ORNL-5032

I&C

Instrumentation and Controls Division

Annual Progress Report

FOR PERIOD ENDING SEPTEMBER 1, 1974

NON-LMFBR PROGRAMS

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DISCLAIMER

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy $6.00; Microfiche $2.25

ORNL-5032
Dist. Category UC-37

Contract No. W-7405-eng-26

INSTRUMENTATION AND CONTROLS DIVISION
ANNUAL PROGRESS REPORT
For Period Ending September 1, 1974

Non-LMFBR Programs

C. J. Borkowski, Director
R. A. Dandl, Associate Director
L. C. Oakes, Associate Director, and
Head, Reactor Controls Dept.

Compiled by G. S. Sadowski

SEPTEMBER 1976

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

Reports previously issued in this series are as follows:

ORNL-714	Period Ending April 15, 1950
ORNL-796	Period Ending July 15, 1950
ORNL-924	Period Ending October 31, 1950
ORNL-1021	Period Ending January 20, 1951
ORNL-1056	Period Ending April 20, 1951
ORNL-1159	Period Ending July 20, 1951
ORNL-1160	Period Ending October 20, 1951
ORNL-1335	Period Ending January 20, 1952
ORNL-1336	Period Ending April 20, 1952
ORNL-1389	Period Ending July 20, 1952
ORNL-1436	Period Ending October 20, 1952
ORNL-1492	Period Ending January 20, 1953
ORNL-1694	Period Ending July 31, 1953
ORNL-1749	Period Ending January 31, 1954
ORNL-1768	Period Ending July 31, 1954
ORNL-1865	Period Ending January 31, 1955
ORNL-1997	Period Ending July 31, 1955
ORNL-2067	Period Ending January 31, 1956
ORNL-2234	Period Ending July 31, 1956
ORNL-2480	Period Ending July 1, 1957
ORNL-2647	Period Ending July 1, 1958
ORNL-2787	Period Ending July 1, 1959
ORNL-3001	Period Ending July 1, 1960
ORNL-3191	Period Ending July 1, 1961
ORNL-3378	Period Ending September 1, 1962
ORNL-3578	Period Ending September 1, 1963
ORNL-3782	Period Ending September 1, 1964
ORNL-3875	Period Ending September 1, 1965
ORNL-4091	Period Ending September 1, 1966
ORNL-4219	Period Ending September 1, 1967
ORNL-4335	Period Ending September 1, 1968
ORNL-4459	Period Ending September 1, 1969
ORNL-4620	Period Ending September 1, 1970
ORNL-4734	Period Ending September 1, 1971
ORNL-4822	Period Ending September 1, 1972
ORNL-4990	Period Ending September 1, 1973
ORNL-5170	Period Ending September 1, 1973

Contents

FOREWORD xv

1. BASIC ELECTRONICS DEVELOPMENTS

1.1 LOW-POWER HYBRID IC ELECTROMETER AMPLIFIERS
J. T. De Lorenzo, E. J. Kennedy, and C. H. Tucker 1

1.2 HYBRID MICROCIRCUIT ACTIVITIES
J. T. De Lorenzo et al 1

1.3 MULTICHANNEL TEMPERATURE TELEMETRY SYSTEM FOR HIGH-VELOCITY ROTATING MACHINES
E. J. Kennedy et al 2

1.4 APPROXIMATIONS FOR THE SYMMETRICAL PARALLEL-PLANE TRANSMISSION LINE
J. M. Rochelle 4

1.5 ENGINEERING ACTIVITIES OF THE SPECIAL ELECTRONICS GROUP
D. D. Bates et al 4

2. ENGINEERING SUPPORT FOR RESEARCH FACILITIES

SUPPORT FOR THE VAN DE GRAAFF ACCELERATOR PROGRAM

2.1 TANDEM ACCELERATOR OPERATION AND DEVELOPMENT
J. W. Johnson and G. F. Wells 5

2.2 CHARGE-STATE SELECTOR FOR TANDEM ACCELERATOR BEAM
J. W. Johnson et al 5

2.3 STABLE SMALL-ANGLE SCATTERING APPARATUS
J. W. Johnson et al 5

2.4 SOLID-STATE REGULATOR FOR MAGNETIC QUADRUPOLE LENS POWER SUPPLY
R. P. Cumby and G. F. Wells 6

2.5 ION SOURCE TEST BENCH
J. W. Johnson et al 6

2.6 SURFACE IONIZATION SOURCE
J. W. Johnson, G. D. Alton, and J. E. Weidley 6

2.7 PENNING ION SOURCE TEST FACILITY
J. W. Johnson, J. E. Weidley, and M. L. Mallory 7

2.8 MAGNETIC-FIELD MAPPING APPARATUS
J. W. Johnson, J. K. Bair, and J. E. Weidley 7

2.9 RESULTS OF TANDEM ACCELERATOR DRIVE MOTOR IMPROVEMENTS
J. W. Johnson and G. F. Wells 7

2.10 CYLINDRICAL ELECTROSTATIC ELECTRIC SPECTROMETER
J. E. Weidley and H. Hazelton 7

ORELA

2.11 ORELA IMPROVEMENT PROGRAMS
T. A. Lewis 9

2.12 ORELA ENGINEERING DEVELOPMENT SUPPORT
J. H. Todd 9

2.13 INSTRUMENTATION FOR NEUTRON MULTIPLICITY MEASUREMENTS
R. W. Ingle 10

2.14 EXPERIMENTAL ELECTRONIC ACTIVITIES FOR NEUTRON PHYSICS DIVISION
J. H. Todd and R. W. Ingle 10

ELMO BUMPY TORUS EXPERIMENT

2.15 TWENTY-FOUR POINT CRT DISPLAY
R. E. Wintenberg 11

2.16 MICROWAVE CRYSTAL SWITCH DRIVER
R. E. Wintenberg 11

2.17 SERVO PRESSURE CONTROLLER
R. E. Wintenberg 11

ORMAK

2.18 ENGINEERING SUPPORT FOR THE THERMONUCLEAR DIVISION
J. L. Anderson et al 11

2.19 A 140-GHz DIGITAL MICROWAVE INTERFEROMETER FOR ELECTRON DENSITY MEASUREMENTS
D. D. Bates, G. R. Dyer, and W. R. Wing 12

2.20 A VERSATILE DIGITAL DELAY GENERATOR
D. D. Bates, M. Murakami, and W. R. Wing 13

2.21 INJECTOR CONTROL MODULE
D. D. Bates, W. R. Wing, and L. A. Berry 13

2.22 PLASMA FEEDBACK CONTROL-CURVE FITTING OF PICKUP COIL RESPONSES DURING DRY RUNS
R. S. Booth 13

2.23 ANALYSIS OF DATA CONTAINING SEVERAL EXPONENTIALS
R. S. Booth 14

ORIC

2.24 ORIC MAGNET REGULATOR IMPROVEMENT PROGRAM
W. E. Lingar 14

3. PULSE COUNTING AND ANALYSIS

3.1 LINEAR, CHARGE COUPLED DEVICE AS AN X-RAY DETECTOR
J. B. Davidson and A. L. Case 15

3.2 DIFFERENTIAL CURRENT PULSE PREAMPLIFIER FOR FISSION COUNTERS
J. T. De Lorenzo 15

3.3 UNFOLDING SPATIAL IMAGES FROM A POSITION-SENSITIVE PROPORTIONAL NEUTRON COUNTER
R. S. Booth et al 18

3.4 SUPERHEAVY-ELEMENT DETECTION SYSTEM
J. H. Todd 18

3.5 SPECTROMETER SUPPORT STANDS
G. W. Allin 19

4. RADIATION DETECTION AND MONITORING

4.1 ANALYSIS OF GAS BREAKDOWN INTEGRATING IONIZATION CHAMBERS
J. M. Rochelle 20

4.2 IN-LINE BETA-SENSITIVE SCINTILLATION DETECTOR FOR OFF-GAS DECONTAMINATION FACILITY
M. M. Chiles, V. A. McKay, and D. M. Levins 21

4.3 TRITIUM AIR MONITORS FOR AN EXPERIMENTAL FUSION REACTOR
R. L. Shipp 21

4.4 G-M SURVEY METER
F. M. Glass, G. A. Holt, and E. E. Waugh 21

4.5 ENGINEERING ACTIVITIES CONCERNING RADIATION MONITORING
C. C. Hall, J. L. Lovvorn, and P. P. Williams 23

4.6 PERFORMANCE OF AN ARGON –3.5% CYCLOPROPANE GAS FLOW PROPORTIONAL COUNTER
R. E. Zedler and Hai-Hsin Chang 24

4.7 IONIZATION CHAMBER FOR KRYPTON ENRICHMENT PROCESS
F. E. Gillespie and H. R. Brashear 25

4.8 CD V-700 MODIFICATIONS
F. M. Glass and H. N. Wilson 25

4.9 G-M TUBE TEST INSTRUMENT
J. M. Rochelle and H. N. Wilson 25

5. INSTRUMENT DEVELOPMENT

BIOMEDICAL INSTRUMENTS

5.1 WHOLE BLOOD ANALYSIS ROTOR DEVELOPMENT
W. F. Johnson 26

5.2 DIGITAL DATA SYSTEM
W. F. Johnson 26

5.3 TECHNIQUES FOR LOADING LIQUIDS INTO THE ROTOR OF THE MINIATURE CENTRIFUGAL FAST ANALYZER
C. A. Burtis et al 27

5.4 AUTOMATED LOADING OF DISCRETE, MICROLITER VOLUMES OF LIQUIDS INTO A MINIATURE FAST ANALYZER
C. A. Burtis, W. F. Johnson, and J. B. Overton 27

5.5 AUTOMATED PLASMA, RED BLOOD CELL, AND HEMOLYSATE PREPARATION
T. O. Tiffany et al 28

5.6 OPTIMIZATION AND ANALYTICAL APPLICATIONS OF THE TECHNIQUE OF DYNAMIC INTRODUCTION OF LIQUIDS INTO CENTRIFUGAL ANALYZERS
C. A. Burtis et al 28

5.7 BLOOD GROUPING WITH A MINIATURE CENTRIFUGAL FAST ANALYZER
T. O. Tiffany et al 29

5.8 SPECIFIC PROTEIN ANALYSIS BY LIGHT-SCATTER MEASUREMENT WITH A MINIATURE CENTRIFUGAL FAST ANALYZER
T. O. Tiffany et al 29

5.9 MINIATURE FLOW FLUOROMETER IMPROVEMENTS
L. H. Thacker 30

5.10 A SMALL BATTERY-OPERATED CENTRIFUGAL FAST ANALYZER SYSTEM
C. D. Scott et al 30

5.11 SMOKE INHALATION PROGRAM
G. W. Allin 32

5.12 KIRLIAN PHOTOGRAPHY AS A BIOINSTRUMENTATION TECHNIQUE
D. W. McDonald 32

5.13 TIME AND FREQUENCY STANDARD
W. R. Miller 32

RESEARCH INSTRUMENTS

5.14 DIGITAL NANOAMMETER
F. M. Glass 35

5.15 NEW FISH TAG DEVELOPMENTS
J. M. Rochelle and J. S. Ryberg 35

5.16 WIND AVERAGING SYSTEM
W. R. Miller 35

5.17 PLUTONIUM AND URANIUM OXIDE AEROSOL DENSITY MEASUREMENTS
L. H. Thacker and D. W. McDonald 37

5.18 ENGINEERING SERVICES FOR ANALYTICAL CHEMISTRY
T. M. Gayle 37

5.19 QUAD CRACK FOLLOWER
J. T. Hutton 37

5.20 LONG-TERM INTEGRATOR
G. K. Schulze 38

5.21 MULTIJUNCTION W-Re THERMOCOUPLE FUEL CENTERLINE TEMPERATURE MEASUREMENTS IN HFIR IRRADIATION CAPSULES
R. L. Shepard and J. K. East 38

5.22 IN-PILE TEST OF JOHNSON NOISE THERMOMETER
R. L. Shepard et al 40

5.23 TUNGSTEN-RHENIUM THERMOCOUPLE TOOLING
G. W. Allin, J. K. East, and R. L. Shepard 40

5.24 INSTRUMENT DEVELOPMENT AIDS
W. R. Miller and L. H. Thacker 42

6. AUTOMATIC CONTROL AND DATA ACQUISITION

COMPUTER-BASED SYSTEMS

6.1 MICROPROCESSOR DEVELOPMENT
M. J. Roberts 43

6.2 WHITE OAK DAM STREAM MONITOR CONTROL SYSTEM
M. J. Roberts 43

6.3 COMPUTER PROGRAM FOR AUTOMATIC DATA ACQUISITION AND PEAK DETECTION
E. McDaniel, J. Hargis, and R. T. Roseberry 43

6.4 AUTOMATIC SAMPLE CHANGER
G. W. Allin, R. T. Roseberry, H. J. Stripling, Jr. 44

6.5 STANDARD FOCAL OVERLAY SOFTWARE PACKAGE
J. M. Jansen, Jr. and A. F. Johnson, Jr. 44

6.6 COMPUTER-BASED DATA ACQUISITION SYSTEM FOR THERMAL HYDRAULIC TEST FACILITY
J. L. Redford and C. D. Martin 45

6.7 DATA COLLECTION FROM A MULTIDETECTOR SYSTEM FOR AN AUTOMATICALLY SCANNING ELECTRON SPECTROMETER: A CONCEPTUAL DESIGN
R. T. Roseberry and M. O. Krause 45

6.8 A FAST CRT DISPLAY CONTROLLER FOR A PDP-8/e COMPUTER
R. T. Roseberry et al 46

6.9 A MAGNETICALLY PULSED NEUTRON TIME-OF-FLIGHT SPECTROMETER FOR INELASTIC SCATTERING
H. A. Mook, F. W. Snodgrass, and D. D. Bates 46

6.10 RADIOISOTOPIC SAND TRACER STUDY
H. R. Brashear, F. N. Case, and K. W. Haff 46

6.11 UPDATE TO DATA ACQUISITION SYSTEM FOR FUEL RECYCLE DEVELOPMENT LABORATORY
A. F. Johnson, Jr. 47

6.12 LOW-SPEED INTERCOMPUTER DATA LINK TO AID PATTERN RECOGNITION STUDIES AT THE HFIR
J. B. Bullock and W. H. Sides 48

6.13 ORIC MAGNET POWER SUPPLY CONTROLLERS
E. Madden et al 48

6.14 PROGRAM FOR COMPUTER CONTROL OF ORIC
E. McDaniel, E. Madden, and C. A. Ludemann 50

6.15 EXECUTIVE SERVICE ROUTINE FOR MODCOMP MAX III
E. McDaniel 51

6.16 COMPUTER DIAGNOSTIC PROGRAM FOR ORIC MAGNET POWER SUPPLY CONTROLLERS
E. McDaniel and E. Madden 51

6.17 CREEP LABORATORY DATA ACQUISITION SYSTEM
J. T. Hutton, J. M. Jansen, Jr., and R. L. Simpson 51
6.18 ACQUATIC LABORATORY STATUS
J. A. McEvers et al 52
6.19 COMPUTER-CONTROLLED DATA ACQUISITION ON THE ELMO BUMPY TORUS
J. W. Reynolds 52
6.20 X-RAY DIFFRACTOMETER CONTROL
E. Madden 53
6.21 UPGRADING THE CAPABILITIES OF A COMMERCIAL FOURIER ANALYZER SYSTEM
R. C. Kryter and V. K. Pare 53
6.22 180° ORSIS COMPUTER SYSTEM STATUS REPORT
J. M. Jansen, Jr., W. K. Dagenhart, and F. R. Gibson 54
6.23 MULTIAXIAL STRAIN TEST FACILITY DATA ACQUISITION SYSTEM
J. L. Redford and K. Liu 54
6.24 ON-LINE COMPUTER DATA SYSTEM FOR THE ORANGE COUNTY "WATER FACTORY 21"
J. L. Redford and S. J. Ball 54

HARD-WIRED SYSTEMS

6.25 STEPPING MOTOR CONTROL AND POSITION READOUT DISPLAY
E. Madden 55
6.26 EXPANSION OF THE SERDEX SERIAL DATA SYSTEM FOR STANDARDS LABORATORY PRINTOUT
M. L. Bauer 55
6.27 ORIC SOURCE AND PROBE CONTROL SYSTEM
J. A. Russell, Jr. 55
6.28 DIGITAL POWER CONTROL
J. T. Hutton and R. W. Tucker 56
6.29 AUTOMATED ELECTROCARDIOGRAM DATA ACQUISITION SYSTEM
R. L. Simpson 56
6.30 PORTABLE DATA ACQUISITION SYSTEM FOR TRANSIENT MEASUREMENTS
A. F. Johnson, Jr. 56
6.31 PROGRAMMED POWER CONTROLLER
W. R. Miller 57
6.32 SUPERCONDUCTOR "NORMAL" DETECTOR AND SHUTDOWN
D. W. McDonald 57

7. PROCESS SYSTEMS AND INSTRUMENTATION DEVELOPMENT

7.1 ADDITIONS AND MODIFICATIONS TO THE ORNL STEAM PLANT CONTROL SYSTEMS
W. R. Hamel and B. C. Duggins 59
7.2 IMPROVEMENTS TO THE HYDROFRACTURE FACILITY
R. E. Toucey 59

7.3 DIGITAL POWER PANEL
W. R. Miller 60

8. REACTOR INSTRUMENTATION AND CONTROLS

8.1 ANALYSIS OF NEUTRON-DENSITY OSCILLATIONS RESULTING FROM CORE BARREL MOTION IN A PWR
D. N. Fry, R. C. Kryter, and J. C. Robinson 61

8.2 NEUTRON NOISE MEASUREMENTS IN A BWR: BROWNS FERRY UNIT 2
D. N. Fry 62

8.3 PROGRESS IN THE APPLICATION OF PATTERN RECOGNITION METHODS TO REACTOR SURVEILLANCE
R. C. Gonzalez, A. S. Mahmoud, and R. C. Kryter 62

8.4 RELIABILITY AND SAFETY ANALYSES OF HIGH-TEMPERATURE GAS-COOLED REACTOR SYSTEMS
P. Rubel 63

8.5 SIMULATION OF THE GAS-COOLED FAST BREEDER REACTOR (GCFBR) STEAM GENERATOR ON THE HYBRID COMPUTER
O. W. Burke and F. H. Clark 63

8.6 NUCLEAR DESALINATION PLANT CONTROL STUDIES
S. J. Ball, N. E. Clapp, Jr., and J. G. Delene 64

8.7 CORE FLOW TEST LOOP DYNAMICS SIMULATION STUDIES
S. J. Ball 64

8.8 CONTROL SYSTEM SIMULATION STUDIES OF A COAL-FIRED GAS TURBINE POWER PLANT
J. W. Mills and S. J. Ball 64

8.9 DYNAMIC TESTS IN THE HTGR FUEL CAPSULE EXPERIMENT
W. H. Sides et al 65

8.10 REVIEW OF ENGINEERING TEST REACTOR (ETR) DOCUMENTS
S. J. Ditto and J. L. Anderson 65

8.11 A CORE-CONSERVING, MODERATELY FAST ALTERNATIVE TO THE FFT FOR FREQUENCY ANALYSIS WITH A MINICOMPUTER
R. C. Kryter and D. L. Campbell 65

8.12 THE USE OF CALIFORNIUM -252 AS A RANDOMLY PULSED NEUTRON SOURCE FOR PROMPT-NEUTRON DECAY MEASUREMENTS
J. T. Mihalczo 66

8.13 OPTIMIZATION OF NONOSECOND FISSION ION CHAMBERS FOR REACTOR PHYSICS APPLICATIONS
N. W. Hill et al 67

8.14 THEORY OF CORRELATION MEASUREMENT IN TIME AND FREQUENCY DOMAINS WITH ^{252}Cf
J. T. Mihalczo and V. K. Paré 68

8.15 CALCULATED AMPLITUDE DISTRIBUTION OF IONIZATION PULSES FOR A PARALLEL-PLATE IONIZATION CHAMBER
J. W. Allen 68

8.16 NEUTRON IMPORTANCE AND FISSION DENSITY IN ENRICHED-URANIUM AND PLUTONIUM METAL SPHERES
J. T. Mihalczo 69

8.17 PRELIMINARY INVESTIGATION OF FILTERING METHODS FOR CORE FLOW TEST LOOP THERMOCOUPLE SIGNALS
M. J. Roberts 69

8.18 HTGR SAFETY STUDIES
J. L. Anderson et al 69

8.19 HTGR SYSTEM RESPONSE AND SAFETY STUDIES
S. J. Ball, N. E. Clapp, Jr., and J. G. Delene 70

8.20 PBF CONTROL AND SAFETY INSTRUMENTATION
J. L. Anderson and S. J. Ditto 70

8.21 NUCLEAR SAFETY JOURNAL
E. W. Hagen 70

8.22 ACQUISITION AND TESTING OF A 14-CHANNEL ANALOG MAGNETIC-TAPE RECORDER
D. N. Fry and R. C. Kryter 70

8.23 IAEA INTERNATIONAL SYMPOSIUMS ON NUCLEAR POWER-PLANT CONTROL AND INSTRUMENTATION
E. W. Hagen and T. W. Kerlin 71

8.24 CHALLENGES FOR POWER INSTRUMENTATION: THE 16TH ANNUAL ISA POWER INSTRUMENTATION SYMPOSIUM
M. D. Sulouff and E. W. Hagen 71

8.25 HFIR INSTRUMENTATION ERROR ANALYSIS
M. J. Roberts 71

8.26 LOCA MODELING ON THE HYBRID COMPUTER
R. S. Stone 72

8.27 REACTOR SIMULATOR FOR AMERICAN MUSEUM OF ATOMIC ENERGY
R. S. Stone 72

8.28 NUCLEAR SAFETY INFORMATION CENTER
E. W. Hagen 72

8.29 LECTURES ON THE HFIR PROCESS CONTROL COMPUTER
J. B. Bullock 73

9. FUEL REPROCESSING AND SHIPPING

9.1 STATE OF THE ART IN NONDESTRUCTIVE ASSAY SYSTEMS AND THEIR APPLICATIONS TO AN LMFBR AQUEOUS FUEL REPROCESSING PLANT
F. Shahrokhi 74

9.2 HTGR FUEL FABRICATION PROTOTYPE PLANT
H. E. Cochran 74

9.3 TRANSURANIUM PROCESSING PLANT STATUS
H. E. Cochran and R. L. Durall 76

9.4 LASER BEAM TRIGGER SYSTEM FOR RECORDING SINGLE EVENTS
N. C. Bradley 77

10. STANDARDS LABORATORY

10.1 ORNL STANDARDS LABORATORY WORK ON THERMOMETRY STANDARDS AND SPECIFICATIONS
W. W. Johnston, Jr., M. B. Herskovitz, and R. L. Shepard 78

10.2 ORNL STANDARDS LABORATORY SERVICES
R. L. Anderson, W. W. Johnston, Jr., and M. H. Cooper 78

10.3 RECENT IMPROVEMENTS IN SERVICES AND CAPABILITIES OF THE ORNL STANDARDS LABORATORY
R. L. Anderson 79

11. INSTRUMENTATION FOR REACTOR DIVISION EXPERIMENTS AND TEST LOOPS

11.1 THERMAL SHOCK CRACK ARRESTMENT EXPERIMENT
P. G. Herndon 80

11.2 FORCED-CONVECTION TEST FACILITY
C. Brashear et al 80

11.3 DATA ACQUISITION AND REDUCTION FOR THE THERMAL-HYDRAULIC TEST FACILITY
N. E. Clapp, Jr. 81

11.4 DATA ACQUISITION AND REDUCTION FOR THE FORCED-CONVECTION TEST FACILITY
N. E. Clapp, Jr. 81

11.5 HYBRID COMPUTER SIMULATION OF THE THERMAL-HYDRAULIC TEST FACILITY (THTF) HEAT REMOVAL SYSTEM
W. R. Hamel, B. G. Eads, and F. H. Clark 81

11.6 GAMMA DENSITOMETER FOR BDHT
R. L. Shipp and V. A. McKay 82

11.7 SUPPORT FOR THE ORNL REACTOR DIVISION SOLID MECHANICS DEPARTMENT
T. M. Cate, W. A. Bird, and R. L. Moore 83

11.8 MOLTEN-SALT FORCED-CIRCULATION LOOP 2
P. G. Herndon 83

11.9 INSTRUMENTATION FOR MSBR GAS SYSTEM TECHNOLOGY FACILITY
P. G. Herndon 83

11.10 INSTRUMENTATION FOR MSBR COOLANT SALT TECHNOLOGY FACILITY
P. G. Herndon 84

11.11 INSTRUMENTATION FOR REACTOR IRRADIATION EXPERIMENTS
J. W. Cunningham 84

11.12 POTASSIUM-STEAM BINARY VAPOR CYCLE TEST FACILITY .....
P. G. Herndon 85

11.13 SPECIAL THERMOMETRY SUPPORT WORK FOR REACTOR PROJECTS
W. W. Johnston, Jr., M. H. Cooper, and M. B. Herskovitz 85

12. MAINTENANCE AND SERVICE

12.1 INSTRUMENTATION AND CONTROLS DIVISION MAINTENANCE INFORMATION SYSTEM COMMITTEE
K. W. West et al 86

12.2 INSTRUMENTATION AND CONTROLS MAINTENANCE INFORMATION SYSTEM
R. L. Simpson 86

12.3 MAINTENANCE ACTIVITIES OF THE SPECIAL ELECTRONIC SERVICES GROUP
J. L. Lovvorn and R. L. McKinney 87

12.4 ACTIVITIES OF THE RADIATION MONITORING SYSTEMS MAINTENANCE GROUP
J. D. Blanton, J. L. Lovvorn, and P. P. Williams 87

12.5 ACTIVITIES OF THE AUDIO-VISUAL SERVICE GROUP
C. C. Hall, J. L. Lovvorn, and J. Miniard 88

12.6 ACTIVITIES OF THE TELECOMMUNICATIONS AND PERSONAL RADIATION MONITOR MAINTENANCE GROUP
J. D. Blanton, J. L. Lovvorn, and J. Miniard 88

12.7 MAINTENANCE ACTIVITIES FOR ENVIRONMENTAL SCIENCES, SOLID STATE, PHYSICS, AND INSPECTION ENGINEERING DIVISIONS
J. D. Blanton, J. L. Lovvorn, and W. Ragan 89

12.8 RADIO COMMUNICATIONS SYSTEMS
J. A. Russell 89

12.9 ACTIVITIES OF THE COMPUTER AND ANALYZER MAINTENANCE GROUP
J. A. Keathley and E. McDaniel 89

12.10 ACTIVITIES OF THE ELECTROMECHANICAL SECTION OF THE COMPUTER AND ANALYZER MAINTENANCE GROUP
E. McDaniel, J. A. Keathley, and L. R. Gitgood 90

12.11 OPERATING REACTORS GROUP – MAINTENANCE ACTIVITIES
K. W. West 90

12.12 MAINTENANCE OF THE ORR
J. M. Farmer, J. B. Ruble, and K. W. West 90

12.13 MAINTENANCE OF THE HPRR
D. D. Walker and K. W. West 91

12.14 MAINTENANCE OF THE TSR-II REACTOR
D. D. Walker and K. W. West 91

12.15 MAINTENANCE OF THE BSR AND THE PCA
J. M. Farmer, J. B. Ruble, and K. W. West 91

12.16 MAINTENANCE OF THE HFIR
D. S. Asquith, J. M. Farmer, and K. W. West 92

12.17 ACTIVITIES OF THE LABORATORY ACCELERATOR MAINTENANCE GROUP
J. L. Lovvorn and E. W. Sparks 92

13. ECOLOGICAL SCIENCE STUDIES

13.1 A NUTRIENT- AND HORMONE-DEPENDENT TREE-GROWTH-RATE MODEL
O. L. Smith and R. A. Goldstein 94

13.2 MODIFICATION OF THE FOREST MODEL, SERENDIPITY
O. L. Smith et al 94

13.3 A MASS-DEPENDENT BIOLOGICAL MODEL OF METAL-ION BINDING IN ANIMAL TISSUE
R. S. Stone, S. R. Bernard, and K. Barnes 95

13.4 INITIAL MODELING OF AN EXPERIMENT TO INVESTIGATE SEDIMENT-WATER DYNAMICS OF PLUTONIUM IN AQUATIC ENVIRONMENTS
R. S. Booth 95

13.5 A SYSTEMS ANALYSIS MODEL FOR CALCULATING RADIONUCLIDE TRANSPORT BETWEEN RECEIVING WATERS AND BOTTOM SEDIMENTS
R. S. Booth 96

13.6 A GENERALIZED MODEL FOR SIMULATING LAKE ECOSYSTEMS
R. A. Park et al 97

13.7 A SPECIFIC ACTIVITY AND CONCENTRATION MODEL APPLIED TO CESIUM MOVEMENT IN AN OLIGOTROPHIC LAKE
H. A. Vanderploeg et al 98

13.8 CONDOS – A MODEL AND COMPUTER CODE TO ESTIMATE POPULATION AND INDIVIDUAL RADIATION DOSES TO MAN FROM THE DISTRIBUTION, USE, AND DISPOSAL OF CONSUMER PRODUCTS THAT CONTAIN RADIOACTIVE MATERIALS
F. R. O'Donnell et al 98

13.9 RESOURCE COMPETITION AND AN ANALYTICAL MODEL OF ZOOPLANKTON FEEDING ON PHYTOPLANKTON
O. L. Smith et al 98

13.10 USER'S MANUAL FOR MODSOV, A TERMINAL-OPERATED PROGRAM SOLVING THE LINEAR MATRIX EQUATION $\dot{x} = Ax + k$
F. H. Clark, R. S. Booth, and H. A. Vanderploeg 99

13.11 LEAKAGE OF RADIOACTIVE MATERIALS OVER A BROAD AREA AND ITS LOCAL IMPACT
F. H. Clark and R. E. Moore 100

13.12 EXPERIMENTAL INVESTIGATIONS OF MOBILE HOME ENERGY USE CHARACTERISTICS
S. J. Ball 100

14. ADMINISTRATION AND TRAINING

14.1 QUALITY ASSURANCE FOR ORNL INSTRUMENTATION AND CONTROLS
C. S. Lisser and H. J. Metz 101

14.2 QUALITY ASSURANCE PROGRAM DEVELOPMENT
W. W. Johnston, Jr., M. H. Cooper, and C. S. Lisser 101

14.3 RDT STANDARDS
C. S. Lisser and J. A. Russell, Jr. 102
14.4 INTRODUCTORY PROGRAMMING COURSE FOR PDP-8/E COMPUTER
A. F. Johnson, Jr., R. K. Adams, and C. D. Martin, Jr. 102
14.5 INTENSIVE RECRUITING PROGRAM
R. K. Adams and L. H. Thacker 103
PROFESSIONAL AWARDS, ACHIEVEMENTS, OFFICES, AND MEMBERSHIPS IN PROFESSIONAL GROUPS HELD BY INSTRUMENTATION AND CONTROLS DIVISION PERSONNEL 104
PUBLICATIONS 107
PAPERS PRESENTED AT PROFESSIONAL MEETINGS 110
THESES COMPLETED 113
PATENTS 114
ORGANIZATION CHART 115

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.

1. Basic Electronics Developments

1.1 LOW-POWER HYBRID IC ELECTROMETER AMPLIFIERS[1]

J. T. De Lorenzo E. J. Kennedy C. H. Tucker

A hybrid integrated-circuit electrometer amplifier that dissipates <4 mW was designed for portable radiological survey meters. An alternative design with greater open-loop gain was developed for application in line-powered instruments. Preliminary measurements indicate an improvement of the input leakage by a factor greater than 10 over a discrete design. Several amplifiers of each type were fabricated, and the results of long-term stability approach that of all-monolithic types. The all-ceramic package and a carefully guarded structure have also resulted in excellent performance in high humidity.

1. Abstract of paper presented at the 1974 Government Microcircuits Applications Conference, University of Colorado, Boulder, June 25–27, 1974. A digest of the paper was published in *1974 Government Microcircuit Applications Conference, Digest Papers*, vol. V, ed. Lewis Winner, June 1974, available from Chief of Naval Research, Dept. of the Navy, Arlington, VA 22217.

1.2. HYBRID MICROCIRCUIT ACTIVITIES

J. T. De Lorenzo E. J. Kennedy V. C. Miller
J. M. Rochelle C. H. Tucker H. N. Wilson

Expansion of the hybrid, integrated-circuit facility, installed in 1971, was continued. Long-term stability tests of the microcircuit electrometer amplifier were completed.[1] Drifts over a five-month period in a laboratory environment were equivalent to $<2 \times 10^{-15}$ A of input current. These tests were conducted with amplifiers having both high and low open-loop gains. Both types of amplifiers were connected as unity-gain followers with a 10^{12}-Ω input resistor and a 10-kΩ load. Effects of humidity changes observed during these tests were reduced significantly by coating the package with Dow Corning DC340 compound.

The University of Tennessee (UTK) at Knoxville and the Instrumentation and Controls Division contracted to share personnel and equipment of this Division and the hybrid thick-film laboratory at UTK. Thick-film resistor and conductor pastes were purchased from several suppliers for evaluation. Stainless steel screens and materials for construction of masks were acquired. Preliminary results from tests of two pastes were encouraging, but they also revealed problems in both mask fabrication and screening techniques. A test mask was designed to evaluate the resistive and conductive properties of pastes.

Two circuits, a fast current-pulse preamplifier for fission counters and a low-noise voltage preamplifier for position-sensitive devices, were selected as the first to be fabricated as thick-film hybrid microcircuits. Transistor and capacitor chips, substrates, and packages were purchased to construct these circuits. Masks were prepared, and the circuits will be fabricated after more complete data are obtained from evaluation of the pastes. The circuits will be fabricated before an extensive evaluation of thick-film pastes is completed so that we can learn as soon as possible some of the problems to be encountered during production of useful

circuits with thick films. The evaluation of pastes will be continued concurrently with fabrication, and if superior materials and techniques are found, they will be substituted to improve the overall capability of the various circuits

Since it will be difficult to connect the thick-film substrate to its external package, tests are being devised to evaluate conductive elastomers for this connection, with a goal of achieving low cost, reliability, and potential contact densities approaching 100 per inch

---

1 J T De Lorenzo et al , *Instrumentation and Controls Div Annu Prog Rep Sept 1 1973* ORNL-4490 (to be published)

1.3 MULTICHANNEL TEMPERATURE TELEMETRY SYSTEM FOR HIGH-VELOCITY ROTATING MACHINES

E J Kennedy[1] A H. Malone[2]
W R. Miller J M. Rochelle

An eight-channel telemetry system (Q-2922) was developed for multipoint temperature measurements of rotating machines. This new solid-state system is useful where conventional slip ring connections are impractical or their performance is marginal. An example is instrumentation of high-velocity machines, such as centrifuges, when slip ring reliability is extremely poor. Another more applicable example is simultaneous multipoint monitoring that otherwise would require many slip rings on one shaft.

Although narrow-band techniques were not applied to this system, it is immune to interference from most common noise sources, particularly to noise spikes generated by brushes and solid-state power rectifiers.

The complete system comprises a rotor electronics package, a stator electronics package, and a rack-mounted readout module (Fig. 1.3.1) The rotor package is an eight-channel, multiplexed FM transmitter, having complementary, metal oxide semiconductor integrated circuits to minimize the on-board power requirements. A multiplexing circuit sequentially connects the eight data thermistors (channels) to the input of a voltage-controlled oscillator (VCO) in response to a three-bit logic code generated by a binary ripple counter. A null interval follows the eighth channel, the VCO output frequency is zero during the null interval.

Power for the rotor electronics is obtained by transformer action between a drive coil on the stator and a tuned pickup coil on the rotor. The power frequency of 20 kHz is supplied by an integrated-circuit oscillator and a power amplifier in the control module. Satisfactory power coupling is obtained with rotor-stator gaps to about ¾ in.

The FM signal output of the VCO is amplified and transmitted across the rotor-stator gap by electrostatic coupling between the rotor and stator electrodes arranged in either parallel-plate or concentric-ring configurations.

The stator electronics package contains an amplifier-driver circuit that interfaces the FM signal detected by the stator plate to a 93-Ω coaxial cable for transmission to the readout module. Transmission of the signal over more than 100 ft of cable is possible.

At the readout module, the FM signal is further amplified, limited, and demodulated by a diode pump count-rate circuit. The transfer characteristic of the diode pump can be adjusted to compensate for nonlinearities in the characteristics of the data thermistors and the rotor VCO. When properly compensated, the output voltage from the diode pump is a linear function of the data thermistor temperature, with a typical full-scale calibration of 10 V dc equal to 100°C. Typical measurement inaccuracies are less than ±0.5°C.

