of-flight scaler portion of the system from 16 to 32 inputs.

The spectrometer utilizes a magnetically pulsed neutron beam for inelastic neutron-scattering of liquids and solids. The beam is pulsed by changing the direction of the atomic magnetic moments in a ferrite crystal with an applied magnetic field. A sequence of pseudorandom pulses is generated, with duty cycles up to 50%. Synchronized to the pseudorandom code, the time-of-flight scaler accepts pulses from up to 16 detectors

and sends the time information with detector information to the computer. Autocorrelation methods are used to extract the desired information.

The electronics of the system consist of plug-in modules contained in a CAMAC crate with a common dataway. This modification required the addition of another four-unit-wide plug-in module to the existing CAMAC crate. To expand the system, 16 detector inputs were added by duplicating the existing 16-detector input circuitry and integrating the two by the use of multiplexers and decoders. The number of detectors that can be monitored by an experimentalist is switch selectable from 2 to 32 in powers of 2. The additional plug-in module was fabricated, installed, and tested, and is in use.

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1. F. W. Snodgrass and H. A. Mook, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1971*, ORNL-4734, pp. 30-31.

9.12 ELECTRON SPECTROMETER CONTROLLER

E. Madden E. McDaniel C. R. Mitchell

A PDP-11/34 computer system was specified, purchased, and installed for the surface defects group of the Solid State Division to automate and control data collection for four angle-resolved electron spectrometers. The system uses a DEC TR11 foreground/background operating system with FORTRAN. The operating system library is configured with selected routines from the DEC laboratory applications package and from the DEC RT11 scientific subroutine package, along with the extended FORTRAN library. A PDP-11/Nicolet 1070 analyzer interface ties the computer system to an existing Nicolet analyzer. Signal averaging routines are used for data reduction of the analyzer data. The system is equipped with a dual floppy disk and point-plot CRT display. The system has an AR11 real-time module to facilitate the interfacing to the spectrometers. The AR11 module is equipped with an 8-bit, programmable, real-time clock; a 10-bit, 16-channel, single-ended analog-to-digital converter with sample and hold; a 2-channel, digital-to-analog converter; and a CRT display control.

9.13 CRYSTAL PHYSICS SPECTROMETER FACILITY UPGRADE

E. Madden

A feasibility study and a conceptual design were prepared for the Solid State Division. This study recommends replacement of four independently controlled, older DEC PDP-8 series, neutron, triple-axis

diffractometer controllers and interface equipment [located at the High Flux Isotope Reactor (HFIR)] with new equipment to accommodate the changed and increased data acquisition and data processing needs of the crystal physics group. Much of the existing equipment is 13 years old, and all of the existing software is in machine language. It is no longer feasible to expand the existing facilities to accommodate new experimental procedures.

The recommended system will be a host computer system with communication network capabilities to four peripheral experiment control computers and to a PDP-10 computer operated by the ORNL Computer Sciences Division in the central research and administration building 4500N. The interfaces between the hardware and the control computer for the experimental apparatus will be designed with CAMAC instrumentation modules. All control and analysis software routines will be prepared in FORTRAN, which is essential since the neutron scattering program will expand to include more users outside ORNL. Time-share operation for storage and analysis of data, for preparation of programs, and for extended analysis and plotting of data via the PDP-10 computer will be accomplished without interrupting data collection at any experimental station.

9.14 POSITION-SENSITIVE PROPORTIONAL DETECTOR SYSTEM

E. Madden C. R. Mitchell

A PDP-8/E-computer-based x-ray diffractometer[1] used in the x-ray diffraction laboratory of the Solid State Division was upgraded. This unit is used for studying irradiation damage in crystals by diffuse scattering. A single-axis position-sensitive proportional detector was added to decrease the experimental run time by a factor of >1000 and, thus, to increase the x-ray diffraction efficiency. Also, an LDN, Inc., model 42418 sealed proportional counter with a high-resistance, carbon-coated quartz anode was installed on the system, along with a high-voltage power supply, amplifiers, cross-over detectors, a time-to-amplitude converter, and an analog-to-digital converter (ADC). A Tracor Northern TN1705 ADC was specified with the required external signals so that it could be interfaced to the PDP-8/E. A point-plot CRT display was added to the system, as was an RX8, dual, floppy disk drive. The system was configured to run DEC OS-8 operating software; DECUS programs 8-620A and 8-620B were modified to handle the single-parameter, single- and double-precision, PHA data acquisition and display.

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1. E. Madden, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1974*, ORNL-5032, p. 53.

9.15 GAMMA SPECTROMETER FOR OCEANOGRAPHIC STUDIES

R. T. Roseberry N. H. Cutshall[1]

A gamma spectrometry system was specified and procured for use in oceanographic studies by the Operations and Environmental Sciences Divisions. The spectrometer consists of a computer-based multichannel analyzer and a large-volume Ge(Li) detector. The analyzer has been delivered and is being tested for compliance to the performance specifications. Upon completion of checkout procedures, the system will be installed in the Environmental Sciences Division annex-B, building 3504.

1. Operations Division.

9.16 AUTOMATED GAMMA-RAY SCANNING SYSTEM FOR WASTE ASSAY IN DRUMS

R. T. Roseberry W. T. Clay

An automated scanning system for assaying low- to medium-density waste material contained in 55 gal drums was specified and purchased for the Operations Division. The system has been delivered for installation and operation in the radioactive waste storage building 7824. After the scanner has been installed and checked out, the limits of detection for various isotopes will be determined experimentally.

9.17 GAMMA SCANNER FOR CORE SAMPLES

R. T. Roseberry W. T. Clay
C. H. Abner[1] L. D. Eyman[2]

A system was built and installed in the Environmental Sciences Division annex-B, building 3504, to scan 4-in.-diam, ~4-ft-long core samples for gamma emitters. The scanner has a sodium iodide detector behind a collimator to sense gamma radiation as the core sample is stepped by increments of 2 in. An interface was designed and built to link the scanner to an existing computer-based pulse height analyzer for control. No special support software had to be generated to operate the core scanner. The design philosophy of the interface was to allow existing program sequences to cause system operation.

1. Plant and Equipment Division.
2. Environmental Sciences Division.

9.18 GAMMA SPECTROMETRY SYSTEM

R. T. Roseberry J. F. Emery[1] L. M. Jenkins[1]

A computer-based gamma spectrometry system was specified, procured, tested for compliance with ORNL performance specifications, and placed in service in the intermediate-level radiochemistry laboratory in building 3019 for the Analytical Chemistry Division. The system utilizes a form of distributed processing for its architecture to provide powerful data processing capability with flexible data accumulation capability.

Two Ge(Li) detectors are in current use, with plans for two more. Each detector is treated as a separate experiment and operated concurrently and independently of any other.

The system also functions as a data base for archival information. Each spectrum acquired is stored on industry-compatible magnetic tape that can be recalled and analyzed at any time or submitted to the computer center for analysis by programs available on the large computers.

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1. Analytical Chemistry Division.

9.19 DATA SCALERS FOR ND4400 SERIES ANALYZERS

R. T. Roseberry K. M. Henry T. A. Love[1]

A module was designed and built for the Neutron Physics Division to provide data scaler capability for their computer-based, ND4499 series pulse height analyzers. The module contains twelve 24-bit binary scalers that can be individually stopped, started, or read by the computer program. The scalers can be read sequentially by utilizing a "read next" instruction, which was implemented to facilitate fast readout.

An input data routing module was also provided to convert NIM fast signals to TTL levels. Fixed-width pulses are generated, limiting the count rate to $\sim$5 MHz.

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1. Neutron Physics Division.

Interfaces

9.20 COMPUTER INTERFACE FOR SMALL-ANGLE X-RAY SCATTERING CAMERA

R. G. Upton

A high-speed interface for passing the digitized x-y position of the incident photon from a two-dimensional detector to a MODCOMP III minicomputer was developed for the Metals and Ceramics Division. In addition to data handling, digital hardware was also provided for interfacing eight stepping motors and ORTEC scaler/timers to the computer.

Hardware for the interface includes a fast analog-to-digital converter (ADC) buffer, an SMS microprocessor, system control electronics, scaler/timer control logic, and stepping-motor control electronics with associated power supplies and drivers. The fast ADC buffer temporarily stores the x and y binary address which appears on the outputs of two ADCs.

The microprocessor generates an absolute memory address from the x and y coordinates and passes it to the MODCOMP III. A custom I/O macroinstruction then reads that word from memory, increments it by one, and stores it back in memory. The system control module handles all computer-microprocessor-interface handshaking and housekeeping. The scaler/timer controller allows the system scaler timers to be controlled and read by the computer. The motor controllers and power supplies allow the system operator to position the different elements of the small-angle x-ray camera, such as the specimen stage, the second pinhole, and the detector.

9.21 PDP-8/L INTERFACE FOR PERTEC MAGNETIC-TAPE DRIVES

E. McDaniel
J. W. Reynolds
A. J. Millet
R. E. Trumbull[1]

An interface was designed for the high-energy physics group of the Physics Division to couple two magnetic-tape transports (PERTEC model 8X40A) through an NRZI formatter (PERTEC model F849-36) to a PDP-8/L attached to the spiral reader. The formatter controls the read/write timing to the tape transports. Two twelve-bit words are written and read on the nine-track magnetic tape as eight-bit characters. The magnetic-tape interface control programs were written so that the operation of the main control program (OAKTREE) of the spiral reader, resident in a PDP-9, was unchanged.

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1. Ball Corporation, P.O. Box 1062, Boulder, Colorado 80302.

9.22 MODIFICATIONS TO A LINE PRINTER CONTROLLER FOR USE WITH A LINE PRINTER

J. W. Reynolds C. R. Mitchell R. E. Trumbull[1]

A model LP-15 line printer controller for a PDP-15 computer used by the nuclear and radiochemical analysis section of the Analytical Chemistry Division was modified to allow the controller to drive and control a Centronics 100 line printer. The system performs as designed.

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1. Ball Corporation, P.O. Box 1062, Boulder, Colorado 80302.

9.23 REMOTE START/STOP CONTROL FOR ADDMASTER PAPER-TAPE READER

C. R. Mitchell

An asynchronous data communication receiver LSI integrated circuit was added to the existing circuit of an Addmaster model 608 reader for the Health and Safety Division. That this reader can not be started or stopped remotely is a disadvantage in most applications. This modification permits the reader to be started and stopped from a remote location such as a computer site.

The timing for the asynchronous data communications circuit was derived from a crystal-controlled oscillator, and a selector switch allows the reader to operate at 110, 150, 300, or 1200 baud.

9.24 ASYNCHRONOUS DATA TERMINAL RECEIVER FOR TELETYPE MODEL 40 PRINTER

C. R. Mitchell

An RS232 compatible asynchronous data terminal receiver was built and interfaced to a Teletype model 40 line printer via a Teletype standard serial interface. The Teletype standard serial interface is a Teletype Corp. standard and is not compatible with the RS232 standard. This line printer is operating in parallel with a CRT terminal, and receives data at 110, 300, or 1200 baud. This model 40 line printer replaces a much slower Teletype model 33 printer previously used as a remote terminal.

Desk Calculator and Microprocessor Systems

9.25 PROGRAMMABLE CALCULATOR-BASED DATA ACQUISITION AND CONTROL SYSTEM DEVELOPMENTS

J. T. Hutton R. G. Upton R R. Bentz

At ORNL there are now 17 programmable, calculator-based data acquisition and control systems installed or on order, with a total value greater than $350 thousand. The systems are used mainly for acquisition of data and control of experimental apparatus, but some also enable data reduction and transmission to the PDP-10 computer in the central research and administrative building 4500N to use its existing programs, larger memory, and greater computing power.

Programmable calculators were interfaced to such laboratory instruments as a microprocessor-based grating drive, a photon counter, a digital calendar/clock, and a pulse-height analyzer, using standard interface units that plug into the programmable calculator. Software subroutines that handle any special formatting, packing/unpacking, etc. required by the instruments, were supplied with the interfaces. The availability of plug-in peripherals (multimeters, floppy disk drives, x-y plotters, and other units) has made assembly of the systems a building-block procedure and has obviated much of the routine interfacing previously required to put together a usable system.

Reliability of the installed systems has been good. All maintenance has consisted of etched wiring board or assembly change-out in the field (the longest system downtime was <24 hr). A maintenance contract covering most of the programmable calculator equipment at ORNL was purchased.

9.26 DATA ACQUISITION SYSTEM FOR PRESSURE VESSEL STUDIES

R. G. Upton J. T. Hutton

A Hewlett-Packard 9825, desktop, computer-based data acquisition system was installed in the pressure vessel technology laboratory for the Metals and Ceramics Division. The system is in use with a dynamics response module and a Nicolet digital oscilloscope to record and evaluate impact testing waveforms. A waveform, which is a description of the loading history of a specimen during impact, is analyzed by elastic-plastic fracture mechanics techniques to determine the dynamic fracture toughness of the material at the test temperature. The Nicolet trace and input parameters are recorded on magnetic tape for reference.

This system will be interfaced to a servohydraulic testing machine to control fracture toughness tests, analyze the data, and plot the results according to programmed curve-fitting instructions.

9.27 STRAIN MEASURING SYSTEM

R. G. Upton

A system for measuring and recording strains in terms of percentage strain was developed for the Metals and Ceramics Division to be used in TIG-A-MAJIG specimen testing. The system comprises a strain gauge conditioner which excites a resistance type strain gauge, amplifies and converts the output to binary coded decimal (BCD), and transmits the BCD to a Hewlett-Packard 9825 desktop computer. The computer formats the strain data and prints and stores them.

9.28 MULTIDECADE PRECISION POTENTIOMETER TO 488 BUS ADAPTER

C. R. Mitchell

For Solid State Division studies of radiation damage in metals at low temperature, a faster and more reliable way of recording information from a multidecade precision potentiometer was needed. An available Hewlett-Packard model 9825A desk calculator was judged suitable for this need because data can be entered into the calculator via a bus that complies with the IEEE 488-1975 Bus Interface Standard. An interface was built that reads the switch positions of a multidecade precision potentiometer and places the data on the 488 bus.

This system is an improvement over the previously used system because it reduces the number of operations and the time required to obtain the data in its final form.

9.29 AUTOMATION OF PRECISION MEASUREMENTS

R. L. Anderson D. W. McDonald R. K. Adams

The design of digital instruments has advanced to the point where they can be used for precision measurements and calibrations with an uncertainty of a few parts per million. Calibration of an instrument or sensor normally requires a large amount of data; furthermore, in calibrations it is always desirable and frequently necessary to include redundant measurements as checks. Automatic data acquisition makes collection of such large amounts of data practical even for routine calibrations, eliminates transcription errors, and can proceed around the clock on long-term tests.

Automation of precision measurements in a calibration laboratory, however, presents special problems, since many different types of

measurements may be performed in a day or a week. Thus, an automatic data acquisition system must be capable of being reconfigured and reprogrammed easily. The automation of precision measurements in the metrology research and development laboratory (MRDL) has emphasized the use of modular units which can be assembled into a special test assembly and then reconfigured for another test by plugging components together or unplugging with a minimum amount of software programming. The increasing availability of instruments compatible with the IEEE 488 general purpose interface bus makes this a viable approach.

Two systems are available in the MRDL for data acquisition: a microcomputer system which can be interfaced to measuring instruments through a multiprogrammer, and a programmable calculator which is interfaced to the IEEE 488 bus.

9.30 MICROCOMPUTER SUPPORT

D. W. McDonald

The Instrumentation and Controls Division operates a small microcomputer development system, consisting of a dual floppy-disk drive, PROM programmers, a high-speed tape reader, a high-speed printer (1200 baud) and the necessary software such as a text editor, and an 8080 assembler. This system, offered as a service to ORNL researchers, was used by researchers outside of this division to aid in modifying the software and hardware of their microcomputer systems. In addition, the staff of this division uses the system for specialized software development for individual researchers who need utility software quickly. These applications were in addition to the hardware and software development done by the Instrumentation and Controls Division on large microcomputer applications.

9.31 WWVB SIMULATOR

D. W. McDonald

The metrology research and development laboratory (MRDL) has an instrument which receives the WWVB timing signals transmitted by the National Bureau of Standards. Maintenance of the instrument is hampered outside of the MRDL since the device requires a special antenna to receive the signals. A microcomputer was used to simulate the WWVB code so that maintenance in remote field shops could be accomplished. The microcomputer uses the power line frequency of 60 Hz as a reference and generates minute, hour, and day of the year information. The entire simulator can be incorporated into a single-chip microcomputer and built into the instrument.

9.32 MICROCOMPUTER-BASED MICROSCOPE CONTROLLER

R. G. Upton

A microcomputer-based remote control system for a hot-cell microscope was developed for the Metals and Ceramics Division. The microscope is located inside a hot cell; a television camera mounted over the eyepiece sends a video display to the operator.

The microprocessor is a KIM-1 by MOS Technology. It positions the microscope table via stepping motors and determines and displays the x-y coordinates of the specimen with respect to a reference location. The microprocessor formats and prints selected data points on a teletypewriter and punches them on paper tape for processing. It can automatically index the microscope table through predetermined coordinates and can perform minor calculations such as summing and averaging data points.

9.33 MICROCOMPUTER-BASED DATA ACQUISITION SYSTEM

R. G. Upton

A microprocessor-based data acquisition system was fabricated for radiation creep experiments by the Metals and Ceramics Division. An Intel 8080 microcomputer module can monitor up to 16 digital instruments with binary coded decimal (BCD) outputs. A precision hardware timer interrupts the computer at 1-sec intervals as a reference for a software clock/calendar.

Two special-purpose instruments were designed and fabricated for the system: a voltage-to-frequency converter/scaler, and a load-cell conditioner. The converter/scaler is a long-term precision integrator for determining beam power, converting voltages to pulses, counting and displaying the pulses, and transmitting the total count to the microprocessor. The load cell conditioner excites a resistance type load cell, amplifies the output, converts the analog to BCD, and transmits the BCD over several hundred feet of cable to the microprocessor and a digital readout.

In addition to the special-purpose instruments, the system also monitors several general-purpose instruments, such as a thermocouple scanner, an infrared pyrometer, and digital voltmeters.