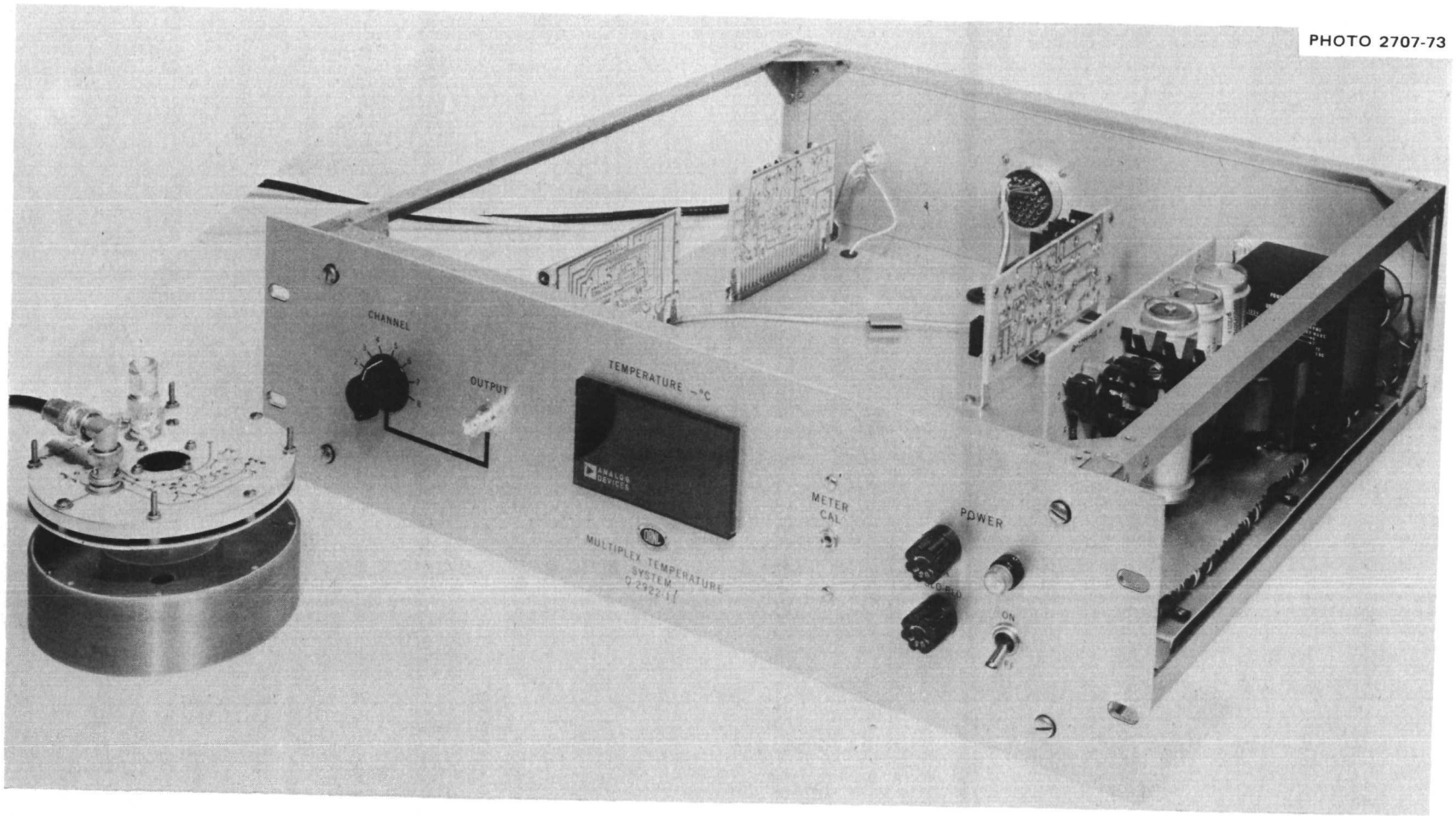


Fig. 1.3.1. Multichannel temperature telemetry system, Q-2922.

The diode pump output is demultiplexed into eight sample and hold circuits, each of which can be monitored with a digital panel meter or a chart recorder. The rotor multiplexer and the stator demultiplexer are synchronized before each scan by a novel technique based on detection of the null interval following the eighth channel.

With additional logic control, the system is expandable into 16, or more, channels of multiplexed data

1 Consultant from the Electrical Engineering Department, the University of Tennessee, Knoxville
2 Separations Division, Oak Ridge Gaseous Diffusion Plant

1.4 APPROXIMATIONS FOR THE SYMMETRICAL PARALLEL-PLANE TRANSMISSION LINE[1]

J M. Rochelle

A single approximation which is valid for the capacitance of both wide and narrow parallel-plane transmission lines is developed by assuming a uniform current distribution. An approximate formula for the repulsive force between the planes is also given.

1 Abstract of paper submitted to *IEEE Transactions on Microwave Theory and Techniques*

1.5 ENGINEERING ACTIVITIES OF THE SPECIAL ELECTRONICS GROUP

D. D. Bates
A. L. Case J L. Lovvorn
J. A. Russell, Jr. G. K. Schulze

Engineering consulting and assistance were provided to a variety of projects as requested or required by Laboratory operations.

Engineering assistance was provided to the Thermonuclear Division in the design, fabrication, and operational support of the microwave diagnostics system for plasma research.

A television monitoring system consisting of a camera, monitor, and videotape recording system was specified, obtained, and installed for the Transmission Processing Facility.

A four-channel video conditioning amplifier was designed and fabricated for the Inspection Engineering Department.

A video-graphic storage terminal was specified, obtained, and modified with an improved sync generator and operating controls for the Basic Instrumentation Group of this Division.

The intercom system for the Digital Systems Group of this Division was redesigned and modified from a "master-slave" system to an "all-master" system.

A six-station master intercom system was designed and installed for the Liquid-Metal Fast Breeder Reactor projects group.

One-half man-year was spent in preparing RDT standards for instrumentation and in assisting in the evaluation of other specifications and standards.

Assistance was given several researchers in the selection and specification of oscilloscopes and other instrument needs.

2. Engineering Support for Research Facilities

SUPPORT FOR THE VAN DE GRAAFF ACCELERATOR PROGRAM

2.1 TANDEM ACCELERATOR OPERATION AND DEVELOPMENT

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

The benefit of the modular design[2] for the ion source housing-insulator-vacuum pump support was demonstrated by the ease with which a new type of negative-ion source[3] was installed and operated. The Cs^+ sputter-cone source has reliably produced C^-, O^-, Cu^-, Ni^-, and Au^- beams of 1 to 20 μA and Al^-, Fe^-, and Bi^{2-} beams of 0.3 to 1.0 μA. The improved model of the charge-exchange ion source, built by ORNL, is routinely used to produce H^-, He^-, C^-, O^-, F^-, S^-, Cl^-, Br^-, and I^- beams. Many of these beams have been used by 62 investigators in 12 different research areas of atomic and nuclear physics.

1. Physics Division.
2. J. W. Johnson and G. F. Wells, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973*, ORNL-4990 (to be published).
3. R. Middleton and C. Adams, University of Pennsylvania, Philadelphia.

2.2 CHARGE-STATE SELECTOR FOR TANDEM ACCELERATOR BEAM

J. W. Johnson
J. A. Biggerstaff[1] C. D. Moak[1] J. E. Weidley

An electrostatic device was designed and built for selecting (analyzing) charge states of heavy-ion beams from the ORNL model EN Tandem Van de Graaff accelerator. A beam of a single charge state will be used for further studies of stripping, stopping power, channeling, etc., in the atomic physics program of the Physics Division.

The device will provide for complete separation of charge states to $q = 20$ for beams 1 mm in diameter and energy to 4 MeV times q. For $q \leq 10$, the beam energy may be 8 MeV times q. To prevent charge changing, metal seals and materials compatible with pressures of 10^{-8} torr were used.

1. Physics Division.

2.3 STABLE SMALL-ANGLE SCATTERING APPARATUS

J. W. Johnson
J. A. Biggerstaff[1] C. M. Jones[1] C. D. Moak[1]

In the atomic physics program of the Physics Division, the hyperchanneling and charge stripping studies were shown to be limited by the mechanical stability of the support structure, including the building floor,

for the experimental equipment. Also, the initial alignment of the critical section of the equipment was time consuming. These problems were overcome by supporting the apparatus on surplus milling machines mounted on concrete piers that are completely free from the building and supported by hard clay. The feeds on the mill tables were utilized for independent *x-y-z* adjustment. By positioning the mills 4 m apart, the built-in rotation of the mill tables was used to provide a long-radius, small-angle scattering chamber. Rotation of ±3° was available, with a resolution of 1/2500°.

1. Physics Division.

2.4 SOLID-STATE REGULATOR FOR MAGNETIC QUADRUPOLE LENS POWER SUPPLY

R. P. Cumby G. F. Wells[1]

The vacuum tube (6336A) series regulators for the power supplies for the magnetic quadrupole lens of the ORNL model EN Tandem Van de Graaff have been very unreliable. To correct this problem, a solid-state unit (Q-5240-1) was designed, built, and installed on one lens supply, using Delco DTS-4065 Darlington power transistors. Special provisions are required to prevent transistor failure when the output voltage is changed too rapidly into the high inductive load (1 H). The regulator has been trouble free since its installation in March 1974. A unit for the second lens supply is being built.

1. Physics Division.

2.5 ION SOURCE TEST BENCH

J. W. Johnson
G. D. Alton[1] J. E. Weidley G. F. Wells

To continue the development of negative-ion sources for heavy-ion Tandem Van de Graaff accelerators, a test bench facility is being built in the Van de Graaff laboratory. The design was completed for the mechanical hardware, and fabrication is 25% completed. The electrical-electronic design has not been started.

The ions from various sources will be accelerated to 100 kV by operating the ion source off-ground. The ions will be analyzed in an $M \times E = 36$, single-focusing magnet having a homogeneous field, a 90° sector, and a ρ of 28.5 in.

1. Physics Division.

2.6 SURFACE IONIZATION SOURCE

J. W. Johnson G. D. Alton[1] J. E. Weidley

Many negatively charged heavy ions can be produced by sputtering from the solid of the element of interest with a beam of Cs^+. To continue the development of sources for negative ions, a surface ionization source for Cs^+ was designed and built. In the source, cesium vapor is ionized by passing it through a porous frit of tungsten heated to 1100°C.

1. Physics Division.

2.7 PENNING ION SOURCE TEST FACILITY

J. W. Johnson J. E. Weidley M. L. Mallory[1]

A test facility was designed and constructed for testing and development of ion sources for the Oak Ridge Isochronous Cyclotron. The facility also has the potential of being used as a low-energy, high-charge-state accelerator for use in atomic physics experiments.

The ion source test facility (Fig. 2.7.1) was constructed in an existing 30-in.-diam magnet. The curved electrostatic plates provide a cross-field channel with the magnetic field for dispersion and extraction of the ions. The ion beam is focused at the slit plane, which allows single-charge-state extraction. The electrostatic quadrupole lens refocuses the ions into the Faraday cup or other experimental equipment.

1. Physics Division.

2.8 MAGNETIC-FIELD MAPPING APPARATUS

J. W. Johnson J. K. Bair[1] J. E. Weidley

To obtain design data for the sector magnets of a heavy-ion cyclotron, it was desired that the magnetic field of model magnets of 0.15 scale be mapped over a uniformly spaced mesh of several thousand points for several magnetic-field levels. The goal was for field measurements with an accuracy of 1 part in 16,000. This set the positioned accuracy of the probe at ±0.001. The required hardware was designed and built, and the four magnets were positioned optically to ±0.002 of a true position to each other and to a known position of ±0.001 on a tape-controlled milling machine. The problems of differential thermal expansion and vibration had to be considered, and solutions were provided.

1. Physics Division.

2.9 RESULTS OF TANDEM ACCELERATOR DRIVE MOTOR IMPROVEMENTS

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

Following improvements in the drive motor and terminal generator of the ORNL model EN tandem accelerator previously reported,[2] there have been no failures of these components since October 1972. At present this is more than 6700 hr of operation without failure, as opposed to an average of 600 hr between failures previously experienced.

1. Physics Division.
2. J. W. Johnson and G. F. Wells, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973*, ORNL-4990 (to be published).

2.10 CYLINDRICAL ELECTROSTATIC ELECTRIC SPECTROMETER

J. E. Weidley H. Hazelton[1]

To study the Auger states from heavy-ion beams, a double-focusing spectrometer for electrons was designed and built. The diameter of the inner cylinder is 4.5 in., and the acceptance angle of the electrons emerging from the target is 42° to the axis. Targets may be either a solid or a differentially pumped gas cell.

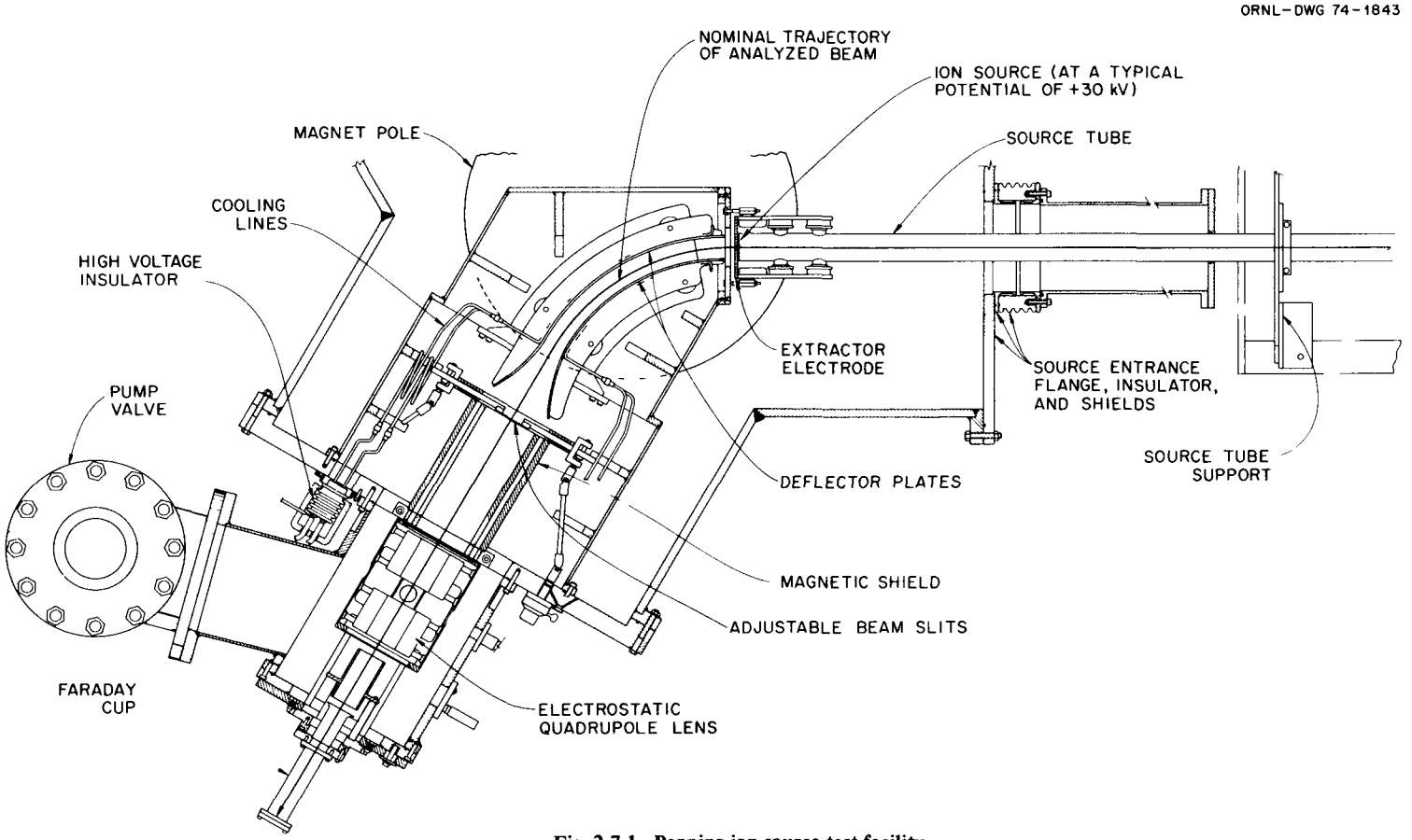


Fig. 2.7.1. Penning ion source test facility.

An energy resolution of 2/1000 was obtained over an energy range from 10 to 2000 V. Provision is made in the acceptance aperture-lens to decelerate the electron beam by a factor of 10, thereby increasing the resolution the same amount. The spectrometer was designed for a base pressure of 1×10^{-9} torr. All parts exposed to the vacuum can be baked to 400°C.

1. Physics Division.

ORELA

2.11 ORELA IMPROVEMENT PROGRAMS

T. A. Lewis

The continuing ORELA improvement programs resulted in achievement of reliable performance at high power. The accelerator was operated at a beam power level of 60 kW for >400 consecutive hr with a reliability factor of 96.6%. The previous power limitations of the target were partially circumvented by installing a continuously operating rapid beam scanner. Although this present beam power capability is now 20% greater than the original design level of 50 kW, we anticipate even higher power operation, primarily by improving the heat exchanger for the target cooling water.

The programs for improving the short-pulse performance of ORELA have progressed significantly. Results from preliminary analytical computer routines and prototype prebunching equipment are promising.

2.12 ORELA ENGINEERING DEVELOPMENT SUPPORT

J. H. Todd

General engineering support was given to development and testing of improved subsystems on the accelerator, along with routine maintenance support. Some of the more important development work is described in the following paragraphs.

Four klystrons produce the rf power in the linear accelerator; each can produce a peak output power of 30 MW. Waveguides transfer this power to the main sections of the accelerator. Voltage standing waves (VSWs) can be generated in this system, and, if excessive, they can be destructive to the klystrons, waveguides, and rf windows. Detectors were installed to observe the VSWs; if the VSWs exceed preset levels, safety circuits will shut down the accelerator. However, if these detectors or associated equipment should fail, excessive VSWs could be unnoticed and could damage the accelerator. A system that monitors the detectors and associated equipment and sounds an alarm if a detector fails was designed and constructed and is being tested.

Since vacuum degradation can result in damage of components inside the accelerator, it is essential to quickly detect a pressure rise and close certain valves to prevent this damage. To achieve the necessary closure speed, the valves are actuated by the detonation of a power charge. An improved and more reliable circuit for pressure-rise detection and valve firing was designed and is being constructed.

One of the programs to upgrade the accelerator is to increase the peak pulse current by decreasing the electron burst width, or "bunching" the electrons, after this pulse leaves the electron gun. The electrons can be bunched by changing their energy as a function of their location in the burst.

A high-voltage pulser of ~40 kV with 5 to 10 nsec rise time into 50 Ω and a repetition rate of 1 kHz is being developed to change the electric field needed for bunching the electron burst. Pulses of 20 kV are being generated; components for operation at 40 kV are being assembled.

2.13 INSTRUMENTATION FOR NEUTRON MULTIPLICITY MEASUREMENTS

R. W. Ingle

The system[1] for the measurement of $\bar{\nu}$, the number of neutrons per fission of fissile isotopes, was completed at the ORELA facility for the Neutron Physics Division. The system detects counts and records the number of fission neutrons vs incident neutron energy from fissile isotopes. During the past year, experiments were conducted with ^{239}Pu and ^{235}U.

The detector is a spherical tank containing a gadolinium-loaded liquid scintillator. Eight photomultiplier tubes detect light produced from reactions within the liquid. Beam neutrons from the accelerator pass through a hollow cylindrical tube in the tank; a fission chamber, containing fissile material, is inside the tube.

The liquid scintillator detects prompt gamma rays that are followed by fission neutrons when an incident neutron causes the fissile material to fission. The fission chamber detects fission fragments and emits a pulse when a fission occurs. When the fission neutrons are captured by the gadolinium in the liquid, gamma rays are emitted, and these produce light scintillations in the scintillator liquid.

The electronic system detects a coincidence between the signal from the fission chamber and the prompt gamma pulse from the liquid within 50 nsec after the fission event. The fission neutrons are slowed down to thermal energy in the liquid and captured by the gadolinium in $\sim$8 μsec av; the maximum time is $\sim$40 μsec after the prompt gamma pulse. Therefore, 0.5 μsec after the prompt gamma pulse, a gate is opened and fast pulses from the liquid are counted. The exact length of the gate is determined experimentally, and for this experiment the length is 32 μsec.

The neutron count is recorded by an ORTEC-770 scaler, which was modified to produce a read-ready signal to an EGG DC-100 time digitizer that records the time of flight of the incident neutrons. The interface produces a binary word that consists of the incident neutron time of flight and the number of neutrons in that particular fission event.

The accuracy of the $\bar{\nu}$ measurement depends on the efficiencies of both detectors, the background, the dead time of the entire detector-electronic system, and the gain and bias stability of the detectors. Elaborate tests were made to measure and improve these characteristics, particularly the dead time and scintillator efficiency.

---

1. R. W. Ingle, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973*, ORNL-4990 (to be published).

2.14 EXPERIMENTAL ELECTRONIC ACTIVITIES FOR NEUTRON PHYSICS DIVISION

J. H. Todd R. W. Ingle

Continuing engineer assistance was given to the fissile isotope, cross-section group of the Neutron Physics Division for such programs as the measurement of the capture and fission cross sections of ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, and ^{241}Am.

We continued to develop and measure the parameters of neutron detectors, fission chambers, and photomultiplier tubes to improve their detection efficiency, timing, and resolution.

ELMO BUMPY TORUS EXPERIMENT

2.15 A 24-POINT CRT DISPLAY

R. E. Wintenberg

A 24-point analog multiplexer, cathode-ray tube display was designed for the ELMO Bumpy Torus Experiment[1] to display the pressure around the torus as measured by 24 ion gages. A 2-kHz clock, binary counter, and decoder control the FET analog switches and reset the sweep generator. The output levels are 10 V, and the unit is packaged in a three-unit-wide NIM module.

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

2.16 MICROWAVE CRYSTAL SWITCH DRIVER

R. E. Wintenberg

A microwave crystal switch driver was designed with a combination of digital and analog circuits. These circuits control and linearize the attenuation characteristics of the switch and permit fast turn-on or turn-off to a preset attenuation level. The switching can be initiated by panel-mounted pushbuttons or by logic signals. Sync signals are available for timing purposes.

2.17 SERVO PRESSURE CONTROLLER

R. E. Wintenberg

Four Granville Phillips, series 213 automatic pressure controllers were extensively modified and repackaged. The mechanical chopper and vacuum tube "front end" were replaced with integrated-circuit operational amplifiers and a chopper circuit. The operational amplifiers enable independent control of dc gain, first-derivative amplitude and time constant, second-derivative amplitude and time constant, and motor drive limiting. The new package contains two units, with all of the new controls in the panel space formerly required by one unit.

ORMAK

2.18 ENGINEERING SUPPORT FOR THE THERMONUCLEAR DIVISION

J. L. Anderson
R. S. Booth R. J. Colchin[1]
R. V. Miskell[2] J. E. Swander[3]

We aided the Thermonuclear Division in preparing a conceptual design description for a Feasibility/Burning Experiment (F/BX).[4] We contributed to or reviewed prepared descriptions of the overall control philosophy, plant instrumentation, diagnostic instrumentation, and concepts for protection of superconducting magnet structures.

Applications design and cost estimates were completed to upgrade some of the ORMAK instrumentation (field current and voltage measurements), but purchasing and fabricating the instrumentation were delayed because of funding difficulties.

In cooperation with the Thermonuclear Division, we conceived, designed, and fabricated a controller for feedback control of the plasma position in the ORMAK by driving the vertical field. In the ORMAK, the plasma position is stabilized somewhat by reactive magnetic forces produced by eddy currents induced by the plasma in a conductive shell surrounding the plasma, but to improve the experimental results, a higher degree of stability is desired than is obtainable with the shell. Feedback control will be essential in future experiments because conductive shells will not be used The plasma position is computed in the controller circuit from signals from magnetic probes and measurements of plasma and vertical field currents. Curve-fitted terms are applied in this computation to correct for the delayed response of the vertical field to changes in the applied field currents, this delay is due to eddy currents in the liner. Further, the magnetic probes are sensitive not only to the poloidal field produced by the plasma but to the applied vertical field as well, which is much larger than the poloidal field at the probe locations. In effect, this yields a signal-to-noise ratio of 1 100, and, as a result, a curve-fitted signal proportional only to the vertical field must be subtracted from the probe signals. The output of the plasma position controller is connected to the existing field controller, which uses a function generator to preprogram the field current. The controller is fabricated from integrated-circuit operational amplifiers, multipliers, and digitally controlled analog switches

1 Thermonuclear Division
2 Y-12 Engineer Department
3 Deceased June 7, 1974
4 P N Haubenreich and M Roberts, *ORMAK F/BX, a Tokamak Fusion Test Reactor,* ORNL-TM-4634 (June 1974)

2.19 A 140-GHz DIGITAL MICROWAVE INTERFEROMETER FOR ELECTRON DENSITY MEASUREMENTS

D D. Bates G R. Dyer[1] W R. Wing[1]

A 140-GHz digital microwave interferometer was developed and placed in operation to enable electron density measurements of the plasma in ORMAK for line densities up to 2×10^{14} cm^{-3}

The interferometer uses trilevel modulation of the klystron to supply sin θ and cos θ signals and a reference signal halfway between the two signals to eliminate the need for ultrawide-band amplifiers. Since the modulation frequency might be $\leq$10 MHz, with sidebands wide enough only to cover the time-varying phase information of the plasma, the low-frequency noise of the detectors and electronics is eliminated in the band-pass amplifiers

The signals, after being detected by a synchronous detector and restored by sample and hold circuits, are routed through digital logic to an up-down counter. Positive and negative zero-crossing of the sin θ and cos θ signals provides a $\pi/2$ (equivalent to quarter fringe of the familiar zebra-stripe interferometer) resolution of the increasing or decreasing density. A digital-to-analog decoder converts the time-varying density information from the up-down counter to an analog signal compatible with the ORMAK computer and monitor oscilloscope.

1 Thermonuclear Division

2.20 VERSATILE DIGITAL DELAY GENERATOR

D. D. Bates M. Murakami[1] W. R. Wing[1]

A crystal-controlled, multichannel, digital delay generator was developed to furnish precise trigger pulses for the laser scattering experiment. Five output pulses from the generator are individually controlled by thumb-wheel switches. The delays are selectable in 0.1-msec increments over a range from 0.1 to 1000 msec and have a time resolution of better than 1 μsec. The generator is contained in a triple-wide NIM module.

1. Thermonuclear Division.

2.21 INJECTOR CONTROL MODULE

D. D. Bates W. R. Wing[1] L. A. Berry[1]

A module was developed to control the ORMAK injectors so that they can be used for preionization of the plasma. With this module the injectors can be (1) turned on initially in the experiment for a selectable time to preionize the plasma, (2) turned off and delayed for a selectable time, and (3) turned back on for injection to heat the plasma.

1. Thermonuclear Division.

2.22 PLASMA FEEDBACK CONTROL-CURVE FITTING OF PICKUP COIL RESPONSES DURING DRY RUNS

R. S. Booth

The empirical function from Colchin,[1]

$$B_v(t) = C_0 I_v(t) + \sum_{i=1}^{N} C_i e^{-t/\tau_i} \int_0^t I_v(t) e^{t/\tau_i}\, dt \,, \tag{1}$$

was least-squares fitted to coil responses obtained during three dry runs of ORMAK. The data supplied by Colchin included the vertical field current, $I_v(t)$, expressed as counts (millivolt level) per channel of 0.421 msec duration. About 400 channels of data, accurate to ~0.5 count/channel, were provided. The general least-squares code ORGLS[2] was used to determine a set of parameters [$(C_i, i = 0,N)$ and $(\tau_i, i = 1,N)$] which could be used in Eq. (1) to approximate $B_v(t)$ for any $I_v(t)$. The coefficients were needed to fix component values in a circuit that generates the vertical field subtraction signal, B_v, for the control system for the ORMAK vertical field.

It was determined that the coil responses could be fitted to within their statistical accuracy with $N = 2$, $\tau = 7$ msec, $\tau_2 = 1140$ msec, and C_0, C_1, and C_2 determined by the least-squares code. Unfortunately, the best C_i's for each run differed from the best C_i's for the other runs by more than the calculated uncertainty in these parameters. However, selection of a reasonable compromise set of C_i's from the optimum set for each run and use of this set in Eq. (1) resulted in predicted $B_v(t)$ values which were usually within ~1 count/channel of the measured $B_v(t)$ values for all three runs. This accuracy was considered adequate.

1. Private communication from R. J. Colchin, ORNL, March 1974.
2. W. L. Busing and H. A. Levy, *ORGLS, a General FORTRAN Least-Squares Program*, ORNL-TM-271 (Aug. 7, 1962).

2.23 ANALYSIS OF DATA CONTAINING SEVERAL EXPONENTIALS

R. S. Booth

The general least-squares code ORGLS[1] was modified so that exponentials could be progressively isolated and stripped from data. The modified code determines the parameters for up to three exponentials and a constant background; these parameters best fit data points over successively smaller sections of the total data set. After the fit is completed in one section, the next section is defined by eliminating data points from the front or back of this current section (channel-chop iteration), and another fit is made. Since, as points are eliminated, the accuracy of the fit usually becomes dominated by a single exponential, the estimated agreement of this single-exponential fit to a section becomes independent of the number of data points in that section. The value accepted for a parameter is a weighted average of its values for several channel-chop fits. Tests are provided so that the channel-chop sequence is terminated if the fits are diverging.

The program was used successfully to analyze thermocouple responses to an impulse change in temperature and responses of coils in the ORMAK to changes of the current in its vertical field.

---

1. W. L. Busing and H. A. Levy, *ORGLS, a General FORTRAN Least-Squares Program,* ORNL-TM-271 (Aug. 7, 1962).

ORIC

2.24 ORIC MAGNET REGULATOR IMPROVEMENT PROGRAM

W. E. Lingar

The ORIC main-field regulator was fabricated, installed in a temporary location, and checked using a local reference. It was installed in such a way that the original regulator could be switched to the new regulator in minimum time during the checkout. A precision voltage source that will be used as a remote reference when long-term stability measurements are made is being interfaced with the computer.

A transducer derives the feedback signal that is of much larger magnitude than could be obtained with a resistive shunt. The transducer is magnetically coupled to the output bus and is sensitive to ambient magnetic fields. Field measurements confirmed that some shielding was required, but for the shielding to be effective, the transductor current path had to be changed to a coaxial arrangement which does not affect the normal operation of the transductor. The magnetic field originating in the center bus, which can be produced by a current as large as 5000 A, is prevented from saturating the external shielding. The shielding is composed of two concentric cylinders, the largest being 20 in. in diameter and $\sim$4 ft long. The total weight of the transductor and shielding is $\sim$800 lb.

Initially, the regulator was used in an open-loop configuration to measure the transfer function of the generator-main-field winding combination. The poles of the measured transfer function were almost identical to those in the theoretical transfer function used in the design.

The system will regulate output current in a range from 100 to 5000 A. The lower bound is limited by the residual magnetism of the generator field. The system bandwidth is greater at high output current because the inductance of the main field decreases at a faster rate with excitation than does the generator gain. The regulator bandwidth was increased by installing parallel transistors in series with the generator field, which decreased the magnitude of one of the dominant time constants.

The circuit design for the trim coil and harmonic coil regulators is $\sim$30% completed. Although the stability requirements are not as critical for these regulators, the design will be as difficult as the main-field design, because the feedback will be derived from a resistive shunt which has an output two orders of magnitude smaller than the signal obtained from the main-field transductor.

3. Pulse Counting and Analysis

3.1 LINEAR, CHARGE-COUPLED DEVICE AS AN X-RAY DETECTOR

J. B. Davidson A. L. Case

As part of the development of filmless radiography systems for the Y-12 Plant, preliminary tests of the direct x-ray sensitivity of a 500-element, charge-coupled photo device were made. The Fairchild CCD101 device is a buried-channel, monolithic, linear image sensor, with sensor elements on 0.030-mm centers. The 24-lead, dual, in-line package contains charge transfer gates for the 500 elements, two 250-element analog shift registers, an analog output register, and an output detector amplifier.

Following an integration period, the analog charge signal developed by each photo element is shifted in parallel to the two 250-element shift registers located on each side of the row of elements. Two registers are used to improve the speed by handling signals from alternate picture elements. The outputs from these two registers are combined at the output of the device in their original order to give a sequence of 500 pulses whose amplitudes are proportional to the light falling on the photo elements during the integration period.

A device "exerciser" obtained from the manufacturer supplied the clock and gate pulses. X rays entering the device produced hole-electron pairs in the photo element region. Gain was obtained in the device, since one pair was produced for 3.5 eV of energy lost by the x rays in the silicon. The x-ray sensitivity was tested with a Picker 50-kVp generator. A vertical sensitivity profile was made using a 25-μ slit which scanned across the linear array with x rays and light (Figs. 3.1.1 and 3.1.2). As the slit was removed to each side of the row of photo elements (Fig. 3.1.1), alternate elements were observed with x rays. Presumably the transfer gate regions and possibly the analog shift registers, both of which parallel the photo elements on the chip, were being excited. The tests were abruptly halted by an accidental short of the output amplifier. A replacement was ordered. The glass window in the new unit will be removed for further tests with x rays and electrons.

A tentative conclusion is that the device tested and similar ones becoming available are potentially useful as light detectors and specialized nuclear detectors, both directly and with appropriate phosphors. Radiation damage and undesirable bulk sensitivity, however, might limit their nuclear applications. Figure 3.1.3 shows the output of the device. The bottom waveform is an expanded view of one line and shows the individual elements. The 500 elements were scanned in 30 msec.

3.2 DIFFERENTIAL CURRENT PULSE PREAMPLIFIER FOR FISSION COUNTERS[1]

J. T. De Lorenzo

A current pulse preamplifier with a differential input was developed for use with fission counters in reactors where there might be severe electrical interference. Tests with a vacuum tester coil show only a slight alteration of the normal noise background curve by the differential preamplifier but a great alteration by the single-ended preamplifier. Additionally, measurements show that if a differential current signal is

ORNL DWG. 74-7664

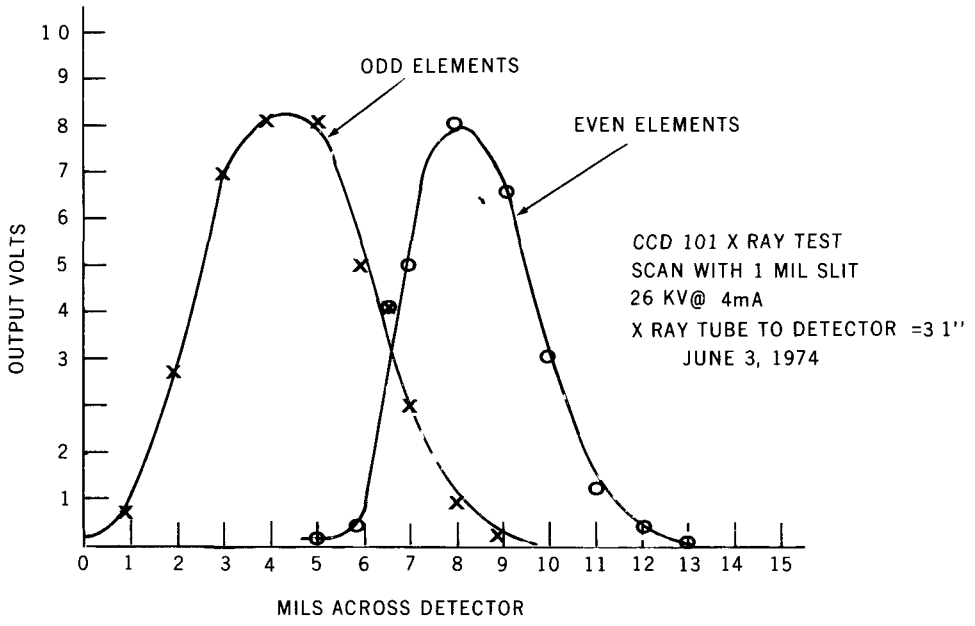


Fig. 3.1.1. Vertical scan across the CCD 101 detector with x rays through a 1-mil-wide horizontal slit.

ORNL DWG. 74-7665

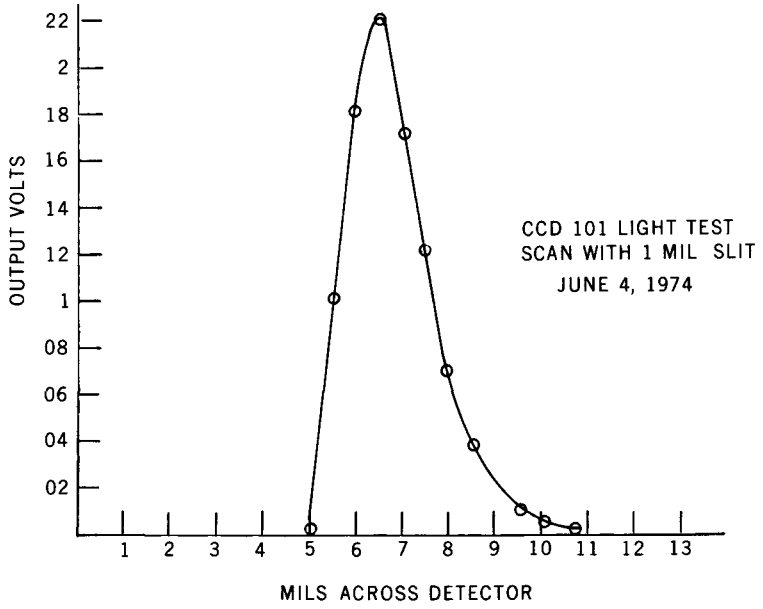


Fig. 3.1.2. Vertical scan across the CCD 101 detector with visible light through a 1-mil-wide horizontal slit.