9.34 MICROCOMPUTER-BASED GAS ANALYZER CONTROLLER

R. G. Upton

A remote controller was developed for a precision mass analyzer used by the Metals and Ceramics Division. The controller, which programs the analyzer to monitor and log the quantities of specific gases present in controlled experiments, consists of a KIM-1 microcomputer module, an associated interface, and a teletypewriter. The software consists of a keyboard monitor that can be interrupted by a variable clock. The monitor accepts commands and parameters from the operator, such as the number of gases per test and the atomic mass unit number of each gas.

In operation, the program instructs the mass analyzer to monitor a specific gas. After a preselected interval, the timer interrupts the computer, and the program specifies another gas to be monitored. The analyzer displays the quantity of each selected gas on a strip chart recorder. The microprocessor also selects the proper range setting for the analyzer, reads the output of the mass analyzer, and automatically adjusts to the peak of a mass waveform.

9.35 IMPLEMENTATION OF A MULTIPROGRAMMER INTERFACE TO A MICROCOMPUTER

D. W. McDonald R. L. Anderson

An HP multiprogrammer was selected to interface the Leeds and Northrup precision digital voltmeter (PDVM) and scanner to the laboratory microcomputer, since it provides the versatility and modularity desired for the overall program of automation of precision measurements in the metrology research and development laboratory (MRDL). Implementation of the interface required four standard HP cards and two specialized cards. The parallel, binary coded decimal (BCD) input and output data codes and binary control codes from the PDVM are converted by the multiprogrammer to 16-bit words for input and output to the controlling microcomputer. The microcomputer is programmed to perform BCD-to-decimal conversions (and vice versa), to read and analyze data, and to generate proper control codes. This interface requires six of fourteen available slots in the multiprogrammer, leaving eight for future expansion to other instruments. By exchanging plugs in the rear, the multiprogrammer can be interfaced to the IEEE-488 general purpose interface bus, as well. Thus, the multiprogrammer provides a versatile means of interfacing older digital instruments to the IEEE-488 bus as well as to the MRDL microcomputer.

9.36 CONTROL AND DATA COLLECTION SYSTEMS FOR IRRADIATION OF HSST STEEL SPECIMENS

G. N. Miller A. A. Shourbaji J. M. Googe[1]

For the heavy section steel technology program, samples of steel are assembled into subcore size rectangles and placed at the face of a nuclear reactor core for prolonged irradiation and testing. Such tests were started at the Oak Ridge Research Reactor (ORR) in 1976. The Instrumentation and Controls Division supported this project by designing instrumentation for data gathering, temperature control, and reactor safety.

Electric heaters at the front and back faces of a specimen, variable-conductivity gas gaps, and cooling water channels were designed to hold the temperature gradient across a test specimen to a minimum over long periods and varied radiation levels.

A model of the heat transfer for the experiment was developed, and a control strategy was selected to maintain constant temperature in the specimen. Analog and digital simulations were run to establish the feasibility of this sytem.

Data collection is managed by a microprocessor-based programmable logger that monitors and records a total of 144 channels, of which 136 are for temperature monitoring and control. Temperatures are measured inside the encapsulated steel samples by thermocouples embedded and distributed on surfaces of the samples to determine the temperature profile during irradiation. Six moisture channels are also monitored to detect any water leakage from the reactor pool into the capsule and to sound an alarm when moisture reaches a preset value. (Moisture within the capsule could cause a specimen rupture due to the high temperature.) The data logger is interfaced with a magnetic tape recorder which stores experimental data for manipulation and output by an IBM/360 computer.

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

Software

9.37 PURCHASE REQUISITION EXPEDITING SYSTEM

R. L. Simpson

A computerized system was developed to expedite and report procurement for the Instrumentation and Controls Division. Information about all outstanding purchase requisitions initiated by the division is maintained in the system data base, which is updated weekly. Each month,

expediting lists are produced that show all past-due purchase orders and all requisitions for which purchase orders have not been issued. The data base may be interrogated at any time to produce lists of active purchase requests by section, group, engineer, buyer, work order/charge account, or date.

9.38 DIVISION ADMINISTRATION SUPPORT PROGRAMMING

R. L. Simpson W. P. Kinser

A computer program was developed using the DISPLA plotting package in the ORNL computer center library to plot the financial plans and actual costs of research accounts controlled by the Instrumentation and Controls Division. Financial plan information is entered via punched cards and stored by account number. Each month the actual costs for each account are entered into the system. These data are sorted, summarized, and plotted for perusal by program managers. Variances between planned and actual costs that exceed 10% are flagged for attention.

9.39 MULTIPLE USER FOCAL SYSTEM FOR THE PDP-8/E COMPUTER

J. L. Redford

A FOCAL software system was developed which will allow a single computer to service three users simultaneously. Each user can acquire and analyze data from outside sources via the analog signal input system of the computer. This FOCAL is a version that has many added functions and commands for user convenience. Each user has access to library programs and data storage on a large disk, and can access a magnetic tape unit, storage display scope, a line printer, and a high-speed paper-tape reader/punch. This system can also be used with two FOCAL tasks and any other real-time data acquisition or analysis program utilizing the third time period. The minimum requirements for the system are a PDP-8/E computer with 32K words of core memory and a 1.2 million word disk.

10. ELECTRONIC ENGINEERING SUPPORT FOR RESEARCH FACILITIES

ORMAK

10.1 STRUCTURES OF MAGNETOHYDRODYNAMIC MODES IN THE ORMAK TOKAMAK

V. K. Paré J. L. Dunlap[1]
R. D. Burris[2] J. H. Harris[3]

We have used digital Fourier analysis of signals from 33 detectors to determine the structure of magnetohydrodynamic instabilities in the ORMAK toroidal magnetic plasma confinement device operated by the Fusion Energy Division. These instabilities are studied because they tend to degrade plasma confinement and sometimes lead to gross disruption of the plasma. They consist of helical toroidal wave structures characterized by the integral numbers of waves or nodes m in the poloidal (short-way around) direction and n in the toroidal (long-way around) direction. The structures rotate at 5-15 kHz and thus produce oscillating signals whose relative phases can be used to deduce the mode structure. The results show that the plasma in ORMAK simultaneously supported two or three modes with m = 1 to 4, all with n = 1, and all phase-locked at the same frequency. The equality of frequency is most easily understood if the entire composite mode structure rotates toroidally.

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1. Fusion Energy Division.
2. Computer Sciences Division.
3. Now at the University of Wisconsin.

10.2 DUAL CURRENT-PULSE PREAMPLIFIERS FOR PLASMA DIAGNOSTICS

J. T. De Lorenzo J. T. Mihalczo
G. H. Neilson[1] J. F. Lyon[1]

A measurement of plasma temperature of the present ORNL tokamak can be obtained from the energy of charge exchange neutrals emitted by the plasma. This measurement requires a charge stripping cell and an electrostatic analyzer that employs a number of continuous electron multipliers ("channeltrons"). The extremely short collection time of the channeltrons (<12 nsec) and a high-count-rate requirement make current-pulse sensing of the channeltron more desirable than charge detection. In addition, the length of the external coaxial cable to the preamplifier will not significantly influence the signal-to-noise ratio of the measurement.

Five dual current-pulse preamplifiers (Q-5467A) with a current gain of 100 were assembled in five single-width NIM modules, giving a total capacity of ten channels of energy analysis. This high density of packaging was achieved with the use of hybrid, thick-film construction for a basic, "gain-of-ten" stage. This ORNL designed preamplifier is being used because of its low noise (∿3.5 dB with a 50-Ω source resistor), fast rise time (∿1.7 nsec), excellent gain stability (∿0.025%/°C), good overload for a 1.5-mA input current pulse, and effective input protection against voltage spikes.

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1. Fusion Energy Division.

Impurities Study Experiment

10.3 CAMAC BRANCH DRIVER OPTICAL-ISOLATOR LINK

E. Madden

An optically isolated CAMAC branch driver link was designed and fabricated for the Fusion Energy Division. The design goal was to extend the length of the transmit, receive, and bidirectional CAMAC branch buses to at least 300 ft and to provide 1500-V isolation between the two ends of the CAMAC branch. The optically isolated CAMAC branch was fabricated as two modules, a near branch end module and an extended branch end module, using differential line drivers and receivers and separate isolated power supplies. The optically coupled extended CAMAC branch will be used in the digital data system of the impurities study experiment (ISX).

10.4 PLASMA POSITION MEASUREMENT AND FEEDBACK CONTROL FOR THE TOKAMAK IMPURITIES STUDIES EXPERIMENT

J. L. Anderson O. Burenko[1] R. J. Colchin[2]

A system was developed for measuring and controlling the vertical and horizontal position of the plasma in the impurities study experiment (ISX) tokamak. The plasma position is computed by detecting the outer flux surfaces of the magnetic field developed by the plasma and by compensating for the effects of other strong magnetic fields which are unavoidably present and which vary with machine operating parameters. Control of the plasma position is accomplished by applying vertical and radial magnetic fields in response to a complex feedback control network. The control algorithm contains fourth-order differential equations synthesized in real time with analog computing elements. The system has performed very well throughout the one-year life of the experiment, which has now terminated.

A similar measurement and control system is now being developed for a new experiment, ISX-B. The control characteristics of the new experiment will be substantially different because of the high-energy, neutron beam injection to be employed, and different magnetic field configurations.

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1. UCC-ND Engineering.
2. Fusion Energy Division.

ELMO Bumpy Torus

10.5 MODIFICATION OF THE DATA ACQUISITION SYSTEM FOR THE EBT EXPERIMENT

J. W. Reynolds

The data acquisition system hardware[1] and the PDP-12 monitor program (EBTDAT) for the ELMO bumpy torus experiment were modified to include communication to a PDP-8/A-620. Both the PDP-8/A and the PDP-8/E experimentalist programs (CXADAT, HPADAT, GIDAT, and IBPDAT) communicate with the PDP-12 via an overlay to EBTDAT. The communication overlay was provided with a request-response list to allow future expansion of the request options. The data at the PDP-12 and the PDP-8s will be correlated with run numbers from the PDP-12 in the data files at the PDP-8s and with file names from the PDP-8s in the data files at the PDP-12.

Hardware interfaces and programs were completed for a charge-exchange experiment (CXADAT), an x-ray analysis experiment (HPADAT), an ultraviolet

grazing-incidence-spectrometer experiment (GIDAT), and an ion-beam probe experiment (IBPDAT). IBPDAT uses a CAMAC interface on a PDP-8/A-620.

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1. J. W. Reynolds, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 29.

10.6 PREPARATION OF SPECIFICATIONS FOR TWO COMPUTER SYSTEMS

J. W. Reynolds
R. A. Dandl[1] J. E. Francis[1]
P. W. Walstrom[1] O. C. Yonts[1]

Computer specifications were prepared and ERDA Manual, Appendix 1801 requirements were completed for two computer systems of the Fusion Energy Division. The computer specifications were TD-SP-No. 207 for "Data Acquisition Expansion on ELMO Bumpy Torus," and FE-SP-No. 220 for "An Interactive Data Acquisition System for the Super Conducting Magnet Development Program" (SCMDP). The EBT PDP-8/A-620 system was installed in November 1977, and the SCMDP PDP-11T60, PDP-11V03 system was installed in March 1978.

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1. Fusion Energy Division.

10.7 ±500 V dc AMPLIFIER

R. E. Wintenberg

A general purpose 500-V amplifier was designed for the ELMO bumpy torus experiment of the Fusion Energy Division. The amplifier gain is 50, it is direct coupled, and its output drive capability is ±500 V at 5 mA. The device is packaged, together with its rf power supply, in a single-wide NIM module.

10.8 STAIRCASE GENERATOR AND 5-kV AMPLIFIER

R. E. Wintenberg

These instruments were designed for the ELMO bumpy torus experiment of the Fusion Energy Division. The staircase generator decodes the digital address from a multiscaler into 16 or 32 analog steps. A breakpoint device allows the staircase to be separated into two slopes.

The 5-kV amplifier may be connected for either output polarity. It is all-solid-state, using series strings of high-voltage *npn* transistors. Incandescent lamps and silicon photocells are used as floating power supplies to provide power for driving each stage in the high-voltage strings.

10.9 DIGITAL INTERFACE FOR ULTRA-UV SPECTROMETER

R. E. Wintenberg

A digital interface and remote control unit was designed for the ELMO bumpy torus experiment of the Fusion Energy Division. This device joins a Tracor-Northern multichannel analyzer/multiscaler to an ultra-UV Minuteman spectrometer. It displays the spectrometer detector position, controls the spectrometer drive to move the detector in switch-selectable increments of thousandths and ten-thousandths of an inch, and inhibits the multiscaler clock and analyze functions during drive. In addition, manual controls are provided for drive, drive direction, and slow speed drive. Optical couplers and power supply isolation are used to keep ground-loop currents out of the detector.

Oak Ridge Electron Linear Accelerator

10.10 CAMAC TIME-TO-DIGITAL CONVERTER WITH MINIMUM DEAD TIME

R. W. Ingle

To determine precisely the neutron multiplicity of the fissile isotopes following a fission event, one must know the capture time of these neutrons in the detector. The neutron detector[1] can resolve events separated by 75 nsec; therefore, to avoid dead-time effects, the time of each neutron event should be measured with little additional dead time.

A multiple-event, digital, time-measuring device with low dead-time was developed to be used by the Neutron Physics Division in their neutron multiplicity experiments. Based on an idea by Hall and MacLeod,[2] this device has a shift register, a crystal-controlled clock source, logic gates, and a series of scalers to effect the time measurement. The system is initialized by a start pulse from the fission chamber. The clock pulses (62.5 MHz) are routed to eight separate scalers through separate front-panel connectors. Successive stop events are stepped through the shift register; its logic outputs stop, in succession, the clock outputs to each scaler. Eight events per start are processed. The clock count in the scalers, representing time-of-flight information, is processed by the CAMAC system computer. The shift register is capable

of stepping at a 25-MHz rate, and the time measurement permits time resolution of ±16 nsec. This technique is expandable to much higher frequencies. At present, the fabrication is incomplete.

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1. R. W. Ingle, J. H. Todd, and H. Weaver, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 34.
2. S. J. Hall and A. M. MacLeod, *Nucl. Instrum. Methods* 140(2), 283-287 (1977).

10.11 ORELA DATA ACQUISITION SYSTEM HARDWARE

Eight reports were issued under the same general title (above) for the Oak Ridge Electron Linear Accelerator. The abstracts of these eight documents follow.

Vol. 1: INTRODUCTION[1]

J. W. Reynolds

This report introduces the ORELA data acquisition system and reviews with a minimum amount of detail the component parts of the system, which are described with engineering and design details in Vols. 2-8 of this report. Each specifically designed piece of hardware is briefly described with a simplified block diagram. Modifications to standard peripheral devices are reviewed. A list of drawings and programming notes are also included.

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1. Abstract of ORNL/TM-5638 (January 1977).

Vol. 2: FOUR-CHANNEL PRIORITY MULTIPLEXERS[1]

J. W. Reynolds

This report describes programming, word formats, control signals, voltage levels, connector layouts, ground isolation, input level-matching, and a theory of operation with a simplified logic diagram for the four-channel priority multiplexer on the SEL 810B data acquisition computers at ORELA.

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1. Abstract of ORNL/TM-5639 (January 1977).

Vol. 3: SCALER INTERFACES[1]

J. W. Reynolds

This report describes programming, word formats, control signals, voltage levels, connector layouts, ground isolation, and a theory of operation with simplified logic diagrams for the scaler interface on the SEL 810B data acquisition computers at ORELA.

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1. Abstract of ORNL/TM-5640 (January 1977).

Vol. 4: ORELA DEVICE CONTROLLERS[1]

J. W. Reynolds R. E. Wintenberg

This report describes the programming, word formats, control signals, voltage levels, connector layouts, ground isolation, and a theory of operation with a simplified logic diagram for the ORELA device controllers. The ORELA isolated pulse generators (Dwg. No. Q-5109) are also described.

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1. Abstract of ORNL/TM-5641 (January 1977).

Vol. 5: SEL 810B/PDP-4/PDP-9 INTERCOMPUTER LINK[1]

J. W. Reynolds J. H. Holladay

This report describes the IOT assignments and programming for the PDP-4 and PDP-9, the ground isolation wiring, the connector pin assignments, a simplified theory of operation for the SEL 810B link interface, a detailed theory of operation for the link interfaces at the PDP-4 and the PDP-9, and the use of the PDP-4 and PDP-9 link interfaces as an input to the SEL 810B four-channel priority multiplexer.

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1. Abstract of ORNL/TM-5642 (January 1977).

Vol. 6: EIGHT-STAGE STACKING BUFFER MEMORY[1]

R. E. Wintenberg J. W. Reynolds

A stacking buffer memory for derandomizing data on high data rate experiments at ORELA is documented by a description of operation, mechanical details of design, and a detailed theory of operation illustrated through six examples of operation.

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1. Abstract of ORNL/TM-5643 (January 1977).

Vol. 7: INSTRUCTION MANUAL FOR THE MULTIPLEXER CHANNEL AND SCALER INTERFACE TESTER[1]

J. W. Reynolds

This report describes the method of use, operating instructions, theory of operation, and assembly details of the multiplexer-scaler tester.

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1. Abstract of ORNL/TM-5644 (January 1977).

Vol. 8: INSTRUCTION MANUAL FOR THE GROUND ISOLATION DRIVER AND RECEIVER CARDS ON THE QUIET GROUND SYSTEM AT ORELA[1]

J. W. Reynolds

This report describes the principle of operation of the ground isolation module, two types of ground isolation at ORELA, and instructions for testing the ground isolation circuit cards.

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1. Abstract of ORNL/TM-5645 (January 1977).

10.12 INCORPORATING CAMAC INTO AN ORELA EXPERIMENTAL SETUP

R. W. Ingle

Improved precision of measurements of experimental nuclear data usually implies the use of more-complex instrumentation. To achieve greater precision of neutron multiplicity measurements at the Oak Ridge Electron Linear Accelerator by the Neutron Physics Division, a CAMAC system was designed and incorporated into the electronic system. The basic data processor of this system is a Digital Equipment Corp., LSI computer, which is contained in a CAMAC module and is integrated directly with a CAMAC crate controller. The high density of CAMAC modules enables the experimentalists to monitor and control more experimental parameters. Experimental data rates are measured by CAMAC scalers and the computer, multiparameter time-of-flight and pulse-height information is processed, and external neutron filter devices are controlled. A primary purpose of this system is to more closely monitor data rates, bias levels, gain shifts, and other variables, and thereby to more accurately determine sources of uncertainty in the measurements.