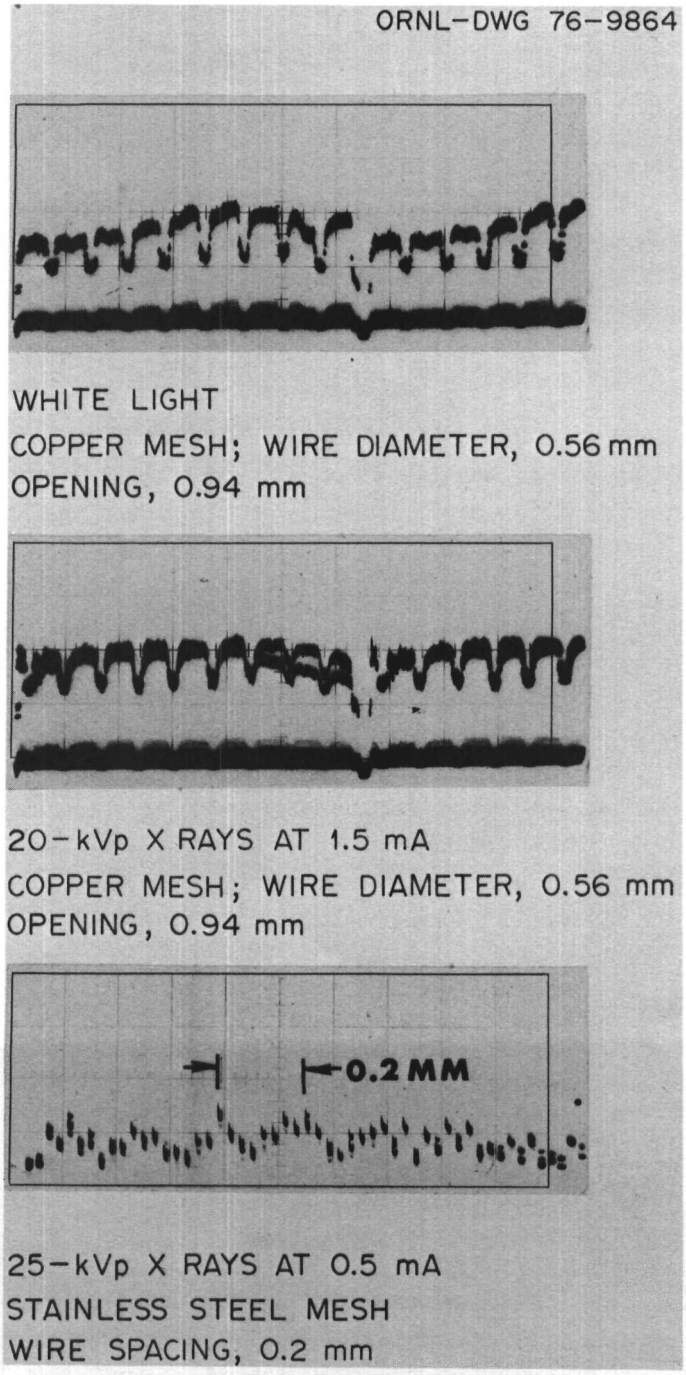


Fig. 3.1.3. Response of the CCD 101 detector to light and x rays through metal mesh.

obtained from the fission counter, the differential preamplifier can improve the signal-to-noise ratio (for electronic noise) over that of a single-ended unit by nearly a factor of $\sqrt{2}$. Tests of five prototypic units built by a commercial manufacturer to RDT standards show good uniformity of performance, including gain stability, rise time, and linearity, well within the specified requirements.

1. Abstract of paper presented at the 1973 IEEE Nuclear Science Symposium, San Francisco, November 14–16, 1973, and published in the *IEEE Trans. Nucl. Sci.* **NS–21**, 757–62 (February 1974).

3.3 UNFOLDING SPATIAL IMAGES FROM A POSITION-SENSITIVE PROPORTIONAL NEUTRON COUNTER[1]

R. S. Booth
M. K. Kopp G. L. Timm[2] J. E. Swander[3]

A data analysis technique was developed and tested for determining the position and intensity of neutron beams incident upon a position-sensitive proportional counter. Solution of this problem of unfolding data is important to the use of the counter in neutron scanning applications. Test data were generated to simulate counts vs y position for 13 neutron beams, and then they were unfolded by several numerical techniques.

The spacing between the beams varied from 1 to 5 cm and their normalized intensity from 0.05 to 1.00. The signature from a single beam covered ~5 cm, or ~30 channels of data. Statistical variation due to counting, after subtraction of a constant background, ranged from ~1% at the peaks of some responses to ~100% for channels dominated by the background.

The most successful technique for unfolding the test data was constrained least-squares fitting, followed by iterative least-squares fitting. The relative positions and intensities of the 13 beams were determined to an estimated accuracy of 0.01 cm and 5% respectively. Similar results were obtained with simulated data where both the y and x positions of the beam were independent variables.

We concluded that the necessity of unfolding counter data for incident neutron beams should not limit the utility of the camera for these beams.

1. Abstract of ORNL-TM-4547 (June 1974).
2. Great Lakes College Association participant (1972) from Kalamazoo College, Kalamazoo, Mich.
3. Deceased June 7, 1974.

3.4 SUPERHEAVY-ELEMENT DETECTION SYSTEM

J. H. Todd

Development work on a neutron multiplicity detector was started. This system will be used to detect the presence of superheavy (i.e., atomic Nos. 112–126) elements by means of a predicted ν (the number of neutrons per fission) from eight to ten.

The system will consist of multiple fast-scintillation detectors, probably 12 arranged in a dodecahedron. Nanosecond logic and data handling will detect and record the time distribution of events. The time distribution of multiple events will be sorted into 6-nsec increments. Special handling of different multiplicities will be possible. Detector efficiencies of 80% for single neutrons with energies down to 100 keV will be attempted.

3.5 SPECTROMETER SUPPORT STANDS

G. W. Allin

Support stands were designed and fabricated for a grazing-incidence spectrometer and a bent-crystal spectrometer. These stands enable a needed versatility for orienting the entrance slit of the spectrometer in relation to the beam.

The grazing-incidence spectrometer with its granite slab can be mounted with the slab in either the horizontal or the vertical plane (Fig. 3.5.1). The positions of both spectrometers can be adjusted both laterally and vertically.

Both units were placed in operation and are functioning adequately.

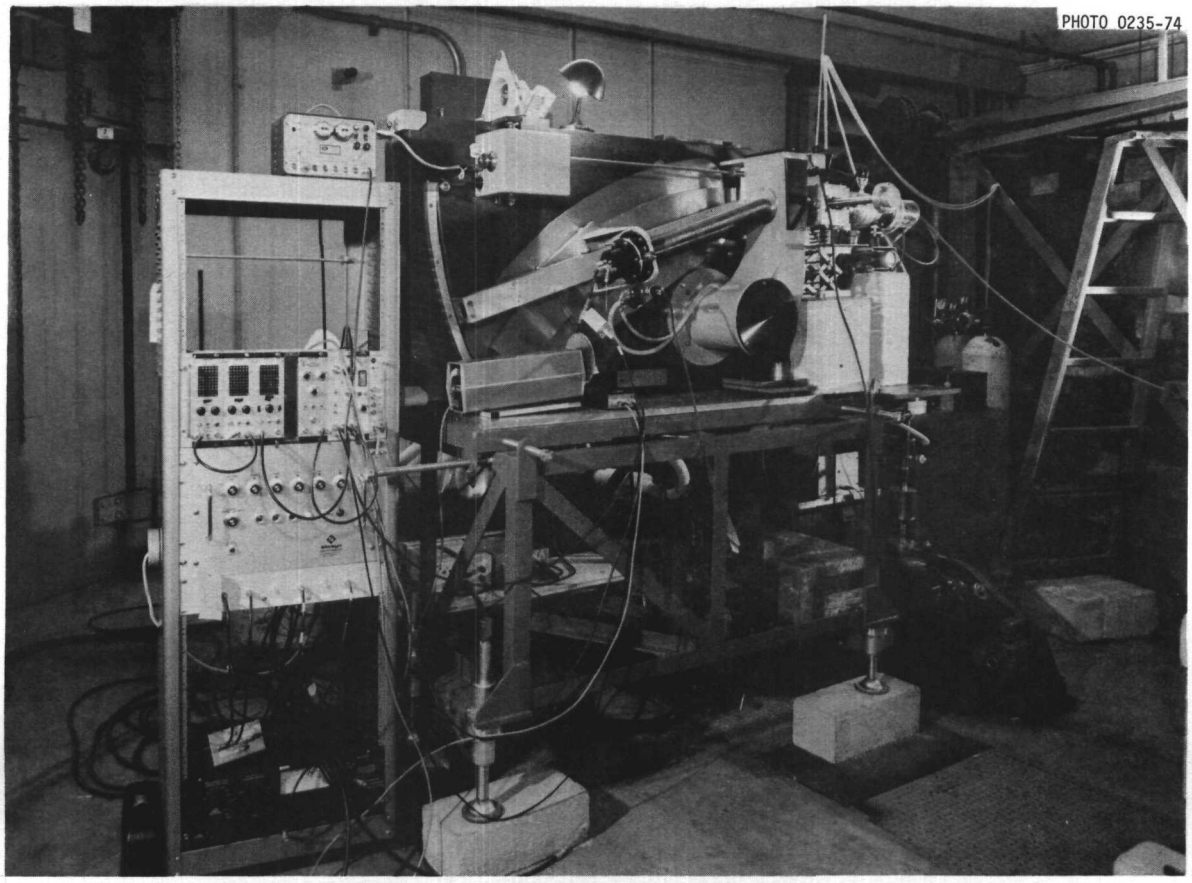


Fig. 3.5.1. Spectrometer support stand.

4. Radiation Detection and Monitoring

4.1 ANALYSIS OF GAS BREAKDOWN INTEGRATING IONIZATION CHAMBERS[1]

J. M. Rochelle

Gas breakdown of a conventional cold-cathode glow discharge device is successfully used to automatically reset an integrating ionization chamber. The currents which can be integrated with this technique range from about 10^{-14} A (due to insulator leakage) to about 10^{-15} A (the onset of a stable glow discharge). For a well-saturated chamber, these currents correspond to a typical gamma dose range from about 10^{-4} to 10^{5} R/hr as evidenced by the data of Distenfeld et al.

The dose per pulse of a gas discharge integrating chamber is generally the sum of stationary and statistical components. The stationary component is the dose received while the gap voltage increases from the extinguishing voltage to the static breakdown voltage (V_s). The statistical component is the dose received during the interval between the instant the gap voltage reaches V_s and the instant breakdown actually occurs. If the chamber volume is too large or too small, the statistical-stationary dose per pulse ratio becomes large, and performance is degraded to that of an insensitive G-M counter.

For large chamber volumes, the statistical component of the dose per pulse is caused by the statistical time lag, which is evaluated for test gaps, using a low-overvoltage approximation of Wijsman's breakdown probability. For an integrating capacitance (C) of 10 pF, the test gaps show a statistical-stationary dose per pulse ratio of 0.1 at chamber volumes of $\sim 10^5$ cc referred to air at 273°K and 760 mm Hg. For small chamber volumes, the statistical component of the dose per pulse is caused by partial breakdowns when the discharge is initiated at low overvoltages. For the test gap with 0.1 cm^2 discharge area, the minimum chamber volume is about 5×10^4 cc compared with only 150 cc when using a test gap with 0.005 cm^2 area (for $C = 50$ pF).

The self-sustaining Townsend discharge between 10^{-9} and 10^{-6} A represents a subtle failure mode for an integrating chamber. Analyses of space charge effects show the Townsend discharge to be stable (once entered) if the parallel capacitance is less than a critical minimum (C_c). Here, again, the effect is a strong function of the discharge area. For two gaps having the same pressure, the Townsend region is significantly less stable for an Ne–5% Ar gas filling than it is for an Ne–0.5% Ar–1.5% Kr filling. This effect is thought to be caused by a difference in ionic recombination rates. Consideration of $\int a\, dx$ indicates that the discharge between parallel rods or spheres is geometrically constricted to the neighborhood of the gap centerline if pd is greater than the Paschen minimum. This effect is primarily responsible for the relatively small areas observed for higher-pressure test gaps. The optimum gap configuration is predicted to be a twin-sphere arrangement with an Ne–5% Ar filling, a centerline $pd = 10$ (mm Hg) cm, and $V_s = 120$–130 V.

Measurements indicate that aftereffects from a previous discharge decay to about 1 count/sec after 10 sec, and that this effect is unimportant if the statistical time lag for breakdown is small. Preliminary investigations indicate that voltage pulse strobing is an effective technique for avoiding the stable Townsend discharge and reducing the effect of partial breakdowns.

---

1. Abstract of ORNL-TM-4574 (March 1974).

4.2 IN-LINE BETA-SENSITIVE SCINTILLATION DETECTOR FOR OFF-GAS DECONTAMINATION FACILITY

M. M. Chiles V. A. McKay D. M. Levins[1]

The Chemical Technology Division has constructed an experimental facility for studying decontamination of the radioactive gases ^{85}Kr and ^{133}Xe. Freon or liquid CO_2 at high pressure is used as a solvent to scrub the radioactive gases. A scintillation detector was designed for in-line monitoring of the radioactivity at several locations in the facility. A 2-mm-thick crystal of europium-activated calcium flouride [CaF_2(Eu)] was selected as the scintillator because it has a high efficiency for the beta radiation emitted by these isotopes.

The scintillations produced in the crystal are detected by a low-dark-noise photomultiplier tube. The crystal is inside the gas pressure vessel and optically coupled to the photomultiplier tube through a two-piece light-pipe window (Fig. 4.2.1). The methylmethacrylate portion of the window is protected from the Freon by a 0.062-in.-thick disk of Kel-F located on the side exposed to the gas in the pressure vessel. The size of the crystal can be changed to optimize the count rate of different concentrations of radioactivity.

Since the pressure vessel was designed to operate up to 600 psi, the containment seal was designed to protect the crystal scintillator from pressure loading (Fig. 4.2.1). Since some experiments might be performed with radioactivity in the liquid CO_2 (low temperature), the detector was sealed to prevent moisture from condensing on the components inside the detector housing.

Output pulses from the detector are amplified by a charge-sensitive preamplifier and an RC shaping amplifier. A single-channel analyzer, operated as an integral discriminator, is adjusted to reject small noise pulses such as photomultiplier-tube dark noise. The discriminator output is connected to a count-rate meter and recorder.

---

1. Chemical Technology Division.

4.3 TRITIUM AIR MONITORS FOR AN EXPERIMENTAL FUSION REACTOR

R. L. Shipp

Literature describing tritium air monitoring techniques and equipment was studied for application to a possible future experimental fusion reactor. In addition to this literature survey, trips were made to the Mound Laboratory and to the Chalk River Nuclear Laboratory. The recommendations from this study are that a small facility be equipped to evaluate and calibrate tritium monitors and that development of tritium monitors be started to meet the requirements of Oak Ridge National Laboratory.

4.4 G-M SURVEY METER

F. M. Glass G. A. Holt E. E. Waugh

A replacement for the Q-2092 G-M survey meter was designed by the Circuit Development Group of this Division and field tested by the Health Physics Division. The new instrument weighs less, requires fewer batteries, and has a longer battery life and a better linearity than its earlier model. One 6.25- to 8.75-V, 500 mA-hr, nickel-cadmium battery will power the instrument for 200 hr of continuous service on a single charge. The rate-meter circuit compensates for counting losses as a function of G-M tube deadtime.

At the request of the Health Physics Division, a few minor changes will be made for the convenience of the users, and the new instrument will replace the older model as ORNL Stores item 06-088-1440.

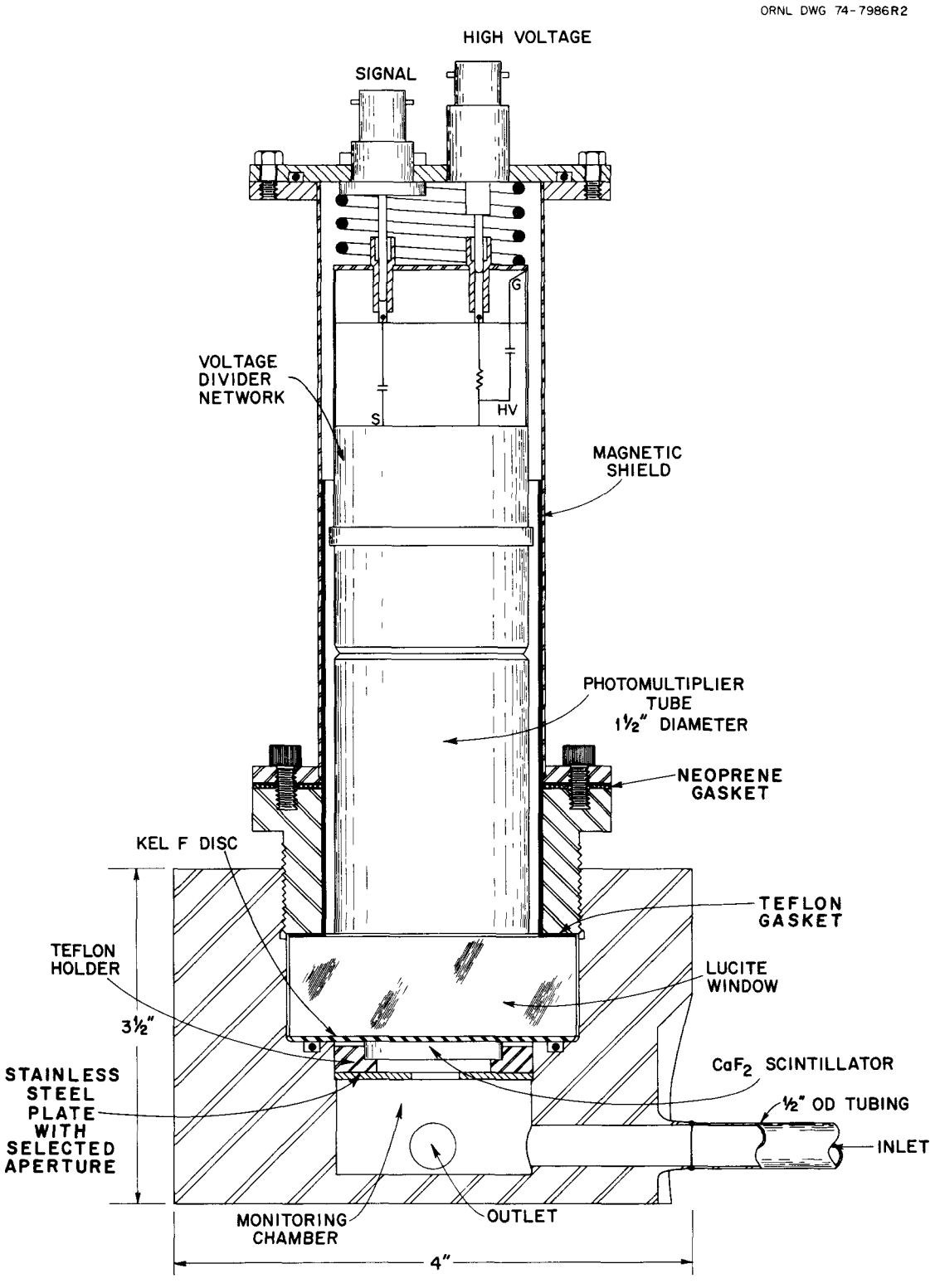


Fig. 4.2.1. In-line beta-sensitive scintillation detector.

4.5 ENGINEERING ACTIVITIES CONCERNING RADIATION MONITORING

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

Facility Radiation and Contamination (FRC) Alarm Systems

The FRC system in the Chemical Technology Alpha Laboratory (Building 3508) was modified so that, when the building is evacuated, the building containment system will be operated by any two alpha air monitors in the coincidence group or by the manual evacuation module. An alarm signal will be telemetered to the Guard Headquarters, Building 2500, when the building is contained.

An additional evacuation horn was added to the FRC system in the Radiochemical Processing Pilot Plant (Building 3019). A neutron monitor, alpha constant air monitor, and evacuation horn were installed in the plutonium storage vault and connected to this system.

Installation of four alpha constant air monitors (CAAMS) was started as an addition to the FRC system in the Fission Product Development Laboratory (Building 3517). "High level" alarms from any two of the four CAAMS will operate the building evacuation system and telemeter an alarm signal to the Guard Headquarters.

A cost estimate was prepared for radiation monitoring and security alarm systems for the Storage Vault (Building 3127).

Drawings were revised to update several minor changes in the FRC systems in various buildings at the Laboratory.

An accidental actuation of an FRC system evacuation horn by vibration showed that the Kl relay in the horn control needed relocation. This was done and the vibration tolerance improved greatly.

Effluent Monitoring

Engineering surveillance was furnished for the radiation monitors in the liquid and gas effluent systems of the Operations Division. Engineering drawings were updated as the equipment was modified.

The telephone telemetering lines from the HFIR stack to the Effluent Waste Monitoring Center (Building 3105) were rerouted to eliminate damage caused by lightning.

Radiation Monitoring and Safety Interlock Systems

Approximately 30 warning-lamp, failure alarm devices were installed at x-ray diffraction machines.

A cost estimate was prepared for a safety interlock system for an x-ray facility to be installed in the Health Physics Technology, Internal Dosimetry Laboratory (Building 2008). Design and engineering drawings were completed, and the system is being fabricated and assembled.

A safety interlock system was designed for the Inspection Engineering Department, X-Ray Facility (Building 2000). Engineering drawings were completed, and system installation will be started in the near future.

A cost estimate was prepared for a radiation monitoring and safety interlock system for the Heavy-Ion Facility.

The safety interlock system for the hazardous areas in the High-Voltage Accelerator Laboratory (Building 5500) was revised. Updated drawings were completed and the system was revised.

Other Radiation Monitoring Systems

Engineering services were furnished for the local air monitoring, perimeter air monitoring, and fallout monitoring systems for Applied Health Physics. Drawing changes were made for several minor modifications.

A cost estimate was prepared for a radiation monitoring system for a new Process Waste Treatment Plant (Building 3544). Engineering drawings were completed for the system, and purchase or fabrication of the instruments was started.

Two alpha constant air monitors (CAAMs) were installed in the Radioisotope Laboratory (Building 3038) and connected to the central monitoring alarm panel.

4.6 PERFORMANCE OF AN ARGON–3.5% CYCLOPROPANE GAS FLOW PROPORTIONAL COUNTER

R. E. Zedler Hai-Hsin Chang[1]

The gas mixture most commonly used in gas flow proportional counters is argon–10% methane. However, many other argon–organic vapor gas mixtures (one of which is argon–3.5% cyclopropane) give better energy resolutions at lower counter operating voltages for amplification factors up to 500 or 1000. Because the vapor pressures of many organic vapors for this service are moderate to low, only a very few are high enough to enable preparation of a high-pressure gas mixture for gas flow purposes.

A large cylinder of a high-purity argon–3.5% cyclopropane mixture at 1700 psig was purchased. This mixture and argon–10% methane were tested in a proportional counter having a 1.5-in.-ID Al cathode and a 0.0004-in.-diam Nichrome anode wire. The counter also had field tubes and a 0.5-in.-diam, 0.00025-in.-thick Mylar window at the center. The gas flow was ∿1.2 scfh. The resolutions were measured with an ^{55}Fe source. The approximate values in Table 4.6.1 show the resolution with the argon-cyclopropane mixture to be better than with argon-methane. Also, with argon-cyclopropane, lower operating voltages will achieve the same gas amplification factors that higher voltages achieve with argon-methane.

1. Exchange visitor from the Institute of Nuclear Energy Research, Taiwan, Republic of China.

Table 4.6.1. Comparison of two gas mixtures for proportional counters

Gas amplification factor	Gas mixtures			
	Argon–10% methane		Argon–3.5% cyclopropane	
	Operating voltage (V)	Resolution (FWHM %)	Operating voltage (V)	Resolution (FWHM %)
80	930	14.2	610	13.1
100	960	14.3	630	13.1
200	1040	14.4	680	13.2
500	1140	14.5	750	13.9
800	1190	14.6	780	14.6

4.7 IONIZATION CHAMBER FOR KRYPTON ENRICHMENT PROCESS

F. E. Gillespie H. R. Brashear

An ionization chamber (Q-5215-2) was developed for monitoring ^{85}Kr enrichment for the krypton thermal diffusion process operated by the Isotopes Division. This process enriches the ^{85}Kr in a gas from 4% to 25–45%. The krypton is contained in a thin-wall, stainless steel tube (0.1875-in.-OD by 0.0025-in.-thick wall, or 50 mg/cm^2) inside the ionization chamber. Beta particles from ^{85}Kr (0.672 MeV maximum) will travel through a 5.5-in.-long section of the thin tubing. The electrodes of the ion chamber are perforated to allow the beta radiation to penetrate into the chamber. The overall dimensions of the chamber are 5 in. in diameter and 7½ in. long. The active volume of the chamber is 1 liter and is filled with 1 atm of argon. This design features ceramic insulators and brazed and welded construction. The thin tubing in the center of the chamber is brazed ¼-in.-OD by $^3/_{16}$-in.-ID copper tubing and is an integral part of the process piping.

4.8 CD V-700 MODIFICATIONS

F. M. Glass H. N. Wilson

The following work was done under the Defense Civil Preparedness Agency (DCPA) contract No. DAHC-20-73-C-0015.

Three commercial alpha scintillation detectors (Victoreen 702, Eberline AC-3-7, and a probe by Ludlum Measurements, Inc.) were tested to determine which would be the most suitable for use with a modified CD V-700 instrument. The Eberline probe, even though far from ideal, seemed to be the best. From many models of the CD V-700 instrument, the Anton model 6 was selected as the best choice to modify for use with the Eberline detector. A printed-circuit board was designed for an add-on amplifier that can easily be mounted on the terminals of the meter.

During this study, the signal from an ORNL Q-2101 alpha scintillation probe was 27 dB larger than from the Eberline probe, with 900 V available from the CD V-700 meter. This signal would enable use of an amplifier with much less gain, which would improve the signal-to-noise ratio.

The CD V-700 model 6B, by Electro Neutronics, was modified for use with the Amperex 200LB, end-window G-M tube. We recalibrated the meter scale in terms of counts per minute because the old calibration in mR/hr was meaningless with the new tube. The excessive battery drain and poor regulation of the model 6B instrument were also studied. This model is powered by four Le Clanche type D cells in a parallel-series, 3-V arrangement. Some of these instruments draw as much as 91 mA when the batteries are new. All of them change calibration by $\geq$25% before the battery voltage reaches an acceptable point. Although we prepared several options for the DCPA for improving the efficiency of the dc-to-dc converter, our best recommendation was that these instruments be fitted with a regulator that we designed for controlling the duty cycle of the oscillator in the dc-to-dc converter. This method of regulation reduces the battery current to 20 mA when the battery is new, thus eliminating two of the four D cells. This could reduce the DCPA inventory by 60,000 D cells. This modification also reduces the calibration shift over the battery life from $\geq$25% to $\sim$1%.

4.9 G-M TUBE TEST INSTRUMENT

J. M. Rochelle H. N. Wilson

A five-channel G-M tube input circuit (Q-5220) was designed and fabricated for the Defense Civil Preparedness Agency to test G-M tubes purchased for use in CD V-700 beta-gamma survey meters. Each input circuit is identical to the G-M tube test module (Q-2903B) previously designed at ORNL.[1]

1. J. M. Rochelle, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1967*, ORNL-4219, p. 34.

5. Instrument Development

BIOMEDICAL INSTRUMENTS

5.1 WHOLE-BLOOD ANALYSIS ROTOR DEVELOPMENT

W. F. Johnson

Because of its importance to operation of miniature and portable centrifugal fast analyzers, the design and development of rotors is one of the most important activities of the Fast Analyzer Program. An ultimate objective is to develop a rotor that will accept a whole-blood sample, which will be automatically processed and analyzed within the rotor. Such a rotor will also contain preloaded reagents that will be reconstituted at the time of analysis by dynamic loading.

A new rotor was designed and is being developed. It is a stacked rotor in which a whole-blood sample is introduced semiquantitatively into the lower level of the rotor, where it is centrifugally processed into plasma and cells. A semiquantitative volume of the plasma is displaced inwardly and vertically upward by injection of a dense, immiscible liquid, and the bulk of the plasma is apportioned into equal aliquots by measuring chambers in the upper level of the rotor. These aliquots are transferred to cuvets by transfer syphons actuated by positive air pressure. A prototype of this rotor was fabricated and is being tested and evaluated. From preliminary results, we believe that it is feasible to process a semiquantitative volume of blood in one compartment, displace a bulk volume of plasma to a separate compartment, and divide the plasma into equal aliquots. We are developing techniques to transfer these aliquots to appropriate cuvets.

5.2 DIGITAL DATA SYSTEM

W. F. Johnson

Centrifugal fast analyzers produce data in a form and at a rate suitable for direct input to a digital computer. However, in some applications it is desirable to have an inexpensive and portable data device for use with such analyzers. Consequently, we started to develop such a device.

The model II digital data system is an electronic unit for acquiring, processing, and printing absorbance or intensity measurements from the optical output of either a 17-cuvet miniature centrifugal fast analyzer or an 8-cuvet portable centrifugal fast analyzer. The unit has an internal clock for monitoring and printing analytical data from an analyzer at any one of four selectable time intervals (5, 15, 30, and 60 sec), for up to ten sampling intervals. The operator can choose the manner in which the data from the analyzer are printed from one of the following modes: (1) absorbance for each cuvet in a range from 0 to 0.8192; (2) absorbance of cuvet 1, which is the reference cuvet, and change in absorbance for each of the remaining cuvets between sampling periods; (3) intensity for each cuvet; and (4) intensity for each of the remaining cuvets.

To process data in the absorbance mode, the unit has a logarithmic amplifier to convert the transmission pulses to absorbance data pulses. These are then digitized by a 12-bit analog-to-digital converter, and the digital data are stored in a 384-bit, random-access memory arranged as 32 words of 12 bits each. After the data are accumulated in the memory, printing begins. The delta-absorbance mode is similar, but it requires an additional 384-bit memory section for storing the previous sampling interval data for calculation of the change in absorbance per sampling interval. The intensity and delta-intensity modes are identical to the absorbance outputs, except that the logarithmic module is not used.

To operate the data system, an operator first selects the output format, sampling time interval, and number of cuvets. The printing sequence is then initiated by depressing the "start" button. The data are subsequently printed at the rate of five lines per second by an eight-digit printer, utilizing a seven-segment print head and thermal-sensitive paper. It prints a two-digit cuvet number and a one-digit interval number, followed by a decimal point and four digits of absorbance or intensity data.

5.3 TECHNIQUES FOR LOADING LIQUIDS INTO THE ROTOR OF THE MINIATURE CENTRIFUGAL FAST ANALYZER[1]

C. A. Burtis[2]
W. F. Johnson T. O. Tiffany[3] C. D. Scott[2]

Sample(s) and reagent(s) can be introduced into the miniature centrifugal fast analyzer via a 17-cuvet rotor in either a discrete or a dynamic mode. A sample-reagent loader has been developed to automatically perform the discrete loading operation and will load a 17-cuvet rotor with microliter aliquots of sample (1 to 10 μl plus 50 μl of diluent) and reagent (20 μl plus 50 μl of diluent) in 5.0 min. The resulting precision ($\pm<1.0\%$) and accuracy ($\pm<1.0\%$) are equal to or better than those for loading systems used for the larger analyzers. Intercompartment carry-over is less than 0.2%. The loader uses separate sample and reagent carousels, which provides versatility and allows operation in either of four analytical modes. Dynamic introduction is an alternative approach to loading liquids and consists in introducing a premeasured volume of liquid onto equally spaced knife edges of the spinning rotor. The volume is thereby divided into equal, discrete aliquots, which are simultaneously transferred into their respective cuvets. Parametric studies have demonstrated that volumes ranging from 10 to 50 μl per cuvet can be dynamically loaded with an accuracy and precision of from ±1 to 4% and from ±0.5 to 1.1 μl per cuvet respectively. Analytical applications of both loading techniques will be presented.

---

1. Abstract of paper presented at the Sixth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, March 14–15, 1974, and published in *Clin. Chem.* 20(7), 866 (1974).
2. Chemical Technology Division.
3. Pathology Associates, Inc., Spokane, Wash.

5.4 AUTOMATED LOADING OF DISCRETE, MICROLITER VOLUMES OF LIQUIDS INTO A MINIATURE FAST ANALYZER[1]

C. A. Burtis[2]
W. F. Johnson J. B. Overton[2]

A miniature fast analyzer is under development at the Oak Ridge National Laboratory. The analyzer combines the inherent advantages of the Anderson fast analyzer concept with those of miniaturization. One of the advantages of the latter is a further decrease in sample and reagent volume requirements. For example, for each assay the miniature analyzer requires only from 2 to 10 μl of sample, which is analyzed

in a total reaction volume of only 120 to 130 μl. Consequently, to fully realize the advantages of the analyzer, it is necessary to have the capability of precisely and accurately introducing volumes of this magnitude into the system.

Samples and reagents are introduced into the miniature fast analyzer via a 17-cuvet rotor into which aliquots of sample(s) and reagent(s) are loaded, transferred, and mixed (within their respective cuvets). The ensuing reactions are then photometrically monitored. One of the two modes in which the aliquots of sample(s) and reagent(s) can be introduced into the rotor is a discrete mode, in which a dispensing device is used to obtain aliquots of the liquids and dispense them into their respective sample and reagent cavities in the rotor. Using two commercially available, automatic pipets and a unique carousel-turntable assembly, a sample-reagent loader which automatically performs this discrete loading operation has been designed and fabricated.

1. Abstract of article published in *Anal. Chem.* **46**(6), 786–89 (1974).
2. Chemical Technology Division.

5.5 AUTOMATED PLASMA, RED BLOOD CELL, AND HEMOLYSATE PREPARATION[1]

T. O. Tiffany[2]
N. E. Lee[3] W. F. Johnson C. D. Scott[2]

As a first step in the development of automated instrumentation for genetic monitoring, the Biochemical Technology Section at Oak Ridge National Laboratory has directed its efforts at the development of an automated whole-blood sample preparation system. The central part of the system is a 16-place blood separation rotor in which plasma is separated from red blood cells, the red blood cells are rapidly washed, and, if desired, the red cells can be lysed and the stroma separated to form clear, usable hemolysates for electrophoresis and enzymatic assays. Different replaceable concentric rings serve to collect the various separated samples through a combination of centrifugal force and vacuum applied at the edge of the rotor. The plasma is free of red blood cells and hemolysis and is usable for clinical chemistry analysis, including radioimmunoassays. The system, which has been evaluated at the University of Michigan, Department of Human Genetics, will be discussed in terms of its general description, operation, and possible future configuration for automated sample preparation in the clinical laboratory.

1. Abstract of paper presented at the Sixth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, March 14–15, 1974, and published in *Clin. Chem.* **20**(7), 866 (1974).
2. Pathology Associates, Inc., Spokane, Wash.
3. Chemical Technology Division.

5.6 OPTIMIZATION AND ANALYTICAL APPLICATIONS OF THE TECHNIQUE OF DYNAMIC INTRODUCTION OF LIQUIDS INTO CENTRIFUGAL ANALYZERS[1]

C. A. Burtis[2]
W. F. Johnson J. B. Overton[2]
T. O. Tiffany[3] J. C. Mailen[2]

The technique of dynamically introducing a measured volume of liquid into the spinning rotor of a miniature centrifugal fast analyzer, where it is subsequently apportioned into equal aliquots, has been further developed and improved. Several important structural and operational factors have been identified

and investigated, including rotor design and geometry, rotor speed, injection volume and rate, and probe diameter To determine the effect of these factors on the precision and accuracy with which a liquid may be dynamically introduced and apportioned, we developed a dye-dilution procedure These studies demonstrate that liquid volumes ranging from 10 to 50 μl per cuvet can be dynamically loaded with an accuracy and precision (expressed as standard deviation) of 1 to 2% and 0.5 to 1.1 μl per cuvet respectively Several analytical applications of this technique have been investigated (1) measurement of true sample-blank absorbance before dynamic reagent introduction, (2) sequential reagent addition, (3) correlation studies involving discrete vs dynamic loading of reagent, and (4) reconstitution of lyophilized reagents.

1 Abstract of paper presented at the Sixth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, March 14–15, 1974, and published in *Clin Chem* 20(8), 932–41 (1974)

2 Chemical Technology Division

3 Pathology Associates, Inc , Spokane, Wash

5.7 BLOOD GROUPING WITH A MINIATURE CENTRIFUGAL FAST ANALYZER[1,2]

T. O Tiffany[3]
J M. Parells[4] C. A. Burtis[3]
W. F. Johnson C D. Scott[3]

The centrifugal fast analyzer was used to develop a semiautomated, computerized blood-grouping system. A miniaturized version of the analyzer was used for the development because, essentially, it enables one to automate "test-tube" grouping procedures. The blood-grouping system is discussed in terms of adaptation of blood-grouping procedures, types of instrumentation used for grouping, cell washing, and Coombs testing, parametric optimization of hemagglutination reactions, subgrouping of A and AB, reverse typing, small-scale blood-grouping evaluation of our approach, and computerization of blood grouping The data reported here indicate that the system reliably provides accurate results.

1 Research supported jointly by the National Institute of General Medical Sciences and the U S Atomic Energy Commission under contract with the Union Carbide Corporation

2 Abstract of paper presented at the Sixth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, March 14–15, 1974, and published in *Clin Chem* 20(8), 1043–54 (1974)

3 Chemical Technology Division

4 Summer employee, 1973

5.8 SPECIFIC PROTEIN ANALYSIS BY LIGHT-SCATTER MEASUREMENT WITH A MINIATURE CENTRIFUGAL FAST ANALYZER[1,2]

T. O. Tiffany[3]
J. M Parella[4] W. F. Johnson C. A. Burtis[3]

A miniature centrifugal fast analyzer has been modified for fluoresence and light-scatter measurements by using several rotors developed for this purpose. The modified system has been used to evaluate the feasibility of adapting specific protein analyses, such as IgG, IgA, IgM, C'3 complement component, and α-1-antitrypsin, to the centrifugal fast analyzer. A study of reaction conditions has revealed that the addition of polyethylene glycol 6000 (Carbowax) to the dilution medium increases the rate of reaction and allows apparent equilibrium to be achieved in less than 60 sec. Furthermore, scatter intensity is enhanced.

This system can be used to make rapid immunoglobulin measurements with only microliter volumes of antibody (2–7 μl), without the need of sample blanks Determination of antigen excess by a method that involves dynamic injection of antibody is also discussed

1 Research supported jointly by the National Institute of General Medical Sciences and the U S Atomic Energy Commission under contract with the Union Carbide Corporation

2 Abstract of paper presented at the Sixth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, March 14–15, 1974, and published in *Clin Chem* **20**(8), 1055–61 (1974)

3 Chemical Technology Division

4 Summer employee, 1973

5.9 MINIATURE FLOW FLUOROMETER IMPROVEMENTS

L. H. Thacker

From a program of testing and development of miniature flow fluorometers, we have produced a new version of the instrument. Its performance characteristics are better and its fabrication cost is significantly lower than those of the previously reported[1,2] versions

All optical components (uv lamp, filters, photomultiplier, quartz flow cell, and lamp-compensating photoconductor) are mounted in a machined, monolithic aluminum block for assembly and rigid, permanent alignment The quartz flow cell is only 2 mm in ID, it is intersected at right angles by optical apertures 3 mm in diameter, yielding a sample volume of ∿9 μl

Three of these instruments are being used routinely.

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

2 L H Thacker, *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973,* ORNL-4990 (to be published)

5.10 A SMALL BATTERY-OPERATED CENTRIFUGAL FAST ANALYZER SYSTEM[1]

C. D Scott[2]

W. F. Johnson L. H Thacker C. A. Burtis[2]

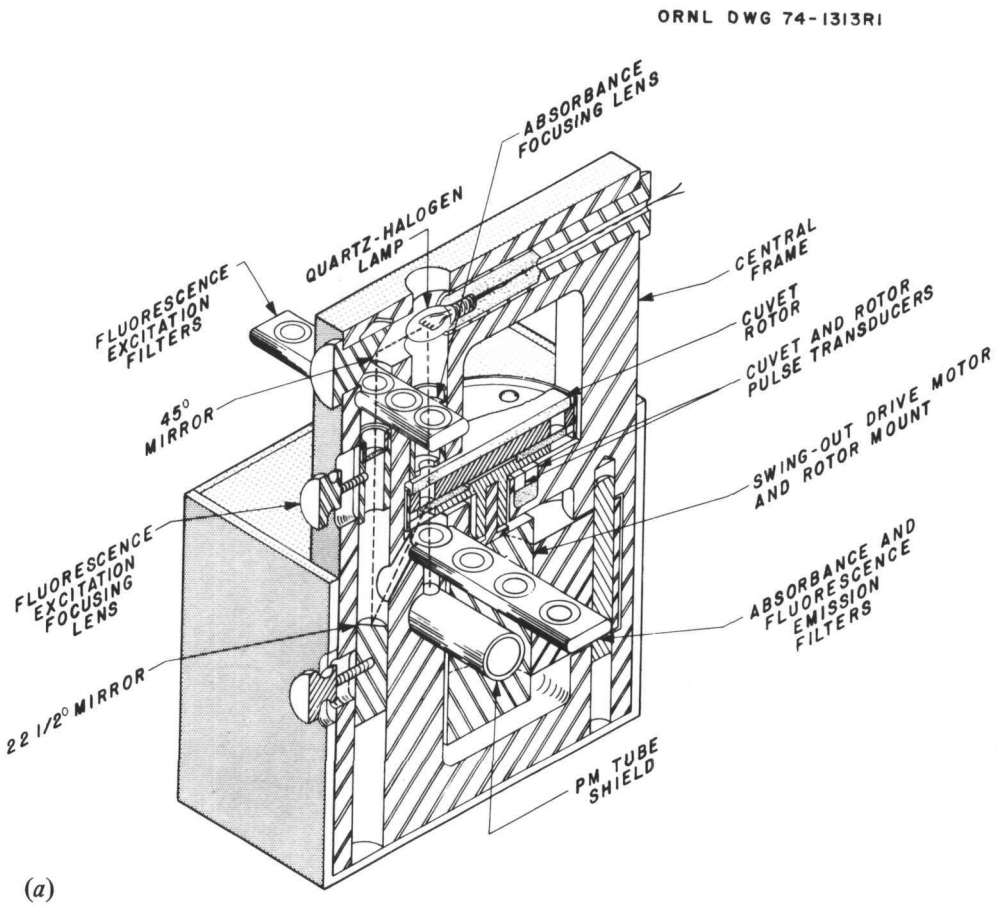
The recent development of miniature fast analyzer systems based on the GeMSAEC principle, coupled with the possibility of direct introduction of unprocessed liquid samples, has been further extended to include a very small analytical system that is inexpensive, battery operated, and portable. The basic analyzer[3] (Fig. 5.10.1) is included in and on a 4-in.[3] cabinet, and a coupled data processing and output system records analytical data in absorbance units. The system is compatible with up to eight simultaneous colorimetric or fluorometric assays on physiologic fluids.

Dynamic sample introduction is used, and the system is compatible with the introduction of unprocessed whole blood. End-point or two-point rate analysis is possible, and the coefficient of variation of multichemistry tests on a single serum sample dynamically introduced is comparable to that obtained with larger centrifugal fast analyzer systems.

1 Abstract of paper presented at the Sixth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, March 14–15, 1974, and published in *Clin Chem* **20**(8), 1003–8 (1974)

2 Chemical Technology Division

3 L H Thacker, *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973,* ORNL-4990 (to be published)



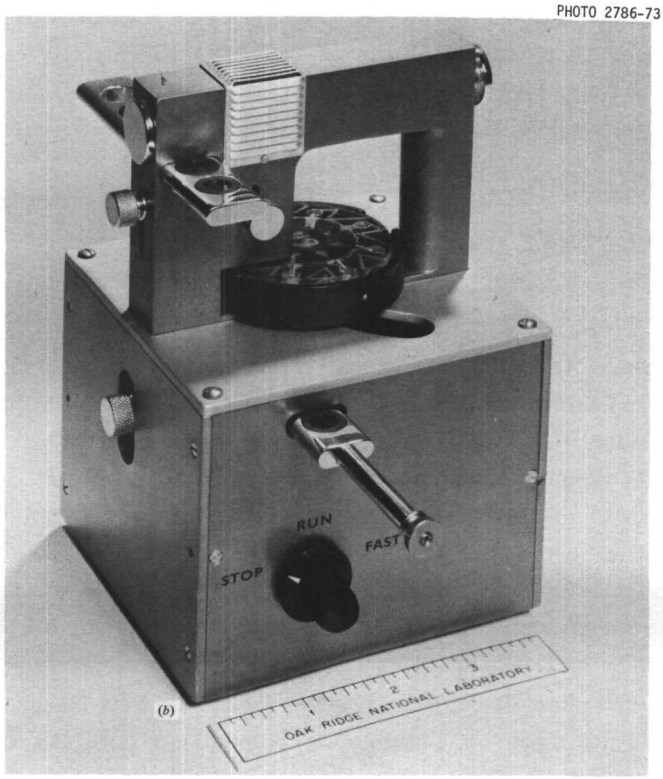


Fig. 5.10.1. Portable fast analyzer. (*a*) Cross-section details; (*b*) external cabinet view.

5.11 SMOKE INHALATION PROGRAM

G. W. Allin

Several improvements were made to the ORNL-designed inhalation smoker that exposes small animals to cigarette smoke. Complete design information is now available for fabricating systems for exposing 10 or 20 animals to smoke from a common, motor-driven, piston-type, puff-producing unit.

A new type of unit that produces smoke puffs was designed, and a working model was built and tested. The desired puff is produced by a standard vacuum source rather than by a motor-driven piston. This unit gives considerably greater control of the time vs pressure puff profile and requires only inexpensive components. Further development will be required to simplify the control of this unit before it will be considered for service.

Two automated smoking machines designed by industrial organizations were evaluated for the Council for Tobacco Research. Both of these machines will smoke batches of 30 cigarettes, and all or part of the smoke can be delivered to a maximum of four groups of animals. Both machines can be programmed to produce various time combinations of smoke exposure to purge air. One machine has hard-wired controls, and the other has computer logic controls.

5.12 KIRLIAN PHOTOGRAPHY AS A BIOINSTRUMENTATION TECHNIQUE

D. W. McDonald

A large number of recent articles in the popular press and in scientific journals on Kirlian photography, or radiation-field photography, has stimulated some interest at the Laboratory in that it might be a way to detect diseases in trees and plants before overt evidence becomes available. The basic technique is to place a biological specimen in direct contact with a photographic plate, sandwich the plate and specimen between two electrodes, and transmit a short, high-voltage, high-frequency pulse through the plate and specimen. The image recorded on the plate shows distributions of color and intensity which are reported to be correlated with the health state of the specimen.

A simple system was assembled, and preliminary images were sufficiently interesting that development was continued.

5.13 TIME AND FREQUENCY STANDARD

W. R. Miller

The advent of high-speed frequency counters and related devices has made it mandatory that we update our ability to calibrate and certify the accuracy of these instruments. To do this, we designed and built a time and frequency standard that is phase locked with the National Bureau of Standards radio station WWVB (60 kHz) located in Boulder, Colorado.

A commercial version of this instrument is available, but the low signal level of WWVB at this location and the high atmospheric static levels here in the Tennessee Valley required a more sophisticated design.

The 14 phase-locked frequency outputs from the instrument can be seen on the front panel view (Fig. 5.13.1). Under average atmospheric conditions these frequencies are accurate to 1 part in 10^{11}.

The condition of phase lock between the instrument and the Bureau is indicated on the "Int. Phase Det." meter. An additional phase detector and readout are provided for comparing any of the reference frequencies to an external instrument under calibration. Both phase-angle signals can be recorded if desired.

PHOTO 2067-74

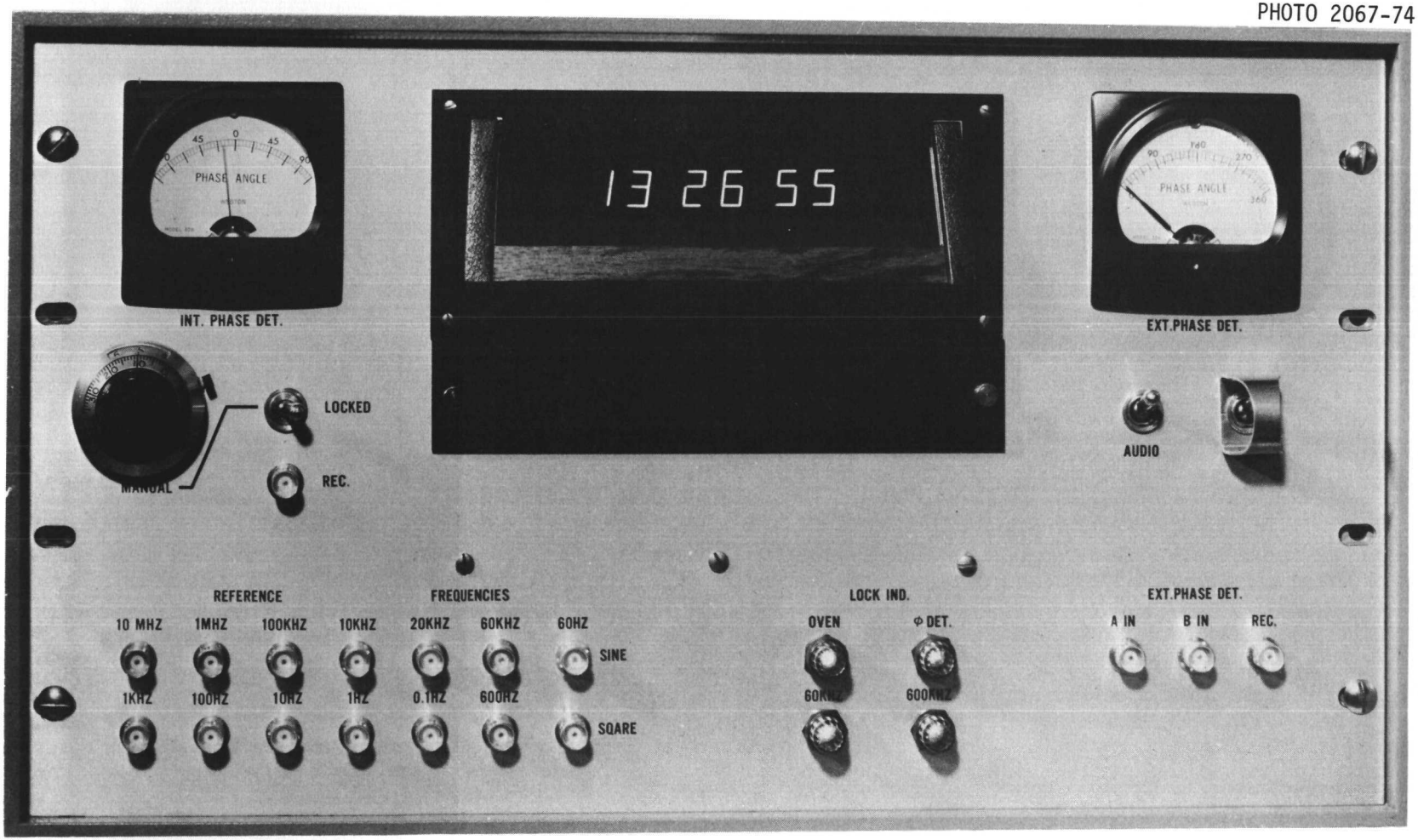


Fig. 5.13.1. Front panel of time and frequency standard.

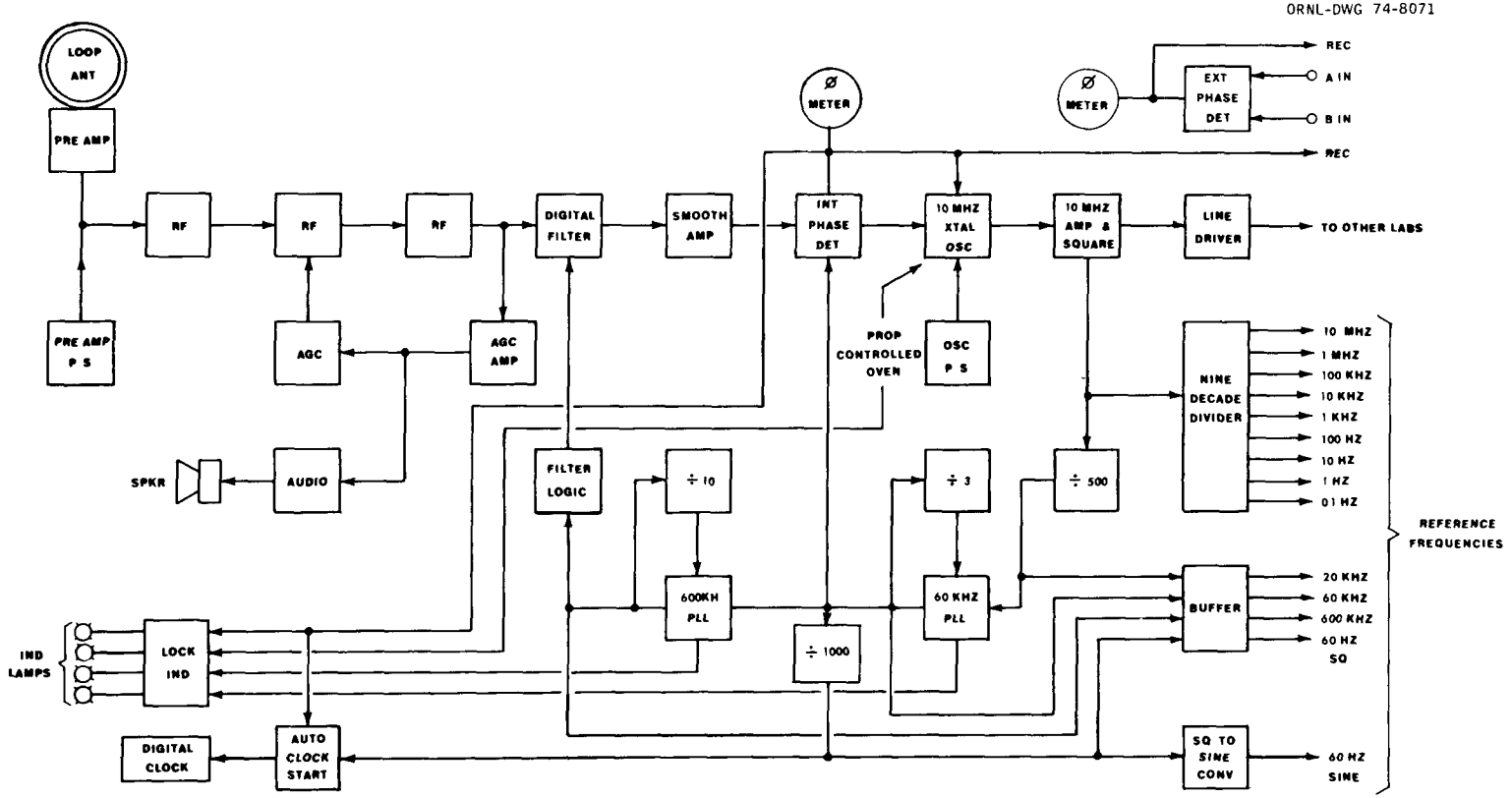


Fig. 5.13.2. Diagram of time and frequency standard.

The digital clock operates from the 60-Hz "locked" signal and can be preset and automatically started at 10 min after the hour when the Bureau induces a 45° phase shift of 5 min duration.

The instrument also features a 10-MHz line driver, which feeds a chain of repeaters at various locations in the building where calibration work is performed. Each repeater contains a nine-decade divider to furnish frequencies from 10 MHz to 0.1 Hz.

The degree of sophistication to achieve the required accuracy at this geographical location is best illustrated by Fig. 5.13.2.

RESEARCH INSTRUMENTS

5.14 DIGITAL NANOAMMETER

F. M. Glass

A digital nanoammeter was designed and built for measuring currents from the ionization chambers in the ^{85}Kr thermal diffusion unit. The following specifications precluded the procurement of this instrument from commercial sources. This meter is a single-range instrument with 3½-digit LED readout. The top of the range is 199.9 nA. The meter has 12 inputs and a selector switch for conveniently monitoring the current from 12 ionization chambers. This specially constructed switch shunts the ionization current from the 11 chambers not being metered to prevent an accumulation of charge. A built-in, well-regulated 500-V, dc-to-dc converter supplies the required saturation voltage for the 12 ionization chambers.

Combining the switch box, nanoammeter, and ionization chamber voltage supply in one instrument simplified and improved the reliability of the cabling and reduced the required panel space. Thirty days of bench testing indicated that this instrument meets the long-term stability specification. The combined zero and calibration drift was less than 1% per month.

5.15 NEW FISH TAG DEVELOPMENTS

J. M. Rochelle J. S. Ryberg[1]

The SG-3801 monolithic breadboard circuit used for fabrication of the Q-5099[2] ultrasonic fish tag is no longer available. We are determining the possibility of replacing the SG-3801 with a device called "Monochip," which is available from Interdesign, Sunnyvale, California.

The type RM mercury cells previously used in the Q-5099 tags were replaced with type PX cells, which are designed specifically for long-life, low-current-drain applications.

Initial prototypes of a new, long-life fish tag, Q-5237, are being built. The new tag is identical with the Q-5099, except that its battery life was increased to approximately one year at an average operating temperature of 20°C.

1. ORAU summer student from the University of Wisconsin, River Falls.
2. J. M. Rochelle and C. C. Coutant, *Temperature Sensitive Ultrasonic Fish Tag, Q-5099*, ORNL-TM-4438 (1973).

5.16 WIND AVERAGING SYSTEM

W. R. Miller

An instrument was developed for the Environmental Sciences Division to measure and record individual 15-min averages for four separate wind velocities, one wind direction, and two wind temperatures (Fig. 5.16.1).

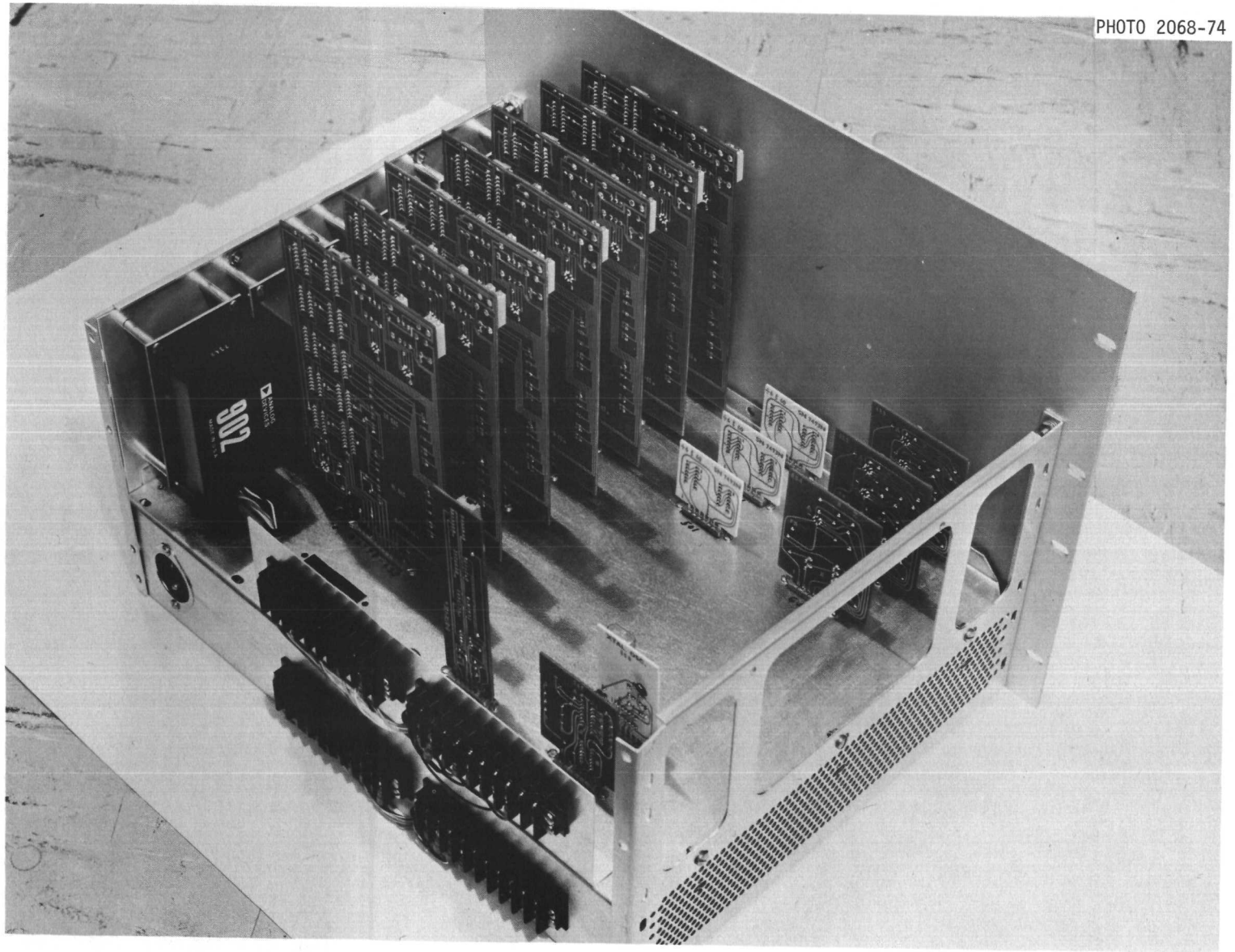


Fig. 5.16.1. Wind averaging system chassis.

All velocity signals are logic pulse trains, with a frequency proportional to wind velocity, which are counted and stored in registers. Direction and temperature signals are first converted to frequency and then handled in the same manner as the velocity signals.

Every 15 min the count in the registers is strobed into digital-to-analog (D/A) converters, and the registers are reset to zero. The analog signals from the D/A converters are recorded on a multichannel recorder with scaling to appropriate units.

5.17 PLUTONIUM AND URANIUM OXIDE AEROSOL DENSITY MEASUREMENTS

L. H. Thacker D. W. McDonald

A prototype instrument was developed for measuring the behavior of plutonium or uranium aerosols in tests simulating fast reactor accident conditions.

The instrument uses a bifurcated fiber-optic light pipe with a light source on one proximal branch and a photodetector on the other; the distal end is inserted into the tank containing the suspended aerosols. The output signal is a measure of the light scattered at 180° from the aerosol particles.

Tests to date have been qualitative measurements of the response to suspensions of unclassified carbon-black aerosols in air streams at room temperature. Based on the success of these experiments, preparations are in progress for tests using UO_2 aerosols.

5.18 ENGINEERING SERVICES FOR ANALYTICAL CHEMISTRY

T. M. Gayle

Engineering and consulting services by the Instrumentation and Controls Division in analytical instrument design, modification, and maintenance were made available to the Analytical Chemistry Division in several areas. A major effort has been in the field of gas chromatography, using microwave emission detectors. This type of analysis, pioneered at ORNL by Yair Talmi of the Analytical Chemistry Division, is one of the most sensitive and selective of all chromatographic techniques. A current application for the Environmental Sciences Division, being carried out in the High-Radiation Laboratory (Building 2026) of the Analytical Chemistry Division, involves the routine detection of mercury from organic tissue at levels of a few nanograms per gram, a measurement heretofore impossible except by exhaustive laboratory procedures. Work on variations of this type of analyzer will be continued, as well as generalized efforts to provide the Analytical Chemistry Division with design assistance and to coordinate any areas of common interest between the Analytical Chemistry Division and the Instrumentation and Controls Division.

5.19 QUAD CRACK FOLLOWER

J. T. Hutton

A power supply and quad instrumentation amplifier system was developed for the Metals and Ceramics Division to study crack growth in vee-notched metallurgical specimens under cyclic tension loads. Instrumentation for this use is not commercially available. A single constant-current supply is series connected to as many as four specimens under test. The millivolt-level voltage drops across the specimens are conditioned and amplified by individual amplifiers and recorded to obtain crack propagation data. Continuity circuitry connected across each specimen under test detects final specimen failure and turns on parallel transistor switches so that current to the remaining specimens is not interrupted.

5.20 LONG-TERM INTEGRATOR

G. K. Schulze

A 1000-sec time-constant integrating operational amplifier with less than 1% decay in 15 hr was designed to enable the Environmental Sciences Division to study cadmium ion transport in aqueous solutions vs time and concentration in their research of toxic materials in the environment.

5.21 MULTIJUNCTION W-Re THERMOCOUPLE FUEL CENTERLINE TEMPERATURE MEASUREMENTS IN HFIR IRRADIATION CAPSULES

R. L. Shepard J. K. East

Tungsten-rhenium thermocouples used in reactor experiments have been shown to drift as much as 1°C per hour at high temperatures. A method of using measurements of thermocouple loop resistance to calculate calibration drift was demonstrated in the HRB-4 HFIR irradiation capsule.[1] This study was continued in HRB-7 and HRB-8 irradiation capsules to investigate the effects of irradiation on individual thermocouple wires and of temperature gradient on decalibration.

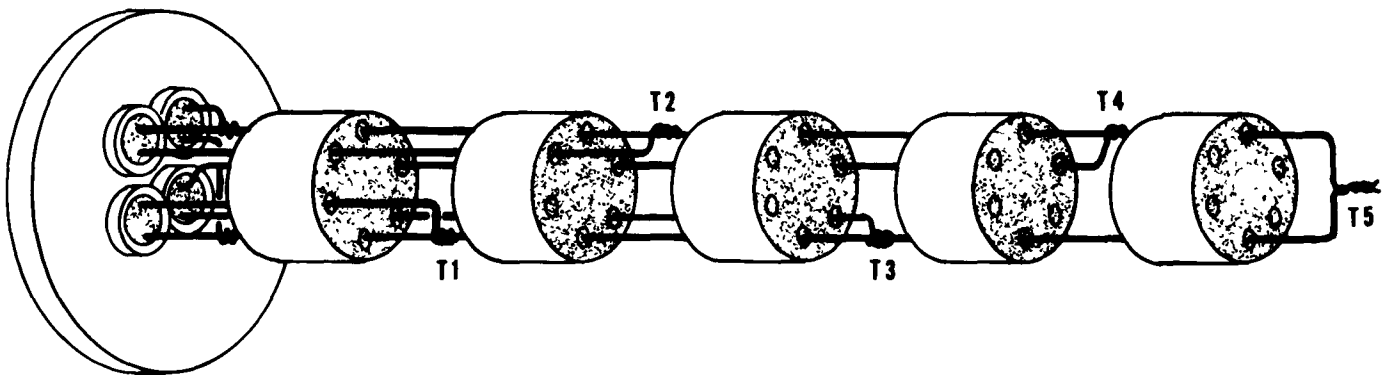
Wires from three sheathed W–5% Re/W–26% Re thermocouples were joined to form five thermocouple junctions along the fuel centerline axis, as shown in Fig. 5.21.1. With the addition of one pair of sheathed extension wires and the use of a current-potential method, this configuration made possible the measurement of five axial temperatures, the resistance of three loops ($T_0-T_5-T_0$), ($T_2-T_5-T_1$), ($T_4-T_5-T_3$), and the resistances of a length of W–26% Re wire (T_2-T_4) and of W–5% Re wire (T_1-T_3) separately. The junctions were formed by tightly wrapping one wire on the other, spaced 1.84 to 3 in. apart over a total length of 14.3 in., and were insulated with six-hole, hard-fired, 0.100-in.-OD beryllia tubes.

In the HRB-7 experiment, the thermocouples decalibrated 600°C at an irradiation temperature of 1500°C in 2200 hr, accumulating a thermal-neutron fluence of 9×10^{21} neutrons/cm^2 ($E < 0.41$ eV) and a fast-neutron fluence of 2×10^{21} neutrons/cm^2 ($E > 0.18$ MeV). Then they failed by forming an open circuit.

In the HRB-8 experiment, a consistent pattern of drift was observed during the entire 5476 hr of irradiation at 1250°C to a thermal-neutron fluence of 3×10^{22} neutrons/cm^2 and a fast-neutron fluence of 8×10^{21} neutrons/cm^2. From an analysis of this pattern of increasing loop resistance and decreasing thermocouple output and using Matthiesen's rule, a method of calculating the decalibration rate (13.3°C/100 hr at 1250°C) was developed, which produced corrections that agreed well with other estimates of decalibration rates and with data obtained using a whole-capsule, in-pool calibration furnace, described previously.[2] This furnace was used to show that at a true temperature of 700°C, the thermocouple decalibration rate after 2200 hr of irradiation could vary from −140 to −210°C, depending on the steepness of the temperature gradient along the thermocouple. These experiments also showed a significant difference in the effect of radiation on the resistance of the high (W–26% Re) and low (W–5% Re) rhenium thermocouple wires after about 3000 hr of irradiation, which may be related to the changing rhenium content as the tungsten is first transmuted to rhenium, then to osmium.

---

1. R. L. Shepard, "Loop Resistance Monitoring of Tungsten-Rhenium Thermocouples in HFIR Fuel Irradiation Capsules," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).
2. R. L. Shepard and W. A. Bird, "In-Pool Calibration Furnace HRB-X," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).



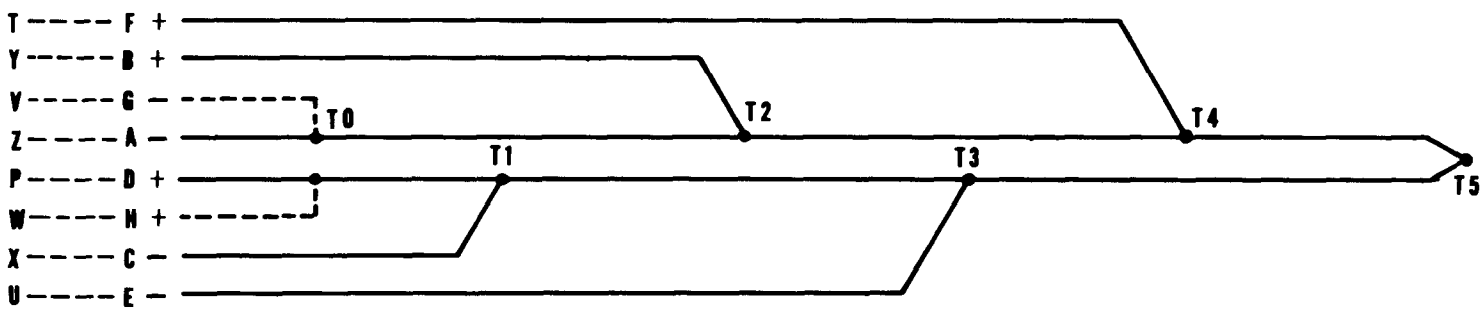


Fig. 5.21.1. Multijunction multiloop thermocouple.

5.22 IN-PILE TEST OF JOHNSON NOISE THERMOMETER

R. L. Shepard

T. V. Blalock[1] J. K. East R. J. Fox J. L. Horton

With a new method of measuring Johnson noise temperatures developed by Borkowski and Blalock,[2] a Johnson noise thermometer (JNT) system was built, and a sensor was used successfully to measure temperatures of 1000 to 1250°C at the center of HTGR fuel irradiated in the HFIR for longer than one 550-hr reactor cycle. No decalibration due to cumulative effects of irradiation was observed, and no prompt effects of detectable magnitude were found. A measured precision of 0.2°C at 1250°C and an estimated cover-all system accuracy of better than ±30°C has been achieved at full reactor power, using a PDP-8/S computer-based noise power measuring system designed for continuous, unattended operation. This system calculates and logs the experiment thermometer temperature and resistance and also logs the temperature and resistance of a standard resistor at the ice point to monitor the gain and accuracy of the system. An analog noise voltage signal is displayed on a strip-chart recorder, which shows the presence of an occasional line voltage spike that invalidates about 5% of the temperature data.

The sensor was made from an 18-Ω coil of 0.003-in.-diam rhenium wire, insulated with hard-fired beryllia and contained within a 0.100-in.-OD, Mo-Re tube (Fig. 5.22.1). This assembly is attached to 10 ft of stainless-steel-sheathed, silica-insulated copper wires, and then to 50 ft of Teflon-insulated triaxial cable leading to the experiment room adjacent to the reactor bay. Special hermetic primary seals and epoxy secondary seals were designed and fabricated for fission gas containment in the capsule.

The first sensor was installed in the HRB-9 experiment. It is operating at 1250°C and is scheduled to continue irradiation for 5500 hr or ten reactor cycles, until May 1975. A duplicate sensor was installed in the HRB-10 experiment. It will be operated at 1500°C and is scheduled for 4400 hr of irradiation (eight cycles) to be started at the end of November 1974 and continued until May 1975. The duplicate sensor was repeatedly calibrated at the zinc melting point of 419.58°C and the copper melting point of 1084.5°C to determine corrections for capacitance and resistance of long cables.

---

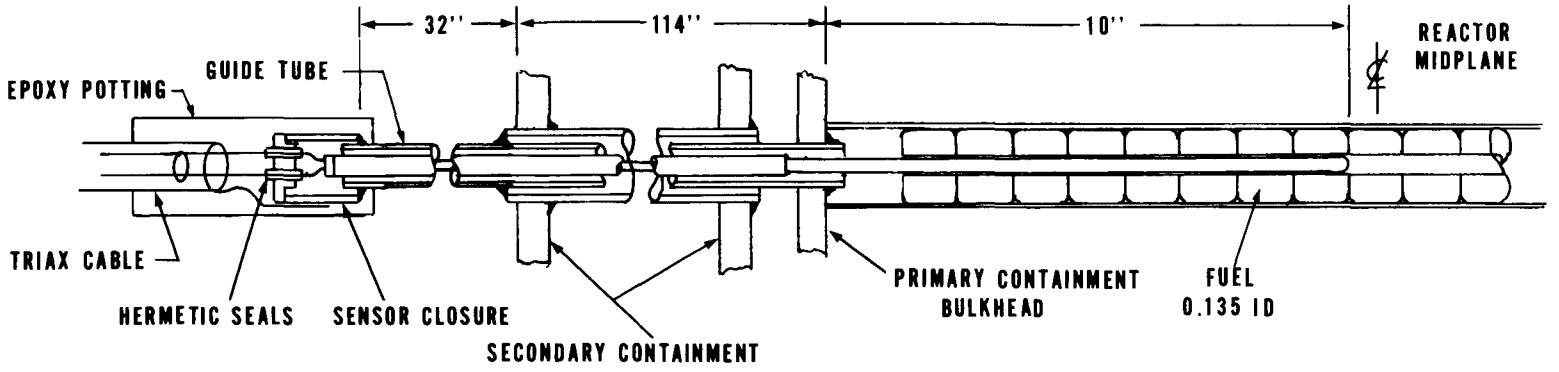
1. Consultant, University of Tennessee.
2. C. J. Borkowski and T. V. Blalock, "A New Method of Johnson Noise Thermometry," *Rev. Sci. Instrum.* **45**(2), 151–62 (February 1974).

5.23 TUNGSTEN-RHENIUM THERMOCOUPLE TOOLING

G. W. Allin J. K. East R. L. Shepard

Tooling was developed to produce W–5% Re/W–26% Re thermocouples for measuring temperatures in the range 300 to 400°C. The finished thermocouple consists of a wire of one material formed into a helix around a central wire of the other material. Sufficient spring-loaded contact is obtained in forming to assure signal stability in operation. A number of thermocouple junctions can be placed along the common central wire.

Several thermocouple junctions made with this tooling performed well under thermal cycling in actual operation.