At present a cathode-ray-tube video terminal with keyboard is used as the input and output terminal for the system. A more intelligent terminal controller is on order.

10.13 ABSOLUTE NEUTRON FLUX MONITOR USING A POSITION-SENSITIVE PROPORTIONAL COUNTER

J. H. Todd

A cylindrical, position-sensitive proportional counter was used as a hydrogen recoil counter. The active volume of the counter was determined by electronically setting the end windows at least four radii inside the physical end windows. Setting the end windows by this technique eliminates the end effect normally found in measurements made with this type of counter and greatly increases the accuracy of the neutron flux determination.

The counter is 60.9 cm in length and 5.08 cm in diameter. Its center-wire diameter is 0.076 mm. The electrical length of the counter is 1645 nsec.

Time instabilities total 2.5 nsec, but they are not directly additive. The maximum error of the volume is 0.15%. The signal-to-noise ratio is ≥10 with 0.83-μsec pulse-shaping time constants at 2 keV neutron energy.

10.14 DATA COLLECTION AND INTERFACE SYSTEM

J. H. Todd

A data collection system was developed and constructed to collect data from a time digitizer, two or more analog-to-digital converters, and eight 100-MHz scalers. The system presents these data for manipulation and storage in any of three SEL 810B computers. Signals to and from a computer were used as monitors to ensure that the overall system was performing as required.

10.15 EXPERIMENTAL ACTIVITIES FOR THE NEUTRON PHYSICS DIVISION

J. H. Todd R. W. Ingle

The Neutron Physics Division was assisted with cross-section measurements of fissile and fertile isotopes, including fission and capture measurements and neutron multiplicity measurements. This assistance was given in all phases of the experimental activity: planning of experiments, development of detectors and instrumentation, acquisition of instrumentation, and assembly of systems and testing to determine the accuracy of the measurements.

Activities in each of the five phases are summarized as follows. During planning of experiments, the authors' knowledge of the capabilities and limitations of detectors and instrumentation was considered in making decisions on the practicality of performing an experiment or in seeking alternative methods. Design and development of state-of-the-art instrumentation was undertaken when commercial instrumentation was not available. Development of new or improved detectors was continued to make measurements with higher accuracy or measurements with isotopes emitting high alpha activity. Both purchased and developed components were assembled into a data acquisition system. The systems were adjusted and tested to determine the overall accuracy of a measurement and to ensure that an unlooked for effect did not render the data invalid.

At other times, assistance was also provided for several Physics Division experiments.

10.16 SPIN DETERMINATION OF RESONANCE STRUCTURE IN (^{235}U + n) BELOW 25 keV[1]

M. S. Moore[2]
J. D. Moses[2] G. A. Keyworth[2]
J.W.T. Dabbs[3] N. W. Hill

Measurements made with a polarized neutron beam and a polarized target of ^{235}U have been analyzed to obtain spin-separated fission cross sections of (^{235}U + n) below 25 keV neutron energy. Analysis of the cross-section data in the resolved resonance region has been carried out to obtain better estimates of average parameters than those previously available. The average parameters have been used as the starting point for an extraction of energy-dependent average parameters in the unresolved resonance region. The results of this analysis show evidence for intermediate structure in the spin-4 component.

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1. Abstract of paper to be published in the *Physical Review C*.
2. Los Alamos Scientific Laboratory.
3. Physics Division.

10.17 THE $^{6}Li(n,\alpha)$ CROSS SECTIONS FROM 80-470 keV[1]

Cleide Renner[2]
J. A. Harvey[3] N. W. Hill
G. L. Morgan[4] K. Rush

The $^{6}Li(n,\alpha)T$ cross section has been measured from 80-470 keV at twelve discrete neutron energies produced using 8- and 12-in. iron filters at ORELA. The $^{6}Li(n,\alpha)$ events were detected with a 1-mm-thick, ^{6}Li glass scintillator whose ^{6}Li content was determined to <1% uncertainty from low-energy neutron transmission measurements. The neutron flux was measured with an NE-110 detector 7.5 cm thick and 10 cm diam. Monte Carlo techniques were used to compute the efficiency of the NE-110 detector and to correct for multiple interactions in the ^{6}Li detector. Values obtained in the vicinity of the resonance are 2.86 ± 0.06 barns at 218.7 keV, 3.30 ± 0.08 barns at 243.7 keV, and 2.46 ± 0.05 barns at 272.7 keV. An R-matrix fit by G. M. Hale (private communication, September 1977) to all our (n,α) data gives a peak cross section at ~240 keV of 3.36 ± 0.06 barns.

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1. Abstract of paper presented at the International Conference on Interactions of Neutrons with Nuclei, Lowell, Massachusetts, July 6-9, 1976.
2. University of Sao Paulo, Brazil.
3. Physics Division.
4. Neutron Physics Division.

10.18 THE 292.4-eV NEUTRON RESONANCE PARAMETERS OF ZIRCONIUM-91[1]

R. L. Macklin[2] J. A. Harvey[2]
J. Halperin[3] N. W. Hill

Resonance parameters, particularly the radiative width of the 292.36-eV s-wave level in $^{91}Zr + n$, have been reinvestigated. The spin assignment $J = 2^{+}$ is supported. The neutron width Γ_n = (866 ± 11) meV and radiative width Γ_λ = (86.8 ± 2.2) meV indicate less neutron capture than do parameters derived from earlier studies. This lower capture, however, is more compatible with integral measurements and a lead slowing down spectrometer measurement.

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1. Abstract of published paper: *Nucl. Sci. Eng.* 62(1) 174-176 (January 1977).
2. Physics Division.
3. Chemistry Division.

10.19 ANGULAR MOMENTUM DETERMINATION OF RESONANCES IN ^{24}Mg + n BY ELASTIC NEUTRON SCATTERING[1]

D. J. Horen[2] J. A. Harvey[2] N. W. Hill

The angular momentum values of fifteen resonances in ^{24}Mg + n have been determined by elastic neutron scattering. The change in shape of the differential cross section [i.e., $\sigma_{lJ}(E,\theta)$] versus angle has been observed for most of these resonances. Assignments of $l = 2$ for five resonances could be made on the basis of their distinct interference pattern in the 90° cross-section data.

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1. Abstract of published paper: *Phys. Rev. C* 15, 1168-1170 (1977).
2. Physics Division.

10.20 INTERMEDIATE STRUCTURE STUDIES OF ^{234}U CROSS SECTIONS[1]

G. D. James[2]
J.W.T. Dabbs[3] J. A. Harvey[3]
N. W. Hill R. H. Schindler[4]

Neutron induced fission and total cross sections of ^{234}U have been measured over the neutron energy range from a few eV to 8.9 MeV. Neutron and fission widths for 118 cross-section resonances below 1500 eV have been determined, and give a class I level spacing of 10.6 ± 0.5 eV and an s-wave strength function of $(0.86 \pm 0.11) \times 10^{-4}$. These fine structure resonances form two narrow intermediate structure resonances in the subthreshold fission cross section of ^{234}U. Parameters for the Lorentzian energy dependence of the mean fission width are deduced by maximum likelihood analysis on the assumption that, relative to this mean, the observed fission widths have a Porter-Thomas distribution. Two large fission widths measured for resonances at 1092.5 and 1134 eV prompted a likelihood ratio test which indicates the presence of a narrow intermediate structure resonances at 580 and at 1227 eV. The class II level spacing derived from the observation of seven intermediate structure resonances below 14 keV is 2.1 ± 0.3 keV. Broad structures in the fission cross section at 310, 550, and 770 keV are assumed to be due to β-vibrational levels in the second minimum of the Strutinsky potential. Fluctuations due to the presence of class II resonances are strongly evident for each of these vibrational levels. It is shown that the fluctuations near 310 keV are consistent with parameters deduced from the low energy data, and this allows parameters for the double-humped fission barrier potential to be obtained.

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1. Abstract of published paper: *Phys. Rev. C* 15(6), 2083 (June 1977).
2. AERE, Harwell.
3. Physics Division.
4. Summer participant, University of Rochester.

10.21 MEASUREMENT OF THE NEUTRON TOTAL CROSS SECTION OF SODIUM FROM 32 keV TO 37 MeV[1]

D. C. Larson[2] J. A. Harvey[3] N. W. Hill

The neutron transmission through an 8.1-cm sample of pure sodium has been measured for neutron energies between 32.5 keV and 37.4 MeV. The Oak Ridge Electron Linear Accelerator (ORELA) was used to provide the neutrons, which were detected at the 200-m flight path by an NE-100 proton recoil detector. The experimental results are tabulated and compared with the total cross section in the ENDF/B-IV file for sodium.

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1. Abstract of published report: ORNL/TM-5614 (October 1976).
2. Neutron Physics Division.
3. Physics Division.

10.22 MEASUREMENT OF THE NEUTRON TOTAL CROSS SECTION OF FLUORINE FROM 5 eV TO 20 MeV[1]

D. C. Larson[2] C. H. Johnson[3]
J. A. Harvey[3] N. W. Hill

Neutron transmissions through Teflon (CF_2) and carbon have been measured to provide high resolution transmission and cross sections for fluorine from 5 eV to 20 MeV. The Oak Ridge Electron Linear Accelerator (ORELA) was used for the neutron source. The 80-m flight path with a ^6Li glass detector was used for the low-energy measurements, and the 200-m flight path with an NE-110 detector was used for the higher-energy measurements. The various background contributions were carefully studied and are discussed in detail.

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1. Abstract of published report: ORNL/TM-5612 (October 1976).
2. Neutron Physics Division.
3. Physics Division.

10.23 MEASUREMENT OF THE NEUTRON TOTAL CROSS SECTION OF SILICON FROM 5 eV TO 730 keV[1]

D. C. Larson[2] C. H. Johnson[3]
J. A. Harvey[3] N. W. Hill

Neutron transmission through natural silicon samples has been measured for neutron energies between 5 eV and 730 keV. The Oak Ridge Electron Linear Accelerator (ORELA) was used to provide the neutrons.

The 80-m flight path with a ^{6}Li glass detector was used for the low-energy measurement, and the 200-m flight path with an NE-110 detector was used for the higher-energy measurements. The 1,488 resulting values are tabulated and compared with the current ENDF/B-IV evaluation.

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1. Abstract of published report: ORNL/TM-5618 (November 1976).
2. Neutron Physics Division.
3. Physics Division.

10.24 ^{7}Li NEUTRON TOTAL CROSS SECTION[1]

J. A. Harvey[2] N. W. Hill K. Rush

Neutron transmission measurements have been made upon three samples of ^{7}Li (N = 0.109, 0.3187, and 0.4675) loaned from LASL from approximately 100 eV to 40 MeV. The low-energy measurements were made at an 80-m flight path using both a ^{6}Li glass detector and a 2-cm NE-110 detector. The 200-m data were obtained with a 7.5-cm thick NE-110 detector using 5-nsec electron bursts. Of particular interest is the structure around 5 MeV.

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1. F. G. Perey and J. C. Gentry, *Status Report to the DOE Nuclear Data Committee*, ORNL/TM-6338 (April 1978), abstract, p. 5.
2. Physics Division.

10.25 TOTAL CROSS SECTION MEASUREMENTS OF THE ISOTOPES OF ZINC AND CHROMIUM[1]

J. B. Garg[2] J. A. Harvey[3] N. W. Hill

Neutron transmission measurements have been made from 50 eV to 500 keV on samples of the five isotopes of zinc and also two thin, natural-zinc samples. The low-energy measurements were made with a ^{6}Li glass detector with an energy resolution of approximately 1/1200. Above approximately 10 keV, an NE-110 detector was used at the 30-m flight station with 5-nsec electron bursts. The data have been analyzed to give neutron widths and strength functions of the individual isotopes.

Transmission measurements have also been made upon three of the isotopes of chromium ($^{52,53,54}Cr$) with an NE-110 detector at 80 m.

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1. F. G. Perey and J. C. Gentry, *Status Report to the DOE Nuclear Data Committee*, ORNL/TM-6338 (April 1978), abstract, p. 6.
2. State University of New York at Albany.
3. Physics Division.

10.26 NEUTRON RESONANCE PARAMETERS OF ^{249}Bk AND ^{249}Cf[1]

R. W. Benjamin[2] J. A. Harvey[3]
N. W. Hill M. S. Pandey[4]

Transmission measurements of two ^{249}Bk samples (98% Bk and 2% Cf) and two ^{249}Cf samples (70% Cf and 30% Bk) have been analyzed to give parameters of the resonances up to approximately 100 eV. Radiation widths for the first nine resonances in ^{249}Bk give an average radiation width of 35.7 ± 1.5 meV. Twelve resonances were observed in ^{249}Cf up to 20 eV which agree with resonances in the fission cross section; however, the total widths of many are considerably smaller than reported fission widths. Some details on this work have been reported in the Transactions of the ANS, San Francisco, Calif., Nov. 27 - Dec. 2, 1977.

We have recently made additional transmission measurements on the samples, which are now approximately 88% ^{249}Cf and 12% ^{249}Bk, from 0.02 to 1000 eV.

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1. F. G. Perey and J. C. Gentry, *Status Report to the DOE Nuclear Data Committee*, ORNL/TM-6338 (April 1978), abstract, p. 17.
2. Savannah River Laboratory.
3. Physics Division.
4. College of William and Mary.

10.27 PARAMETERS OF THE 203.4 eV RESONANCE IN ^{59}Ni + n[1]

J. A. Harvey[2]
J. Halperin[3] N. W. Hill
R. L. Macklin[2] S. Raman[2]

Transmission, capture, (n,α), and (n,p) measurements have been reanalyzed to correct for a misunderstanding of the ^{59}Ni content in the low-enrichment sample of ^{59}Ni. The original mass analysis of the thin sample used for transmission and capture measurements was 2.96 ± 0.03% of mass 59 (the sample also contained 0.4% Co). However, a recent mass analysis of the sample after it had been purified to remove cobalt showed the mass 59 content to be only 2.65 ± 0.02%. The initial analysis of the transmission data assumed the ^{59}Ni content was 2.96%. Hence, the value originally quoted for Γ_n from the sample is too low (by ~13%). The revised values for the 203.4 eV resonance are Γ_n = 9.6 ± 0.3 eV (J = 1), Γ_γ = 3.0 ± 0.3 eV, Γ_α = 0.43 ± 0.03 eV, and Γ_p = 0.055 ± 0.005 eV. The sum of these partial widths (13.1 eV) is in good agreement (within experimental uncertainties) with the measured total width (13.3 ± 0.2 eV) from transmission measurements. The contribution of this resonance (E_o in eV) to the thermal cross section can be computed from the equation

$$\sigma_{th}(n,x) \text{ barns} = \frac{0.6510 \times 10^6}{E_o^2} \frac{g\Gamma_n\Gamma_x}{\sqrt{0.0253\ E_o}} \left(\frac{A+1}{A}\right)^2$$

$$= 2{,}690\ \Gamma_n \text{ (in eV)}\ \Gamma_x \text{ (in eV)} .$$

The values obtained for the thermal capture, (n,α), (n,p), and absorption cross sections (at 0.0253 eV) are 78 ± 8, 11.4 ± 0.8, 1.43 ± 0.13, and 95 ± 9 barns. These are in good agreement with the experimental values for these thermal cross sections. Thus, the contributions of higher energy resonances or a bound level are unimportant.

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1. F. G. Perey and J. C. Gentry, *Status Report to the DOE Nuclear Data Committee*, ORNL/TM-6338 (April 1978), abstract, p. 7.
2. Physics Division.
3. Chemistry Division.

10.28 S- + D-WAVE NEUTRON ADMIXTURES LEADING TO RESONANCES IN ^{208}Pb: EFFECTS ON THE INTERPRETATION OF GIANT MI RESONANCE

D. J. Horen[2] J. A. Harvey[2] N. W. Hill

Numerous reactions have been utilized to study the excitation of excited states in the unbound region of ^{208}Pb. These include inelastic electron, proton, ^{3}He, and alpha-particle scattering on ^{208}Pb, as well as the ^{207}Pb(n,γ) and ^{208}Pb(γ,n) reactions. From this multitude of studies much information has been derived pertaining to the existence of giant resonances other than the well-known giant dipole resonance (GDR). However, there still exists considerable disagreement as to the existence and location of the giant monopole and magnetic dipole resonances, as well as the fine structure of the GQR. Although one cannot determine giant resonances in neutron transmission and scattering experiments, such measurements do have the advantage of very high resolution which can resolve the fine structure, as well as the capability of determining spins and parities of resonances in the unbound region. Such data can be utilized in some instances to test the validity of conclusions by others pertaining to giant resonances based upon other types of measurements with much poorer resolution.

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1. Abstract of published paper: *Phys. Rev. Lett. 67B*, 268-270 (1977).
2. Physics Division.

10.29 ABSOLUTE NEUTRON FLUX MEASUREMENTS USING AN NE-110 SCINTILLATION COUNTER[1]

Cleide Renner[2]
N. W. Hill G. L. Morgan[3]
K. Rush J. A. Harvey[4]

A neutron detector consisting of an NE-110 plastic scintillator has been calibrated for absolute neutron fluence measurements in the energy range from 80 to 500 keV. Efficiencies were determined by Monte Carlo calculations. Comparisons of measured and calculated pulse-height spectra are presented.

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1. Abstract of paper accepted for publication by *Nuclear Instruments and Methods*.
2. Institute of Atomic Energy, Sao Paulo, Brazil.
3. Neutron Physics Division.
4. Physics Division.

10.30 OAK RIDGE ELECTRON LINEAR ACCELERATOR IMPROVEMENT PROGRAMS

T. A. Lewis

The prebuncher program for improving the performance of ORELA in the short pulse (3 to 5 nsec) region is progressing favorably and nearing completion. The design work was completed, and all equipment was procured. The project is within the original budget and schedule, and the final phase of installation and tests is expected to be completed during the third quarter of 1978.

10.31 DEVELOPMENT OF A COMPUTER INTERFACE FOR ORELA

K. Rush

A computer interface was developed for the Physics Division to allow multiparameter data entry into the Oak Ridge Electron Linear Accelerator data acquisition computers. The interface incorporates a first-in, first-out buffer and appropriate TTL steering circuits. A full-panel display is provided to monitor the status of an experimentalist's data flow.