FUEL PIN CENTERLINE INSTALLATION

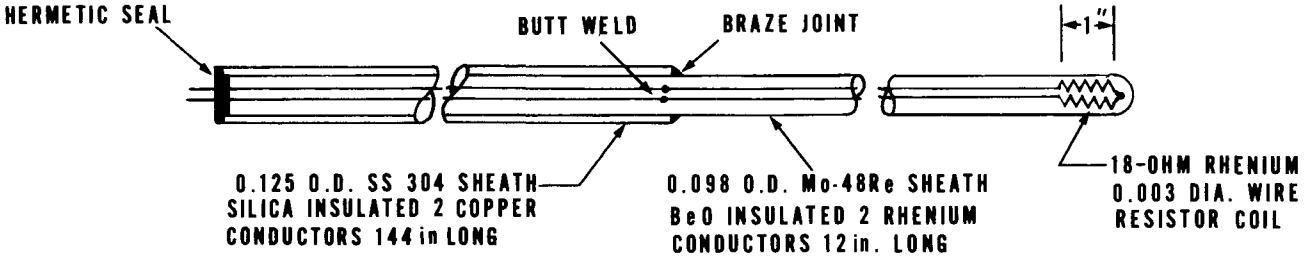


Fig. 5.22.1. Johnson noise thermometer, HRB-9.

5.24 INSTRUMENT DEVELOPMENT AIDS

W. R. Miller L. H. Thacker

A new and improved miniaturized system for breadboarding instrument circuits was developed[1] (Fig. 5.24.1). The new system consists of a compact mother-board, with printed-circuit power and ground buses, which accommodates up to four plug-in amplifier boards. The individual amplifier boards have accommodations for a variety of input and feedback circuit elements and can be individually shielded in a small, stock, aluminum chassis box, or the entire mother-board with its amplifier board complement can be shielded in a larger, stock, chassis box. Important features of the new system are that it has a high degree of freedom from electrical noise pickup and can be easily transported to field sites for testing before permanent instruments are built.

Additionally, the library of standard circuit modules (on printed-circuit boards) now numbers over 100. Modules for crystal oscillators, phase detectors, frequency dividers, phase-locked loops, amplifiers, detectors, and converters are a few of the categories available.

---

1. W. R. Miller and L. H. Thacker, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1966*, ORNL-4091, p. 124.

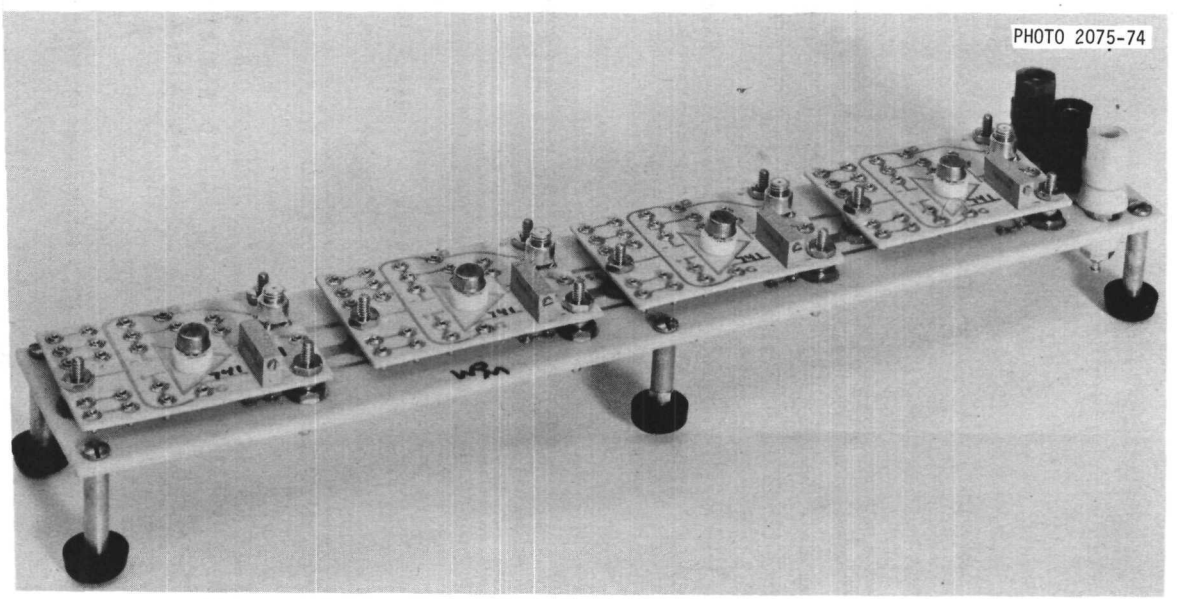


Fig. 5.24.1. Miniaturized system for breadboarding instrument circuits.

6. Automatic Control and Data Acquisition

COMPUTER-BASED SYSTEMS

6.1 MICROPROCESSOR DEVELOPMENT

M. J. Roberts

The microprocessor promises to be a dominant component in new digital logic dedicated controllers and data handlers. Because it operates under program control, the special hardware requirements are greatly reduced, thereby reducing labor costs. The program control also allows the system controlled by a microprocessor to be functionally changed by simply reprogramming it.

We have developed program writing and editing capabilities to enable an engineer to quickly program a system. We also have a breadboarding system so he can then check out his program. The immediate goals in this area are to become familiar with the latest developments in microprocessors and to develop modular building blocks for signal processors and dedicated controllers. The ultimate goal is to develop a set of functional blocks that will be analogous to the operational amplifier in that they can be easily configured to accomplish a wide variety of tasks.

6.2 WHITE OAK DAM STREAM MONITOR CONTROL SYSTEM

M. J. Roberts

Compliance with EPA guidelines concerning possible stream contamination from ORNL discharge water requires frequent and accurate sampling of the water flowing over the White Oak Dam. A control system was designed, using a microprocessor, to control the water sampling. The accuracy specification was 0.1% for a range of water flows from 0 to 334 cfs. Since these accuracy and rangeability requirements would be hard to meet with an analog system, a digital system was designed.

The stream flow must be accurately measured and integrated so that a sample of the water can be collected at accurately known integrated volumes (each 10,000 ft^3). Hardware interfacing and the microprocessor control programming were developed to enable the microprocessor to solve the nonlinear weir equations and control the samplers. Construction of this system is under way, and installation is planned for late 1974.

6.3 COMPUTER PROGRAM FOR AUTOMATIC DATA ACQUISITION AND PEAK DETECTION

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

A machine language computer program was written for the Nuclear Data 4410 data acquisition system for use by the Chemical Technology Division for HTGR fission product release studies. The program

minimizes operator interaction in the acquisition and analysis of gamma spectra. At the end of each acquisition period, the spectra are searched and the following information is listed on the teleprinter: beginning and end channel number, full-width half-maximum of the photopeak, area of the peak, gammas per second, and maximum error. Information is also punched on paper tape for further data reduction using ORCAL.[2]

The operator can choose to output the spectra on magnetic-tape cassette to be analyzed later or on paper tape that can be read and analyzed by a PDP-10 computer.

---

1. Consultant.
2. Myron T. Kelly, "ORCAL – A Conversational Calculating Language for the ND-812 Computer."

6.4 AUTOMATIC SAMPLE CHANGER

G. W. Allin R. T. Roseberry H. J. Stripling, Jr.

An improved sample carousel indexing drive for the automatic sample changer previously reported[1] was installed. This corrected a positioning difficulty that was being experienced with an old indexing drive unit from salvage that had been supplied by the customer for the original installation.

This new drive has an eight-point Geneva indexing unit with a reduction of 2.5:1 to accommodate the 20-sample capacity of the carousel. A synchronous motor drives a single-revolution, spring-wrapped clutch on the Geneva input shaft which is set to declutch when the index drive is in the approximate center of the dwell period. This drive produces a sample positioning accuracy of 0.025 in. total indicated runout on a 24-in. diameter.

---

1. G. W. Allin et al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL–4990 (to be published).

6.5 STANDARD FOCAL OVERLAY SOFTWARE PACKAGE

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

A standard FOCAL overlay software package is being developed to supply system software for performing the varied tasks associated with research, development, and engineering testing, while providing uniformity and modest software development effort from system to system. The overlays to the basic FOCAL interpreter are in source file format, which is assembled with the PAL8 or PAL10 assemblers, using option parameters to select software modules for operation of the available peripheral devices. In addition to the standard device handlers included in the overlay file, additional assembly parameters include software modules for custom peripherals by supplying entry points in the interrupt service routine, power failure–restart routine, system restart routine, FOCAL command list, and FOCAL function list.

The following software modules with the features described are available for the PDP-8/E peripherals listed:

1. Mass storage – program and data storage–retrieval: DEC RK8E, SYKES C/C 100, and SYKES C/C 200.
2. Digital input-output – input sensing and input interrupt, output on-off control: DEC DR8EA (up to eight units).
3. Real-time clocks – time-of-day, day-of-year: DEC DK8EA, DEC DK8EC, and DEC DK8ES (including Schmitt triggers).

4. BCD device input and control – control of up to eight devices such as voltmeters and counters: ORNL-designed BCD instrument interface.
5. Low-speed reader control – replaces high-speed reader if unavailable.
6. Power failure–auto-restart – provides calls to restart routines for peripherals.

Several software modules previously developed which have seen extensive use are planned for future additions to the overlay source file: ORNL-designed storage display, ORNL-designed 16-channel analog input subsystem, DEC DF32 disk, DEC UDC8 digital input-output system, and a high-speed paper-tape punch.

The overlay package has been used as the software base for the PCOAT system (Sect. 6.11) and the MTAX system (Sect. 6.23). Documentation describing the overlay package will be available following the completion of the additional software modules planned for inclusion.

6.6 COMPUTER-BASED DATA ACQUISITION SYSTEM FOR THERMAL HYDRAULIC TEST FACILITY

J. L. Redford C. D. Martin

Specifications were written, equipment purchased, and software developed for a high-speed (10,000 channels/sec) digital data acquisition system for the Thermal Hydraulic Test Facility. The system will be used for data acquisition and analysis of simulated coolant system ruptures in pressurized-water reactors.

The software for the system is based on the FOCAL package provided for the Failed Fuel Mockup System.[1] Modifications were incorporated to expand the analog input capacity from 128 to 384 channels and to utilize a moving-head cartridge disk rather than the smaller capacity, fixed-head disk.

Additional features are automatic limit checking of input variables in the single-scan mode and access to a time code generator for synchronization of data acquired by the digital system, with data recorded on FM magnetic tape during a transient test.

1. J. M. Jansen and C. D. Martin, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973*, ORNL-4990 (to be published).

6.7 DATA COLLECTION FROM A MULTIDETECTOR SYSTEM FOR AN AUTOMATICALLY SCANNING ELECTRON SPECTROMETER: A CONCEPTUAL DESIGN

R. T. Roseberry M. O. Krause[1]

In a dispersive system, a multidetector array placed in the focal plane of the apparatus can increase the data acquisition speed many times without significant loss of resolution.[2] Data collection, however, is complicated because each detector must view the same spectral range displaced in time from the others.

A conceptual design was completed for a data collection system for a multidetector array for use by the Chemistry Division in the transuranium element research program. The system contains a simple arithmetic and logic unit and a buffer memory of 1024, 12-bit words. Following an arbitrarily selected number of spectrometer scans, data in the buffer memory will be transferred to the memory of an existing multi-channel analyzer.

1. Chemistry Division.
2. M. O. Krause, "A Multidetector System for an Automatically Scanning Electron Spectrometer," *Chem. Div. Annu. Prog. Rep. May 20, 1973*, ORNL-4891, p. 36.

6.8 FAST CRT DISPLAY CONTROLLER FOR A PDP-8/e COMPUTER[1]

R. T. Roseberry
P. R. Bell[2] W. J. McClain[3] R. S. Dillon[3]

A controller for the PDP-8/e computer has been developed to provide fast, program-controlled alphanumeric and intensity-modulated mapping displays on a CRT device. These displays are used in an imaging system for use in nuclear medicine. The controller provides the capability of displaying data in two modes: (1) a point-by-point mode and (2) an interpolated mode. The point-by-point mode provides displays of the basic data points only. In the interpolated mode, all data points and interpolated points (the average of adjacent data points) as well as interpolated lines between adjacent lines of data are displayed. Interpolation results in the display of four times the number of actual data points, resulting in a smoother and more readable display of the mapped data. An interpolated display of 4096 data points (16,384 displayed points) is provided in one-tenth of a second.

1. Abstract of paper to be published.
2. Thermonuclear Division.
3. Computer Sciences Division.

6.9 A MAGNETICALLY PULSED NEUTRON TIME-OF-FLIGHT SPECTROMETER FOR INELASTIC SCATTERING[1]

H. A. Mook[2] F. W. Snodgrass[3] D. D. Bates

A time-of-flight spectrometer utilizing a magnetically pulsed beam has been placed in operation at the High Flux Isotope Reactor at the Oak Ridge National Laboratory. The pulsing is accomplished by rapidly changing the magnetic moment direction in a ferrite crystal that serves to both monochromate and pulse the beam. Good neutron reflectivity is obtained from the ferrite crystal, and pulse risetimes of the order of 1 μsec are available. The spectrometer is interfaced to a Digital Equipment Corporation PDP-15-30 computer which drives pulsed motors to set up the desired scattering geometry and collects and analyzes the time-of-flight data. The magnetically pulsed beam is ideal for use with the cross-correlation technique, and spectra are presented which show the accuracy of the pulsing technique and the power of the cross-correlation methods in obtaining neutron scattering data.

1. Abstract of paper published in *Nucl. Instrum. Methods* **116**, 205–16 (1974).
2. Solid State Division.
3. Former member of the Instrumentation and Controls Division.

6.10 RADIOISOTOPIC SAND TRACER STUDY

H. R. Brashear F. N. Case[1] K. W. Haff[1]

A joint program between the National Oceanographic and Atmospheric Agency (NOAA) and the Atomic Energy Commission was initiated to adapt the equipment and techniques developed in the Radioisotopic Sand Tracer (RIST)[2–10] Study to sediment transport in the off-shore regions of the ocean. RIST equipment and techniques are being employed in the Marine Ecosystem Analysis (MESA) Program directed by NOAA in the New York bight. The MESA program is a unified effort of disciplines applicable to forming a data base to describe the insult to the marine environment in the New York bight due to waste dumping in the ocean (principally from New York City). Knowledge of the sediment (and waste) transport within the bight is an essential segment of the data base.

Two field tests were conducted The first test was to define the problems associated with utilizing the RIST equipment from an ocean-going vessel and to observe sediment transport off the coast of New Jersey on a short-time basis in November 1973 The sand was "tagged" with $^{198-199}$Au, and transport was observed for a ten-day period All objectives were met

The second test was designed to observe sediment transport over a longer period of time and, hopefully, to encompass at least one major storm The test duration was from April 22 to July 3, 1974 The sand was tagged with ^{103}Ru, and transport was observed during surveys in May, June, and July Only minor storms occurred in the bight during this time period All other objectives were met, and approximately 75,000 lines of data were collected Data processing on the ORNL IBM 360 computers is in progress

---

1 Isotopes Division

2 H R Brashear, E H Acree, and F N Case, "Scintillation Gamma Ray Detector for Littoral Transport Studies," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1967*, ORNL-4219, p 42

3 H R Brashear, E H Acree, and F N Case, "Data Collection System for Littoral Transport Studies," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1968* ORNL-4335, p 42

4 H R Brashear et al , "Computer Plotting of Data from the Mobile Amphibious Detection System Used in Radioactive Isotope Sand Tracer Studies " *Ibid* , p 42

5 H R Brashear et al , "Radioisotopic Sand Tracer Study (RIST) Status Report for May 1966–April 1968," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1969*, ORNL-4459, p 43

6 H R Brashear, E H Acree, and F N Case, "Radioisotopic Sand Tracer Study (RIST) Radiation Data Obtained from $^{198-199}$Au Tagging in the October 1968 Field Test at Surf, California," *Ibid* , p 43

7 H R Brashear et al , "Processing and Analysis of Radioisotopic Sand Tracer (RIST) Study Data," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1970*, ORNL-4620, p 63

8 H R Brashear et al , "Radioisotopic Sand Tracer Study," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1971* ORNL-4734, pp 43–44

9 R L Simpson and J M Jansen, Jr , "Radioisotopic Sand Tracer (RIST) Studies Computer System," *Ibid* pp 44–45

10 H R Brashear, E H Acree, and F N Case, "Radioisotopic Sand Tracer (RIST) Study Final Report," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1972* ORNL-4822, pp 43–44

6 11 UPDATE TO DATA ACQUISITION SYSTEM FOR FUEL RECYCLE DEVELOPMENT LABORATORY

A F Johnson, Jr

The FOCAL language was modified to support the hardware expansion of the computer-based data acquisition system in the GCR Fuel Recycle Development Laboratory [1] Standard functions and commands were added to enable program and data storage or retrieval from the cassette tape unit (Sect 6 5) The cassette unit can be used for rapid switching between application programs, larger application programs (by utilizing chaining), and increased variable storage Custom functions were added to control data transmission from the Particle Size Analyzer System[2] and retrieve data from the buffer for processing

Software compatibility was maintained in the updated computer system so that all previous application programs will operate without modification, and new programs can take full advantage of the updated system

---

1 J M Jansen and J T Hutton, *Instrumentation and Controls Div Annu Prog Rep Sept 1 1973*, ORNL-4990 (to be published)

2 L H Thacker and W R Miller, *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973*, ORNL-4990 (to be published)

6.12 LOW-SPEED INTERCOMPUTER DATA LINK TO AID PATTERN RECOGNITION STUDIES AT THE HFIR

J. B. Bullock W. H. Sides

A telephone line data link between the CDC-1700 process computer at the HFIR and the PDP-10 time-share computer was put into routine service in January 1974. Although some revisions in the details of the sign-on and sign-off sequences were found to be desirable after the initial trial, the basic features of the system are the same as previously reported.[1] This implementation has proved to be a reliable, error-free, and efficient way to transmit noise data to the analysis computer.

---

1. J. B. Bullock and A. F. Johnson, Jr., "Low-Speed Intercomputer Data Link to Aid Pattern Recognition Studies at the HFIR," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

6.13 ORIC MAGNET POWER SUPPLY CONTROLLERS

E. Madden J. M. Domaschko[1] K. Hagemann[2]
C. A. Ludemann[3] E. McDaniel S. W. Mosko[3]

The conceptual design, implementation, and installation of a computer control system for the ORIC magnet power supplies began in the Physics Division in 1972.[4] Project development was reinforced by sojourn members[1,2] of the Physics Division through 1972 and 1973. After their departure in late 1973, the Instrumentation and Controls Division supplied project support.

The computer-based control system for the ORIC magnet power supplies was designed to reduce the cyclotron experiment setup time and to monitor the accelerator magnet power supplies.

A modular computer system (MODCOMP) MCS III/5 computer is interfaced by way of a MODCOMP I/O system, a branch driver, 4 crate controllers, and 44 power supply control modules to the ORIC magnet power supplies. The crate controllers and power supply controllers are packaged in CAMAC[5] enclosures and CAMAC crates but are electronically non-CAMAC.

The computer is equipped with 40K, 16-bit words of memory; a high-speed serial printer; a 1.2-million word disk storage unit; and a magnetic-tape drive. The magnetic tape stores permanent files of operation data, and the disk enables ready access to programs and set-point data for tuning the cyclotron.

The operator maintains control with a computer interactive alphanumeric-graphic CRT display and keyboard, and via a control panel consisting of 16 lighted function pushbuttons and 14 pairs of reassignable pushbuttons, each pair labeled by a 4-digit LED alphanumeric display.

At the ORIC, all magnet windings and power supplies are isolated from ground and from each other. Consequently, all associated circuits require common-mode isolation ratings up to 400 V. The power supply controllers are individually powered and are isolated by optical couplers.

As indicated in Fig. 6.13.1, each power supply controller supplies a voltage reference to a power supply regulator by means of a microcircuit, 12-bit, digital-to-analog converter (DAC). In addition, the controllers serve as surveillance modules to monitor power supply regulation and excessive ripple in the voltage across the magnet coils.

Stable cyclotron operation is severely hampered if errors in power supply regulation of a few tenths of 1% occur. A magnet supply regulating shunt voltage is compared with the generated reference voltage to indicate the dc behavior of the power supply. An 8-bit DAC reference can generate comparator offset levels that define error windows within which the power supply is expected to operate. Under program control, magnet supply ripple frequencies up to 360 Hz or oscillations at frequencies up to a few kHz may also be

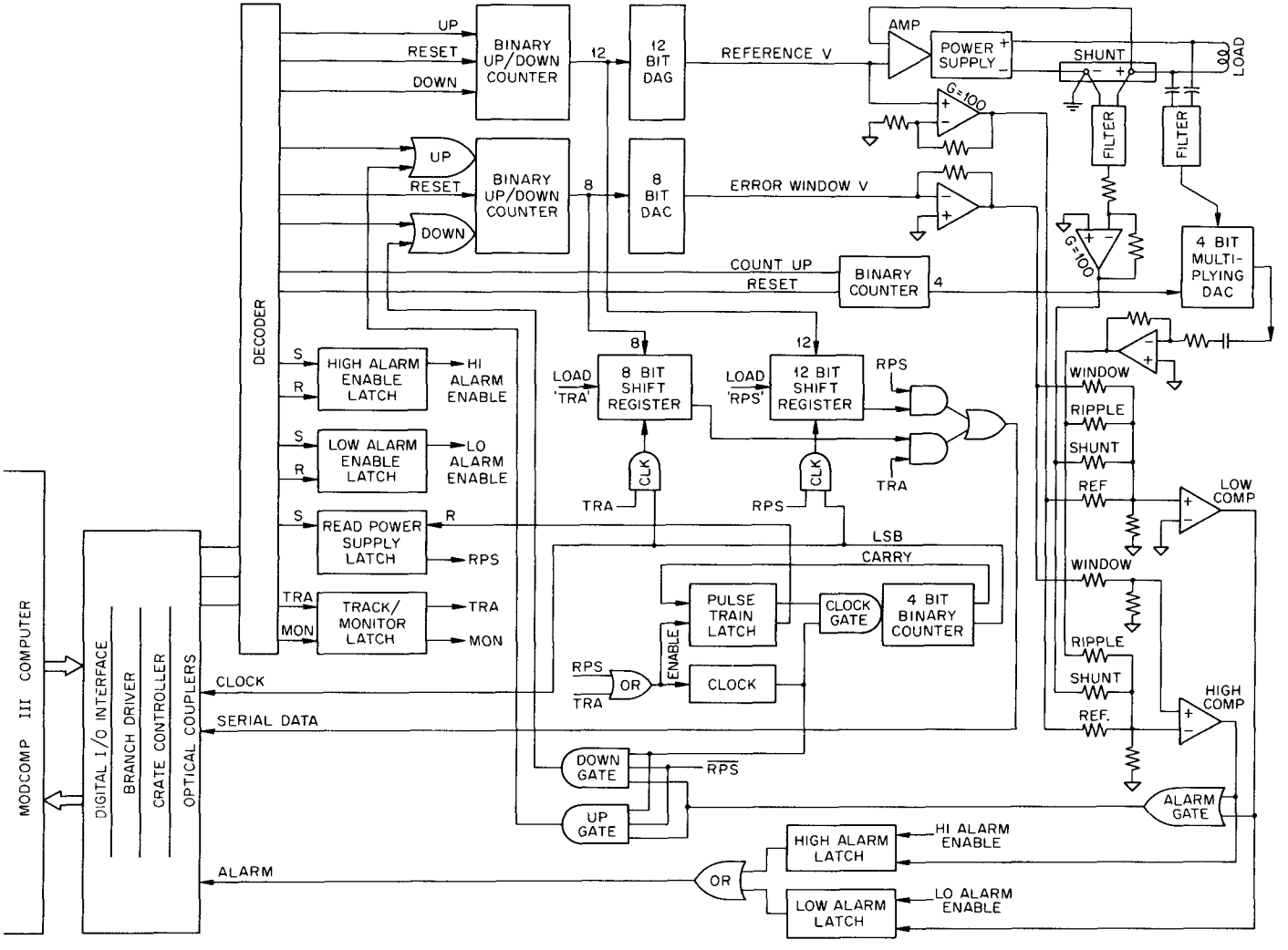


Fig. 6.13.1. Diagram of power supply controller-monitor.

compared with an error window. If an error signal exceeds the programmed window, the appropriate comparator trips the alarm latch, and the CPU and operator are alerted to such a malfunction.

A tracking mode is provided in which the power supply error signal wave form is digitized. The tracking mode has a bandwidth of about 4 kHz for sinusoidal wave forms, and sampling rates up to 40,000 per second are possible. Error signal sensitivity is about 30 μV.

To set up the accelerator for an experiment, the cyclotron operator will choose the appropriate operation parameters from the disk library of previous run data via a menu on the CRT screen. The power supplies will be switched automatically to the appropriate loads and run up to the listed settings. The operator then assigns the pairs of pushbuttons to various power supplies as needed for manual control of the fine tuning of the cyclotron. He will do this rapidly by means of function keys that will automatically make "standard" assignments for most frequently used power supply combinations. He will be able also to make "special" assignments via CRT menu picking or keyboard entry. In all cases the LED displays will label the pushbutton pairs so that the operator will know that he is raising or lowering the reference of a particular power supply. The CRT will update the status of all parameters being adjusted by the push-buttons.

The computer monitors the response of the power supplies and keeps track of their settings. If it detects abnormal power supply operation, the computer will alert the operator by CRT messages and audible signals. At the operator's option, the computer will store new run information in the disk library for future reference.

---

1 One-year appointment with the Physics Division (former NSF Presidential Intern)
2 Visiting scientist from Niels Bohr Institute, Copenhagen, Denmark
3 Physics Division
4 C A Ludeman et al , *Physics Div Annu Prog Rep Dec 31, 1972,* ORNL-4844, p 138
5 *CAMAC – Description and Specification,* AEC Reports TID-25875 and TID-25876

6.14 PROGRAM FOR COMPUTER CONTROL OF ORIC

E. McDaniel E. Madden C. A. Ludemann[1]

The program for computer control of the ORIC[2] is a MODCOMP III machine language program designed to run under supervision of MAX III (Modular Computer System's Applications Real Time Executive). The operating system is the extended disk version. It is a multiprogramming system that supports foreground tasks in a priority range from 0 to 127 and middle-ground tasks with priorities from 128 to 255. The highest priority is zero and the lowest is 255.

The program is composed of a group of tasks of different priorities that may be activated, suspended, or aborted by the operator at any time. In addition, tasks may be activated, suspended, or aborted by another task as a result of system events, timer expirations, or satisfied conditions.

Since all I-O instructions are privileged, global executive service routines have been written to handle all communications between the computer and the magnet power supply controllers and the DVM-crossbar scanner data acquisition system.

---

1 Physics Division
2 E Madden et al , "ORIC Magnet Power Supply Controllers," *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973,* ORNL-4990 (to be published)

6.15 EXECUTIVE SERVICE ROUTINE FOR MODCOMP MAX III

E. McDaniel

Modular's Applications Real Time Executive MAX III (Sect. 6.14) does not offer an easy way to handle floating-point input-output without using FORTRAN. Since the tasks comprising the program for control of ORIC[1] do not need FORTRAN except for I-O, a global executive service routine was written to handle floating-point INPUT-OUTPUT, which saves approximately 3K of core.

1. E. McDaniel et al., "Program for Computer Control of ORIC," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

6.16 COMPUTER DIAGNOSTIC PROGRAM FOR ORIC MAGNET POWER SUPPLY CONTROLLERS

E. McDaniel E. Madden

A comprehensive diagnostic computer program was written to test and assist in debugging the ORIC magnet power supply controller modules.[1] All of the 16 possible functions of the controllers and the stability of the digital-to-analog converters are thoroughly tested. A conversational mode of operation via a teleprinter or an alphanumeric-graphic CRT and keyboard is used to initiate tests and repetitive loops to isolate or pinpoint malfunctions to a specific microcircuit.

A modified version of this program will be incorporated as one of the tasks in the program for control of ORIC.[2] This will enable the cyclotron operator to quickly verify the integrity of the controller modules before starting the accelerator for an experiment.

1. E. Madden et al., "ORIC Magnet Power Supply Controllers," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).
2. E. McDaniel et al., "Computer Program for Control of ORIC," ibid.

6.17 CREEP LABORATORY DATA ACQUISITION SYSTEM

J. T. Hutton J. M. Jansen, Jr. R. L. Simpson

A computer-based data acquisition system, employing commercially available hard-wired data loggers as analog input signal scanners and digitizers and ORNL-designed interfaces, was designed for use in the Metals and Ceramics Division Creep Laboratory. When fully implemented, the system will acquire data from as many as 250 testing machines and record the data digitally on magnetic tape for processing by the Central Computing Facility. Data were previously recorded manually from readings taken from dial gages and strip-chart recorders and manually keypunched for computer processing. This automatic system will eliminate human error in transcribing data while speeding up data analysis. The use of data loggers as input subsystems provides recording redundancy. If a computer or magnetic tape should fail, the computer–data logger interface will enable the line printer built into the data logger to record data periodically from the creep machines until the computer is back on line.

6.18 AQUATIC LABORATORY STATUS

J. A. McEvers B. C. Duggins W. R. Hamel
C. D. Martin T. F. Sliski R. E. Toucey

The digital computer for the Aquatic Laboratory control system[1,2] was acquired, process interfaces were fabricated, applications programs were written, and the integrated system was installed. A checkout of the system was begun, using the system to provide set-point control of water temperature in two tanks. After the checkout, a time-temperature profile controller of water temperature will be added and other tanks will be put on computer control. The system is designed to control water temperature in 120 tanks.

1. B. C. Duggins et al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1972,* ORNL-4822, p. 53.
2. B. C. Duggins, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

6.19 COMPUTER-CONTROLLED DATA ACQUISITION ON THE ELMO BUMPY TORUS

J. W. Reynolds

Two computers, a PDP-12 and a PDP-8/E, with a 2400 bps asynchronous communication channel between them and a 4800 bps synchronous communication channel to a PDP-11/45 remote access terminal (RAT),[1] monitor and control data acquisition at the ELMO Bumpy Torus (EBT).[2,3] The PDP-12 monitors and acquires, with on-line display, three samples of data from each of the 24 sectors of the EBT, and the PDP-8/E acquires, in a batch mode, x-ray data from a Hewlett-Packard model 2400 pulse height analyzer, microwave interferometer data from the Biomation model 8100 fast transient recorder, and undefined data through the 16 multiplexed ADC channels.

The computer configurations are:

1. A Digital Equipment Corporation PDP-12 with 32K words of memory, a 96-channel multiplexer with ADC, two LINCtapes, an 8- by 10-in. digital x-y display with a dot matrix character generator, a 262K-word fixed-head disk memory, and two communication channels.
2. A PDP-8/E with 8K words of memory, a 16-channel multiplexer with ADC, two DECtapes, an 8- by 10-in. digital x-y display, a 1.6M-word, movable-head, disk-pack memory drive, a 2400 bps asynchronous communication channel, and two interfaces connected to Hewlett-Packard and Biomation equipment. The PDP-8/E was delivered in April 1974.

The data acquisition and control program was written for the PDP-12, with on-line data display of the last 14 scans, a variable scan period under control of either an internal real-time clock during data acquisition or the keyboard during calibration, a circulating data buffer in memory and on the disk, data file storage on LINCtape, data file displays and listings from either disk or LINCtape, data file transmission to the RAT, and a command log for the above operations on the Teletype.

The data acquired from each cavity of the 24 sectors of the EBT consist of three samples: a pressure in a range from 10^{-5} to 10^{-8} torr, a microwave power input in a range from 0 to 1 kW, and the perpendicular plasma energy from an integrator that is compensated for variations in the dc generator currents supplying the field coils of the torus.

Programs were written for communication between the PDP-8/E and the PDP-12 in ASCII, binary, and image modes by adding two communication handlers to the OS/8 monitor on the PDP-8/E and modifying PIP, a file transfer program, on the PDP-12.

1. R. A. Dory et al., "Data Handling Group," *Thermonuclear Div. Annu. Prog. Rep. Dec. 31, 1973,* ORNL-4982.
2. R. A. Dandl et al., "High-Beta Plasmas," ibid.
3. R. A. Dandl et al., *The ELMO Bumpy Torus Experiment,* ORNL-TM-3694 (November 1971).

6.20 X-RAY DIFFRACTOMETER CONTROL

E. Madden

An x-ray diffractometer control interface (Q-5240) for use with a PDP-8/E computer was built and installed. The system will be used by the Solid State Division for studies of irradiation damage in crystals by various diffuse scattering techniques. The interface provides a 12-bit data scaler, a 12-bit monitor scaler with switch-selectable scale modulus, an 8-bit interrupt register and 8-bit control register, a 300-pulse/sec clock for basic motor stepping rate, two stepping motors and drive circuits, and limit of travel protection circuits for each motor. Automatic reduced holding current circuits were added to maintain the motor case at reduced temperatures.

6.21 UPGRADING THE CAPABILITIES OF A COMMERCIAL FOURIER ANALYZER SYSTEM

R. C. Kryter V. K. Pare

A previous progress report[1] described the capabilities of a commercial real-time digital Fourier signal processing system purchased to aid Development Section activities. Subsequent to acquisition, a significant amount of manpower (~1½ man-years) has been, and continues to be, invested in improvements to the accuracy, versatility, and computational power of this important tool of reactor surveillance and diagnostics. ORNL additions and complements to the analyzer system supplied by the manufacturer fall into three categories: (1) detecting and correcting processing errors and deficiencies; (2) restructuring the software so as to make a wide variety of convenience features readily available to all users of the machine without recourse to complicated "program overlaying" procedures; and (3) creating highly specialized computational routines as the need for them arises in particular programmatic activities.

Examples of ORNL upgrades in these categories are (1) reformulation of transfer function and coherence calculations in double-precision arithmetic, so as to improve accuracy and dynamic range; (2) incorporation of paper-tape punching, variable-frequency grouping, logarithmic display, keyboard stack, title and format control, etc., programs into the base Fourier operating system as "residents" rather than "overlays"; and (3) creation of nonlinear least-squares fit, maximum-minimum search, variance estimation, "virtual memory" core swapping, variance-to-mean ratio estimation, frequency response corrections, multichannel normalization, etc., routines to satisfy special research needs.

1. R. C. Kryter and D. N. Fry, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

6.22 180° ORSIS COMPUTER SYSTEM[1] STATUS REPORT

J. M. Jansen, Jr. W. K. Dagenhart[2] F. R. Gibson

The phase III hardware expansion to the Oak Ridge Sector Isotope Separator (ORSIS) data acquisition and control system was completed with the installation of a 24K memory module, 1.6M-word removable disk cartridge system, a teleprinter, and a CRT alphanumeric-graphics terminal.

Additional digital and analog input-output capacity was provided to permit control studies with an existing calutron separator modified for the automated computer control studies.

The RTX/FOCAL multitasking operating system software development effort, scheduled for completion in the first quarter of 1975, will provide control of all peripherals in a device-independent manner, priority scheduling of time and event activated tasks, and input-output spooling of all low-speed terminals and paper-tape equipment. Operator-invoked utility functions for process monitoring and control will be provided via the alphanumeric-graphics terminal.

---

1. J. M. Jansen, Jr., and W. K. Dagenhart, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).
2. Isotopes Division.

6.23 MULTIAXIAL STRAIN TEST FACILITY DATA ACQUISITION SYSTEM

J. L. Redford K. Liu[1]

A computer-based data acquisition system was designed and assembled for the Multiaxial Strain Test Facility. Commercially available subsystems were used, and the FOCAL language was expanded to provide control of all peripheral devices.[2] This approach resulted in both a cost savings and increased user facility over complete systems offered commercially for similar applications.

The system will be used to collect data and control rates of strain in the investigation of material yield limits in multiaxial stress space. The plastic strain trajectory in the corresponding plastic strain space will be used for the development of elastic-plastic-creep constitutive equations for application in high-temperature structural design for LMFBR components. The system is capable of controlling up to three parameters for each of two testing machines.

---

1. Reactor Division.
2. J. M. Jansen and A. F. Johnson, "Standard FOCAL Overlay Package," this report.

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

J. L. Redford S. J. Ball

A computerized data system was designed, assembled, programmed, and installed at "Water Factory 21," a Vertical Tube Evaporator/Multistage Flash (VTE/MSF) desalination plant in Orange County, California. The data system is for use in on-line analysis of plant operation and for assisting in running and analyzing special tests. The work is sponsored by the Office of Saline Water, U.S. Interior Department.

Since installation of the computer system in January 1974, ORNL has provided some assistance with the tie-in to the plant and with instrument tie-ins and checkouts. Further assistance will be provided during the plant startup and during several initial experiments.

HARD-WIRED SYSTEMS

6.25 STEPPING MOTOR CONTROL AND POSITION READOUT DISPLAY

E. Madden

A dual control, two-motor position controller and position readout display (Q-5239) was designed and fabricated for use by the Chemistry and Physics Divisions in studies of heavy-ion-induced fusion and fission of light nuclei at the Oak Ridge Isochronous Cyclotron.

The system has two control panels with all essential controls duplicated. The angular position of two detector and proportional counter assemblies is controlled and monitored by visual display on either of two control panels. One control panel will be mounted in the target chamber for experiment setup motor control. The other control panel will be mounted in an experiment control room located above the target chamber and will provide remote control of motor shaft positioning.

The position of either detector–proportional counter assembly is indicated on both control panels at all times. Desired angular position of an assembly is entered by setting a thumbwheel switch register and depressing a run button.

6.26 EXPANSION OF THE SERDEX SERIAL DATA SYSTEM FOR STANDARDS LABORATORY PRINTOUT

M. L. Bauer

The SERDEX serial data system was designed and built during the summer of 1973 to take data from the switches of a Guildline potentiometer and print it out on a Teletype. As designed, it had the capacity to print 12 different characters consisting of the decimal digits 0 through 9, the special character "J," which FOCAL decodes as a "10," and a carriage return. The system could output up to 12 characters in sequence from a ten-line or BCD source.

The expansion consisted in raising the printing capacity to 16 columns and adding two more special characters, a line feed and a semicolon, bringing the total to 14. An additional ten-line to BCD conversion system was added. This made it possible to automate the data taking and handling, though the potentiometer must still be balanced by hand.

6.27 ORIC SOURCE AND PROBE CONTROL SYSTEM

J. A. Russell, Jr.

The installation of a new heavy-ion radial source and probe mechanism for ORIC required the modification of the insertion and withdrawal mechanism and associated controls. This is an automatically sequencing system which, when initiated by the operator, performs all the steps required to remove the mechanism from its operating position or to reinsert it in the machine. Provisions are made to permit the operator to stop it in any position and reverse the direction of movement. The system is interlocked with the axial source so that neither source can be inserted while the other one is in its operating position. Additional controls and position measuring instrumentation were added to permit remote operation of the system, including speed control of the rotating anodes and/or repositioning of the collimator disk. Precision indicating equipment was incorporated in the system to permit digital indication of critical source and probe position information.

6.28 DIGITAL POWER CONTROL

J. T. Hutton R. W. Tucker

A zero-fired ac power control rated at 115 V ac, 0 to 30 A, was developed for use with duration adjusting type (DAT) three-mode electronic controllers. The use of digital logic to replace the previously used autotransformer to proportion power and the replacement of mercury relays by zero-fired solid-state contactors eliminates undesirable line voltage transients (noise) and electromagnetic interference (EMI) caused by the old power control design. The first application of the new power control is on 1.5-kW furnaces used for elevated-temperature materials testing for the Molten-Salt Reactor Program.

The power control is built around an ORNL-designed CMOS (complementary magnetic oxide semiconductor) digital logic power proportioning circuit and a commercially available solid-state contactor (a zero-firing driver photocoupled to a high-power load thyristor with an integral heat sink). When set for 100% power, the proportioning circuit turns on the solid-state contactor every 60-Hz power cycle for the duration of each ON-signal from the three-mode controller. When set for an intermediate power, such as 25%, the proportioning circuit turns on the solid-state contactor for one cycle and off for the next three cycles. This power proportioning action is required for optimum temperature regulation at lower temperatures in the furnace's range. Although designed for use with DAT controllers, the power proportioning circuit could be easily adapted for use with current adjusting type (CAT) controllers and would give the power control a stepless input-signal-to-output-power transfer characteristic.

6.29 AUTOMATED ELECTROCARDIOGRAM DATA ACQUISITION SYSTEM

R. L. Simpson

The Automated Electrocardiogram Data Acquisition System[1] was upgraded to process automatically the electrocardiograms (ECG's) from all four Union Carbide Nuclear Division plants. This was accomplished by the addition of an on-line digitizer and digital magnetic-tape recorder and four new patient instrument carts compatible with the data system. Modifications to the existing computer program were made to accommodate the new data format, to provide separation of output for the four plants, and to print a summary of the processed ECG's.

A cost reduction from $0.54 to $0.12 per ECG was realized with the upgraded system. This reduction is attributed to the more compact data format provided by the new equipment, which results in less computer time for processing an ECG and a decrease in labor from approximately 5 hr per week to 1 hr per week for operation of the system.

1. R. L. Simpson, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

6.30 PORTABLE DATA ACQUISITION SYSTEM FOR TRANSIENT MEASUREMENTS

A. F. Johnson, Jr.

A portable data acquisition system is being assembled for use in measurement of thermocouple time response by the loop-current step-response method. Three vendor-supplied items comprise the system: a four-channel digital transient recorder, a data terminal with dual cassette units, and an interface unit to couple the recorder and terminal together. The transient recorder digitizes and stores the input signals as 10-bit data words. Flexibility is provided for configuring input channels and memory segments, depending

on the experiment requirements. The data terminal will be used on-line with the experiment to record selected data from the transient recorder onto cassette tape at 1200 baud. The terminal will then be used later to play the data off the cassette into the PDP-10 time-sharing network and interactively process the data.

The system will replace a less sophisticated one currently in use,[1] pieces of which are on loan from other projects. The primary advantages of the new system over the old are (1) better resolution in acquired data, (2) simultaneous multichannel acquisition, (3) faster transfer of data onto a storable media, and (4) ease in handling storable media (cassette vs paper tape). The system is expected to go into operation in the fourth quarter of 1974.

1. R. B. McFarland and A. F. Johnson, Jr., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

6.31 PROGRAMMED POWER CONTROLLER

W. R. Miller

An updated version of a twice-reported standard program generator has been designed and built.[1,2] The first version required a full chassis of components, the second version required a small box of components, and the new version is all contained on a single small circuit board (Fig. 6.31.1).

The advent of integrated-circuit multipliers has made possible power programming as well as temperature programming with this unit.

In addition, isolation amplifiers developed for heart monitoring in the medical field now provide a means of interfacing the programmer to power sources whose control inputs are not isolated.

All of these features have recently been utilized in a high-temperature furnace control system for the Isotopes Division.

1. W. R. Miller, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1967,* ORNL-4219, p. 81.
2. W. R. Miller, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1969,* ORNL-4459, pp. 73–74.

6.32 SUPERCONDUCTOR "NORMAL" DETECTOR AND SHUTDOWN

D. W. McDonald

In investigating the use of superconductors in the control of a fusion process, it became necessary to determine the amount of current passable through a superconductor in the presence of a high magnetic field (≈30 kG). At some high current value in this field the superconductor loses its infinite conductance and becomes resistive, or goes "normal."

The Instrumentation and Controls Division was asked to design a voltage programmer for the required power supply with a built-in "normal" detector and shutdown device. The programmer had to have the ability to control a slow approach by the power supply to the "normal" point. The economy programmer designed by Miller[1] proved ideal, allowing the ramping rate of 1 mV/sec requested by the customer. A Keithley model 155A null detector was used to detect a 1-μV signal across the superconductor as it began to go normal. The output of the 155A triggered an RS flip-flop which in turn activated a transistor, shorting the programmer output. The shutdown process is completed within 0.01 sec, preventing the helium coolant from boiling off as a result of the heat generated during the change of state. An indicator light notifies the operator that the superconductor has gone "normal," and an X-Y plotter gives the amperage at that point.

1. W. R. Miller, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1969,* ORNL-4459, pp. 73–74.

PHOTO 2204-74

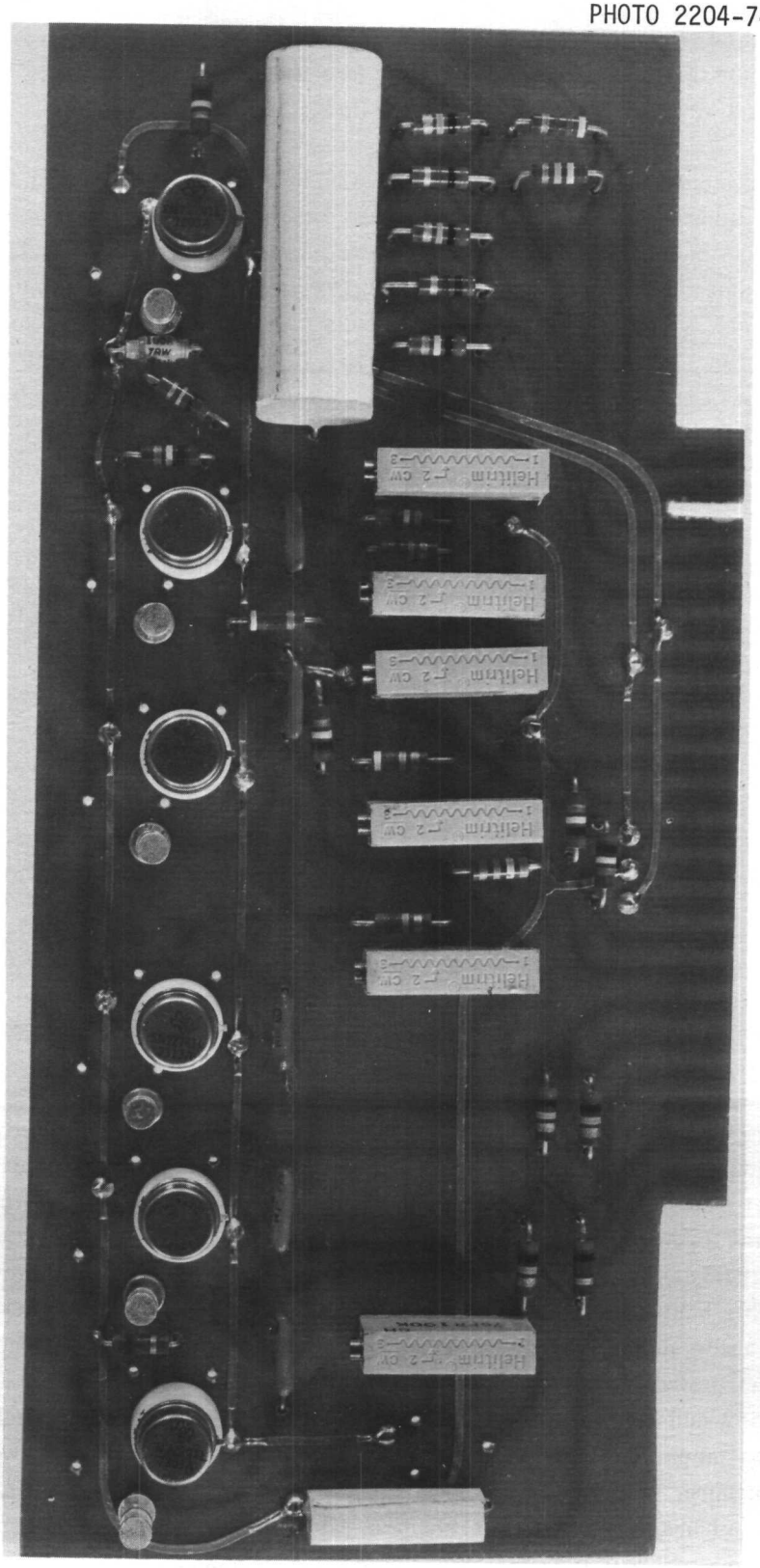


Fig. 6.31.1. Circuit board of new programmed power controller.

7. Process Systems and Instrumentation Development

7.1 ADDITIONS AND MODIFICATIONS TO THE ORNL STEAM PLANT CONTROL SYSTEMS

W. R. Hamel B. C. Duggins

The project activity reported earlier[1] concerning the additions and modifications to control systems of the No. 1, 2, 3, and 4 boilers of the ORNL Steam Plant continues at this time. AEC funding authorization for the modification of two boilers was received. Instrumentation and Controls personnel have reviewed a procurement specification for the required work which was written by the Instrument Engineering Section of the General Engineering Division. This specification has been issued for bids and calls for work to begin on boilers No. 1 and 2 in April 1975. It is expected that equipment delivery times will have some impact on current scheduling. Instrumentation and Controls engineering personnel continue to assist General Engineering personnel on this project in a consulting capacity.

---

1. W. R. Hamel et. al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973*, ORNL-4990 (to be published).

7.2 IMPROVEMENTS TO THE HYDROFRACTURE FACILITY

R. E. Toucey

The existing hydrofracture facility was reconditioned and improved to increase reliability and efficiency. The original facility was designed and implemented by the Halliburton Company to demonstrate the feasibility of the hydrofracture method.

The instrumentation has been modified as follows:

1. The manually operated solids addition valve was replaced with a pneumatically operated valve.

2. A controller was added to the pounds per gallon recorder so that automatic operation of the solids addition valve is possible.

3. The densitometer was replaced with a viscosity detector and recorder. The original densitometer proved to be a problem and was inoperable most of the time.

4. An orifice flowmeter was installed to measure waste liquid flow as a backup device for the existing turbine flowmeter.

5. Level sensors were installed on the four dry-mix storage bins to indicate the amount of dry mix existing in each bin.

7.3 DIGITAL POWER PANEL

W. R. Miller

A modernized version of the much used Q-1699B power panel was designed and built. Used as a power pre-regulator for furnaces and processes, this unit (Fig. 7.3.1) utilizes a pulsed solid-state relay in place of the variable autotransformers used in the earlier version.

Line frequency cycles are dial-selected through a front panel control to provide 10% power steps from 0 to 100%. A logic fail-safe circuit and low-level control and safety monitoring are added features. A 3:1 size and price reduction has been achieved with a simultaneous 4:1 increase in power output capability.

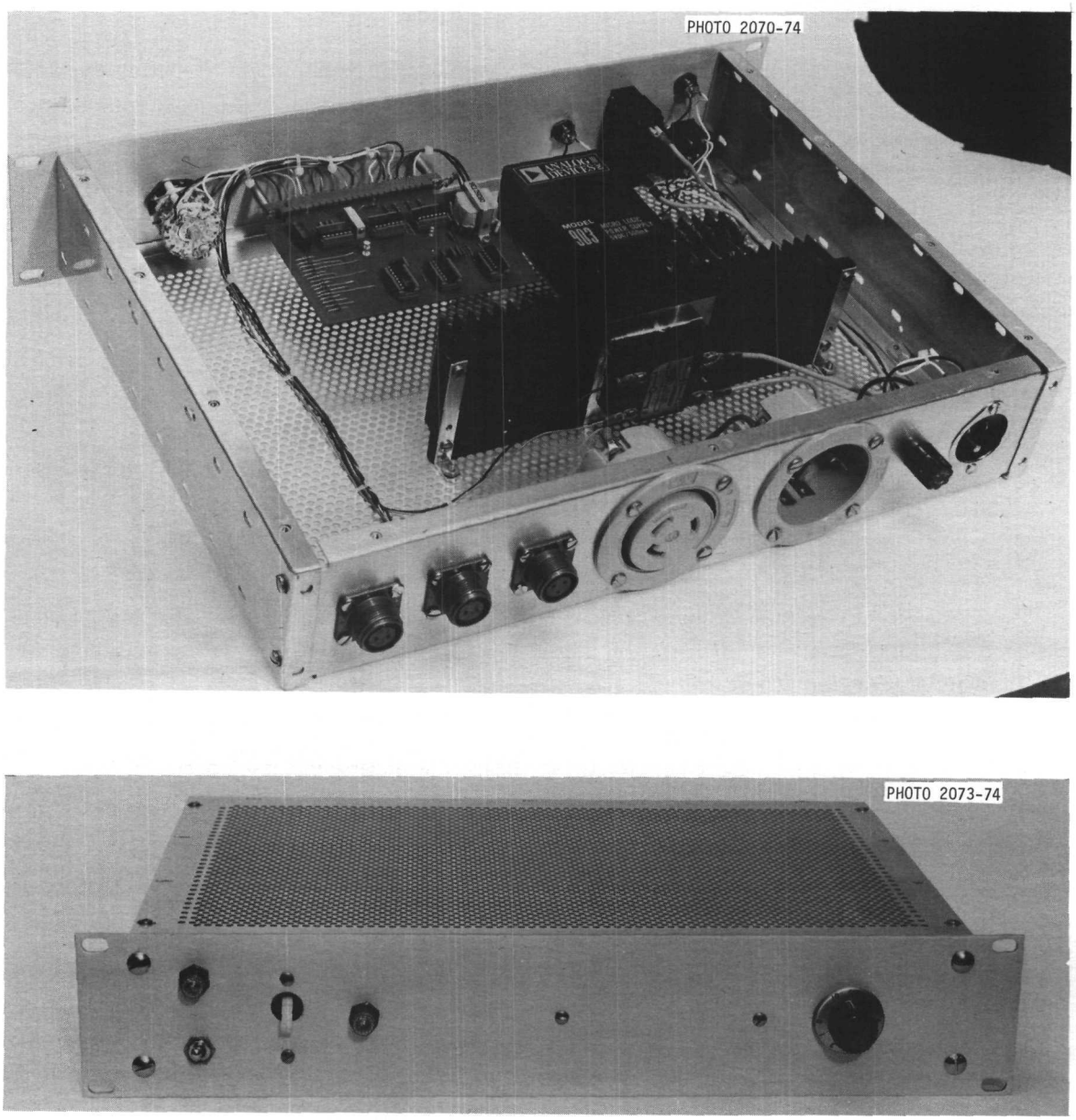


Fig. 7.3.1. Digital power panel. (*a*) Front panel, enclosed view; (*b*) rear panel, open view.

8. Reactor Instrumentation and Controls

8.1 ANALYSIS OF NEUTRON-DENSITY OSCILLATIONS RESULTING FROM CORE BARREL MOTION IN A PWR[1]

D. N. Fry R. C. Kryter J. C. Robinson[2]

At the request of the U.S. Atomic Energy Commission, the authors investigated unusual noise at the Palisades Nuclear Plant in late July 1973. The plant operator, Consumers Power Company (CPCO), and the plant designer, Combustion Engineering (CE), had previously observed abnormal flux oscillations on the output from ex-core detectors in the plant, had investigated and characterized the signals with noise-analysis techniques, and had speculated that the oscillations resulted from flow-induced motion of the reactor core barrel. On-site noise diagnosis by ORNL of plant signals such as in-core and ex-core neutron flux, temperature, and vibrations (sensed by ex-vessel accelerometers) with the aid of a computer-based noise analyzer substantiated the previous conclusions of CPCO and CE: the abnormal ex-core detector flux oscillations were attributable to changes in neutron leakage to these detectors caused by a rocking motion of the core barrel and core as a unit inside the pressure vessel.

Following the on-site measurements, an analog magnetic-tape recording of plant neutron detector signals was obtained from CE so that an in-depth study could be conducted at ORNL. Shortly thereafter, while Palisades was shut down for inspection of the steam generator, the reactor pressure vessel internals were visually inspected to confirm the noise-analysis diagnosis that the core barrel had rocked during operation. The inspection revealed that an ~0.25-in. thickness of metal had worn from the mating surfaces of the core support barrel flange and pressure vessel, thus confirming the speculated mode of motion.

Our objectives in reporting this work are to (1) show the advantage of using a variety of plant signals, each processed statistically in several ways, in performing unambiguous diagnoses; and (2) illustrate the reasoning by which an investigator can assimilate the various complementary pieces of information to diagnose the performance of reactor internals. We stress the need for presentation of experimental results in absolute, universally recognized units of measurements from other plants of similar construction.

Some of the more important observations of the Palisades study were as follows:

1. In-core detector rms noise was about four times smaller than ex-core noise in the 0.03- to 5-Hz range. From this observation, we concluded that the cause of the larger ex-core noise was not due to power fluctuations.

2. Some ex-core detectors had considerably higher rms noise levels in the above range than others. Furthermore, the relative phase shift among ex-core detectors varied from 0 to 180° with detector circumferential position. These facts indicate a preference direction of motion.

3. The amplitude distributions of the ex-core detectors were not symmetric with respect to their mean values; that is, fluctuations in signal amplitude had a preferred sign. This fact reinforces other indications of preferentially oriented core barrel rocking.

We believe that the neutron noise signatures associated with the movement of the core barrel in this PWR will be helpful in diagnosing similar abnormalities if they occur in other PWRs.

---

1. For additional details, see report by above authors entitled, *Analysis of Neutron-Density Oscillations Resulting from Core Barrel Motion in the Palisades Nuclear Power Plant,* ORNL-TM-4570 (May 1974). Similar information was also reported by the same authors in a paper of similar title presented at the Power Plant Dynamics, Control, and Testing Symposium, University of Tennessee, Knoxville (Oct. 8–10, 1973).
2. Consultant from the Department of Nuclear Engineering, the University of Tennessee, Knoxville.

8.2 NEUTRON NOISE MEASUREMENTS IN A BWR: BROWNS FERRY UNIT 2

D. N. Fry

Neutron noise measurements are being made during startup of TVA's Browns Ferry Unit 2 at power levels of 5, 25, 40, 50, and 100% of full power. These measurements will provide a catalog of neutron noise signatures for this plant unit and data to determine the feasibility of measuring the slip ratio between steam and water in the reactor core.

Interface modules were designed and constructed to allow direct connection of in-core fission detectors to ORNL recording equipment. Noise signals from 43 in-core detectors at nominal reactor power levels of 5, 25, and 40% were recorded on analog magnetic tape during August 1974 for subsequent analysis at ORNL using the Fourier time series analyzer of the Development Section. In addition to signal recording, the time series analyzer was moved to the plant for a brief period to provide "quick-look" on-line analyses of selected detector signals at 5 and 25% of full power.

Results from the measurements made to date are not yet available.

8.3 PROGRESS IN THE APPLICATION OF PATTERN RECOGNITION METHODS TO REACTOR SURVEILLANCE

R. C. Gonzalez A. S. Mahmoud R. C. Kryter

Previous investigations[1] of the feasibility of applying pattern recognition theory and techniques to detect incipient failure of reactor internal components and other abnormalities, thereby automating data interpretation and eliminating the need for assessment by highly trained analysts, were continued. The measure of success[2] achieved with neutron noise data from the ORNL High Flux Isotope Reactor has encouraged us to follow two distinct approaches in furthering the development.

The first utilizes "statistical" concepts, primarily the so-called Kolmogorov-Smirnov hypothesis test.[3] Basically, this approach consists in developing algorithms capable of "learning" the statistical parameters of specified probability density functions from noise samples and then using the Kolmogorov-Smirnov test to determine how closely the data conform to the specified functions. Once density functions that fit the experimental data have been identified, they can be used as templates for automatic recognition of anomalies sensed by noise monitors. This approach has three strengths: (1) no assumption of Gaussian properties need be made, (2) it is easily expressed in a learning framework, and (3) it is computationally simple.

The second approach utilizes "clustering" concepts (similar to those of last year's work) with an added refinement: labels to identify data clusters in multidimensional space. These labels describe reactor operating parameters (e.g., control rod positions, coolant pump speeds, power level, etc.); while this same information is also used in the alternative statistical approach, the manner in which it is incorporated is quite different. Clustering treats each noise observation as a single entity in multidimensional space, where-

as the statistical approach now being investigated considers each frequency of the noise observation independently (the labels are merely appendages)

The decoupling of variables practiced in the statistical approach inevitably causes a certain loss of information. Therefore, a major objective in pursuing these two development paths is to establish the importance of such cross-linked information in determining pattern abnormalities. If the information loss of the statistical approach is not excessive, there would be strong incentive to develop further this simpler method of attack for the automatic data classification problem

1 R C Gonzalez, D N Fry, and R C Kryter, "Application of Pattern Recognition Methods to Reactor Core Component Surveillance," *Instrumentation and Controls Div Annu Prog Rep Sept 1 1973,* ORNL-4990 (to be published)

2 R C Gonzalez, D N Fry, and R C Kryter, "Results in the Application of Pattern Recognition Methods to Nuclear Reactor Core Component Surveillance," *IEEE Trans Nucl Sci* **21** (1), 750–56 (February 1974)

3 J D Gibbons, *Nonparametric Statistical Inference,* McGraw-Hill, New York, 1971

8.4 RELIABILITY AND SAFETY ANALYSES OF HIGH-TEMPERATURE GAS-COOLED REACTOR SYSTEMS

Paul Rubel

Participation in the HTGR Safety Program at ORNL in the areas of system reliability and accident risk analyses was continued.[1] This work serves the immediate purpose of translating accident considerations into specific technical criteria, for example, stresses imposed on components or consequences of component failures. Ultimately, the accident analyses should provide a basis for an objective safety assessment of the HTGR

Effort was concentrated on the development of methods for organizing comprehensive safety studies The resulting analysis strategy combines tree logic, describing accident event progressions, with simulations of system or process behavior to establish plant conditions. Further insight regarding the relative importance of various accident outcomes may be derived from probabilistic analyses based on the events logic. A partial analysis of the cooling interruption accident was executed to demonstrate the methods, and preliminary work was done toward similar evaluation of the moisture ingress and depressurization accidents. A draft report describing this work was prepared.

Chapters were contributed to the expanded *Planning Guide for HTGR Safety and Safety-Related Research and Development* report ORNL-4968, describing previous accident analyses by others and outlining proposed additional work for the HTGR Safety Program.

1 P Rubel, *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973,* ORNL-4990 (to be published)

8.5 SIMULATION OF THE GAS-COOLED FAST BREEDER REACTOR (GCFBR) STEAM GENERATOR ON THE HYBRID COMPUTER

O. W. Burke F H. Clark

This work is a continuation of that presented in the 1973 annual report The reasons for developing this very detailed hybrid computer model of the GCFBR steam generator were (1) to serve as a check on a less-detailed model developed and used by General Atomic personnel, (2) to perform further transient studies on the steam generator, and (3) to study the control aspects of the steam system. The continuous-space, discrete-time model is operational, and a test transient has been run in order to compare its perfor-

mance with that of the General Atomic model. The results from the two models were quite similar; however, some instabilities in the hybrid computer model were encountered at low water and helium flow rates. The possible reasons for these instabilities are being investigated. This work will continue into next year, and other components in the steam system will be added to the simulation model.

8.6 NUCLEAR DESALINATION PLANT CONTROL STUDIES

S. J. Ball N. E. Clapp, Jr. J. G. Delene[1]

Control studies of large dual-purpose desalination plants utilizing multistage flash (MSF) evaporators were completed. Studies of more advanced systems utilizing a combined vertical-tube evaporator (VTE) and an MSF evaporator are continuing in support of the Water Factory 21 (WF21) experiment. A digital simulator developed for WF21 is being used to predict the plant dynamic response and to aid in planning experiments. Data from these experiments are to be used in turn to improve the simulator models.

1. Reactor Division.

8.7 CORE FLOW TEST LOOP DYNAMICS SIMULATION STUDIES

S. J. Ball

Dynamic simulations were made of several preliminary designs of the Core Flow Test Loop (CFTL) experiment to assist in determining an optimum loop design configuration. The CFTL is a gas-cooled, high-temperature, high-pressure loop intended to test electrically heated "fuel rod" bundle design performance for the Gas-Cooled Fast Breeder Reactor program. The objective of the design was to ensure that the required (rather severe) flow, temperature, and pressure transients could be inflicted on the test section bundle (to simulate accident conditions), while minimizing the trauma to the rest of the loop at the same time (i.e., the circulators, heat exchangers, etc.).

Satisfactory loop and control system designs were developed. Further detailed simulations will be developed and run as the detailed loop design is established.

8.8 CONTROL SYSTEM SIMULATION STUDIES OF A COAL-FIRED GAS TURBINE POWER PLANT

J. W. Mills[1] S. J. Ball

A preliminary dynamic simulation was made of a proposed coal-fired gas turbine plant experiment to determine the plant's control characteristics. The plant is to demonstrate the feasibility of a closed-cycle gas turbine with a fluidized-bed coal burner as an energy supply system for a large residential complex. The system would provide energy for home heating, air conditioning, and hot water, as well as electric power.

Dynamic models for the system components were developed, and preliminary transient runs have been made. Proposed control schemes will be investigated and the results will be utilized in the detailed system design, which is to be completed in December 1974.

1. Summer Participant, Massachusetts Institute of Technology, Mechanical Engineering Department.

8.9 DYNAMIC TESTS IN THE HTGR FUEL CAPSULE EXPERIMENT

W. H. Sides J. E. Swander T. W. Kerlin[1]
O. C. Cole J. Thakkar

A study was made of the feasibility of utilizing dynamic testing techniques to determine the heat transfer characteristics of HTGR fuel capsules. Existing computer codes were used to calculate the steady-state temperature distributions in the capsule and to calculate the frequency responses of the temperatures at various locations within the assembly to perturbations in the reactor heat generation rate. An experiment was then performed in the HRB-8 fuel irradiation facility of the HFIR to measure these same frequency responses over the range 0.02 to 1.5 Hz at four spatial positions in the assembly.

The results indicated that the measured responses had considerably longer time constants than predicted by the theoretical model. The differences were attributed to the near-stagnant gas gap in which the thermocouples were located but which was not included in the model. The experimental results also suggested the presence of a break frequency above 1.5 Hz, not predicted by the model, that may be due to gamma heating within the thermocouple junction itself.

Further work should be directed toward improvement of the theoretical model by including the effects of the gas gap on thermocouple response and gamma heating in the thermocouple junction.

1. Consultant from the Nuclear Engineering Department, the University of Tennessee, Knoxville.

8.10 REVIEW OF ENGINEERING TEST REACTOR (ETR) DOCUMENTS

S. J. Ditto J. L. Anderson

During this reporting period we continued our review of ETR Plant Protection System Subsystem Design Descriptions (SDDs)[1] for AEC's Division of Reactor Research and Development (RRD). Six formal reviews were submitted to RRD, and several informal comments were made by telephone.

At the present time, Aerojet Nuclear Corporation is completing the final SDDs for the upgrading program of the ETR protection system. We are not currently in the review chain and do not expect our formal involvement to continue. Informal contact with RRD will continue, and we expect to provide consultation services upon request by them.

1. S. J. Ditto and J. L. Anderson, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973*, ORNL-4990 (to be published).

8.11 A CORE-CONSERVING, MODERATELY FAST ALTERNATIVE TO THE FFT FOR FREQUENCY ANALYSIS WITH A MINICOMPUTER

R. C. Kryter D. L. Campbell

Since the advent of the fast Fourier transform (FFT) algorithm, little attention has been paid to alternative, less glamorous computational algorithms. However, for some types of discrete Fourier transform problems, the FFT is far from optimal: (1) core storage requirements are high, since incoming data points cannot be processed individually and then discarded but instead must be processed as a simultaneously resident block of size 2^n, typically $6 \lesssim n \lesssim 12$; and (2) the algorithm commits overkill, in the sense that all 2^{n-1} nonredundant Fourier coefficients must always be produced regardless of some user's lesser

requirements. We sought an alternative Fourier transform computational technique that overcomes these two faults while retaining high numerical accuracy and ease of programming on a minicomputer lacking sophisticated hardware and instruction repertoire.

We found that a well-documented (but apparently little used) modification of the so-called Goertzel shifting algorithm[1,2] met our objectives. This procedure operates on single data points as received without recourse to an entire array and can produce Fourier coefficients at any desired number of arbitrarily spaced harmonic positions by repeated application. While not nearly so computationally efficient as the FFT, we found that in cases where only a few select harmonics were desired, the algorithm's throughput rate could equal that of the FFT, and core storage requirements were reduced by as much as a factor of 10^3

The Goertzel algorithm has been implemented on a commercial time series Fourier analyzer system, using floating-point arithmetic. We are currently investigating scaling and numerical roundoff considerations so that the coding can be changed to fixed-point arithmetic, thereby yielding greater real-time throughput speed.

1 D E Dick and H J Wertz, "Analog and Digital Computation of Fourier Series and Integrals," *IEEE Trans Electron Comput* EC-16(1), 8 (February 1967)

2 T W Kerlin, *Frequency Response Testing in Nuclear Reactors*, chap 4, Academic Press, New York, 1974

8.12 USE OF CALIFORNIUM-252 AS A RANDOMLY PULSED NEUTRON SOURCE FOR PROMPT-NEUTRON DECAY MEASUREMENTS[1]

J T. Mihalczo

Cross-correlation measurements between the pulses from an ionization counter containing a ^{252}Cf neutron source, which provided the initiators of fission chains in a neutron-multiplying assembly, and the pulses from a detector observing the particles from the fission chains leaking from the assembly were performed for unmoderated and polyethylene-moderated uranium (~93 wt % ^{235}U) metal cylindrical assemblies with uranium masses varying from 12 to 160 kg and with prompt-neutron decay constants varying from 3×10^3 to 10^8 sec^{-1}. The applicability of this randomly pulsed neutron method with ^{252}Cf as the neutron source for the determination of the prompt-neutron decay in plutonium was investigated in experiments with unmoderated plutonium metal assemblies with masses varying from 2.2 to 16 kg and with spontaneous fission rates from ^{240}Pu varying from 4.5×10^4 to 8.2×10^5 fissions/sec. These assemblies included spheres and parts of spheres of plutonium with 4.5 or 20.1 at. % ^{240}Pu.

The ratio of the correlated count rate in the randomly pulsed neutron method to that in a Rossi-α method is inversely proportional to the detector efficiency and was as large as 8000 for some assemblies where both measurements were made. Thus the randomly pulsed neutron method allowed the determination of the prompt-neutron decay without the use of a complicated pulsed-neutron source where the Rossi-α method was not practical In assemblies for which Rossi-α measurements were also made, the prompt-neutron decay constant agreed within the precision (<1%) of the measurements with those obtained in much less time by this technique. Since the prompt-neutron decay can also be determined for plutonium metal assemblies with ~20 at. % ^{240}Pu, using a californium source as small as 3000 fissions/sec, this technique can be used for the subcriticality determination for both unreflected and unmoderated uranium (93.2) or plutonium metal assemblies.

1 Abstract of paper published in *Nucl Sci Eng* 53, 393 (April 1974)

8.13 OPTIMIZATION OF NANOSECOND FISSION ION CHAMBERS FOR REACTOR PHYSICS APPLICATIONS[1]

N. W. Hill J. T. Mihalczo J. W. Allen M. M. Chiles

The characteristics of parallel-plate fission chambers were studied to determine the precise time of a fission in the chamber, to minimize the electron collection time of the ionizing event, and to maximize the ratio of the amplitude of the minimum fission product pulse to the maximum alpha particle pulse. These results can be applied to optimize the design of ionization chambers used with fast current amplifiers for a variety of applications such as (1) chambers for measurement of fission cross sections for elements with high specific alpha activity to provide data for the investigation of the actinide burnup methods,[2] and (2) chambers with ^{252}Cf for measurements of interest in reactor physics (such as subcritical reactivity determination[3]) and total cross-section measurements.[4,5]

A variable-spacing fission chamber was constructed to study the effects of plate spacing, filling-gas pressure, and collecting electric field on chamber characteristics. One of the two parallel plates was electroplated with 0.8×10^{-2} μg of ^{252}Cf (5000 fissions/sec) within a 0.6-cm circle centrally located on the 2.03-cm-diam plate. The plate spacing could be adjusted from 0.025 to 0.635 cm with a bellows-micrometer arrangement. The chamber was filled with methane gas at pressures of 380, 570, 770, 1530, or 2300 mm Hg. The collecting electric field was varied from 0 to 500 V. The output from the chamber was connected directly (with a short connector) to the input of a fast, transistorized, high-gain, low-input-impedance ($\sim$20 Ω), low-noise current amplifier.[6,7] The output was observed on an oscilloscope and photographed to record the amplitude of the maximum alpha pulse, if observable above electronic noise; the width of the pulse at 10% of the peak amplitude; and the amplitude of the maximum fission product pulse.

At a gas pressure of 1530 mm and a plate spacing of 0.15 cm, the ratio of the minimum fission pulse to the maximum alpha pulse was as large as 4. Thus, ionization chambers can be designed for alpha discrimination. Integral bias curves, that is, plots of the discriminated output count rate, showed that for a wide range of the three variables, >99.5% of the spontaneous fission events of the ^{252}Cf were detected. For the five pressures studied, the electron collection time was <11 nsec with a plate spacing $\leq$1 mm. For example, the pulse width at 0.75 mm spacing and 1530 mm pressure was <9 nsec, and the ratio of the minimum amplitude of the fission pulses to the maximum amplitude of the alpha pulses was 2.

Chambers were constructed in conformance with the results of this study, and the time resolution of the fission events detected was <0.5 nsec.

---

1. Abstract of paper to be presented at the 1974 IEEE Meeting Nuclear Science Symposium, Washington, D. C., Dec. 11–13, 1974 .
2. H. C. Claiborne, *Neutron Induced Transmutation of High Level Radioactive Waste,* ORNL-TM-3964 (December 1972).
3. J. T. Mihalczo and N. W. Hill, *Trans. Am. Nucl. Soc.* **14**, 60 (June 1971).
4. L. Green, J. A. Mitchel, and N. M. Steen, *Nucl. Sci. Eng.* **50**, 262 (1973).
5. J. T. Mihalczo, *Nucl. Sci. Eng.* **53**, 353 (1974).
6. N. W. Hill and W. P. Albritton, *Nucl. Instrum. Methods* **75**, 18 (1969).
7. N. W. Hill, J. T. Mihalczo, and F. E. Gillespie, "^{252}Cf as a Nanosecond Pulsed Fission Neutron Source," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1970,* ORNL-4620.

8.14 THEORY OF CORRELATION MEASUREMENT IN TIME AND FREQUENCY DOMAINS WITH ^{252}Cf[1]

J T. Mihalczo V. K. Paré

The theory of cross-correlation measurements between the pulses from an ionization counter containing a ^{252}Cf neutron source, which furnished the initiators of fission chains in a neutron-multiplying assembly, and the pulses from a detector observing the particles from the fission chains is presented. The expression for the detector response in this type of measurement is first developed in the time domain, and then the cross-power spectral densities in the frequency domain measurements are presented. The theory of the usual two-detector noise measurement is reformulated to incorporate a modified Diven factor that includes the effects of neutrons from external sources such as spontaneous fission of the californium and the reactor fuel. Finally, the equivalence between both the time and frequency domain expressions is demonstrated.

A new method of reactivity determination is proposed that avoids some of the difficulties of the present methods, such as dependence on detection efficiency, inherent source strength, and the requirement for a calibration near delayed criticality

1 Abstract of paper presented at the 1974 SMORN 1 NEACP Specialists' Meeting on Reactor Noise From Critical Assemblies to Power Reactors, Rome, Italy, October 21–25, 1974

8.15 CALCULATED AMPLITUDE DISTRIBUTION OF IONIZATION PULSES FOR A PARALLEL-PLATE IONIZATION CHAMBER[1]

J. W. Allen

The determination of reactivity, using neutron noise analysis method measurements with an ionization mode fission chamber, requires the value of the average square of the charge collected and the square of the average charge collected for both fission fragments and alpha particles. These values appear in the reactivity equations as the ratios $\overline{q_F^2}/\overline{q_F}^2$ (Bennett factor) and $3\overline{1q_\alpha^2}/\overline{q_F^2}$ These ratios were calculated for an ionization chamber with a plate spacing of 0.035 in. and an 11-mm-diam ^{252}Cf source centered on one plate filled with methane gas at both 1 and 2 atm pressure.