Oak Ridge Isochronous Cyclotron

10.32 MONITOR AND ALARM SYSTEM FOR TRANSIENT PROTECTION CIRCUITS

G. K. Schulze

A system was designed and built to monitor the outputs of the transient protection circuits of the Oak Ridge Isochronous Cyclotron (ORIC). The new design replaces equipment originally designed and placed in operation in 1963, with only minor revisions since then. The new equipment has operated without failure since October 1976. The performance of the system has been adequate and has met the criteria established for its design. A complete description of its theory of operation was written to aid in its maintenance.

The equipment consists of one nest of eleven circuit cards for the functions of signal comparator/detectors, alarm generator/drivers, and voltage regulators. With this system the universal signal comparator/detector card can be interchanged with any other card, and each card has a built-in test feature.

The signal comparator card consists of a differential input instrumentation amplifier, a voltage comparator/detector, and a dual alarm-bus driver circuit, as well as a 1-sec alarm timer circuit. The signal input range is determined by signal conditioner networks on each card connector. Also, the choice between "soft" and "hard" limiting is programmed by jumpers added to the card connector. The alarm timer circuit ensures that an audible alarm is generated for a minimum time when a fast transient is detected. The dual alarm-bus feature provides the option of driving the audible alarm and/or driving the rf drive alternator circuit to reduce power.

One other function provided is a circuit card that monitors the output of each of four high-power, rf linear power amplifiers. They are each compared against the average of the four. Alarms are generated if one or more is below or above average by a preset increment, or if any one exceeds the maximum rating.

10.33 MAGNET REGULATOR IMPROVEMENT PROGRAM

W. E. Lingar

The magnet regulator improvement program[1] at the Oak Ridge Isochronous Cyclotron (ORIC) was continued with the installation of eight trim-coil regulators. In early 1977, a prototypic trim-coil regulator consisting of two chassis of electronics was fabricated and, along with components and hardware, was sent to an outside firm for fabrication of ten additional sets of regulators. Installation of the new regulators

was started in July 1977 and was continued as permitted by ORIC downtime. While the regulators were being installed, new transistor banks, shunts, and rectifiers were also installed on each supply. Each regulator is interfaced with a computer to obtain on-off and set-point control from the cyclotron control room.

Since the installation was started, there have been no component failures and no cyclotron downtime that could be attributed to regulator malfunction.

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1. W. E. Lingar, *Instrumentation and Controls Div. Biann. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, p. 31.

10.34 MODCOMP III/CAMAC BRANCH INTERFACE

E. Madden

An interface to connect a CAMAC branch transmission bus to a MODCOMP III computer was designed, fabricated, and placed in operation for the Physics Division on the magnet power supply control computer for the Oak Ridge Isochronous Cyclotron (ORIC). The MODCOMP III differential I/O transmit and receive data buses were interfaced to the CAMAC standard single-ended branch transmit, receive, and bidirectional data buses. The interface was fabricated on a MODCOMP II I/O board. The interface was initially used to drive a color CRT display terminal via Kinetic Systems model 3232, programmable, color display modules.

Van de Graaff Accelerator

10.35 VAN DE GRAAFF ACCELERATOR ENGINEERING ACTIVITIES

R. P. Cumby

The control circuit of a 400-kV accelerator was modified to have two sets of double-transmitting Faraday cups to sense the helium ion beam output. The output is a signal to a circuit consisting of a differential amplifier, a ramp generator, and a light-pipe to control the beam focusing voltage. This replaces a dc motor drive and provides a much faster response time.

A neutron-gamma discrimination experiment was set up using a Nuclear Enterprises NE-213 liquid scintillator and a 56AVP photomultiplier tube to read the intensity of neutrons associated with the impurities study experiment (ISX) in the Fusion Energy Division.

A new Arhus ion source was installed with all new power supplies, except for the extract power supply, for the physics ion source test bench. Engineering support was provided for making instrument set ups for experiments for the 6-MeV tandem accelerator and the 5- and 3-MeV Van de Graaff accelerators. Technical support was provided for maintenance as needed.

Holifield Heavy Ion Research Facility

10.36 PROGRAMMABLE INTERCOMMUNICATIONS SYSTEM

W. L. Bryan C. C. Hall R. L. Robinson

An intercommunications system was developed at the request of the Physics Division for the Holifield Heavy Ion Research Facility. This system provides a user programmable intercommunication network throughout the facility for experimentalists and operations and maintenance personnel. The design, fabrication, and bench check out were completed, and field installation was started.

With this system, a user can define one- or two-way communication between two or more of sixteen areas in the building. A full 16 × 16 input-to-output assignment matrix was implemented. A general and emergency public address capability was integrated into the system.

Los Alamos Scientific Laboratory

10.37 TEMPORARY ASSIGNMENT TO THE LOS ALAMOS SCIENTIFIC LABORATORY

N. W. Hill

The author was temporarily assigned to LASL to participate and consult in many areas of nuclear physics and nuclear instrumentation. These activities were generally confined to neutron spectroscopy programs involving total, capture, scattering, and fission cross-section measurements, with active participation in high-energy physics measurements of π^+ cross-sections as well. One of the most intensive and interesting areas of research and consultation was in the area of weapons physics and diagnostics, which required a degree of reliability and ingenuity at a pace not normally encountered in conventional physics.

The author had many discussions with members of the Los Alamos Scientific Laboratory Health Physics and Laser Fusion Divisions and with WNR accelerator personnel on a variety of neutron spectroscopy problems.

Collaboration and consultation were continued in similar programs at ORNL for the Oak Ridge Electron Linear Accelerator (ORELA), both in conceptual designs and planned investigations in the same general area.

These collaborative programs between ORNL and LASL were continued in 1978 by virtue of an open-ended consulting contract with LASL for up to 20% of the author's time.

10.38 NEUTRON TOTAL CROSS-SECTION MEASUREMENTS OF ^{9}Be, $^{10,11}B$, AND $^{12,13}C$ FROM 1.0 TO 14 MeV USING THE $^{9}Be(d,n)^{10}B$ REACTION AS A "WHITE" NEUTRON SOURCE[1]

G. F. Auchampaugh[2] C. E. Ragan, III[2]
S. Plattard[3] N. W. Hill

High-resolution and high-accuracy total cross sections of ^{9}Be, $^{10,11}B$, and $^{12,13}C$ have been measured from 1.0 to 14 MeV. The Los Alamos Scientific Laboratory (LASL) tandem accelerator was used to produce a "white" source of neutrons by stopping a pulsed beam of 15-MeV deuterons in a thick beryllium target. The neutron energy resolution [full width at half maximum (fwhm)] achieved in kiloelectron volts is given by $1.4E(MeV)^{3/2}$, and the accuracy of the neutron energy scale in kiloelectron volts is given by $\pm 0.060E(MeV) \times \sqrt{1.79E(MeV) + 0.75}$. The statistical uncertainties in the transmission vary from 0.5% to 2%, and the systematic error in the transmission is estimated to ±1.7%. The high statistical accuracy of the ^{11}B data, for example, has revealed fine structure at high excitation energy (around 9 MeV) which correlates with the structure observed in charged-particle measurements on the same compound nucleus. There are also indications of additional structures that have not been seen previously in the ^{12}B compound nucleus at this excitation energy.

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1. Abstract of published LASL report: LA-6761 (June 1977).
2. Los Alamos Scientific Laboratory.
3. Centre D'Etudes De Bruyeres-Le-Chatel.

10.39 IMPROVED π^{+} SCINTILLATION SPECTROMETER WITH PARTICLE IDENTIFICATION[1]

N. W. Hill M. A. Moinester[2]
F. E. Bertrand[3] D. J. Malbrough[4]

The performance of a plastic scintillation spectrometer for use with positive pions in the energy range 10-60 MeV has been optimized.

The detector has a high efficiency for pion identification, and can be used in a wide range of pion physics applications.

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1. Abstract of paper submitted to *Nuclear Instruments and Methods*.
2. Tel Aviv University.
3. Physics Division.
4. University of Louisiana.

10.40 QUENCHED SCINTILLATORS FOR USE IN PION DETECTION[1]

N. W. Hill M. A. Moinester[2] D. J. Malbrough[2]

Tests were made with three types of scintillators: NE-111, NE-111 doped with 1% benzophenone [NE-111(1%)], and NE-111 doped with 2% benzophenone [NE-111(2%)]. Doping with benzophenone reduces the total light output, but improves, in principle, the decay characteristics of the output light pulse of the scintillator. The tests were carried out using gamma rays from a ^{60}Co source and with the NE-111 scintillators coupled to an EMI9822B phototube. The tube voltage was varied from 1800 to 2650 V. A comparison of the light output at the same operating voltage shows that NE-111(1%) gave 21% as much light as NE-111, but NE-111(2%) gave 6.9% as much light as NE-111.

With 50-MeV pions, the tubes were operated at 1800 V. From 1800 to 2500 V, there was a gain factor of twelve in the output voltage. Since with NE-111(1%) there was a loss of a factor of only about five in the output voltage, NE-111(1%) could be used with pions at operating voltages of approximately 2300 V, and the output voltages would still be reasonable ($\sim$1 V).

The NE-111(1%) was better (about 2 nsec) than the NE-111 in its decay characteristics. There was almost no more gain with NE-111(2%). The decay time was limited mainly by the EMI phototube and base characteristics. With a pole-zero circuit on the output pulse, the decay time could be reduced to about 9 nsec using NE-111, and to about 8 nsec using NE-111(1%).

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1. Abstract of a study for the π^+ scattering cross-section group at the Los Alamos meson physics facility.
2. Tel Aviv University.
3. University of Louisiana.

11. MISCELLANEOUS ENGINEERING SERVICES, STUDIES, AND DEVELOPMENTS

Engineering Services

11.1 CALIBRATIONS IN THE METROLOGY RESEARCH AND DEVELOPMENT LABORATORY

M. H. Cooper W. W. Johnston
J. D. Lyons R. L. Anderson

The following calibrations of a routine nature have been performed in the MRDL in the past year.

Temperature

Optical pyrometers, windows, and lamps	45
Resistance thermometers	35
Thermocouples	81
Liquid-in-glass thermometers	10
Thermistors	18

Electrical

Digital multimeters	37
Potentiometers	11
Bridges	9
Current and potential supplies	10
Ammeters	28
Picoammeters	4
Standard cells	25
Frequency	5
Resistors	6

Force, Pressure, and Acceleration

Tensile test machines	10
Pressure gauges	6
Accelerometers	4
	344

Over the past three years, the work load in routine calibrations has remained fairly constant; however, the manpower required for this work has decreased from about 2.5 to about 1.5 man-years, mainly because of a greater use of automatic and semiautomatic data acquisition and control. Special calibrations that were performed in the MRDL because of the availability of highly accurate equipment available are described in other sections of this report. In addition to the routine calibrations and special calibration work, the research on the properties of small-diameter (0.5 mm) sheathed thermocouples for the core flow test loop was continued and development of flowmeter calibrations has begun.

11.2 SPECIAL CALIBRATIONS, TESTS, AND EVALUATIONS IN THE MRDL

M. H. Cooper R. L. Anderson
W. W. Johnston J. D. Lyons

Because of a unique collection of many types of precision measuring equipment, the metrology research and development laboratory is frequently requested to perform special calibrations, tests, or evaluations of instruments or components. Some of these which were performed in the past year are as follows:

1. Evaluation of Bell & Howell pressure transducers, Arbor electronic weighing system, Orbitran weighing system, and differential pressure transmitters.
2. Evaluation and calibration of portable voltage and current standard.
3. Test of Vanzetti fiber optics infrared thermometer, Ircon blackbody source, two-phase flow sensors, and effect of gamma irradiation on thermistor probes.
4. Measurement of pressure drop in a specified length of instrument tubing at low flow rates, and capacitance of a 1/8-in.-OD, 10-ft-long thermocouple to 500°F.
5. Test of an active filter for the core flow test loop, and F. W. Bell Hall-effect power transducers.
6. Test and evaluation of photo detector for optical pyrometers.
7. Calibration of multirange, high-current standard resistors for ac and dc use.

11.3 POISSON RATIO DETERMINATION

D. W. McDonald

The work of the Metals and Ceramics Division in material research includes the determination of tensile strength, phase transitions, stress and strain tensors, and other properties of many sophisticated alloys.

Investigations of the Poisson ratio for a newly developed alloy were hampered because the signals to be measured were too small for the capabilities of the existing instrument. Because of funding and time constraints, the Instrumentation and Controls Division was asked to extend the measuring capabilities of the instrument, allowing the experiments to proceed on schedule. The addition of simple signal-conditioning circuitry involving multiple-pole active filters was sufficient to allow successful completion of the experiments.

11.4 REMOTE JOB ENTRY TERMINAL

E. Madden

A remote job entry (RJE) terminal was specified, purchased, and installed for the Solid State Division. The terminal transmits and receives Solid State Division theory group data files to/from the ORNL IBM 360 HASP facility. The batch terminal is a HASP-RJE multileaving workstation which will simultaneously transmit and receive from the ORNL IBM system 360, executing HASP with the RJE feature. The batch terminal consists of a DATA 100, HASP-RJE system 76 terminal; a 1000-line per minute, 132-column line printer, a 1000-card per minute card reader, and an interactive keyboard-CRT display operator console.

11.5 AUDIO-VISUAL FACILITIES FOR ENVIRONMENTAL SCIENCES LABORATORY

J. L. Lovvorn T. R. Barclay

Selection, procurement, testing, and installation of audio-visual equipment for the new environmental sciences laboratory building was completed. Items installed in the auditorium include chalkboards; a lecturn; a six-microphone input, two-column-speaker audio system, a monochrome closed-circuit television camera-video recorder/playback system; a high intensity, 16-mm motion picture projector; a high-intensity, 2 × 2 slide projector; a "long-throw" overhead projector; and an audio-tape-controlled, dual-slide-projector dissolve system. Hard-wired control circuits between the auditorium stage and the projection booth were installed to allow a speaker to control the slide projector by remote program control. The magnetic-tape-recorder-controlled, dual-slide-projector dissolve system will provide for the preparation of a hands-off slide presentation with prerecorded audio commentary.

11.6 TELEVISION MONITORING AND RF CABLE TRANSMISSION SYSTEM

A. L. Case J. A. Russell

A multichannel coaxial cable transmission system is to be installed at ORNL for video and data information from one location to another within the Laboratory and between the Laboratory and its outlying facilities. Outline specifications for the system were prepared by the Instrumentation and Controls Division. The system will be installed and operational early in 1979.

The cable system will consist of a network of coaxial cables. Up to 35 channels will be carried on each cable, using the 54- to 300-MHz spectrum. Originally, the system will be equipped for 40 cameras to be located in the field and 40 monitors at a central location. Relocation or addition of cameras and additional monitoring sites will be provided for by cable taps in the original installation. The system will be capable of carrying a variety of signals in either direction and will have substantial reserve capacity.

Specifications were prepared for equipment to be used with the system, including silicon, target-type interior cameras; intensified-silicon, target-type weatherproof cameras; video monitors; and camera remote controls. Multichannel, digital, video motion detectors will be installed; a continuous display and observation of all scenes will not be necessary, thus reducing operator fatigue and making him available for other tasks. Each video motion detector will continuously monitor up to 16 channels and display only the alarmed channels on the monitor screen.

11.7 RADIO COMMUNICATIONS SYSTEMS

R. L. McKinney J. A. Russell

Additions were made to the ORNL radio communications system by the procurement of seven base stations, five mobile units, and thirty-six portable radios.

Three of the main base stations were replaced as part of the program to bring the equipment into compliance with Office of Telecommunications policy regulations which will become effective on January 1, 1979. These regulations apply more stringent spurious and harmonic emission limits, which are needed to reduce interference resulting from increasing spectrum crowding.

Plans were made and specifications issued for the procurement and installation of a new radio control console in the communications center.

The 27-MHz, radio-paging system was replaced by a solid-state, ultra-high frequency transmitter (operates at 416 MHz) and 180 new paging receivers. Coverage inside the central research and administration building 4500 was greatly improved.

Some members of the engineering staff of this division served on a U.S. Department of Energy task force and a UCC-ND telecommunications coordination committee to study the needs, usage, and means of meeting the communication needs of UCC-ND and other contractor organizations. The proposal of a consulting engineering firm for an overall communications study was reviewed, and aspects of the plan will be used as a guide for the UCC-ND plan.

11.8 ENGINEERING SERVICES FOR ANALYTICAL CHEMISTRY

T. M. Gayle

The Analytical Chemistry Division was assisted in three areas: (1) consultation on special detector problems, (2) general engineering assistance in the development of on-line analyzers, and (3) modification and improvement of maintenance procedures.

A major effort was devoted to the development of detectors and instrument systems for characterizing cigarette smoke, both in the aerosol and gas phases. The previously developed optical concentration sensor was further refined and applied to multichannel exposure systems both at ORNL and other installations. New electronics packages, including improved amplifiers and digital integrators, were developed for use with the optical detector and with several gas-phase detectors in use.

Development engineering work was continued on a dedicated, flameless atomic absorption system for mercury, a total organic carbon analysis system, and a microwave emission spectrometer for gas chromatography.

11.9 ELECTROSTATIC PHOTOELECTRON SPECTROMETER

L. D. Hunt

Technical assistance was provided for assembly and testing of an electrostatic photoelectron spectrometer in the Analytical Chemistry Division for an electron spectroscopy for chemical analysis program. The spectrometer was assembled, and preliminary adjustments to optimize its resolution were started. The final assembly and the development of auxiliary equipment are in process.

11.10 INSPECTION AND MAINTENANCE OF LOW-LEVEL GAMMA-RAY SPECTROMETER SHIELD AT THE LUNAR RECEIVING LABORATORY

T. F. Sliski M. M. Chiles
R. E. Wintenberg V. C. Miller

In April 1977 an inspection of the spectrometer shield structure disclosed a continuing growth of the fill material (Chemtree cement and lead shot) and consequent further degeneration of the structure.[1] If this damage goes uncorrected and the degeneration continues, as now seems likely, serious damage to the shield could result. A procedure for repairs has been recommended.

The inner anticoincidence mantle on the spectrometer had developed very nonuniform rejection sensitivity. This was corrected by optically recoupling the photomultiplier tubes to the scintillator and adjusting the voltage on the tubes to produce approximately equal pulse amplitudes from each tube when the scintillator was exposed to a monoenergetic gamma source. After the gamma-ray spectrometer was completely reassembled, the Compton rejection sensitivity was very uniform throughout the inner mantle.

All the electronics associated with the gamma-ray spectrometer were tested and were performing properly.

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1. T. F. Sliski and V. A. McKay, *Instrumentation and Controls Div. Bienn. Prog. Rep. Sept. 1, 1974, to Sept. 1, 1976*, ORNL-5196, pp. 107-108.

11.11 REPAIR OF THE LOW-LEVEL GAMMA-RAY SPECTROMETER SHIELD AT ORNL

T. F. Sliski

In 1976 the low-level gamma-ray spectrometer shield was repaired to correct structural weaknesses. The fill material (Chemtree cement, a proprietary cement containing a high lead content, and lead shot) had either grown or expanded, resulting in ruptured welds and deformed structural members. The spectrometer was unsafe to operate.

To repair the unit, some fill material was removed, the structure was "pulled together" with clamps, and a jacket of steel plate was welded around the old structure.

11.12 CYTOLOGY SAMPLER

G. W. Allin W. L. Maddox[1]

Two cytology samplers were fabricated for the Research and Technical Support Division of the Veterans Administration Hospital in Tampa, Florida. This device is used for taking samples of exfoliated cells from the trachea of rodents that are being studied in cancer research.

Existing documentation which was used to build a prototype had to be upgraded and some improvements were incorporated into the design.

These units have been in service for over a year, and are performing satisfactorily.

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1. Oak Ridge Gaseous Diffusion Plant.

11.13 SHEATHED THERMOCOUPLE SOURCE OF SUPPLY DEVELOPMENT

J. H. Holladay
M. B. Herskovitz N. D. McCollough
R. L. Shepard R. M. Tuft

The large-scale procurement of temperature sensors (LSPTS) program continues to provide thermocouple testing, test method development, technical advice, and procurement assistance in obtaining thermocouples qualified to RDT Standard C7-6T for breeder reactor development applications. Since its inception, the LSPTS program has (1) written and revised RDT Standard C7-6T, (2) qualified four thermocouple manufacturers to meet this standard, (3) purchased over 28 km (93,000 ft) of certified bulk thermocouple material, and (4) supplied 17,700 thermocouple assemblies to 25 users in the FFTF plant and related test and development programs. The major activity the past two years was supplying high-quality Chromel/Alumel thermocouples for the FFTF and other breeder reactor development programs. All quality assurance problems were satisfactorily resolved. Users were supplied with a monthly status report showing priority allocations. ORNL was chosen to procure thermocouples for the Clinch River Breeder Reactor Plant (CRBRP). Atomics International, coordinator for the procurement of thermocouples for the CRBRP, estimates that 3925 thermocouple assemblies will be needed, requiring 5000 m (16,270 ft) of bulk material.

Specialized thermocouples have also been procured to provide high-quality temperature sensors for ORNL research groups. These sensors have been mainly those with small sheathed diameters and special sheath materials including tantalum, Inconel, and platinum and 0.5, 0.71, and 1.42 mm (0.020, 0.028, 0.052 in.) OD sheaths. Some orders, such as those for

the blowdown heat transfer (BDHT) bundle 2 and 3 required 3500 thermocouple assemblies. Thermocouples were also purchased for other Engineering Technology Division projects, including the thermal transient test, rod burst test facility, thermal hydraulic test facility, high temperature structural design (nozzle-to-sphere), thermal shock test, and the potassium topping cycle. Special thermocouples included fabrication of four and seven thermocouples in a single, 1.42-mm-OD sheath. Silica-insulated-coaxial and alumina-insulated-triaxial instrument cables were also procured. Sources of supply were developed for platinum-sheathed, 0.5-mm-OD thermocouples.

11.14 OPERATING REACTORS GROUP MAINTENANCE ACTIVITIES

K. W. West

Maintenance activities for the six operating reactors and associated experiments have required 10.5 man-years of instrument technician assignment. The overall amount budgeted for engineering and maintenance was $550,000, not including experiment instrument maintenance.

Some 7200 instruments have been entered in the I&C Maintenance Information System, with all primary control and safety instruments on the semiautomatic computer-controlled maintenance program. A total of 6515 maintenance calls have been reported during this period, requiring 2939 man-hours.

Eighteen reactor controls design change requests were processed. Four man-months was expended on preparation and updating of reactor controls maintenance procedures for the HFIR and BSR.

11.15 MAINTENANCE OF THE HFIR

D. S. Asquith J. M. Farmer K. W. West

Maintenance activities continued essentially as those of the previous reporting period. Approximately 90% of the programmed maintenance was performed on-line with the reactor operating. The remaining 10% required reactor shutdown, generally involving single-channel instrument systems essential for reactor operation or instruments in areas of high radiation.

System checkout procedures for the nuclear safety, servo, and counting channels were reviewed and updated. These procedures and accompanying check sheets were approved and are available for use.

The setpoints of all safety and control switches were reviewed and adjusted as required to assure conformance with the High-Flux Isotope

Reactor technical specifications. An analysis was performed which indicated that the rate trip was not required for safety protection for modes 2 and 3; it was subsequently disabled for these two low-power modes of reactor operation. This change was necessary to eliminate electrical noise problems encountered during modes 2 and 3 operation. These changes were authorized by reactor instrument and controls design change memoranda.

Three unscheduled reactor shutdowns occurred during routine testing of the safety channels when the second of three channels in the two-of-three coincidence system was tripped from unknown causes. These shutdowns accounted for 0.350 hr of a total of 0.483 hr of unscheduled reactor downtime.

11.16 MAINTENANCE OF THE BSR, PCA, AND ORR

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

There were no unscheduled shutdowns due to instrument failure during the reporting period.

Reactor control circuit changes included:

1. Removal of the negative period inhibit from the "preferred rod" insert. The net effect of this change will be to allow the preferred rod to help the regulating rod maintain the 27-sec negative period called for by automatic reduction in the servo demand setpoint.
2. Modification of an experiment tie-in system which provides two independent channels of experiment setback protection with backup reverse. The change involved a modification to improve the reliability; it does not change the function of the protection system.
3. Addition of a BSR power level readout to the NSST experiment for data logging purposes.
4. Replacement of the shim-rod position indicators. The change provides a more reliable and accurate position readout of the rods by replacing the six analog displays with six digital displays by using synchro-to-digital techniques. The resolution of the digital display is 0.01 in. The pool critical assembly was continued as an experimental facility for intermittent use by the University of Tennessee, University of Kentucky, Louisiana State University, University of Oklahoma, Mississippi State University, Memphis State University, Central Florida Community College, the Tennessee Valley Authority, and personnel from the Oak Ridge Associated Universities.

Due to greatly curtailed operation of the reactor, no major maintenance activities occurred during this reporting period.

11.17 MAINTENANCE OF THE TSR-II REACTOR

J. M. Farmer D. D. Walker K. W. West

Performance of the TSR-II reactor control system was satisfactory for this two-year reporting period. There was one shutdown of the reactor, attributed to instrumentation.

The control ball was replaced with a new unit having new lune plates and an increased amount of fuel to compensate for burnup in the core. Instrumentation and Controls Division personnel provided considerable assistance to operations personnel during removal of the old ball, installation of the new ball, and checkout of the completed installation.

The TSR-II was being maintained in operational standby condition from April 1978 until September 1978.

Continued assistance was provided to maintenance of instrumentation for various experiments.

11.18 MAINTENANCE OF THE HEALTH PHYSICS RESEARCH REACTOR

J. M. Farmer D. D. Walker K. W. West

The instrumentation and controls system for the Health Physics Research Reactor performed satisfactorily. There was no reactor shutdown attributed to instrument trouble, and no major change was made to the instrumentation and controls system.

11.19 PROCEDURES AND INSTRUCTION FOR FABRICATION, ASSEMBLY, AND TEST OF PCP III MULTISECTION IONIZATION CHAMBER (Q-2633) FOR REACTOR CONTROL[1]

M. M. Chiles W. T. Clay C. E. Fowler

This document is a collection of procedures for fabrication, assembly, and testing of a PCP III multisection ionization chamber (Q-2633) for reactor control.

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1. Abstract of ORNL/TM-5835 (1978).

11.20 CONTINUING EDUCATION COURSES IN COMPUTER TECHNOLOGY

D. W. McDonald

Several courses were taught in the field of computer technology as part of the Division commitment to continuing education. Recently promoted engineering assistants were taught a comprehensive course in the high level computer language, BASIC. This was a self-paced course involving 15 interactive computer/student lessons and weekly supplemental lectures. The computer programs used in the interactive lessons were modified from programs obtained from a local college. This course proved successful, and has since been used at the Oak Ridge Gaseous Diffusion Plant. Additional courses in FORTRAN, FOCAL, and various machine languages are planned.

The Division also conducted a course on microcomputer architecture which was open to the entire ORNL staff and attracted 50 participants. The course introduced general computer architecture concepts and culminated in a comparison of the more popular microprocessors. Additional topics covered by the course included semiconductor and magnetic bubble memories, hardware interfacing, and machine language programming. The participants were given many hours of "hands-on" experience with the KIM-1 microcomputer.

A detailed course on microcomputers and microprocessors was presented to new members of the Division professional staff and included 30 participants.

11.21 TECHNICAL INTERPRETING -- OBSERVER ASSISTANCE TO USDOE AND USNRC

J. Lewin

From November 25 through December 12, 1977, technical interpreting assistance was provided to the U.S. Department of Energy, Division of International Affairs, in connection with the Second U.S.-U.S.S.R. Joint Committee on Energy Problems meeting, held in Moscow on December 4-11. In addition to several energy-related agencies in Moscow, visits were made to the Konakovo petroleum-fired, eight-unit, 2400-MW(e) power station and to the 2000-MW(e) Leningrad nuclear power station.

From February 4-19, 1978, similar assistance was provided to the USNRC Division of International Programs. In addition to some R&D institutes and design organizations, visits were made to two operating PWR stations and one pressure-tube BWR station.

On March 27 and 28 and again on April 5-7, 1978, similar assistance was provided during a return visit by a Russian group of power reactor

engineers. Some Russian documents pertaining to reactor safety that were provided during this visit were evaluated for possible translation into English or for summarization in English.

Engineering Studies

11.22 CFTL DESIGN REVIEW

S. M. Babcock A. F. Johnson R. A. Mollenkamp[1]

Review of the core flow test loop (CFTL) instrumentation and controls design was started to determine whether it meets ORNL quality assurance standards. This work is part of a general CFTL design review required by the CFTL contract with the DOE. The review was started in the third quarter of FY 1978, and is expected to continue through the second quarter of FY 1979.

1. Consultant, University of Missouri, Rolla.

11.23 INITIAL SIMULATION AND CONTROL SYSTEM STUDIES OF THE MIUS COAL-FIRED TURBINE EXPERIMENT[1]

S. J. Ball

The fluidized-bed coal-fired gas turbine (CFGT) experiment is part of the modular integrated utility system program, which is jointly sponsored by the Department of Housing and Urban Development and the Energy Research and Development Administration. The dynamic characteristics of the CFGT experiment are investigated to determine specific control system designs required to satisfy varying electrical and waste heat demands and, at the same time, to keep plant component temperatures and stresses within acceptable limits. The simulations indicate that the present control system design is capable of handling expected load transients satisfactorily.

1. Abstract of published report ORNL/HUD/MIUS-42 (February 1978) and of paper "Dynamics and Control Studies of a MIUS Coal-Fired Gas Turbine Experiment," pp. 30-1 to 30-20 in *Proc. Third Power Plant Dynamics, Control and Testing Symposium, Knoxville, Tennessee, Sept. 7-9, 1977.*

11.24 INSTRUMENTATION EVALUATION LABORATORY AND PREFERRED INSTRUMENT LIST

G. N. Miller W. L. Zabriskie

The hardware available to the instrumentation and controls field has grown rapidly in recent years, creating considerable confusion for the engineer. New types of instruments, new vendors of the same instruments with alternative features, and, most of all, microcircuit and microprocessor instruments have continued to create a confusing proliferation of available hardware.

The Instrumentation and Controls Division has begun a project to establish a preferred instrument list for use by designers of instrumentation and control systems. A test facility housing an environmental chamber and equipment for test and evaluation of all types of instrumentation was established. Specialized equipment to investigate such characteristics as microprocessor susceptibility to power line variations and noise was included in this new facility. All vendor specifications and user requirements can be examined in this laboratory.

Several instruments were tested, including a Barber-Colman model 520 controller, electronic differential pressure transmitters, and a Foxboro Spec 200 distributed control system.

11.25 PROGRAMMABLE LOGIC CONTROLLER TASK GROUP

G. N. Miller B. J. Bolfing

Programmable logic controllers (PLCs) are used at ORNL for controlling sequential processes. Specifications were written for two PLC systems to be used as standards at ORNL. An internal report was written that describes the proper method for programming and documenting a PLC based control system. The computational and analog control capabilities of large PLC systems were investigated.

A study was started to develop a simple computer-aided technique for PLC program development. A high-level programming language was written that permits the programmer to enter a PLC task at a computer time-shared terminal, using state diagrams. Ladder diagram solutions to the state diagram are generated in the proper format for entry into the PLC system.

11.26 QUALITY ASSURANCE PROGRAM IN THE INSTRUMENTATION AND CONTROLS DIVISION

C. W. Ricker[1] D. G. Prater[2]

The quality assurance (QA) program in the Instrumentation and Controls Division has been maintained and strengthened during this biennial reporting period. The effectiveness of the divisional program was maintained by audits. Divisional procedures were reviewed and, where necessary, revised or deleted, or new procedures were written. Because the division is becoming directly involved in program management tasks, new QA procedures were written that address the functions and responsibilities of these tasks.

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1. Coordinator.
2. Assistant Coordinator.

Engineering Developments

11.27 SAFEGUARDS AND SECURITY IMPROVEMENTS

A. L. Case C. C. Hall
K. M. Henry E. Madden
J. A. McEvers R. L. McKinney
J. A. Russell R. L. Shipp

A major program was initiated in 1976 to design and install new and improved existing physical security measures at ORNL. Much of the instrumentation design work was assigned to the Instrumentation and Controls Division, including perimeter monitors, intrusion detectors, television monitoring, video assessment systems, a multichannel RF cable transmission system, walk-through metal and radiation detectors, a facility inventory computer system, a computerized alarm monitoring system, and a new emergency control center. This division also furnished instrument engineering design support for the design of building additions and a new, special nuclear material vault.

Design of the subsystems of the project were completed, and procurement and installation of equipment were started. The project is scheduled for completion in early 1979.

11.28 VISIBLE NOISE ALARM

R. M. Farnham[1] K. C. Knight

A visible noise alarm was designed for Plant and Equipment Division shops at ORNL. A standard noise monitoring instrument was combined with a high intensity strobe light, both commercially available.

Three alarms were fabricated by modifying the original units so that the strobe light flashed repeatedly when a preset noise level is exceeded. The flashing strobe light warns personnel within its visible range that ear protection should be worn.

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1. Plant and Equipment Division.

11.29 CALIBRATION OF ACCELEROMETERS FOR SHOCK TESTING

M. H. Cooper R. L. Anderson

A calibration facility was set up for comparative calibration of shock accelerometers, using a standard accelerometer connected to the accelerometer under test. The two accelerometers are mounted together on an anvil, and the anvil is accelerated by striking it with steel balls released from a height of about 80 cm. The outputs of the standard and accelerometer under test are recorded on a dual-trace storage oscilloscope, and the deviation from the standard at the peak of the acceleration is measured. Accelerations which can be attained range from 20 to 10,000 g, and uncertainties of the system are approximately 5%. Initial accelerometer sensitivity determinations indicated a difference of 8% from the manufacturer's value. This difference was reduced to 1% with the use of a digital memory scope and electrical calibration of both the standard and test accelerometer amplifier channels.

11.30 MODIFICATION OF AN NMR SPECTROMETER FOR SPIN RESONANCE SPECTROSCOPY IN SOLIDS

G. K. Schulze

A Varian model XL100 NMR spectrometer was modified for the Chemistry Division to enable spin resonance spectroscopy in solids. (Most NMR work is done only on liquid samples.) The modified instrument is operational and is being evaluated.

To modify the spectrometer, three high-power, linear rf amplifiers, an interface, and rf control circuits were installed. Several new pieces of equipment were designed and constructed, including a 23-dB-gain, 100-MHz amplifier capable of 200 mW output and a circuit that controls the number of cycles the experiment is run and the phase of the 100-MHz signal applied to the sample. A new sample coil and a tuning and matching network were designed for the sample probe, and a high-power, pin-diode duplexing scheme was designed to couple the rf amplifiers and receiver to the probe.

11.31 TEMPERATURE REGULATOR AND POSITION DETECTOR FOR TEMPERATURE PREFERENCE DETERMINATION OF FISH BY SELF-REGULATION

G. K. Schulze

An instrument was designed and constructed for the thermal aquaculture group of the Environmental Sciences Division to allow the study of temperature preference of specific fish. The instrument services four separate chambers, and studies are in progress using the equipment. The system is unique in that it allows the fish to establish the temperature preference it desires.

The system is housed in a 10-1/4-in. relay chassis. It functions by causing one side of the chamber to track, at a 2°C differential, the temperature of the opposite side of the chamber. The position of the fish is sensed by two phototransistor sensors in the tunnel between the chamber halves. As the fish swims from one side to the opposite side, the detected motion sets or resets a C-Mos flip-flop to cause heating or cooling of the master side, respectively -- the slave side tracking the master. When too cool, the fish learns to move to the warm side; when too hot, it moves to the cool side. Thus, the fish establishes a mean temperature with the slow variations.

The system proved valuable. It not only determines temperature preference, it also helps to study the effect of super-imposing other stimuli simultaneously to determine the correlation of a second stimulus on the temperature preference.

11.32 TYPING COPY STAND

G. W. Allin H. J. Stripling, Jr.

An improved typing copy stand was designed for use by typists to aid in the prevention of skipped lines of text.

A motor-driven follower arm, controlled by a foot switch, allows the typist to pick up each line regardless of the spacing of the copy. The stand is pivot mounted from a desk bracket, and can hold two sheets of standard 8 1/2- by 11-in. paper or larger Photomasters side by side. One prototype is being used and has given good service.

11.33 THERMOCOUPLE REEL DEVICE

G. W. Allin

A reel device was designed to provide supply and take-up capabilities for a sheathed thermocouple which is used to monitor the temperature experienced by hybrid circuit devices as they travel through a processing furnace on a continuous belt.