Monte Carlo techniques were used to determine the spectrum of path lengths for isotropically emitted fission fragments or alpha particles arising from a uniform disk source. For each given path length, the energy loss was determined from stopping power vs distance (dE/dx vs x) for methane, which was derived for median heavy and median light fission fragments from a known dE/dx vs x curve for argon by using ratios of stopping powers for different stopping mediums given by Northcliffe and Schilling.[2]

The ratios as calculated by this method were $\overline{q_F^2}/\overline{q_F}^2 = 1.61$ for 1 atm pressure and 1.41 for 2 atm pressure, and $3\overline{1q_\alpha^2}/\overline{q_F^2} = 0\ 010$ for 1 atm pressure and 0.025 for 2 atm pressure

1 Paper accepted for presentation at the 1974 ANS Winter Meeting, Washington, D C , October 27–31, 1974

2 F C Northcliffe and R F Schilling, "Range and Stopping Power Tables for Heavy Ions," *Nucl Data* A7, 233 (1970)

8.16 NEUTRON IMPORTANCE AND FISSION DENSITY IN ENRICHED-URANIUM AND PLUTONIUM METAL SPHERES[1]

J. T. Mihalczo

The spatial distribution of the neutron importance in bare and natural-uranium-reflected uranium (~93.2 wt % ^{235}U) and plutonium (~4.8 at. % ^{240}Pu) metal spheres was measured using ^{252}Cf neutron sources. The spatial distributions of the fission density from activation measurements in the bare spheres and those previously measured for the reflected spheres are presented.

Comparison of these distributions with those from S_{16} transport theory calculations showed that the measured and calculated results agreed very well for the bare spheres and in the central core of the reflected spheres. The disagreement in the natural-uranium reflector increased with radius and attained values as large as 40% at the outer surface. The sensitivity of the calculations to the cross sections is examined.

These measurements were undertaken to properly account for spatial effects in the point reactor kinetics description of Rossi-α measurements. The spatial effects factors obtained from these measurements, which multiply the correlated amplitude of the Rossi-α measurement, were 1.123, 1.109, 1.163, and 1.214 for the bare uranium, bare plutonium, reflected uranium, and reflected plutonium sphere respectively. The error in these values is ±0.010.

1. Abstract of paper to be published in *Nuclear Science and Engineering* (1974).

8.17 PRELIMINARY INVESTIGATION OF FILTERING METHODS FOR CORE FLOW TEST LOOP THERMOCOUPLE SIGNALS

M. J. Roberts

Preliminary plans and investigations are in progress for Core Flow Test Loop experiments to thoroughly determine the operating and safety characteristics of the Gas-Cooled Reactor. An important part of the experiment is the measurement of the temperature profile in the simulated reactor core during many different normal and abnormal operating conditions. Because of the small size and high temperature of the reactor core environment, the temperature measurement is much more difficult than it would otherwise be. Added to these difficulties is the pickup of interference from the electrically heated, simulated fuel elements in the reactor core mockup. The Instrumentation and Controls Division is in the process of evaluating various types of filtering to eliminate this interference from the temperature measurement. We are also evaluating both new thermocouple fabrication techniques and different electrical power sources to find the best combination for the least money.

8.18 HTGR SAFETY STUDIES

J. L. Anderson N. J. Ackermann R. K. Adams
S. J. Ditto B. C. Duggins R. L. Shepard

The above Instrumentation and Controls Division personnel prepared the safety instrumentation section of a *Planning Guide for HTGR Safety and Safety-Related Research and Development*, ORNL-4968, which was published in May 1974. As a result of this work, a task has been initiated to assess the current status and development needs for HTGR safety instrumentation.

8.19 HTGR SYSTEM RESPONSE AND SAFETY STUDIES

S J. Ball N E Clapp, Jr. J G Delene[1]

Work was begun in July 1974 on developing a better understanding of the safety-related technology for high-temperature gas-cooled reactors (HTGRs) being built and planned in the U S. Specific studies were begun on system and component response to postulated accident sequences and on development of mathematical models used in predicting plant behavior

1 Reactor Division

8.20 PBF CONTROL AND SAFETY INSTRUMENTATION

J. L Anderson S. J. Ditto

Engineering assistance and consultation for the Power Burst Facility (PBF) at the National Reactor Testing Station were continued.[1] Activities included continued assistance with modifications to the reactor protection system for 40-MW operation and review and assistance with a single-failure analysis of the revised system. Some additional spare modules were fabricated for the system by ORNL.

1 J L Anderson and S J Ditto, *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973*, ORNL-4990 (to be published)

8.21 NUCLEAR SAFETY JOURNAL

E. W. Hagen

Publication of *Nuclear Safety* under the auspices of the Nuclear Safety Information Center was continued.[1] *Nuclear Safety* is now in its 15th year of providing topical reviews and new information that have a particular significance for safety to members of the technical nuclear community. It places primary emphasis on safety in reactor design, construction, and operation, however, safety considerations in reactor fuel fabrication, spent-fuel processing, nuclear waste disposal, handling of radioisotopes, and environmental effects of these operations are also treated. Responsibility continued for the acquisition, preparation, and editing of material related to reactor controls and instrumentation.[2] One member of the Instrumentation and Controls Division coauthored 2 of the 11 articles [15(1) and 15(4)] in the "Control and Instrumentation" section of *Nuclear Safety* during this past year.

1 E W Hagen, *Instrumentation and Controls Div Annu Prog Rep Sept 1, 1973*, ORNL-4990 (to be published)

2 E W Hagen (ed), *Nucl Safety* **14**(5), 461 (September–October 1973), **14**(6), 605 (November–December 1973), **15**(1) 15 (January–February 1974), **15**(2), 151 (March–April 1974), **15**(3), 292 (May–June 1974), **15**(4), 417 (July–August 1974)

8.22 ACQUISITION AND TESTING OF A 14-CHANNEL ANALOG MAGNETIC-TAPE RECORDER

D. N. Fry R C. Kryter

An instrumentation tape recorder was purchased to upgrade the noise-signal-recording capability of the surveillance and diagnostics group. The portable recorder (Bell and Howell model 4010) has the capability for recording and reproducing (either FM or direct) seven channels of data on ½-in. tape and 14 channels on

1-in. tape. However, the recorder is presently equipped to record and reproduce only seven channels FM and seven channels direct at seven speeds, increasing by factors of 2 from $1\frac{5}{16}$ to 60 in./sec. The recording bandwidth at 60 in./sec is 0 to 40 kHz FM and 300 Hz to 300 kHz direct.

This wide bandwidth capability, combined with lower noise characteristics than our older equipment, will provide increased fidelity for recording noise signals for all surveillance and diagnostics development programs. This recorder is being used for (1) recording neutron noise signals at the Browns Ferry Nuclear Plant, (2) recording sodium boiling and temperature noise at the Fuel Failure Mockup, and (3) recording conductivity noise in proof-of-principle experiments studying methods for locating failed fuel in LMFBRs.

8.23 IAEA INTERNATIONAL SYMPOSIUMS ON NUCLEAR POWER-PLANT CONTROL AND INSTRUMENTATION[1]

E. W. Hagen T. W. Kerlin

In recognition of the significant advances being made in the field of nuclear power plant control and instrumentation, the International Atomic Energy Agency organized a series of biannual symposiums on the subject. These meetings provide specialists from the member states an opportunity for a comprehensive exchange of information on the current international status of this important field. This article summarizes the discourse from the first meeting (Vienna, 1969), reviews the proceedings from the second meeting (Vienna, 1971), and discusses some of the presentations made at the third meeting (Prague, 1973).

1. Abstract of published article: *Nucl. Safety* 15(1), 15 (January–February 1974).

8.24 CHALLENGES FOR POWER INSTRUMENTATION: THE 16TH ANNUAL ISA POWER INSTRUMENTATION SYMPOSIUM[1]

M. D. Sulouff[2] E. W. Hagen

The 16th Annual Instrument Society of America Power Symposium, geared to the theme "Challenges for Power Instrumentation," is reviewed. The symposium presented new concepts in using existing process control instrumentation, a discussion of USAEC regulatory guides affecting instrumentation for environmental monitoring of power plants, and the need for industry standards. New approaches were presented relative to control room design, seismic qualification of instrumentation, direct digital control designs, and NO_x abatement.

1. Abstract of published article: *Nucl. Safety* 15(4), 417 (July–August 1974).
2. Pittsburgh Power and Light Company.

8.25 HFIR INSTRUMENTATION ERROR ANALYSIS

M. J. Roberts

In accordance with the AEC's requirements for in-depth error analysis of the safety systems of new reactors, to be included in their technical specifications, the Instrumentation and Controls Division has done a complete statistical worst-case accuracy analysis of the HFIR safety system instrumentation. The electrical safety system monitors reactor heat power, coolant temperature, and coolant flow. When any of

these parameters falls beyond its limiting safety system setting, the reactor is automatically shut down. To assure that a dangerous condition is avoided, confidence limits on the safety system measurements must be established and corresponding margins of safety allowed. To this end, a complete statistical error analysis of the safety system has been made, and the original system accuracies and margins of error established by Foxboro Instruments, Inc., and the Division have been found correct and adequate.

8.26 LOCA MODELING ON THE HYBRID COMPUTER[1]

R. S. Stone

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

1. Abstract of paper presented at Topical Meeting on Water-Reactor Safety, Salt Lake City, Mar. 26–28, 1973, and published in CONF-730304.

8.27 REACTOR SIMULATOR FOR THE AMERICAN MUSEUM OF ATOMIC ENERGY

R. S. Stone

An operational reactor simulator is planned for installation in the new building of the American Museum of Atomic Energy, which is currently under construction in downtown Oak Ridge, Tenn. An analog computer installed in the control console will allow demonstrations of reactor startup, change of load, loss of coolant, and other transient conditions possible during operation of a pressurized-water power reactor. Our part in this project has been to supply the analog programming, utilizing a surplus process computer provided by the Operations Division. In order to accommodate a five-decade startup, a logarithmic simulation was chosen, with conversion to a linear output for thermal effects in the power range. Nuclear power, coolant temperature, and steam temperature will appear on display meters, and control-rod signals and a voltage proportional to coolant velocity will be provided as control inputs to the physical model. Although primarily a facility for lecture-demonstration, a small amount of visitor interaction may be provided.

8.28 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 (NSIC).[1] The NSIC at ORNL is in its 11th year as a national center for collecting, storing, evaluating, and disseminating nuclear safety information generated throughout the world.

The documents handled relate 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 1940 of these documents were reviewed, as were another 1242 pertaining to the licensing process, and abstracted for the computerized information retrieval system. Direct requests for specific information totaled 56 from the national and international nuclear communities, and three visitors to the Center were given VIP attention.

1. E. W. Hagen, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

8.29 LECTURES ON THE HFIR PROCESS CONTROL COMPUTER

J. B. Bullock

A series of lectures was presented for Operations Division personnel to provide a detailed understanding of the CDC-1700 computer; applications, systems software, assembly language programming, and system reconstruction procedures were discussed.

9. Fuel Reprocessing and Shipping

9.1 STATE OF THE ART IN NONDESTRUCTIVE ASSAY SYSTEMS AND THEIR APPLICATIONS TO AN LMFBR AQUEOUS FUEL REPROCESSING PLANT[1]

F. Shahrokhi[2]

A state-of-the-art study for determination of fissile and fertile isotopic contents of nuclear fuel materials without destruction (nondestructive assay) was performed. The object of this study was to select and recommend nondestructive assay instruments and techniques for the purpose of criticality prevention, safety, safeguards, process control, and accountability throughout a Liquid-Metal Fast Breeder Reactor fuel reprocessing plant, namely the Aqueous Fuel Reprocessing Plant (AFRP) proposed by the Chemical Technology Division of ORNL.

The nondestructive instrumentation of a presently operating fuel reprocessing plant was investigated in order to set guidelines for the selection and recommendation of instrumentation for the proposed AFRP. The overall flow diagram of the reference AFRP was described, the selected assay areas were identified, and the nondestructive assay instruments were recommended.

It was concluded that the present state of the art is inadequate for most of the assay requirements of the reference AFRP. The major problem is the assay of the nuclear fuels in the presence of high radiation background. Nondestructive techniques, namely, (1) active neutron interrogation counting of either prompt neutrons or short-lived high-energy gamma rays and (2) passive gamma-ray spectroscopy detecting of high-energy gamma lines of $^{144}Ce + {}^{144}Pr$, which are directly related to the presence of plutonium, are recommended for further evaluation.

---

1. Abstract of paper presented at the 1974 American Nuclear Science Winter Meeting, Washington, D.C., Oct. 27–31, 1974; also ORNL-TM-4586 (1974).
2. Consultant from the Nuclear Engineering Dept., the University of Tennessee, Knoxville.

9.2 HTGR FUEL FABRICATION PROTOTYPE PLANT

H. E. Cochran

Instrumentation and controls for the HTGR Fuel Refabrication Prototype Plant (FRPP), which is to be installed in the Thorium-Uranium Recycle Facility (TURF) at ORNL, will provide all the necessary information and corresponding control to permit the plant to be operated safely and efficiently. The FRPP is a specific task area within the National HTGR Fuel Recycle Development Program, the objective of which is to develop recycle technology such that commercial plants for reprocessing and refabrication of HTGR fuels can be built and operated economically. The FRPP must be designed, constructed, and operated to demonstrate the equipment and processes required to fabricate HTGR fuel elements. Cold operation of FRPP is scheduled to begin June 1980, with hot operation 18 months later.

The project schedule required the completion of the conceptual design descriptions by FRPP systems and a cost estimate of each system. Instrumentation and Controls Division personnel contributed to each system.

The FRPP instrumentation and controls philosophy was developed with considerations for state-of-the-art methods in both analog and digital instrumentation and with the goal for maximum built-in flexibility for providing safe and efficient plant operation within the following restraints:

1. Radiation hazards associated with reclaimed ^{233}U require that the process equipment be remotely operated and maintained. Instruments and sensors located with the process equipment must meet these requirements also. Since nuclear materials exist, criticality is a potential hazard; therefore, their exact location and the quantity must be known continuously. Instrumentation is required to maintain close accountability to prevent any criticality.

2. Since the FRPP will be housed in the TURF Building 7930, the existing spaces dictate the physical arrangement of instruments and intercell connections to a large extent.

3. Since the FRPP is a prototype plant, an unusually large amount of data will be collected and processed into useful form to provide a solid design basis for follow-on commercial plants (see paragraph 1 above). Also, there is a need to maintain exact accountability of all the materials entering and leaving the plant as well as between the various in-line processing systems. This presents a challenge to provide the necessary instrumentation and controls.

4. The FRPP consists of six in-line systems, each in sequence, that provide feed material for the next system. Five other systems are directly related to all six of the in-line systems and to each other. An all-instrumentation system is the plant management system. Each in-line system is required to be separate and complete; therefore, each must be instrumented to operate for a period of time without interference due to another system being down for repairs.

5. The FRPP presents a unique condition of requiring off-line data obtained from laboratory analysis of product line samples to control on-line product quality. The analysis instrumentation and sample handling controls must minimize the time required to return control data to the product line after a sample is taken.

6. The plant management system instrumentation must meet the challenge presented by the hybrid technology of the chemical and the mechanical systems in acquiring the data necessary for operating the plant.

Instrumentation and Controls Division contributions for the subsystem design descriptions were completed. These included analog instrumentation for systems 1 through 9 and general plant, programmable logic controllers and computers for systems 2 through 10 and general plant, and computers for the plant management system (PMS).

The analog instrumentation comprises sensor-transmitter-indicator-recorder-control loops suitably buffered to provide an analog standardized signal (volts). The standardized signal system will branch to computer-compatible control modules and to monitors and alarm instruments. Operators may interact with the process through local control consoles located adjacent to the cell windows. Control modes (automatic, semiautomatic, and manual) provided within the local process instrumentation will reduce the need for operator interaction to a practical minimum.

Programmable Logic Controllers and Computers

Programmable logic controllers (PLCs) will be used to control all sequential (ON/OFF) operations associated with the different HTGR-FRPP process systems. The PLCs are all-solid-state devices designed to replace traditional relay logic circuits. Since binary operations are implemented via software, additional control system configuration flexibility, in keeping with the developmental nature of the pilot plant, is realized. All PLCs will be interconnected with either local computers or the PMS computer system. This

interconnection will permit computer-based data analysis and control functions to be coupled with the PLC-based sequential process operations.

Local, or dedicated, computer systems will be used in support of systems 5, 6, and 7. A single computer system will service both systems 5 and 6. Local computers will be used to perform basic data acquisition and analysis in support of product inspections and quality assurance. Numerical position control and supervisory control of analog control loops will also be performed. The two local computer systems will couple systems 5, 6, and 7 to the PMS through high-speed data links.

Plant Management System

The PMS is designed to interface to the various process and support systems of the pilot plant to provide for the centralization of all information relative to operation of the processes and support systems of the pilot plant. Accountability of material, interlocking of material transfers, process and plant monitoring, and archival record generation data will be gathered and communicated to the plant manager, production manager, and quality-assurance manager via a stored program digital computer system with the necessary peripheral devices. The system will acquire the necessary data from the Local Instruments and Control Subsystems (LICS) of all process and support systems. The real-time multiprogramming software system will provide the ability for real-time response to material movement requests, process and plant variable limit checking, operator requests for display of process and plant variables, and requests from LICS for support services such as engineering units conversion and printout.

The FRPP conceptual design report and cost estimates have been completed. The detailed design phase is scheduled to start within six months.

9.3 TRANSURANIUM PROCESSING PLANT STATUS

H. E. Cochran R. L. Durall

The Transuranium Processing Plant (TRU) recovers quantities of transuranic elements and distributes them to researchers. Since it began operation in 1966, the TRU has been the only source of significant quantities of berkelium, californium, einsteinium, and fermium in the United States. During this report period, 22 HFIR targets plus rework material were processed, from which 386 mg of ^{252}Cf and smaller amounts of the other elements were recovered.

Installation of a new process equipment rack and preparation for two additional equipment racks required changing the full graphic instrument control panel.[1] To provide adequate controls within the space designated, the full graphic concept was discarded and replaced by a semigraphic panel display. A Metal-photo panel was designed, fabricated, and installed. Color-coded pilot lights mounted on the panel indicate the status of valves and pumps.

In addition to routine instrument maintenance, the following peripheral process additions and modifications were instrumented and are operating:

1. A 12-point master intercom system.
2. A vertical air compressor, replacing the two horizontal units. HFIR now supplies air to TRU only during emergency conditions.
3. Modification and addition to the TRU Building 7920 alarm system to indicate an alarm sounding in Building 7930.

4. For the target fabrication cubicle 3, a mechanical handling device equipped with a linear displacement transducer and a weigh cell, to automatically measure pellet length and weight. Operation is remote from a panel located near the viewing window.

Manpower for instrumentation continues at a minimum level; one technician full time, one engineering aide half time, and one engineer on call were used during the past year.

1. H. E. Cochran et al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1965,* ORNL-3875, p. 94.

9.4 LASER BEAM TRIGGER SYSTEM FOR RECORDING SINGLE EVENTS

N. C. Bradley

A milliwatt helium-neon laser-based trigger system was designed to initiate a single-sweep oscilloscope recording of accelerometer and strain gage data from the impact of a free-falling prototype radioactive-material shipping cask. The laser beam is projected across the path of the falling cask into a modified monocular that focuses the beam onto a photoelectric cell. The signal derived from beam interruption is amplified and provided with a variable delay to allow fast recording times. This laser-based concept is very reliable because it is not sensitive to variations in ambient light as is a simple photoelectric system.

The recorded impact data plus the measured damage on the cask are compared with the damage predicted by engineering calculations to instill confidence in damage prediction and design integrity and to provide positive evidence of shipping cask integrity.

10. Standards Laboratory

10.1 ORNL STANDARDS LABORATORY WORK ON THERMOMETRY STANDARDS AND SPECIFICATIONS

W. W. Johnston, Jr. M. B. Herskovitz R. L. Shepard

The Standards Laboratory participates in the development and writing of standards and specifications for all levels of ORNL, AEC, and national standards organizations. Membership and representation are maintained in the American Society for Testing and Materials (ASTM), the American National Standards Institute (ANSI), and the Instrument Society of America (ISA), as well as in AEC and ORNL standards programs. This year's effort included work on ORNL specifications for sheathed Chromel/Alumel thermocouples, for tungsten-rhenium thermocouples, and for platinum-rhodium/platinum thermocouples; the conversion of RDT standards to national standards through ASTM and ANSI; and the writing of an ASTM "Standard Method for Testing of Industrial Resistance Thermometers."

In addition, contributions to International Standards are made in an unofficial advisory capacity to the members of the International Electrical Commission and the International Organization for Legal Metrology.

10.2 ORNL STANDARDS LABORATORY SERVICES

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

The establishment of procedures for recall and calibration under the Quality Assurance Program has been substantially completed. Because of the additional work load imposed by the QA program calibrations, plans are being formulated to automate some of the high-volume calibrations and to provide data logging for others which generate large amounts of data.

The Standards Laboratory provides routine calibrations in the following areas: (1) temperature, which includes calibration of thermocouples, resistance thermometers, and optical pyrometers; (2) electrical measurements, which include calibration of standard cells, bridges and potentiometers, resistors, capacitors, and inductors, as well as analog and digital meters; (3) time and frequency standards synchronized with WWVs; (4) pressure and force calibrations.

While routine calibrations represent the largest fraction of the work in the Standards Laboratory, a very significant part of our work is done by request on nonroutine special measurements. Because of the special equipment available and because of the broad range of measurement experience available in the Standards Laboratory, we are frequently asked for advice or assistance in making or evaluating measurements in other laboratories.

10.3 RECENT IMPROVEMENTS IN SERVICES AND CAPABILITIES OF THE ORNL STANDARDS LABORATORY

R. L. Anderson

The capabilities of the Standards Laboratory were reviewed, and recommendations were made for improvements through the acquisition of additional staff and more modern equipment to help meet our responsibilities.

In the area of temperature measurement, new fixed-point equipment was acquired to improve the accuracy of thermocouple and resistance thermometer calibrations. The Laboratory's temperature measurements were converted to IPTS-68, and work was begun on extending the Standard Laboratory's realization of IPTS-68 down to 13.43K.

In electrical standards, construction was begun on two highly stable stirred-oil baths for the ORNL bank of standard cells and for the standards of resistance.

An optical bench for pyrometry and photometry calibrations was acquired and will be installed in the new quarters of the Standards Laboratory.

The SERDEX system was expanded to facilitate the recording of thermocouple calibration data, using our DDC potentiometer.

The time and frequency standards were improved with an instrument developed at ORNL.

A vigorous program was begun to provide up-to-date NBS calibrations for our primary standards for temperature, the electrical units, and pressure and force.

11. Instrumentation for Reactor Division Experiments and Test Loops

11.1 THERMAL SHOCK CRACK ARRESTMENT EXPERIMENT

P. G. Herndon

The conceptual design was completed on a 4000-gpm cooling loop that will be used to perform thermal-shock crack-arrestment experiments in support of the AEC's Heavy-Section Steel Technology Program. An estimate of the cost of instruments and controls based on the conceptual process flow diagram was prepared and included in the preliminary proposal submitted to the AEC.[1] The proposal was approved, and we have been directed to proceed with the design and construction.

The test loop is composed of a 3000-gal tank, a 4000-gpm canned-rotor pump, and a heated test vessel, all interconnected by 6-, 8-, and 10-in. stainless steel pipes. The loop contains methyl alcohol cooled to $-100°F$ in a liquid-nitrogen heat exchanger and circulated at rates varying from 1000 to 4000 gpm. The system is arranged so that the test section can be heated to $+55°F$ and then subjected to the flow of cold liquid. A data acquisition system, in addition to the process instrumentation and controls for the circulating loop, is required to record the behavior of the test vessel.

1. Preliminary Proposal to AEC Thermal Shock Test Facility, Proposal No. 486, June 28, 1974.

11.2 FORCED-CONVECTION TEST FACILITY

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

The blowdown (depressurization) testing of single rods at the Forced-Convection Test Facility (FCTF)[1] was continued. In these tests, loss-of-coolant and pressure accidents are simulated for light-water reactors with various lengths of fuel rods to obtain data for reactor safety analysis and to determine the similarity between electrical rods experiencing blowdown transients and nuclear fuel rods under similar environmental conditions. These tests will complement the blowdown testing of multirod arrays to be performed in the Thermal-Hydraulic Test Facility (THTF). Each test had three objectives: heater evaluation, testing and evaluation of instruments to be used on the THTF, and determination of the blowdown heat transfer correlations for various operating conditions. Twenty-nine blowdown tests were performed during the year.

Modifications to the facility have continued for the purpose of obtaining more useful noise-free data, for reducing the downtime between tests, and for evaluating more recent concepts of instrumentation and control systems.

Modifications included the addition of a crowbar power control circuit for heater rod protection, new thermocouple isolation amplifiers that greatly improve the accuracy and dependability of temperature data, a precision-regulated power source for the bridge completion circuits to the strain gages, and an air conditioner for the data acquisition cabinet that eliminates the random malfunctions caused by excessive heat. New air-cooled fast-transient pressure transducers were installed, and a new air header system was

fabricated to permit control of air flow to the transducers. New dual-element platinum resistance temperature detectors (RTDs) were installed to obtain a more accurate temperature profile, and all RTDs were recalibrated. New solid-state transmitters were installed as replacements for old differential temperature transmitters, which have excessive fluctuations and short-term drifts due to their constant current sources being referenced to gas tube voltage regulators.

A program to reduce the noise level on data signals is continuing, as are programs to evaluate different types of pressure and temperature sensors and to evaluate the components of the two-phase (steam-water) flow measurements system.[2] A turbine-type flowmeter has been placed on order and will be added to the two-phase flow measurement instrumentation system.

---

1. C. Brashear et al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).
2. R. L. Moore et al., *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

11.3 DATA ACQUISITION AND REDUCTION FOR THE THERMAL-HYDRAULIC TEST FACILITY

N. E. Clapp, Jr.

As part of the Blowdown Heat Transfer Program, the Thermal-Hydraulic Test Facility is being constructed to investigate the performance of a 49-heater-rod bundle during depressurization of the loop. Data are to be taken using a computer-controlled data acquisition system. Computer codes are being developed for the PDP-8E computer used in the data acquisition system to provide several modes of data acquisition and to provide the loop operator with information about loop performance. Programs for the IBM 360 are being developed for converting data obtained by this system from millivolts to engineering units.

11.4 DATA ACQUISITION AND REDUCTION FOR THE FORCED-CONVECTION TEST FACILITY

N. E. Clapp, Jr.

As part of the Blowdown Heat Transfer Program, the Forced-Convection Test Facility is being used to investigate the heat transfer during blowdown (depressurization) of the loop with a single heater rod. Data are taken by an Anscan data acquisition system that collects millivolt data and stores it on a magnetic tape. During the past year the facility has been used to evaluate the performance of heater rods to be used in the Thermal-Hydraulic Test Facility. In support of this evaluation, several computer codes were developed to analyze the data obtained from blowdowns to verify repeatability of heater rod performance.

11.5 HYBRID COMPUTER SIMULATION OF THE THERMAL-HYDRAULIC TEST FACILITY (THTF) HEAT REMOVAL SYSTEM

W. R. Hamel B. G. Eads F. H. Clark

The dynamic simulation of the THTF heat removal system[1] has been implemented on the Instrumentation and Controls Division AD-4/PDP-10 hybrid computer system.

The simulation is scaled for real-time operation and will be used to study the performance of control systems; to determine system operating procedures; and to train operators in system startup, operation, and

shutdown techniques. Actual process controller modules have been used in the simulation to implement control loops. By virtue of the use of process controllers, a control panel board, which is functionally identical to portions of those to be used in the THTF, has been fabricated and connected to the hybrid computer system at the AD-4 patch panel. Having analogous control knobs and switches on the panel greatly enhances the value of the simulation as an operator training tool.

The methods of implementation for the system parameters used in programming the heat removal system theoretical model are summarized below. The AD-4/EAI-221R analog computer consoles and the PDP-10 digital computer were used. The AD-4/EAI-221R analog computer consoles incorporated (1) heat exchanger dynamics, (2) time delay, (3) actuator dynamics, (4) sensor dynamics, and (5) main loop energy balance. The PDP-10 digital computer included (1) a loop flow model, (2) fluid mixing energy balances, (3) fluid density temperature dependence, (4) fluid specific heat temperature dependence, (5) heat transfer coefficients, (6) multiplication of computed variables, and (7) control valve nonlinearities.

The simulation is operational at this time, and some preliminary analysis work has been executed. The simulation response has been verified against other available sources of data, and, in particular, heat exchanger performance results have compared well with digital computation results performed in the Reactor Division.

Preliminary results have demonstrated the value of the simulation in developing suitable operating procedures. Establishing THTF blowdown conditions with the heat removal system will be a very delicate operation as suggested by the simulation.

Because of project priorities and schedules, the simulation is idle at this time. A test program will continue when project personnel are available.

---

1. W. R. Hamel, *Instrumentation and Controls Div. Annu. Prog. Sept. 1, 1973,* ORNL-4990 (to be published).

11.6 GAMMA DENSITOMETER FOR BDHT

R. L. Shipp V. A. McKay

Gamma densitometers are being developed to measure the water-steam density in various pipes of the Thermal-Hydraulic Test Facility (THTF)[1] during blowdown heat transfer tests. These BDHT tests simulate a loss-of-coolant accident in a pressurized-water reactor.

The densitometers consist of a collimated 25-Ci ^{137}Cs gamma-ray source and a shielded and collimated scintillation detector located on opposite sides of a 4½-in.-OD by 0.5-in.-wall steel pipe. The scintillation detector (Q-5233-6) consists of a 1½-in.-diam by 5-in.-long NE 102 plastic phosphor optically coupled to an RCA C7151N multiplier phototube. The choice of scintillator and multiplier phototube is dictated by test requirements and environment. During part of the blowdown, detection of water droplets in the flowing steam is desired; also during the blowdown the pipe and attached densitometer will undergo severe shock and vibration. The plastic phosphor was selected in preference to sodium iodide because of its faster response, less afterglow or hysteresis, and greater resistance to shock. The C7151N multiplier phototube is a ruggedized tube that is designed and tested to meet MIL-E-5272C specifications for shock, acceleration, and vibration. In addition, this tube shows less fatigue effect than some of the other ruggedized tubes. The detector assembly is also cushioned from shock and vibration by enclosing it in ¼ in. of polyethylene foam. Protection from a pipe temperature of 650°F is provided by a water-cooled detector housing.

The current signal from the multiplier phototube is connected to the densitometer amplifier, where is is converted to a 0- to 1-V signal and conditioned for recording and observation at response times of 0.1 msec, 16 msec, and 1 sec. The 0.1-msec signal is connected to the FM tape recorder,[1] the 16-msec signal is

connected to the digital data acquisition system,[1] and the 1-sec signal connects to a digital voltmeter that is used in normalizing the system before the start of a test. The densitometer amplifier Q-5233 uses three integrated circuit-type operational amplifiers with FET inputs. The first stage is a current-to-voltage converter with a conversion ratio of 10 V/μA and a response time of 0.1 msec. The two following stages are noninverting integrators with time constants of 16 msec and 1 sec and essentially unity gain.

1. R. L. Moore et al., "Thermal Hydraulic Test Facility," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1972,* ORNL-4822, p. 99.

11.7 SUPPORT FOR THE ORNL REACTOR DIVISION SOLID MECHANICS DEPARTMENT

T. M. Cate W. A. Bird R. L. Moore

Approximately 1¾ man-years of effort has been provided in support of a variety of experimental programs undertaken by the Solid Mechanics Department.

The major portion of this effort was provided to the Liquid-Metal Fast Breeder Reactor Structural Design Methods Program. Continuing assistance has been provided for the elevated-temperature beam test and the circular-plate test facilities. Design has started and cost estimates have been prepared for the nozzle-to-sphere tests, which are similar in concept to the beam and plate tests, except for some additional control parameters and the complex shape of the test specimen. Design and development assistance has been provided on the biaxial creep test facility.

Division personnel continued to provide assistance to the intermediate vessel test series under the Heavy-Section Steel Technology Program.

Instrumentation and controls were provided for an additional test associated with the thermal cylinder test in the prestressed-concrete reactor vessel program. This test is designed to investigate the cause of severe corrosion discovered in tendons removed from the thermal cylinder test specimen during posttest inspection.

11.8 MOLTEN-SALT FORCED-CIRCULATION LOOP 2

P. G. Herndon

This molten-salt circulation facility[1] was placed in operation again after more than one year in standby. The instruments and control circuits performed satisfactorily after routine inspection and adjustment.

The loop, which was previously operated for about 7000 hr with $NaBF_4$-NaF coolant salt, is now being operated to obtain salt chemistry data, using electrochemical probe techniques, and to evaluate the tellurium intergranular cracking problem of Hastelloy N at nominal salt velocities of 10 and 20 fps.

Definitely one and possibly two new facilities similar to this one are planned for fiscal year 1975.

1. G. W. Greene, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1971,* ORNL-4734, p. 121.

11.9 INSTRUMENTATION FOR MSBR GAS SYSTEM TECHNOLOGY FACILITY

P. G. Herndon

The Molten-Salt Reactor Program was reactivated in March 1974, and the construction of the molten-salt circulation facility has proceeded as originally planned.[1] The design and most of the procurement had

been completed before the program was terminated in February 1973. Some purchase orders were canceled, but these have been placed again. All other instrument components have been identified and retrieved from standby storage. The instrument cabinets had been completed and installed, but three of the seven were removed for use on another project and must be replaced. These are now being fabricated in the ORNL shops. Initial operations are scheduled to begin in December 1974.

1. P. G. Herndon, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

11.10 INSTRUMENTATION FOR MSBR COOLANT SALT TECHNOLOGY FACILITY

P. G. Herndon

The instruments and controls for this facility were activated after approximately one year in standby.[1,2] Only routine maintenance and minor adjustments were required. The facility is used to evaluate sodium fluoroborate eutectic as a secondary coolant for molten-salt reactors and will be placed in operation early in fiscal year 1975.

One of the first tasks after the loop is operating satisfactorily is to design and install a system for injecting deuterium into the circulating salt for the purpose of studying the tritium containment problem.

1. C. Brashear, R. L. Durall, and A. H. Anderson, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).
2. C. Brashear, R. L. Durall, and A. H. Anderson, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1972,* ORNL-4822, p. 102.

11.11 INSTRUMENTATION FOR REACTOR IRRADIATION EXPERIMENTS

J. W. Cunningham

Instrumentation has been provided for eight irradiation capsule experiments to test fuels for use in gas-cooled reactors, including the high-temperature and fast breeder types. These experiments are being done at the HFIR and the ORR. In addition to the gas-cooled type of experiment, one experiment is in progress to test the corrosion of three promising fuel containment metals in the Molten-Salt Reactor concept.

The requirements of the instrumentation are to monitor the experiment for reactor safety and to collect data for the experimenters. To satisfy these requirements, instrument application drawings and electrical schematics are prepared for each experiment.

At the HFIR, certain features of the Dextir data system are used to operate an external relay system that applies a momentary excitation current (forward then reverse) to thermocouples to measure their resistance. These data are used in studying the behavior of tungsten-rhenium thermocouples in the radiation environment of the HFIR.

In an experiment at the ORR, a control valve is used to maintain a constant pressure of approximately 1000 psi on the sweep gas that passes through the fuel containment. A continuing problem has been that galling occurred between the Stellite 6B stem and the type 416 stainless steel seat. Sometimes the valve seized after only 30 days of operation.

To eliminate the problem of galling, the seat was bored to allow the insertion of a graphite seat into which the stem could operate. The results have been very satisfactory during six months of operation. Under steady flow, the pressure variations are less than ¼ psi and are only slightly greater as flow is carefully changed.

11.12 POTASSIUM-STEAM BINARY VAPOR CYCLE TEST FACILITY

P. G. Herndon

The design of the instrumentation and controls for the combustion system for this facility was nearing completion when the allotted funds were depleted; the project was terminated in February 1974. At that time, the construction of four instrument cabinets was almost completed, and special thermocouples had been installed on the boiler tube bundle. These were high-quality Chromel-Alumel thermocouples, some of which were 35 ft long.

This facility had been funded by the National Science Foundation as part of a program to achieve better fossil fuel economy and reduced environmental thermal pollution.[1,2]

There is a possibility that this project will be reactivated during fiscal year 1975.

---

1. *Potassium-Steam Binary Vapor Cycle, A Research Proposal Submitted to the National Science Foundation, Research Applied to National Needs (RANN),* ORNL/NSF-AG-392 (January 1973).
2. A. P. Fraas, *Preliminary Assessment of a Potassium-Steam-Gas-Vapor Cycle for Better Fuel Economy and Reduced Thermal Pollution,* ORNL/NSF-EP-6 (August 1971).
3. P. G. Herndon, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

11.13 SPECIAL THERMOMETRY SUPPORT WORK FOR REACTOR PROJECTS

W. W. Johnston, Jr. M. H. Cooper M. B. Herskovitz

Considerable effort has been made to design special temperature sensors for use in Reactor Division projects such as the Potassium Topping Cycle, the Blowdown Heat Transfer, the Failed-Fuel Mockup, and the Advanced Heater Development experiments. Among these special sensors are dual-diameter sheathed thermocouples, small-diameter thermocouples, multiple-junction small-diameter bundle thermocouples, and resistance thermometer bubble sensors. The work includes the design of hardware from a conceptual design, preparation of specifications, and development of a supply source.