This device is mounted in a standard electronic cabinet which is fitted with casters for easy manipulation. It has a drag brake to eliminate slack in the thermocouple, and it has a unique mechanical stop and limit switch combination to shut off the belt drive when the travel through the hot zone of the furnace is completed.

11.34 PRECISION WELDING POSITIONER

G. W. Allin

A precision welding positioner was designed for use with laser welding equipment for fabrication of very small parts required in thermocouple thermometry. This system provides semiautomatic positioning of parts. Circles, arcs, and straight lines can be run automatically after certain manual adjustments are made to orient the part in the positioner.

The system consists of four stacked stages (a manual translational, a stepper-motor-driven translational, a manual rotary, and a stepper-motor-driven rotary), a chucking device, an optical centering scope, and a controller for the motor-driven stages. The controller operation is normal when the welding involves preset step-size moves; however, the controller also allows for single-step-jog and rapid-traverse types of operation.

11.35 ISOPIESTIC TEST FACILITY

G. W. Allin S. J. Ball

A redesign of the air bath heating arrangement for the isopiestic test facility reduced the temperature gradients experienced in the data taking apparatus an order of magnitude. This improvement resulted in increasing the accuracy of the thermodynamic data to 0.2% for dilute high-temperature electrolyte solutions and, at the same time, allowed the experimentalist to concentrate on improvements to other parts of the apparatus.

An enclosure was made of copper sheet and fitted inside the existing insulated enclosure, leaving an annular air space of ~0.5 in. between the two enclosures. A small-diameter, sheathed heating cable rated at 3 kW was mounted on insulated standoffs on its outer surfaces. This has minimized local hot-spots by providing intermediate, radiant heating planes which quickly equalize any thermal gradients. By eliminating a need for several local auxiliary trim heaters and their controls, the operation of this unit was simplified considerably.

12. MAINTENANCE

12.1 ACTIVITIES OF THE COMPUTER MAINTENANCE GROUP

J. W. Woody
C. R. Cinnamon J. A. Keathley R. P. Rosenbaum
C. C. Johnson C. W. Kunselman L. W. Williams

A supervisor and five work teams, each team made up of an engineering technologist and an instrument technician, were responsible for the maintenance of the following 136 computer systems and batch stations in use at ORNL:

1	CDC 1700 computer system
5	Data 100 batch stations
4	Data General computer systems
90	DEC PDP-8/PDP-11 computer systems
8	DEC PDP-15 computer systems
2	G.E. numerical controlled machines
1	General automation batch station
10	H.P. computer systems
5	MODCOMP II computer systems
2	MODCOMP III computer systems
2	MODCOMP IV computer systems
4	SEL 810B computer systems
2	SEL 840 computer systems

The responsibility for these systems with their peripherals, was assigned to a team on a type or manufacturer basis; one team had major responsibility and another team supplied support when needed.

Preventive maintenance was carried out on all systems, some each week, and others at three-month intervals.

12.2 MAINTENANCE SUPPORT FOR COMPUTER SCIENCES DIVISION AND TERMINAL USERS

J. A. Keathley B. A. Tye J. W. Woody

Support for the CSD was expanded owing to an increased number of users of the facilities at ORNL. An engineering technologist and three instrument technicians were available for maintenance of the more than 550 computer terminals and modems used at ORNL. They were also available for maintenance of the "smart" MUX systems connected to the PDP-10 system, including six plotting systems, tape cleaners and certifiers, and two multiplexers controlling the hard wired inputs, modem inputs, and dial-up phone inputs. Assistance was given to the input from an additional 80 phone lines into the PDP-10 through multiplexers from the Oak Ridge Gaseous Diffusion Plant and the Y-12 Plant. Fault isolation was done on telephone lines used for data transmission and for the CC-70 and CC-8 communication computers used to control inputs for dial-up phone lines and recon and batch station inputs to the IBM computers.

Off-site assistance was given to the Paducah facility and to the Information Division for a meeting at Durham, North Carolina.

12.3 MAINTENANCE ACTIVITIES FOR THE ENVIRONMENTAL SCIENCES AND SOLID STATE DIVISIONS AND THE INSPECTION ENGINEERING DEPARTMENT

J. D. Blanton J. L. Lovvorn

Instrument services were furnished to the Environmental Sciences and Solid State Divisions and to the Inspection Engineering Department by a supervisor and five technicians located in two shops. The services included routine maintenance, fabrication, modification, troubleshooting, and repair of electronic instruments and systems.

Approximately 685 instruments are in the Maintenance Information System to date. A total of 1420 service orders were completed during the report period.

An additional field shop was established in building 2026 to serve the Analytical Chemistry and Chemical Technology Divisions.

An instrument shop was established in building 1505, the new administration and research laboratory building of the Environmental Sciences Division.

12.4 LABORATORY ACCELERATOR MAINTENANCE GROUP

J. L. Lovvorn E. W. Sparks

The laboratory accelerator maintenance group consists of one supervisor and nine technicians. Shops are located at the Oak Ridge Isochronous Cyclotron (ORIC, building 6000), the Oak Ridge Electron Linear Accelerator (ORELA, building 6010), and the Van de Graaff Accelerator Laboratory (building 5500). At the ORIC, maintenance coverage was ten shifts per week; regular day-shift maintenance was provided at the ORELA and the Van de Graaff Laboratory. Emergency maintenance for the ORELA and the Van de Graaff Laboratory was provided from the ORIC shop for the evening shift.

At all facilities, the first priority was machine maintenance. Items on the machines needing most attention were gun tanks, high-current regulated power supplies, and rf systems. Maintenance services were also provided for experimental equipment, including NIM systems, CAMAC systems, vacuum measuring equipment, and power supplies. Field fabrication services were provided for engineers and experimentalists at all three facilities.

Maintenance was provided at the ORIC on a Hughes controlled machine for magnetic field measurements, and new instrumentation was fabricated for ORIC field measurements.

Maintenance was provided on atomic collisions for plasma applications and the University Isotopes Separator - Oak Ridge (UNISOR).

Some measurements at the Holifield Heavy Ion Research Facility (HHIRF) were installed and calibrated.

12.5 SPECIAL ELECTRONICS SUPPORT GROUP

J. L. Lovvorn G. G. Underwood

The maintenance section of the special electronics support group consists of one supervisor, one diagnostic specialist, and nine technicians in four shops. These four shops service instruments for about 18 of the divisions in the Laboratory.

The shop in the instrument laboratory building 3500 maintained all of the oscilloscopes in ORNL, as well as the NIM systems, power supplies, amplifiers, digital multimeters, scalers, electrometers, induction furnaces, and similar equipment for all divisions of the Laboratory.

The shop located in room E-1 of building 4500N maintained many types of electronic instrumentation, including x-ray machines, electronic microscopes, pyrometers, etc., that are used by the Chemistry, Analytical Chemistry, Chemical Technology, Metals and Ceramics, and Physics Divisions that are located in buildings 4500N, 4500S, 4501, 5505, and other buildings where the various experimentalists are working.

The two shops located in building 4500S, rooms H-147 and Y-17, were concerned with maintenance for the research groups of the Health Physics and Health and Safety Research Divisions and the nondestructive testing groups of the Metals and Ceramics Division.

The maintenance section of the special electronics support group repaired ∿3500 instruments and gave 192 man-weeks of on-site construction and user's assistance.

Work control for all shops was accomplished by the instrument inventory and maintenance information system. About 3400 instruments are in the inventory of this system.

12.6 AUDIO-VISUAL SERVICES GROUP

J. L. Lovvorn J. Miniard

Public address systems and equipment for visual-aid projection and audio- and video-tape recording were furnished and operated for 1,068 meetings at the Laboratory and for 50 off-site meetings (25 in Oak Ridge, 15 in Gatlinburg, and 10 in Knoxville). The audio-visual equipment used by this group, as well as similar equipment for other groups, was maintained. Audio and video tapes were duplicated for several customers. Four technicians were employed full time for this work, with a shared-time supervisor. In addition, the supervisor planned and supervised off-site meetings where required. Technicians from other groups assisted during periods of peak loads to equalize overtime.

12.7 TELECOMMUNICATIONS AND PERSONAL RADIATION MONITOR MAINTENANCE GROUP

J. L. Lovvorn J. Miniard

A total of 1,614 service orders were completed on some of the 400 pieces of two-way radio equipment in service at the Laboratory. All radio equipment is on a six-month schedule for performance checks.

There are 275 personal radiation monitors (PRMs) in the maintenance information system, and 80 service orders were completed for these monitors. Halfway through the reporting period, the PRM service was assigned to the radiation monitoring maintenance group.

Service was also provided on public address, intercom, and closed-circuit television systems; radio paging receivers; and a microwave television system.

The old radio paging system was salvaged and a modern system was put in service. A plant security system was installed and maintained at the Laboratory.

12.8 RADIATION MONITORING SYSTEMS

J. D. Blanton J. L. Lovvorn

The maintenance organization for monitoring systems consists of nine instrument technicians and one supervisor. Four technicians performed approximately 3532 services on 1150 stationary health physics instrument systems installed throughout the Laboratory. These technicians performed bimonthly performance checks of fixed instruments installed in 13 facility radiation and contamination alarm systems, 4 facility alarm and containment systems, and 5 remote radiation alarm systems. These systems are in 22 buildings, and consist of 305 radiation monitoring stations. Twenty-two local air monitor and fallout monitor stations were checked semimonthly, and seven perimeter air monitors were checked monthly for proper operation; the conditions were logged and corrected as required.

Three technicians maintained and calibrated 1250 portable health physics instruments at the health physics calibration laboratory. About 8165 service orders were completed by this group.

Two technicians assigned to the Operations Division serviced and maintained approximately 30 gas and 31 liquid-waste-effluent monitors that relay alarms and other information by telemetry to the Waste Disposal Control Center (building 3105). The conditions were logged, and any malfunctions were corrected. Servicing and maintenance was also provided for the instrumentation located in the control center and other building locations in the Laboratory. Performance checks were made on these systems on a biweekly basis.

The personal radiation monitor repair and calibration work was moved from the audio-visual services group into this group about halfway through the report period. Three hundred sixty-eight personal radiation monitors have been entered into the maintenance information system to date.

12.9 ACTIVITIES OF THE ELECTROMECHANICAL MAINTENANCE GROUP

L. R. Gitgood J. A. Keathley
L. R. Ruth J. W. Woody

During the two-year report period, this group was staffed by an engineering technologist and four instrument technicians whose major responsibility was the maintenance of Teletype page printer terminals at ORNL. A rigid three-month or 500-hour lubrication schedule was followed, resulting in few major overhauls of the equipment. User downtime was low because of the use of replacement terminals. Of the 240 Teletype terminals in use at ORNL, 60 units have running time meters registering in excess of 10,000 hr.

Other activities of this group included the maintenance of microfiche and film readers and printers, sample changing devices, paper-tape punches and readers, card punches, and sample oxidizing equipment.

After some page printers were replaced by more modern terminals, the manpower requirement of this group was reduced to its present staff of an engineering technologist and three instrument technicians.

12.10 ACTIVITIES OF THE ANALYZER MAINTENANCE GROUP

J. A. Keathley A. J. Millet
D. G. Prater J. W. Woody

The maintenance of pulse height analyzer systems and liquid scintillation counting systems and the performance of acceptance tests to ensure compliance with purchase specifications were the major responsibilities of this group of two engineering technologists and three instrument technicians. Equipment of these types include 90 hard-wired, pulse-height analyzer systems; 34 computer-based, pulse-height analyzer systems; and 40 liquid scintillation counters.

During this report period, six computer-based, pulse-height analyzer systems, seven hard-wired analyzer systems, and two liquid scintillation counters were purchased and acceptance tests were performed.

Other maintenance responsibilities included the spiral reader system for high-energy physics, which utilizes two computer systems with magnetic tape outputs and four manual film readers and scanning tables.

12.11 ORELA ELECTRON INJECTION SYSTEM MAINTENANCE

G. W. Allin

The window in the ORELA electron injection system pressure vessel, after some six years of service, was replaced with a standard, commercially available unit of an improved design. Both the original and the replacement windows use a double-thickness lens arrangement with an intermediate laminating layer of plastic. The improved design provides sealing by clamping a peripheral gland which compresses the lens radially, rather than clamping the edge of the lens itself.

The 120-kV feed-through terminals were beginning to show signs of breakdown, as evidenced by carbon tracking, and were replaced with spare units. Replacements for the spares are being fabricated as a routine maintenance precaution.

13. ENVIRONMENTAL SCIENCE STUDIES

13.1 FACTORS AFFECTING CALCULATIONS OF DOSE RESULTING FROM A TRITIUM RELEASE INTO THE ATMOSPHERE[1]

P. J. Otaduy[2] C. E. Easterly[3]
R. S. Booth D. G. Jacobs[4]

The amount of tritium produced and possibly released from a commercial power station using a fusion reactor could be significantly greater than the tritium released from fission power stations of comparable size. Since tritium is radioactive and it will be incorporated into environmental systems in the same way as ordinary hydrogen, accurate predictions were needed of its transport and deposition after being released into the air.

Tritium releases in the form of HT represent a lower hazard to man than releases as HTO. However, during movement in the environment, HT is converted into HTO. The effects of the conversion rate on calculations of dose are described, and a general method is presented for determining the dose from tritium for various conversion rates and relative HTO/HT risk factors.

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1. Abstract of paper presented at the Second ANS Topical Meeting International on the Technology of Controlled Nuclear Fusion, Richland, Washington, September 21-23, 1976, and published in *Proc. 2nd ANS Topical Meet. Int. Technol. Cont. Nucl. Fusion*, Conf. 760935-P4 (1976), pp. 1425-1431.
2. Guest assignment, University of Florida, Gainesville.
3. Health Physics Division.
4. Office of Environmental Policy Analysis.

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13.2 CUMEX -- A CUMULATIVE HAZARD INDEX FOR ASSESSING LIMITING EXPOSURES TO ENVIRONMENTAL POLLUTANTS[1]

P. J. Walsh[2] G. G. Killough[2]
D. C. Parzyck[2] P. S Rohwer[2]
E. M. Rupp[2] B. L. Whitfield[3]
R. S. Booth R. J. Raridon[4]

A hazard index methodology called CUMEX has been developed for limiting human exposure to environmental pollutants. Hazard index is defined as Q/Q_L where Q is exposure or dose to total-body, organ or tissue from all environmental pathways and Q_L is a limit which should not be exceeded because of health risk to humans.

Mathematical formulations for hazard indices are developed for each sampling medium corresponding to each effluent type. These hazard indices are accumulated into composite indices such that total human intake or dose would not exceed the health risk limit. Mathematical formulation for composite hazard indices or CUMEX indices for multiple pollutants are presented.

An example CUMEX application to cadmium release from a smelter complex in East Helena, Montana, demonstrates details of the methodology for a single pollutant where human intake occurs through inhalation and ingestion.

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1. Abstract of published report: ORNL-5263 (April 1977).
2. Environmental Sciences Division.
3. Information Division.
4. Computer Sciences Division.

13.3 NITROGEN, PHOSPHORUS, AND POTASSIUM UTILIZATION IN THE PLANT-SOIL SYSTEM: AN ANALYTICAL MODEL[1,2]

O. L. Smith

An intermediate-resolution analytical model of nitrogen, phosphorus, and potassium utilization in the plant-soil system was developed and tested. Starting from specified natural or artificial sources in the soil, element transport to root absorption surfaces was modeled in terms of diffusion, mass flow, and soil buffering mechanisms. Element uptake was described by carrier theory formalism, and assimilation was based on four premises about the roles of N, P, K, and photosynthate in cell chemistry. There were three main objectives of the model. The first was to predict the first-order interactive growth response of particular plant species to any combination of these macronutrients supplied in the soil medium. Species parameters required by the model include root absorption rate and certain cell chemistry reaction rates. The second

objective was to make the model sufficiently general to describe a broad range of species. It was built upon common denominator principles of physiology condensed from available experimental data on corn (*Zea mays* L.), bean (*Phaseolus vulgaris*), pine (*Pinus elliottii* Var. *Elliottii*), etc. In this generic sense it is a measure of what plants have in common. The third objective was to use the model to test several well-known theories of plant growth.

The model was validated against reported experiments in ryegrass (*Lolium perenne* L.), oat (*Avena sativa*), a legume (*Stylosanthes humilis*), and rutabaga (*Brassica napobrassica*, Mill.), in which dry matter yield was measured as a function of factorial application of N, P, and K to the soil. The model shows that much of the deficient, optimal, toxic, and interactive response of plants to N, P, and K can be explained in terms of strong linear response of cell chemistry to low nutrient concentrations and inhibition by N, P, and K at high nutrient concentrations. Applying the model in a test of plant response to suboptimal nutrient concentrations, the model strongly confirms the Liebig Law of the Minimum and refutes the opposing multi-limiting-element Baule Product Law. The model also shows that the Liebig theory of linear growth response to nutrient concentration and the opposing, nonlinear Mitscherlich Law of Diminishing Return are not necessarily in disagreement, but rather may apply to different parts of the nutrient concentration range. And the model confirms that the effects on growth of nitrogen, phosphorus, and potassium levels are more often additive on the reciprocal scale than on either the logarithmic or untransformed scales.

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1. Abstract of paper published in *Soil Science Society of America Journal* 40, 704-714 (September-October 1976).
2. Research supported by the Environmental Sciences Division.

13.4 DECOMPOSITION OF SOIL ORGANIC MATTER I. AN ANALYTICAL MODEL[1,2]

O. L. Smith

An intermediate resolution model of the decomposition of soil organic matter was developed from a comprehensive study of experimental work in the literature. The many organic and inorganic forms of soil nitrogen, phosphorus, and potassium were mathematically treated, together with the various transformations between forms. Most of the transformations are microbe moderated, and the dynamics of the microorganisms was explicitly represented. A general heterotrophic population using primarily organic carbon for energy was simulated, as well as important chemotrophic nitrifiers which oxidize nitrogenous compounds for energy. The explicit treatment of microbe dynamics permits among other things the study of microbe immobilization of important plant nutrients. In addition to the simulation of biological aspects of decomposition, the model treats

the physiochemical processes of precipitation, fertilizer and native mineral inputs, leaching loss, sorption of organic and inorganic ions on soil colloids, condensation between organic N and aromatic compounds, and exchange reactions. Model parameters are dealt with in detail in order to base them as firmly as possible on experimental information. The process rates include functional dependence on the environmental factors of soil temperature and moisture. For clarity of presentation, the model is divided into four submodels, one each for N, P, and K, and the carbon energy substrate. The total model is coupled with a previous plant growth model, and thereby simulates complete element cycles in the plant-soil system.

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1. Abstract of paper submitted for publication in *Soil Biology and Biochemistry* journal.
2. Research supported by the Environmental Sciences Division.

13.5 DECOMPOSITION OF SOIL ORGANIC MATTER II. APPLICATION OF THE MODEL[1,2]

O. L. Smith

A mathematical model of the decomposition of soil organic matter was tested against experimental results and used to study important soil processes and to offer explanations of well-known but incompletely understood experimental observations. The complete cycles of the three macronutrients N, P, and K through the plant-soil system were treated under both equilibrium and dynamic conditions. The equilibrium equations show that in many ecosystems the annual-average soil solution concentrations of P and K are independent of the soil biota activity, whereas the relative concentrations of the various N-forms in solution remain dependent on related microbe activity. The dynamic equations were compared with and shown to agree closely with a number of experimental observations, including (1) the overall pattern of decomposition and growth of both heterotrophs and chemotrophic nitrifiers, (2) the immobilization and mineralization of nitrogen as a function of substrate C:N ratio, (3) waste use of substrate by various groups of microbes, (4) the N priming effect, (5) the effect on microbes of oscillating low soil temperatures, and (6) the effect on microbes of soil moist-dry cycles. Among the conclusions drawn from the full model equations are the following: (1) the N priming effect is the consequence of a two-step substrate limitation involving first N and later carbon because of microbial waste metabolism, (2) oscillating low soil temperature results in lower population levels than does the mean temperature at least in part because nonlinearities give a net reduction in growth under oscillating conditions, (3) moist-dry cycles, lethal to soil organisms, enhance CO_2 evolution in part because of the organisms' self-metabolism, (4) plant and microbes compete for N to a greater or lesser extent depending on the kind of N available, the C:N ratio, the amount of leaching, and whether or not microbe use of

nitrate is suppressed, and (5) in fertilizing some crops with ammonium, nitrate, or organic N, multiple-batch application is preferable with the mineral forms, whereas a single batch is best with the organic form because of differences in microbial immobilization.

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1. Abstract of paper submitted for publication in *Soil Biology and Biochemistry* journal.
2. Research supported by the Environmental Sciences Division.

13.6 THE INFLUENCE OF ENVIRONMENTAL GRADIENTS ON ECOSYSTEM STABILITY[1,2]

O. L. Smith

The dynamic behavior of ecosystems with spatially varying species characteristics may differ substantially from that of uniform systems with the same mix of species. If system behavior is to be correctly assessed, the spatial complexity must be treated in sufficient detail to account for the contribution of each significantly different part of the system to overall response. Systems along environmental gradients, one of the most common types of spatial heterogeneity, were evaluated in terms of the linear stability formalism. The more rapidly a perturbed system returns to equilibrium, the more stable it is, and a normalized system time constant was developed as a measure of the dynamic properties which aid species in their persistence. This index of relative stability, based on log-phase dynamics, was shown to be strongly correlated with the behavior of a variety of experimental systems.

The diffusion theory formalism provides a useful representation of the ecosystem characteristics of particular interest in this study. System size, dispersal of seeds, symmetric and asymmetric distributions of growth and mortality, and the consequent spatially varying population profiles are readily treated. From the formalism a number of basic relationships between distributed parameters and system dynamics were deduced and related to experimental observations in the literature.

The formalism developed here is instructive in problems of experimental data analysis and mathematical modeling in which it is desired to represent a spatially complex system by a simpler average. The results show that two common averaging techniques, one of using the parameter arithmetic average and the other of population weighting the parameter distribution, can result in large errors in such estimates of system behavior. The two procedures may be adequate to represent systems having small edge effects associated with biomass loss from the borders, but in steep-gradient systems where edge effects may be significant, ignoring them can result in large over- or underestimates (100% or more) of system performance. A better procedure for forming either a data or model average is to formulate a detailed comparison between the

actual system equations and the averaging equations and define an equivalent averaging procedure which results in a conceptual match that omits none of the important system properties.

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1. Abstract of a paper submitted for publication to *The American Naturalist*.
2. Research supported by the Environmental Sciences Division.

13.7 RESOURCE COMPETITION AND AN ANALYTICAL MODEL OF ZOOPLANKTON FEEDING ON PHYTOPLANKTON[1]

O. L. Smith
H. H. Shugart[2] R. V. O'Neill
R. S. Booth D. C. McNaught[3]

A new consumer-resource model was developed with specific reference to zooplankton feeding on phytoplankton. In principle, the model can be extended to any terrestrial or aquatic community in which the consumers graze nearly randomly on food which has relatively little mobile escape capability. In contrast with the intuitive or phenomenological approaches often used in constructing competition models, the consumer-resource interaction term was derived as much as possible from first principles. A general form was developed with clearly defined parameters that represent fundamental system processes such as consumer filtering rate. The model parameters were particularized to describe two known forms of feeding: (1) saturation feeding in which the rate remains constant above a given food density while the filtering rate decreases, and (2) inhibited feeding in which a decline appears at high food density. From an examination of the model's equilibrium equations for strongly similar zooplankton species feeding on similar phytoplankton species, the following conclusions were drawn: (1) The competitive exclusion principle has only limited validity. For a community in which the consumers exhibit no intraspecific competition and have identical assimilation efficiency to death-rate ratios, $\bar{e}/d$, any number of consumer species may, in fact, coexist and compete for the same food. Communities in which the consumer species have identical $\bar{e}/d$ are probably rare. However, in a community with intraspecific competition (a common occurrence) any number of consumer species, with a wide spectrum of $\bar{e}/d$ ratios, may exist and compete for the same food. (2) The equations for a complex community composed of many consumer and food species can be reduced to a single equation whose form is identical with that of a single-consumer, single-food system. This implies that, at equilibrium, structurally complex communities may behave functionally like simple ones. (3) The standard competition coefficient, α, of the Volterra equation is a poor measure of competition in nonlinear systems. It exhibits incongruous variations with changes in system parameters. We have proposed a new definition of competition coefficient, C_{in}, which is based on derivatives of state variables evaluated at the system operating point and which eliminates the incongruities exhibited by α. In a community with

no intraspecific competition, all C_{in} are unity. In a community with intraspecific competition, the C_{in} tend to equalize as the number of food species increases, resulting in equal competitive strength of all consumer species in systems of the type studied here.

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1. Abstract of published paper: *Amer. Nat.* 109(969), 571 (September-October 1975), and a popularized version by O. L. Smith: "Resource Competition: An Analytical Model of Zooplankton Feeding on Phytoplankton -- So What?" *ORNL Review* 9(3), 13-16 (Summer 1976).
2. Environmental Sciences Division.
3. State University of New York, Albany.

13.8 SALTY: A HYBRID COMPUTER PROGRAM FOR THREE-DIMENSIONAL HEAT TRANSFER FROM A DISCRETE SOURCE[1]

R. S. Stone O. W. Burke

SALTY, a hybrid computer code, has been written for calculation of the temperature distributions in an extended medium with spatially varying properties and one or more discrete energy sources. Such complex, multidimensional, time-dependent simulations constitute one useful application of the parallel computation and continuous integration capabilities of the analog-digital hybrid computer. An application of SALTY to a problem involving nuclear waste disposal in salt is described, and the results are compared to those from the pure digital code HEATING5. SALTY gives much the same results at a lower computer cost. Differences in the results are discussed.

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1. Abstract of published report: ORNL/TM-6355 (1978).

13.9 EXPERIMENTAL INVESTIGATION OF RETROFIT OPTIONS FOR MOBILE HOMES[1]

S. J. Ball

A mobile home located (outdoors) in Oak Ridge, Tennessee, was tested to determine its energy-use characteristics for both space heating and cooling. The main objective was to determine the energy savings that can be achieved by the addition of retrofit items such as storm windows, skirting, and extra insulation and how these savings vary with weather conditions. Analyses of space heating data show

that energy savings approaching 50% can be achieved, but analyses of space cooling data were inconclusive.

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1. Abstract of published report: ORNL/CON-9 (March 1977).

13.10 ANNUAL CYCLE ENERGY SYSTEM HOUSE

G. N. Hiller R. K. Adams D. R. Miller

The ACES house is an energy conservation technique being studied by the ORNL Energy Division. The ACES concept is based on a large-thermal-capacity tank from which heat may be extracted during the winter and into which heat may be stored during the summer. The capacity should be properly sized such that the energy stored is on an annual cycle. The storage medium is ice in a water tank. At the end of the winter, the tank is designed to have 57 tons of ice; at the end of summer the tank should be all water (of course, there will be variations).

The controls and instrumentation and data systems were installed by the Energy Division. The data system acquires data on 40 analog points (mostly temperature measurements) and 26 digital points (watt-hour meters, flowmeters, etc.), performs computations to yield component heat flows, and prints out a report every hour. The Instrumentation and Controls Division was requested to provide documentation to help complete the sensor and data system checkout and to evaluate the Hewlett-Packard, 9830-calculator-based data system which was not providing adequate performance, including an operation uptime of less than 50%.

To improve the data quality and reliability, some sensor interface circuits were reworked and several changes were made to the data system, as follows:

1. A watch dog was added that will cause the program to be reloaded from tape upon a failure (halt) of the program for whatever reason.
2. An uninterruptable power supply was provided to allow the data system to operate over short power outages and to provide isolation of the data system from power line transients. The data system program will fail (halt) with short power dropouts.
3. The digital voltmeter was replaced by a more reliable version.
4. The calculator program was changed to provide a polling technique for screening the data and rejecting bad data which would otherwise compromise the computations.

After these changes, the recent system reliability increased to 90-100%. In addition, several improvements made in the instrumentation and controls resulted in an improved quality of the data.

The data system is being expanded to provide sensors for several additional energy conservation studies.

A programmable logic controller was installed for the equipment control in the ACES complex, resulting in improved reliability over the previous relay logic controller and greater flexibility for future reconfiguration of the equipment control.

13.11 AUTOMATED ANALYSIS OF CONSTANT CURRENT SUPPLY BOARDS FOR ACES INSTRUMENTATION

M. H. Cooper R. L. Anderson

The flexibility of the IEEE-488, general purpose interface bus was demonstrated in a special calibration of four newly designed and fabricated, constant-current-supply printed-circuit (PC) boards for resistance thermometer measuring circuits at the annual cycle energy system (ACES) house. Each board contained four outputs, and the output current was monitored by reading the voltage drop across standard resistors connected externally. Furthermore, each output could be adjusted by a trimpot to give an exact milliampere output. In all, twelve outputs were connected to the data system scanner by means of a plug-in breadboard which allowed the PC boards to be interchanged without disturbing the connections to the scanner. The data system was used to read the emf outputs and to calculate each of the four output currents, as well as the values of the on-board standard resistors. The stability of the supplies was evaluated by using the system clock to actuate a reading sequence every 1 or 2 hr for several days.

The set-up time for this experiment was about 3 hr, which included about 1 hr to find and correct a wiring error on the PC boards, writing and debugging the program for the calculator, and wiring the scanner. In addition, the data were recorded on magnetic tape, and, at the end of the experiment, the calculator computed the average outputs and standard deviations to give more accurate information from which to judge the day-to-day stability of these supplies.

13.12 MODIFICATION OF WATER SAMPLER AT WHITE OAK CREEK DAM

M. L. Bauer

The water sampling system at White Oak Creek was modified to improve its reliability and freedom from problems caused by power outages. First put in service in the summer of 1974, this system has experienced many failures of the power supply module and much downtime due to power line

outages. This unit was rebuilt and equipped with a battery-backed, noninterruptable power source for the microcomputer-based sampler and an improved automatic restarter to get the system back in operation after a power line outage. Because only the microcomputer system is maintained during outages, losses of power lasting more than 2 sec will cause other parts of the system, such as the water pumps, to turn off, leading to a loss of the continuity of the data. Since most of the outages are much shorter than 2 sec, the system will continue to run through these periods, and there should be fewer nuisance failures.

The battery-backed supply also increases the isolation of the microcomputer system from line transients, which could cause component failures or microcomputer malfunctions.

13.13 ENVIRONMENTAL MONITORING

S. M. Babcock C. C. Hall R. T. Roseberry

Conceptual design and cost estimate information was provided for two environmental monitoring conceptual design reports. The first project, environmental and emergency system upgrading, is concerned with modernizing the liquid-effluent monitoring equipment such as water samplers and water quality monitors at several locations. The second, streamflow monitoring and control system improvement, is concerned with instruments for multiple weir installations at White Oak Dam, White Oak Creek, and Melton Branch which are designed to accurately monitor water flows over wide ranges.

PROFESSIONAL AWARDS AND ACHIEVEMENTS, OFFICES, AND ACTIVITIES IN PROFESSIONAL GROUPS BY INSTRUMENTATION AND CONTROLS DIVISION PERSONNEL

American National Standards Institute (ANSI)

E. B. Johnson: Secretary of Standards Committee N-16, Nuclear Criticality Safety

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 Instrumentation

C. S. Lisser: Member of U.S. Technical Advisory Group for the International Electrotechnical Commission, Technical Committee 65, Process Instrumentation

F. W. Manning: Member of Committee N-42, Nuclear Instrumentation

American Nuclear Society (ANS)

J. L. Anderson: Member of Subcommittee ANS-4, Reactor Dynamics and Control, Standards Committee

R. S. Booth: Member of the National Technical Program Committee; member of Program Committee, Reactor Physics Division

C. J. Borkowski: Fellow

J. B. Bullock: Member of Computer Standards Working Committee 4.3.2

E. P. Epler: Fellow

E. B. Johnson: Secretary of Subcommittee 8, Fissionable Materials Outside Reactors, of the ANS Standards Committee; member of Executive Committee of Nuclear Criticality Safety Division; member of National Local Sections Committee; member of National Nominating Committee, 1977-78; member of Bylaws Committee, Oak Ridge Section

F. W. Manning: Member of Subcommittee ANS-16, Nuclear Instruments Standards Committee

American Society of Engineers (ASE)

R. C. Kryter: Member of Subcommittee on Vibration Monitoring; chairman of Subgroup on Data Acquisition and Processing Systems

American Society for Testing and Materials (ASTM)

M. B. Herskovitz: Member of Committee E-40, Technical Aspects of Products Liability Litigation; member of Committee E-20, Temperature Measurement

W. W. Johnston, Jr.: Member of Committee E-20, Temperature Measurement; Chairman of Subcommittee E-20.03, Resistance Thermometers; member of subcommittees and sections under Committee E-20.04, Thermocouples

J. A. Russell: Member of Committee F-12, Security Systems and Equipment; member of Task Group F-12.40, Detection and Surveillance Systems and Devices

R. L. Shepard: Secretary of Main Committee; Chairman of Subcommittee E-20.06, Acoustical Thermometry, under Committee E-20, Temperature Measurement; member of subcommittees and sections under Committee E-20.04, Thermocouples

Burst Reactor Experiment Review Committee

K. M. Henry: Member

J. T. Mihalczo: Chairman

Department of Energy Committee

J. A. Russell: Member of DOE Radio Task Force

Engineering Physics Division Safety Review Committee

J. L. Anderson: Member

H. A. Todd: Member

Institute of Electrical and Electronic Engineers (IEEE)

R. S. Burns: Member of IEEE-ISA Industrial Control Committee

M. K. Kopp: Member of Program Committee for the Nuclear Science Symposium

H. J. Metz: Liaison Member of Industrial Control Systems Subcommittee of the IEEE Industry Applications Society

L. C. Oakes: Member of Advisory Committee of the Nuclear and Plasma Science Society

Paul Rubel: Member of Subcommittee SC-5.2 (Risk Assessment and Public Acceptance) of the Nuclear Power Engineering Committee

Instrument Society of America (ISA)

R. K. Adams: Fellow

E. W. Hagan: Managing Editor, [illegible], Oak Ridge Section

Instrumentation and Controls Division Committees

J. L. Blankenship: Advisory Planning Group

H. E. Cochran: Design and Drafting Standards

J. W. Cunningham: Design and Drafting Standards

J. B. Davidson: Advisory Planning Group

W. R. Hamel: Advisory Planning Group

P. G. Herndon: Design and Drafting Standards

P. W. Hill: Maintenance Information System

J. A. Keathley: Maintenance Information System

D. J. Knowles: Maintenance Information System

F. W. Manning: Design and Drafting Standards

C. W. Ricker: Advisory Planning Group

J. M. Rochelle: Advisory Planning Group

R. L. Simpson: Maintenance Information System

H. J. Stripling: Design and Drafting Standards

R. E. Toucey: Maintenance Information System

K. W. West: Chairman, Maintenance Information System; Chairman, Design and Drafting Standards

V. J. Zedler: Advisory Planning Group

National Conference of Standards Laboratories

R. L. Anderson: ORNL Delegate

National Council of Engineering Examiners Certification

H. J. Metz: PE

National Council on Radiation Protection and Units

F. H. Clark: Consultant

Nuclear Safety Journal

E. W. Hagan: Section Editor, Control and Instrumentation

ORAU Traveling Lectures Program

R. K. Adams:
1. The Evolution and Use of the Minicomputer and Microcomputer in Research and Engineering Experiments and Processes
2. Communication Between Engineering Experiments and Digital Computers

T. G. Kollie:
1. Temperature – Its Measurement
2. Thermocouples Are Not Infallible

M. J. Roberts:
1. Microprocessors: Their Capabilities and Applications
2. Application of Statistical Methods to Errors in Instrumentation Systems

ORNL Audio-Visual Committee

J. L. Lovvorn: Member

ORNL Director's Committees

B. G. Eads: Accelerators and Radiation Sources Safety Review

P. G. Herndon: Reactor Operations Review

M. B. Herskovitz: Chairman, Electrical Safety

E. B. Johnson: Reactor Operations Review

J. Lewin: Reactor Operations Review

L. C. Oakes: Reactor Experiments

E. R. Rohrer: Reactor Operations Review

J. A. Russell: Chairman, Accelerators and Radiation Sources Safety Review

W. H. Sides: Reactor Operations Review

H. A. Todd: Accelerators and Radiation Sources Safety Review

H. N. Wilson: Electrical Safety

ORNL Management Information System Committee

J. W. Woody: Member

ORNL In-House Continuing Education Program

R. K. Adams: Member of Professional Education Resource Committee for Engineering

ORNL Stores Stock Advisory Committee

W. L. Bryan: Semiconductors

J. T. De Lorenzo: Semiconductors

C. C. Hall: Vacuum tubes

J. T. Hutton: Semiconductors

R. W. Ingle: Chairman, capacitors

E. J. Kennedy: Semiconductors

W. E. Lingar: Semiconductors

J. L. Lovvorn: Operational amplifiers; semiconductors

W. R. Miller: Semiconductors

K. Rush: Semiconductors

J. A. Russell: Batteries

P. E. Satterlee: Semiconductors

G. K. Schulze. Semiconductors

L. H. Thacker: Semiconductors

R. A. Todd: Chairman, semiconductors

J. H. Todd: Resistive components

J. W. Woody: Semiconductors

Professional Engineers Registered in Various States

R. K. Adams
J. L. Anderson
T. R. Barclay
O. W. Burke
H. E. Cochran
S. J. Ditto
T. M. Gayle
E. W. Hagan
J. L. Horton
R. W. Ingle
F. W. Manning
H. J. Metz
G. N. Miller
L. C. Oakes
J. A. Russell
R. S. Stone
R. M. Tate
H. A. Todd
J. H. Todd
R. E. Toucey

Sigma Xi

E. B. Johnson: Member of Admissions Committee, Oak Ridge Branch

Special Awards

C. J. Borkowski and T. V. Blalock, with R. J. Fox, J. A. Harter, and R. L. Shepard, *Industrial Research* magazine IR 100 Award in 1977 for Johnson Noise Power Thermometer

R. W. Hendricks,[1] with J. A. Ramsey, W. T. Clay, C. E. Fowler, M. K. Kopp, and R. G. Upton, *Industrial Research* magazine IR 100 Award in 1977 for Small-Angle X-Ray Scattering System

G. S. Hurst,[2] W. H. Nayfeh,[2] and J. B. Young,[3] with C. E. Fowler and R. E. Zedler, *Industrial Research* magazine IR 100 Award in 1977 for One-Atom Detector

C. D. Scott[4] and J. E. Mrochek,[4] with R. K. Genung,[4] W. F. Johnson, M. L. Bauer, C. A. Burtis,[5] and D. G. Lakomy,[6] *Industrial Research* magazine IR 100 Award in 1977 for Portable Centrifugal Fast Analyzer

J. B. Davidson: Second prize in "New and Unusual Techniques Class" (poster, invited exhibit), by the International Metallographic Society Convention Metallographic Exhibit, Houston, Texas, July 17-20, 1977

W. B. Cottrell, ed., and E. W. Hagen, Section ed.,[7] "Control and Instrumentation," *Nuclear Safety*, East Tennessee Chapter of the Society for Technical Communication Award to the staff of the Journal in the 1977 and the 1978 (both years) STC Publications Competition

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1. Metals and Ceramics Division.
2. Health and Safety Research Division.
3. Analytical Chemistry Division.
4. Chemical Technology Division.
5. National Center for Disease Control, Atlanta.
6. University of Rochester.
7. These awards were shared by all staff members of the journal.

Special Laboratory DOE/UCC-ND Assignments

J. B. Davidson: Consultant to the Institute for Nuclear Energy Research, Taiwan, Republic of China, September 27-October 10, 1976

J. A. Russell: Consultant to the University of Maryland Physics Department

Union Carbide Corporation Nuclear Division Committees

J. W. Woody: Computer Maintenance Review

J. A. Russell: Radio Advisory

U.S. NIM Committee

N. W. Hill: Member, Subcommittee on Analog Signals

G. A. Holt: Member, Executive Committee

J. W. Woody: Member, NIM Committee

U.S. Nuclear Regulatory Commission

S. J. Ditto: Consultant to the Advisory Committee on Reactor Safeguards

E. B. Johnson: Member of Atomic Safety and Licensing Board Panel

Visiting Lecturer

J. B. Davidson:

1. Institute for Nuclear Energy Research, Taiwan, Republic of China, October 1, 1976.
2. Institute for Solid State Physics, University of Tokyo, Tokyo, Japan, October 12, 1976.
3. Japan Atomic Energy Research Institute, Tokai, Japan, October 13, 1976.

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Some of the publications listed below were prepared jointly with members of other divisions and with consultants and other nonemployees. Their affiliations are noted.

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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 noted.

Symposium of Plasma Physics Heating in Toroidal Devices, Varenna (Lake of Como), Italy, September 6-17, 1976

Berry, L. A.,[1] C. E. Bush,[1] J. D. Callen,[1] R. J. Colchin,[1] J. L. Dunlap,[1] P. H. Edmonds,[1] A. C. England,[1] C. A. Foster,[1] J. H. Harris,[1] H. C. Howe,[1] R. C. Isler,[1] G. L. Jahns,[2] H. E. Ketterer,[1] P. W. King,[1] J. F. Lyon,[1] J. T. Mihalczo, M. Murakami,[1] R. V. Neidigh,[1] G. H. Neilson,[1] V. K. Paré, D. L. Shaeffer,[3] D. W. Swain,[1] J. B. Wilgen,[1] W. R. Wing,[1] and F. J. Zweben,[4] "Neutral Beam Injection Experiments in ORMAK."

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Ackermann, N. J., Jr., C. W. Thayer,[5] S. K. Showe,[5] J. W. Hardy,[5] and J. E. Mott,[6] Instructors, "Nuclear Reactor Instrumentation, Control and Protection Systems," Course 24.

Robinson, J. C.,[6] J. E. Mott,[6] R. C. Kryter, D. N. Fry, and K. R. Piety, Instructors, "Power Reactor Surveillance and Diagnostics by Noise Analysis," Course 25.

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Kollie, T. G., "Temperature--Its Measurement" (invited paper).

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Otaduy, P. J.,[7] C. E. Easterly,[8] R. S. Booth, and D. G. Jacobs,[9] "Factors Affecting Calculations of Dose Resulting from a Tritium Release into the Atmosphere."

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Davidson, J. B., "Principles and Applications of a Television-Based Neutron Camera," October 1 (invited paper); "Principles and Applications of Position-Sensitive Proportional Counters and Solid-State Charge Transfer Devices," October 8 (invited paper).

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Han, J. T.,[10] M. H. Fontana,[10] J. L. Wantland,[10] P. A. Gnadt,[10] and C. M. Smith, "Thermal Hydraulic Correlations of a Six-Channel Blockage in a Sodium-Cooled Simulated LMFBR Fuel Assembly."

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Kelly, M. J.,[12] T. S. Kress,[10] G. W. Parker,[13] J. M. Rochelle, and M. H. Fontana,[10] "Development and Application of Capacitor Discharge Vaporization Technique for Fuel Aerosol Studies."

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Davidson, J. B., "Application of the Fly's Eye Neutron Camera to Diffraction Topography, Topography, and Phase Transition Studies" (invited paper).

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Higgins, C. E.,[14] T. M. Gayle, and J. R. Stokely,[14] "A Light Scattering Sensor for Detection of Tobacco Smoke Particles in Exposure Systems."

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Borkowski, C. J., and M. K. Kopp, "Electronic Discrimination of the Effective Thickness of Proportional Counters."

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Gonzalez, R. C.,[6] and L. C. Howington,[6] "Machine Recognition of Abnormal Behavior in Nuclear Reactors."

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Mathis, M. V., "Noise Analysis and Its Relevance to Reactor Safety" (invited paper).

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Robinson, J. C.,[6] and R. C. Kryter, "Bandwidth-Related Errors in the Inference of PWR Barrel Motion from Ex-Core Neutron Detector Signals."

Saxe, R. F.,[11] "The Effects of Noncondensable Gas Bubbles on Propagation of Boiling Acoustic Noise."

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Harris, J. H.,[1] J. L. Dunlap,[1] and V. K. Paré, "Internal Mode Measurements in ORMAK."

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Shepard, R. L., and R. M. Carroll, "Thermocouple Response Time-Measurements and Improvement."

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Leavell, W. H., and F. Shahrokhi,[6] "Tracking Nonstationary Velocity in Two-Phase Flow by an Adaptive Cross-Correlation Algorithm."

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Allen, J. W.,[6] "The Autoregression Time-Series Model for Analysis of a Noisy Signal."

Kryter, R. C., C. W. Ricker, and J. E. Jones,[6] "Loose-Parts Monitoring: Present Status of the Technology, Its Implementation in U.S. Reactors."

Mathis, M. V., C. M. Smith, D. N. Fry, and M. L. Dailey,[18] "Characterization Studies of BWR-4 Neutron Noise Analysis Spectra."

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Lyon, J. F.,[1] R. C. Isler,[1] M. Murakami,[1] C. E. Bush,[1] J. L. Dunlap,[1] H. C. Howe,[1] G. L. Jahns,[2] H. E. Ketterer,[1] J. T. Mihalczo, R. V. Neidigh,[1] V. K. Paré, and J. B. Wilgen,[1] "Relation of Neutral Beam Injection to Impurity Behavior and Extension of Plasma Parameters in ORMAK."

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Dunlap, J. L.,[1] V. K. Paré, and R. D. Burris,[15] "Internal Mode Structures in ORMAK."

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Ellis, W. H.,[7] V. K. Paré, and R. S. Burns, "An Automatic Counting Channel and Analysis for Neutron Sensor Performance Testing."

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Mathis, M. V., C. M. Smith, D. N. Fry, and M. L. Dailey,[18] "Characterization Studies of BWR-4 Neutron Noise Analysis Spectra."

Piety, K. R., and J. C. Robinson,[6] "Application of Surveillance Techniques for the Improvement of Nuclear Power Plant Availability."

Sides, W. H., Jr., and M. V. Mathis, "Identification of Neutron Noise Sources in a Boiling Water Reactor."

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Rush, K., "Applications of Charge Coupled Devices to Electronic Filters" (invited Paper).

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Mitchell, R. J.,[20] and R. C. Gonzalez,[6] "Multilevel Crossing Rate for Automated Signal Classification."

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Kopp, M. K., "Position-Sensitive Proportional Counters for Radiological Imaging in Medical and Industrial Applications."

Davidson, J. B., and A. L. Case, "Neutron Diffraction Tomography: A Unique, 3D Inspection Technique for Crystals Using an Intensifier TV System."

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Kryter, R. C., J. C. Robinson,[6] and J. A. Thie,[21] "U.S. Experience with In-Service Monitoring of Core Barrel Motion in PWRs Using Ex-Core Neutron Detectors."

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Mihalczo, J. T., and V. K. Paré, "Feasibility of Reactivity Determination from Neutron Noise Spectral Density with ^{252}Cf, in the Internal Loading of Light Moderated Water Reactors."

Ragan, G. L., C. W. Ricker, M. M. Chiles, G. C. Guerrant, and C. O. McNew, "Experimental Evaluation of a System for Assay of Spent Fuel Subassemblies."

ASTM Committee E-20 on Thermometry, Boston, Mass., June 27-30, 1978

Shepard, R. L., "Thermocouple and Resistance Thermometer Response Time-Measurement and Improvement" (invited paper).

1977 Engineering Foundation Conference-Applications of New Signature Analysis Technology, Franklin Pierce College, Rendge, New Hampshire, July 24-26, 1978

Fry, D. N., "Inverse Nuclear Plant Availability with Noise Signature Analysis" (invited paper).

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PATENTS

C. J. Borkwoski, "High Temperature Furnace," U.S. Patent No. 3,973,075 (August 3, 1976).

A. L. Case and J. B. Davidson, "Real Time, TV-Based, Point-Image Quantizer and Sorter," U.S. Patent No. 3,958,079 (May 18, 1976).

W. F. Johnson, "Photomultiplier Tube Gain Regulating System," U.S. Patent No. 3,988,590 (October 26, 1976).

D. G. Lakomy,[1] M. L. Bauer, and W. F. Johnson, "Dynamic Multistation Photometer," U.S. Patent No. 4,030,834 (June 21, 1977).

C. J. Remenyik,[2] W. K. Sartory,[3] W. Z. Penland,[4] J. P. Breillatt, Jr.,[5] and L. H. Thacker, "Closed Continuous-Flow Centrifuge Rotor," U.S. Patent No. 3,955,755 (May 11, 1976).

J. M. Rochelle, "Ultrasonic Temperature Telemetry System," U.S. Patent No. 3,878,502 (1975).

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L. H. Thacker, "Compact Fast Analyzer of Rotary Cuvette Type," U.S. Patent No. 3,982,838 (September 28, 1976).

R. G. Upton, "Digital Scale Converter," U.S. Patent No. 4,071,743 (January 31, 1978).

K. H. Valentine, E. L. Long, Jr.,[6] and M. G. Wiley,[7] "Nuclear Fuel Microsphere Gamma Analyzer," U.S. Patent No. 4,021,669 (May 3, 1977).

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THESES COMPLETED

For the Ph.D. degree by the University of Tennessee:

Allen, James W., "Characterization of Stochastic Time Domain Data from Reactor Instrumentation Using Autoregression-Moving Average Techniques on a Mini-Computer."

For the M.S. degree by the University of Tennessee:

Mitchell, Rick J., "Multilevel Crossing Analysis for Automated Classification of Random Signals."

Shahrokhi, Farshid, "State-of-Art Study in Nondestructive Assay Systems and Their Applications to an LMFBR Aqueous Fuel Reprocessing Plant."

For the M.S. degree by Pennsylvania State University, University Park, Penn.:

Mullens, J. A., "ARMA Models of Nuclear Reactor Noise."

SUMMARY OF DIVISIONAL MANPOWER ALLOCATION IN FY 1978

1. Allocation of Programmatic Manpower by Programs

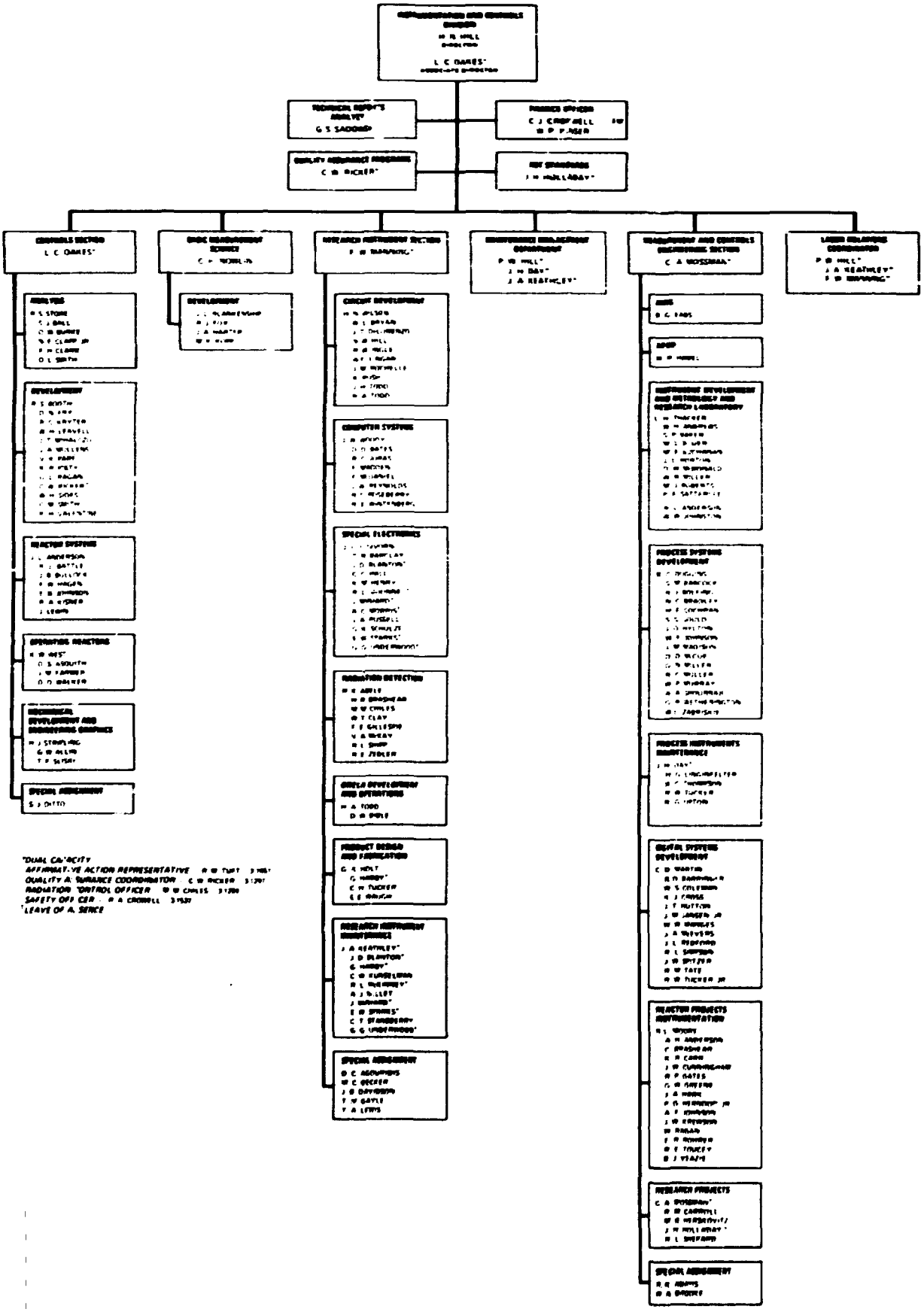
Program	Division Manpower (man-years)		
	Research	E and M[a]	Total
AG Breeder Reactors	8.6	13.0	21.6
GK Environmental R&D	4.0	1.4	5.4
40 Work for Other Federal Agencies	10.2	13.7	23.9
41 Cash Work for Others	0.4	0.3	0.7
42 Cash Work for Others	0.7	1.3	2.0
To Other Divisions	10.1	300.3	310.4
Total, man-years	34.0	330.0	364.0

[a]Engineering and maintenance.

2. Percentage Allocations[a]

Program	Research (%)	E and M (%)
1 Reactor Research and Technology	25	4
2 Environmental R&D	12	0.5
3 USNRC	30	4
4 Work for Others	3	0.5
5 To Other Divisions	30	91

[a]Percentage of column totals.



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