A major part of the effort is the development of the supply source. Nearly all the items listed are special, experimental, nonstandard products involving untried technology. For example, the multiple-junction bundle consists of up to seven 0.010-in.-diam sheathed thermocouples assembled in a 0.056-in.-diam stainless steel sheath, with the junctions located at different points to provide temperature data at various locations. After adequate sources are established, the sensors are purchased and, upon delivery, are subjected to acceptance and quality-assurance testing and certification.

12. Maintenance and Service

12.1 INSTRUMENTATION AND CONTROLS DIVISION MAINTENANCE INFORMATION SYSTEM COMMITTEE

K. W. West (Chairman) D. J. Knowles (Secretary)
P. W. Hill J. A. Keathley J. L. Lovvorn
R. L. Simpson R. E. Toucey

The Maintenance Information System program was reported previously.[1] The system is now considered completely operational and is being used in its final form by most of the Instrumentation and Controls Division. It is estimated that some 20,000 items, 8623 of which are inventoried, may eventually fit the concepts of the system.

In this reporting period, the Committee completed and issued two documents, a general description (IPD-1) and an instruction book (IPD-2). The IPD-2 has been reviewed several times, and minor additions were made. The IPD-1 is being rewritten to better describe the present form of the system. The committee is also redesigning the job assignment form to incorporate improvements suggested by the maintenance foremen based on experience to date.

Approximately 7000 maintenance jobs have been assigned and completed since March 1973. The costs in nine categories for each serviced instrument have been accumulated and can be printed out by the computer. In addition, the computer produces a partially filled-in job assignment form on schedule for those instruments on a recall plan for programmed maintenance and/or calibration.

With the issuance of the general description and instruction book, the committee's activities have diminished to holding meetings to handle specific problems that have been brought to their attention. An estimated man-hour per month per man has proven sufficient for this purpose. In addition, 6 man-hours/month for the programmer and 6 man-days/month for an aide have been sufficient to cover the routine operation of the system.

---

1. K. W. West et al., "Instrumentation and Controls Division Maintenance Information Committee," *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

12.2 INSTRUMENTATION AND CONTROLS MAINTENANCE INFORMATION SYSTEM[1]

R. L. Simpson

The Maintenance Information System computer program[2] was expanded to provide retrieval of information on selected groups of instruments from the data base. Instruments may be selected from one or more of several categories such as instrument location, owner division, custodian, manufacturer, model number, and maintenance history.

The inventory report provides all available descriptive information from the 22 information data groups on the instruments selected. Reported items include identification number, description, manufacturer, model, property number, cost, etc.

The maintenance detail report provides a subset of the inventory information data groups plus the maintenance record history of the instruments selected. The number of hours charged and number of service calls made are reported in all nine reporting categories for each instrument. In addition, the mean time between failure is reported for the selected instrument group.

The maintenance summary report includes information from the maintenance detail report plus the calibration and maintenance schedules; the last calibration and maintenance dates are supplied for the selected instruments.

---

1. K. W. West et al., sect. 12.1.
2. R. L. Simpson, *Instrumentation and Controls Div. Annu. Prog. Rep. Sept. 1, 1973,* ORNL-4990 (to be published).

12.3 MAINTENANCE ACTIVITIES OF THE SPECIAL ELECTRONIC SERVICES GROUP

J. L. Lovvorn R. L. McKinney

The maintenance section of the Special Electronic Services Group presently consists of one foreman and eight technicians. Shops are located in the Instrument Laboratory (Building 3500) and in Buildings 4500N and 4500S.

The shop in Building 3500 maintains all the oscilloscopes in the Laboratory and the electronic instrumentation for the Instrumentation and Controls Division, the Isotopes Division, and that part of the Analytical Chemistry Division located in the west end of the Laboratory. This shop also repairs digital multimeters, pulse amplifiers, nuclear scalers, electrometers, power supplies, and similar equipment of all divisions on a call-in basis.

The shop located in Room E-1, Building 4500N, maintains all types of electronic instrumentation, including all Laboratory spectrophotometers, for the Chemistry, Analytical Chemistry, Chemical Technology, and Physics Divisions located in the main research laboratories in Buildings 4500N and 4500S on a request basis.

Two shops in Building 4500S are concerned respectively with maintenance for the research group of the Health Physics Division and the Nondestructive Testing Group of the Metals and Ceramics Division.

During the report period, the Instrument Inventory and Maintenance Information System, as specified in IPD-1 and IPD-2, was instituted. Programmed maintenance and calibration of certain instruments are on computer recall. Approximately 970 instruments have been put into the system to date.

12.4 ACTIVITIES OF THE RADIATION MONITORING SYSTEMS MAINTENANCE GROUP

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

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

Approximately 1150 stationary health physics instrument systems are installed throughout the Laboratory. Four technicians performed approximately 1500 services on these instruments in this reporting period. These technicians performed bimonthly performance checks of fixed instruments installed in 13 facility radiation and contamination alarm systems, 3 facility alarm and containment systems, and 5 remote

radiation alarm systems. These systems were in 21 buildings and consisted of 295 radiation monitoring stations. Twenty-two local air monitor and fallout monitor stations were checked semimonthly for proper operation, and the conditions were logged and corrected as required.

Three technicians maintained and calibrated approximately 1300 portable health-physics instruments at the Health Physics Calibration Laboratory. About 4000 portable instrument service orders were completed. Two technicians assigned to the Operations Division serviced and maintained approximately 30 gas- and 31 liquid-waste-effluent monitors that telemeter alarms and other information to the Waste Disposal Control Center (Building 3105). The conditions are logged and any malfunctions are corrected. Three water-quality monitoring stations at three sites along the stream into which plant waste water flows and the instrumentation located in the control center are serviced and maintained by these two technicians. Performance checks were made on these systems on a biweekly basis.

12.5 ACTIVITIES OF THE AUDIO-VISUAL SERVICE GROUP

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

Equipment and operators for public-address systems, visual-aid projection, and audio and video tape recording were furnished as requested for 433 meetings at the Laboratory and 15 off-site meetings (8 in Oak Ridge, 5 in Gatlinburg, and 2 in Knoxville) during this report period. Our own audio-visual equipment, as well as similar equipment for other groups, was maintained. Audio and video tapes were duplicated on request for several customers.

Two technicians were employed full time for this work as well as a shared-time foreman. In addition, an engineer was used to supervise and oversee the off-site meetings. Technicians from other groups were used for peak loads to equalize overtime. Work increased considerably toward the end of the report period. Assistance was provided to the Motion Picture Group in sound recording.

During the report period, implementation of the Instrument Inventory and Maintenance Information System, as specified in IPD-1 and IPD-2, was begun; this is a rather long process because of the large number of items and the fact that we are converting from a previously established system. Approximately 300 items have been put in the system to date.

12.6 ACTIVITIES OF THE TELECOMMUNICATIONS AND PERSONAL RADIATION MONITOR MAINTENANCE GROUP

J. D. Blanton J. L. Lovvorn J. Miniard

There are 303 pieces of two-way radio equipment in service at the Laboratory, and 724 service orders were completed during the report period. An instrument technician was assigned full time to service and maintain this equipment. The computerized program was changed from our old program to the new Instrument Inventory and Maintenance Information System (MIS) specified in IPD-1 and IPD-2. Power, frequency, deviation, and sensitivity performance checks are made twice each year.

Seventy-seven pagemaster receivers and transmitters were put into the new MIS, and 151 service orders were completed during the report period; in addition, 106 personal radiation monitors were put into the MIS, and 149 PRMs were serviced. These units are put into the MIS program as service is required. The major portion of one technicians's time was required. Manpower was provided for the installation and service of plant security systems.

One technician serviced and maintained closed-circuit television, a microwave TV system, video recorders and monitors, audio paging, and intercom systems.

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

J. D. Blanton J. L. Lovvorn W. Ragan

The group that provides instrument service for Environmental Sciences, Solid State, Physics, and Inspection Engineering Divisions is staffed with one foreman and four technicians. Two repair shops are maintained, one in Building 2001 and the other in Building 2000.

Services provided for the customer include routine maintenance, fabrication, modification, and trouble-shooting and repair of complex electronic systems. Liaison is provided between the experimenter and the various Instrumentation and Controls engineering groups to solve special design problems.

During the report period, the Instrument Inventory and Maintenance Information System, as specified in IPD-1 and IPD-2, was implemented. Approximately 170 instruments have been put in the system to date.

Changing fiscal and program conditions during the report period required the assignment of the foreman to a reactor program and reassignment of another foreman to supervise on a shared-time basis.

12.8 RADIO COMMUNICATIONS SYSTEMS

J. A. Russell

Additional radio equipment was added to several of the Laboratory radio communications networks. Three mobile radio units were added to the Plant and Equipment Division maintenance network for the electrical line crew vehicles. One of the units was equipped with an external speaker and the necessary switching so that crewmen may stay in radio contact when working away from their vehicle. Two 5-W portable units were procured for use by steam plant personnel and the electrical line crew supervisor. Two portable 5-W units and seven 1.8-W portable units were procured for the Fire and Guard Departments. Two 5-W, two-frequency portable units were procured for use by Instrumentation and Controls Division personnel on the maintenance network.

12.9 ACTIVITIES OF THE COMPUTER AND ANALYZER MAINTENANCE GROUP

J. A. Keathley E. McDaniel

Maintenance of minicomputers, multichannel analyzers (MCAs), and data transmission terminals at the X-10 site is the responsibility of this group.

Acceptance tests on incoming equipment of this type to ensure compliance with purchase specifications required approximately ½ man-year of effort. Under this program, ten ADCs, three computer-based MCAs, two hard-wired MCAs, seven visual terminals, and six high-speed printout devices have been checked.

A continual training program is required to keep personnel ready to maintain the new types of equipment being acquired at the Laboratory. Factory schools on the PDP-11, MOD-COMP II, and the CCI-70 computers were attended.

12.10 ACTIVITIES OF THE ELECTROMECHANICAL SECTION OF THE COMPUTER AND ANALYZER MAINTENANCE GROUP

E. McDaniel J. A. Keathley L. R. Gitgood

The number of Teletype page printers increased to 211 units at ORNL. These units are now on a rigorous lubrication schedule made necessary by their design and made possible by the new Maintenance Information Service computer scheduling. Magnetic tape units are now being scheduled for lubrication and cleaning by this system.

A large ultrasonic tank has been acquired from surplus by Material Services for use by this section. The large tank area will accommodate the complete printer mechanisms for ultrasonic cleaning. Following the cleaning, the mechanisms are dipped in an oil bath next to the tank. This new procedure is invaluable on major overhauls of this equipment.

A data communication test terminal is now operational within this section for the purpose of maintenance checks. Laboratory personnel using 110 baud rate communication terminals may use this terminal for checking their equipment.

12.11 OPERATING REACTORS GROUP – MAINTENANCE ACTIVITIES

K. W. West

Field maintenance activities for the six operating reactors and associated experiments have been performed by six instrument technicians reporting to foreman J. M. Farmer during this report period. J. D. Lyons, following eight weeks of training at the Control Data Institute, has assumed the primary responsibility for maintenance of the CDC-1700 computer at the HFIR.

C. T. Carney has completed the instrument inventory and assignment of identification numbers in accordance with IPD-2, Maintenance Information System Instructions, for some 2300 instruments during this report period. The listing now comprises the major reactor control and safety instruments as well as those on the operating experiments. A total of 1247 maintenance calls, requiring 1647 man-hours, have been reported on these instruments.

Fourteen reactor controls design change requests have been processed for the group by D. S. Asquith with the assistance of Reactor Projects Group personnel during this report period. Modifications to the change memoranda process, QA-1C-C2, are being made in light of the new requirements of the AEC Manual, Chapter OR 0540.

J. L. Anderson, D. S. Asquith, S. J. Ditto, and J. B. Ruble presented 16 lectures in the training program for reactor controls instrument technicians. The subjects covered reactor kinetics and nuclear and process instrumentation. T. P. Hamrick of the Operations Division gave instruction in PCA critical experiments. Five of the six instrument technicians and two that are not assigned to the Operating Reactors Group attended these lectures in order to supplement the strength of the group if needed.

12.12 MAINTENANCE OF THE ORR

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

Only one unscheduled shutdown due to instrument failure occurred at the ORR during the last 12 months, when a vacuum tube in the ^{16}N electrometer short-circuited and caused its associated recorder to drive upscale and initiate a slow scram.

Reactor control circuit changes included (1) power failure relays in the two outlet temperature recorders and the two ΔT recorders to monitor the source of scram protection for high reactor outlet temperature and high ΔT temperature, (2) a modification of the safety trouble monitor to replace relays that are no longer manufactured with relays that are readily available and to make the monitor interchangeable with the BSR monitor.

Maintenance, technical, and engineering support was provided for seven in-core experiments.

12.13 MAINTENANCE OF THE HPRR

D. D. Walker K. W. West

The Instrumentation and Controls system for the Health Physics Research Reactor (HPRR) performed satisfactorily during this reporting period.

Reactor Controls Change Memo 36 replaced a two-pen recorder with two single-pen recorders. Annunciation of power loss to all recorders was incorporated. Change Memo 37 interposed additional contacts in the safety block and mass adjustment rod-drive circuitry to prevent fuse burnout.

Spurious signals increased the magnet current and caused reactor shutdown. These occurred about nine months apart and have not recurred.

12.14 MAINTENANCE OF THE TSR-II REACTOR

D. D. Walker K. W. West

Performance of the TSR-II reactor control system was satisfactory for this reporting period. Number 1 seat flapper valve is not opening when the No. 1 shim plate is fully inserted. To determine that this shim plate is operating normally, a system employing a multichannel analyzer is used to measure reactivity worth of a shim plate.

The main flow turbine developed a bad bearing, resulting in the loss of three of the ten magnets pressed into the rotor blades which generate the flow signal.

Instrumentation for the experiments associated with this reactor received considerable effort from the Instrumentation and Controls Division. In particular, a thermoluminescence detector unit required attention to make it operate according to specifications and to the requirements of the experimenters.

12.15 MAINTENANCE OF THE BSR AND THE PCA

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

There were no unscheduled shutdowns of the Bulk Shielding Reactor (BSR) during the last 12 months due to instrumentation, but there was one unscheduled shutdown caused by an electrical power outage.

One BSR control circuit change was made to the Safety Trouble Monitor (Change Memo No. 40) that involved changing obsolete sensing relays for a readily available type and to make the monitor interchangeable with the ORR Safety Trouble Monitor.

One Dual PCP-III-106 Ionization Chamber was replaced because of faulty saturation characteristics of the uncompensated section.

The reactor was shut down Jan. 25, 1974, for repairing pool water leaks and for painting. This work will be completed about Sept. 1, 1974, at which time the reactor will resume operation, providing neutron flux for Solid State Division experiments and others.

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

12.16 MAINTENANCE OF THE HFIR

D. S. Asquith J. M. Farmer K. W. West

Maintenance activities continue essentially as those of the previous reporting period. Through proper scheduling, approximately 90% of the programmed maintenance is performed on-line with the reactor operating. The remaining 10%, which requires reactor shutdown, is primarily for process instrument systems that are single channel in nature (no redundancy provided) and cannot be removed from service while the reactor is operating and for instruments located where radiation levels prohibit access except during reactor shutdown.

Essentially all of the instrumentation associated with the HFIR has been included in the laboratory-wide Maintenance Information System. Since this system provides a recall function for maintenance and calibration purposes, selected instrument systems were also assigned inventory numbers and placed in the program. This eliminated the need of maintaining additional work schedules when these systems are serviced or calibrated on a routine basis during the calendar year. Experience with this program has been quite satisfactory thus far.

Maintenance procedures are now being prepared for routine testing of the annunciator circuits associated with the HFIR. These circuits include nearly 200 annunciators and approximately 400 field contacts. This work is now 30% completed. When finalized, these procedures will become part of the HFIR Maintenance Manual.

During this reporting period, an unscheduled shutdown occurred three times during routine testing of the safety channels when the second of three channels in the two-of-three coincidence system was tripped. These shutdowns accounted for 0.351 hr of a total 0.651 hr of unscheduled reactor downtime. It is suspected that these shutdowns are a result of the susceptibility of the new safety flux signal conditioners to electrical noise. An investigation is being undertaken to determine means of reducing this susceptibility without degrading the overall response of the safety system.

The maintenance of the CDC 1700 computer at the HFIR has now been assumed by the Operating Reactors Group. J. D. Lyons has been given the primary responsibility for the maintenance effort in this area.

12.17 ACTIVITIES OF THE LABORATORY ACCELERATOR MAINTENANCE GROUP

J. L. Lovvorn E. W. Sparks

The Laboratory Accelerator Maintenance Group consists of one forman and eight technicians. Shops are located in the ORIC (Building 6000), ORELA (Building 6010), and Van de Graaff Accelerator Laboratory (Building 5500). During the report period, maintenance coverage was changed from 11 shifts per week to 10 at the ORIC. Regular day-shift maintenance is provided at ORELA and at the Van de Graaff Laboratory.

Machine maintenance was provided at all facilities as first priority. The 42 high-current supplies and the radio-frequency system at the ORIC required a large portion of the support given. Field fabrication was

performed for modules for the Modular Computer interface to the ORIC. Our usual maintenance services were also provided to experimenter's equipment, including NIM systems, vacuum measuring equipment, and power supplies.

The University Isotopes Separator Oak Ridge (UNISOR) was maintained and assistance in procurement provided. Assistance was also provided to the Electron Microscope Project. Emergency maintenance for the ORELA and the Van de Graaff was provided from the ORIC shop for the evening shift.

Beginning in May, the three shops were to be supervised by one foreman to facilitate coordination of instrument craft services in contiguous areas. During the report period, implementation of the Instrument Inventory and Maintenance Information System, as specified in IPD-1 and IPD-2, was begun.

13. Ecological Sciences Studies

13.1 A NUTRIENT- AND HORMONE-DEPENDENT TREE-GROWTH-RATE MODEL[1]

O. L. Smith R. A. Goldstein[2]

The prediction and analysis of forest ecosystem development require among other things an understanding or at least a hypothesis about the complex biodynamics of nutrient availability, absorption, and assimilation by trees. As part of the Eastern Deciduous Forest Biome's watershed studies, a model is being developed that expresses nutrient absorption in terms of the carrier theory of ion transport across root cell membranes. Currently included in the model are the principal macronutrients nitrogen, phosphorus, and potassium. Assimilation of the absorbed nutrients into cell tissue is treated by means of coupled enzyme reaction processes. The effect of air and ground temperature on reaction rates is included. The model thus permits explicit simulation of day-night growth patterns that appear to be important in tree development and presently assumes that nutrients are transported through the soil to the root surface in the transpiration stream and by gravity flow of groundwater. The possible importance of diffusion will be considered later. The processes whereby nutrients become available in the soil also remain to be simulated.

Since enzyme-catalyzed processes are controlled to a large extent by hormones, a phenomenological simulation of the promotion-antagonism hormonal effects on tree development is included in the model. For example, experiments indicate the biological need of a chilling period before winter dormancy can be broken and new growth can begin. Chilling evidently reduces the level of certain hormones that inhibit growth.

The nutrient-hormone model will ultimately be coupled into the Terrestrial Ecosystem Energy Model, which simulates many of the other aspects of forest ecosystem development.

1. Research supported by the Eastern Deciduous Forest Biome, US-IBP, funded by the National Science Foundation under Interagency Agreement AG-199, 40-193-69, with the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

2. Environmental Sciences Division.

13.2 MODIFICATION OF THE FOREST MODEL, SERENDIPITY[1]

O. L. Smith R. A. Goldstein[2] W. F. Harris[2]
G. S. Henderson[2] H. H. Shugart[2]

As part of an overall objective of simulating forest ecosystems, the model SERENDIPITY was developed to study the mineral-biomass dynamics of a closed-canopy forested watershed on a yearly basis. The original version of the model simulated the biomass dynamics, using fixed-growth-rate parameters that

represent long-range average nutrient availability. The model is being expanded to incorporate the effect on growth of annual variation in nutrient availability. The first nutrient to be treated is calcium.

1. Research supported by the Eastern Deciduous Forest Biome, US-IBP, funded by the National Science Foundation under Interagency Agreement AG-199, 40-193-69, with the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

2. Environmental Sciences Division.

13.3 A MASS-DEPENDENT BIOLOGICAL MODEL OF METAL-ION BINDING IN ANIMAL TISSUE

R. S. Stone S. R. Bernard[1] K. Barnes[2]

An understanding of the dynamics of the intake and retention of radioisotopes in living animals is immediately important in health physics and medicine and has derivative importance for determining the environmental impact of these isotopes. Experiments done at a number of laboratories give evidence that augmented intake of a stable isotope will increase the rate at which a radioactive body burden of the same element is excreted. In order to put this observed and measured behavior on a predictable and calculable basis, a plausible set of equations for ion uptake in tissue was derived and then programmed on the analog portion of the hybrid computer. Inputs corresponding to those used in various published experiments were applied, and the parameters of the equations were varied to make the simulator results match the experimental data. In the course of this process the equations were modified to achieve a better fit, always in a physically defensible way. The resulting equations and sets of coefficients match a variety of experimental data very well and show promise of aiding quantitative understanding of an important process.

1. Health Physics Division.

2. Summer student, North Carolina A&T State University, Greensboro.

13.4 INITIAL MODELING OF AN EXPERIMENT TO INVESTIGATE SEDIMENT-WATER DYNAMICS OF PLUTONIUM IN AQUATIC ENVIRONMENTS

R. S. Booth

Theoretical predictions were made for the time- and space-dependent concentrations of plutonium in the interstitial water and overlying water within an experimental tank described by Eyman, Trabalka, and Reichle[1] in their recent proposal to the AEC. In the proposed experiment, small tubes packed with sediment from the Clinch River will be placed in the bottom of a 55-gal polyethylene tank. Water from the Clinch River will be added, the tank will be sealed, and its contents allowed to equilibrate while air or N_2 is pumped through it for several days. The overlying water will then be spiked with ^{237}Pu (45.6-day half-life) at an initial concentration of 1000 dpm/ml. The activity in overlying water, interstitial water, and particulate matter over time will be measured. Activity vs depth in the sediment column will also be measured at several times after the spike is introduced.

Initial modeling of this experiment was desired to help reestablish an appropriate sampling schedule and to estimate the sensitivity of the experiment to important environmental parameters. The excellent work of Lerman[2-4] in similar modeling problems provided the theoretical foundation and parameter identification for the model used.

The concentration of plutonium in the overlying water was assumed to be independent of space, and a single balance equation was written for its time-dependent concentration. The concentration of plutonium in the interstitial water was assumed to be a function of both space (depth into the sediment column) and

time as predicted by a time-dependent diffusion equation. A closed-form solution to these equations obtained from a text on heat conduction[5] was programmed and run on a digital computer.

It was concluded that the radioactive half-life of ^{237}Pu *may* be too short to expect accurate determination of the parameters from the proposed experiment. A close look at the changes in concentration (resulting from changes in parameters) compared with expected uncertainties in the measured concentrations was recommended.

---

1. L. D. Eyman, J. R. Trabalka, and D. E. Reichle, *Distribution of Plutonium in Sediment Components and Exchange Rates in the Interstitial Water-Sediment-Overlying Water System Under Aerobic Conditions,* Subproject under Plutonium in Humid Environments of Eastern United States.
2. A Lerman and G. J. Brunskill, "Migration of Major Constituents from Lake Sediments into Lake Water and its Bearing on Lake Water Composition," *Limnol. Oceanog.* **16**(6), 880 (November 1971).
3. A. Lerman, "Transport of Radionuclides into Sediments," *Proc. Third National Symposium on Radioecology, May 10–12, 1971, Oak Ridge, Tenn.*, pp. 936–44.
4. A. Lerman and R. R. Weiler, "Diffusion and Accumulation of Chloride and Sodium in Lake Ontario Sediments," *Earth Planet. Sci. Lett.* **10,** 150 (1970).
5. H. S. Carslaw and J. C. Jaeger, *Conduction of Heat in Solids,* Oxford Press, London, 1959.

13.5 A SYSTEMS ANALYSIS MODEL FOR CALCULATING RADIONUCLIDE TRANSPORT BETWEEN RECEIVING WATERS AND BOTTOM SEDIMENTS[1]

R. S. Booth

Equilibrium radionuclide concentrations in waters receiving radioactive effluents and in bottom sediments associated with the receiving waters were calculated so that potential doses to man and the biota and radionuclide buildup in the environment could be determined realistically. These calculations were performed to test the accuracy of simpler models where receiving water concentrations were determined by neglecting the influence of bottom sediments. The simplified calculations were incorporated into environmental impact statements for nuclear power stations prepared by Oak Ridge National Laboratory for the U.S. Atomic Energy Commission.

A four-compartment systems analysis model was developed to predict dynamic radionuclide transfer. The dependent variables of the model are the receiving water, interstitial water intermingled with the bottom sediments, bottom sediment particles that undergo sorption-desorption reactions with the interstitial water, and bottom sediment particles that undergo only sorption reactions with the bottom sediments.

The model was used to generate two tables. One table lists factors that enable conversion of equilibrium radionuclide concentrations calculated for a receiving water that do not include transfers to its sediments, to water concentrations that include transfers to its sediments. These factors are always less than unity, since radioactivity must be conserved, and adding sediments to the system adds another compartment where radionuclide concentrations will equilibrate. The other table lists ratios of equilibrium radionuclide concentrations in sediments divided by their corresponding receiving water concentrations. These concentrations in the sediments can be used to calculate external doses to a person sunbathing or fishing.

Preliminary results indicate that the usual effect of neglecting sediment interactions is an overestimate of the total potential dose to man from the radionuclides. The reason is that a neglect of sediment interactions overestimates receiving water concentrations, which, in turn, overestimates potential doses from important pathways (drinking water or eating fish) directly related to the receiving water concentration. However, this would not be the case for a situation where exposure to radionuclides in sediments is the critical pathway.

The results for ^{137}Cs are particularly interesting, since ^{137}Cs often causes a major dose during a typical release. For example, environmental parameters appropriate to freshwater lakes in the northeastern states, neglecting sediment interactions, could result in potential doses about four times too high from ^{137}Cs contained in potable water and edible fish. Further, increasing only the K_d value of a sample of sediment from 27,000 to 270,000 (which reflects measured variations between various freshwater environments) increases this factor from ~4 to ~25. For the sample calculation (K_d = 27,000), exposure to contaminated sediment contributed a potential dose ~0.1 of that from eating contaminated fish.

1. Abstract of ORNL-TM-4751 (March 1975).

13.6 A GENERALIZED MODEL FOR SIMULATING LAKE ECOSYSTEMS[1]

R. A. Park[2]	R. V. O'Neill[3]	J. A. Bloomfield[2]	H. H. Shugart, Jr.[3]
R. S. Booth[3]	J. F. Koonce[4]	M. S. Adams[5]	Lenore S. Clesceri[2]
E. M. Colon[6]	E. H. Dettmann[5]	R. A. Goldstein[3]	J. A. Hoopes[5]
D. D. Huff[5]	Samuel Katz[2]	J. F. Kitchell[5]	R. C. Kohberger[2]
E. J. LaRow[7]	D. C. McNaught[8]	J. L. Peterson[5]	Don Scavia[2]
J. E. Titus[5]	P. R. Weiler[5]	J. W. Wilkinson[2]	Claudia S. Zahorcak[2]

CLEAN, a generalized lake ecosystem model with strong ecologic realism, was developed in response to a growing need for models suitable for environmental management. The model presently consists of 28 ordinary differential equations representing approximately 16 compartments, including attached aquatic plants, phytoplankton, zooplankton, bottom-dwelling aquatic insects, fish, suspended organic matter, decomposers, sediments, and nutrients. These equations can be linked in any meaningful combination to simulate a given point in a lake (a separate model for lake circulation is available to represent spatial variations and to couple simulations of different lake regions). Subprogram functions exist for each principal physiologic and ecologic process, and a submodel for lake water balance is being implemented. The program is written in FORTRAN for UNIVAC and IBM time-sharing systems.

Realistic simulations have been obtained, and insight into the effects of nutrient enrichment on whole-system functionalities has been gained. Sensitivity analysis has indicated priorities for further studies to obtain more precise parameter estimates; also, evaluation of the constructs and experimentation with the model are providing feedback useful in planning new experimental approaches. CLEAN is being tested using data from Lake George, N.Y., and Lake Wingra, Wisc.

1. Contribution No. 152 from the Eastern Deciduous Forest Biome, U.S. International Biological Program, to be published in *Simulation* (August 1974).

2. Rensselaer Polytechnic Institute, Troy, N.Y.
3. Oak Ridge National Laboratory.
4. The University of Wisconsin; present address: Case Western Reserve University, Cleveland, Ohio.
5. The University of Wisconsin, Madison.
6. Rensselaer Polytechnic Institute; present address: Calle G. Maranon 339, Urb. El Senorial, Rio Piedra, Puerto Rico.
7. Siena College, Loudonville, N.Y.
8. The State University of New York, Albany.

13.7 A SPECIFIC ACTIVITY AND CONCENTRATION MODEL APPLIED TO CESIUM MOVEMENT IN AN OLIGOTROPHIC LAKE[1]

H. A. Vanderploeg[2] R. S. Booth[3] F. H. Clark[3]

A linear systems analysis model was derived to simulate the time-dependent dynamics of specific activity and concentration of radionuclides in aquatic systems. Transfer coefficients were determined for ^{137}Cs movement in the components of an oligotrophic lake and defined in terms of basic environmental and ecological data so that the model can be applied to a wide variety of sites. Simulations with a model that ignored sediment-water interactions predicted much higher ^{137}Cs specific activities in the lake water and biota than those of the complete model. Comparisons of model predictions with ^{137}Cs concentrations reported for the biota of an experimentally contaminated oligotrophic lake indicated that the transfer coefficients derived for the biota are adequate.

1. Abstract of paper presented at the Symposium on Linear Cycling in Southeastern Ecosystems, May 1–3, 1974, University of Georgia, Augusta; to be published in the proceedings.
2. Environmental Sciences Division.
3. Instrumentation and Controls Division.

13.8 CONDOS – A MODEL AND COMPUTER CODE TO ESTIMATE POPULATION AND INDIVIDUAL RADIATION DOSES TO MAN FROM THE DISTRIBUTION, USE, AND DISPOSAL OF CONSUMER PRODUCTS THAT CONTAIN RADIOACTIVE MATERIALS[1]

F. R. O'Donnell[2] O. W. Burke F. H. Clark L. R. McKay[2]

A model and computer code (CONDOS) is being developed that estimates radiation doses to man from distribution, use, and disposal of a variety of consumer products that contain radioactive materials. CONDOS utilizes a generalized format that requires division of the life span of a consumer product into five main stages and that requires descriptions of the activities by which man will be exposed to the product (events) during each stage. These descriptions delineate homogeneous groups of exposed persons, thus facilitating the selection of individuals who represent the exposed groups. Annual and long-term doses to the total body and selected reference tissues of representative individuals are estimated for each mode of exposure that is applicable to each event. Summation of the doses from each exposure mode to a representative individual yields the individual's total dose. Summation of the doses received by all individuals yields group and total population doses.

CONDOS will be applied to the assessment of the radiation doses to man from several consumer products. An example of the use of CONDOS is presented.

1. Abstract of ORNL-TM-4663 (May 1975).
2. Environmental Sciences Division.

13.9 RESOURCE COMPETITION AND AN ANALYTICAL MODEL OF ZOOPLANKTON FEEDING ON PHYTOPLANKTON[1,2]

O. L. Smith H. H. Shugart[3] R. V. O'Neill[3] R. S. Booth
D. C. McNaught[4]

Theoretical studies on competition generally proceed by accepting the Volterra competition model as at least a reasonable approximation of nature. There have been discussions in the literature of possible

shortcomings of the Volterra model on both theoretical and experimental grounds, but the model has nonetheless served as the basic mathematical framework upon which the generalizations and axioms of the theory of competition are built. In the work reported here, competition is investigated using an alternative model shown to be at least as reasonable an approximation of nature as the Volterra model. The new model permits inspection of the robustness (in the sense of Levins) of the theories of competition. The present model also permits specific identification of known biological processes as they relate to competition.

The model parameters and derivation are based on zooplankton feeding upon phytoplankton. The negative effect of one consumer population upon another is expressed only through the effects of each on the phytoplankton food supply. Thus, the resource competition can be directly investigated, since the resources available are explicit in the model rather than implicit in parameters (e.g., r, α, K in Volterra equations). The model has been utilized to investigate resource competition, with specific emphasis on strongly similar zooplankton populations feeding upon similar phytoplankton populations, that is, on situations in which the strongest competitive interactions would be intuitively expected to occur.

From an examination of the model's equilibrium equations for such situations, we have drawn the following conclusions:

1. The competitive exclusion principle (which says competing species cannot occupy the same ecological niche in a community) has only limited validity. For a community in which the consumers exhibit no intraspecific competition and have identical ratios of average assimilation efficiency $\overline{e}$ to death rate d, any number of consumer species may, in fact, coexist and compete for the same food. Communities in which the consumer species have identical $\overline{e}/d$ are probably rare. However, in a community with intraspecific competition (a common occurrence), any number of consumer species may coexist and compete for the same food, regardless of $\overline{e}/d$ ratios.

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 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 values of C_{in} are unity. In a community with intraspecific competition, the C_{in} values 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.

---

1. Research supported by the Eastern Deciduous Forest Biome, US-IBP, funded by the National Science Foundation under Interagency Agreement AG-199, 40-193-69, with the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

2. Contribution No. 146 from the Eastern Deciduous Forest Biome, US-IBP, submitted to the *American Naturalist.*

3. Environmental Sciences Division.

4. Department of Biological Sciences, State University of New York, Albany.

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

F. H. Clark R. S. Booth H. A. Vanderploeg

To meet day-to-day calculation requirements of ecological systems, the linear matrix equation $\dot{x} = Ax + k$ was programmed for terminal operation. The existing program MATEXP, which deals with this problem class, was adapted to the task. A simple conversational structure was created to enable use of the program

with only a few minutes of training. The user can designate a specific activity or a radioactivity model, thereby causing the program to undertake some of the coefficient processing from minimal input, or he may choose to solve a more general problem and supply all coefficients explicitly.

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

1. Abstract of ORNL-TM-4404 (January 1974).

13.11 LEAKAGE OF RADIOACTIVE MATERIALS OVER A BROAD AREA AND ITS LOCAL IMPACT

F. H. Clark R. E. Moore[1]

In instances where a radioactive material might be leaked over a broad area, the impact would require assessment. A case in point could be the tritium contamination of natural gas, which is used in many households in an urban area. The computer program AIRDOS includes most of the effects of interest but applies only to a point source. The problem is readily written as

$$C(\mathbf{r}) = P(\mathbf{r}')\, F(\mathbf{r} - \mathbf{r}')\, d\mathbf{r}',$$

where

$P(\mathbf{r}')$ = area source,

$F(\mathbf{r} - \mathbf{r}')$ = point kernel solution provided by AIRDOS,

$C(\mathbf{r})$ = derived solution.

A computer program, AIRDT, embracing P and F as above was written to produce C.

This work was performed for the Environmental Sciences Division.

1. Environmental Sciences Division.

13.12 EXPERIMENTAL INVESTIGATIONS OF MOBILE HOME ENERGY USE CHARACTERISTICS

S. J. Ball

A series of experiments were run on a commercially built mobile home in order to characterize its energy use characteristics. Data on mobile home heating and cooling energy requirements were needed in order to determine the economics of changes that might be made in construction, heating-cooling equipment, temperature control strategies, etc.

The trailer and a "weather station" were instrumented in March 1974, and data were taken through the rest of the heating season and again after installation of a central air-conditioning system in July. Optimized models were developed to characterize the trailer's dynamic thermal performance as a function of weather and heating-cooling. To a certain extent, these models can be used with U.S. Weather Bureau data tapes for various regions of the country to predict energy usage and the possible economies of implementing proposed energy-saving schemes.

14. Administration and Training

14.1 QUALITY ASSURANCE FOR ORNL INSTRUMENTATION AND CONTROLS

C. S. Lisser H. J. Metz

Quality-assurance (QA) work for the Instrumentation and Controls Division during this report period included a wide variety of subjects. QA verification programs offered by five bidders on ORNL instrumentation requirements were reviewed, and three vendor qualification inspections were made. In continuing cooperation with the ORNL QA coordinators for other disciplines, many QA-level determinations were made for work being performed with the help of Division forces, and many QA program indices were reviewed for such work. Training in advanced assembly and installation techniques was given to Division and other ORNL personnel.

A Division QA mailing list of over 120 names was prepared and kept current, and a computerized listing of divisional work procedures was supplied to the ORNL QA director. Personnel training sessions were held for foremen and engineers to explain the ORNL QA program and the forms and tags it uses. Formal and informal audits within and outside the Division were performed throughout the year, and continuing assistance was rendered to Division staff in the proper execution of QA measures.

Four procedures were added to the divisional QA manual, and seven work procedures were written and implemented. A list of these documents follows:

QA-IC-5 Calibration of End-Use Instruments
QA-IC-10 I&C Division Quality Levels of Instruments, Controls, and Systems
QA-IC-14 I&C Division Procurement
QA-IC-C2 Procedure for Making Design Modifications for Reactor Protection and Operations Systems
IPD-1 Maintenance Information System
IPD-2 Maintenance Information System Instruction Manual
IPD-3 I&C Division Quality Levels for Instruments, Controls, and Systems
IPD-4 Index of Procurement Procedures
IPD-5 Drafting Manual
IPB-1 Calibration of Electrical Welding Instruments
IPB-2 Procedure for Calibration of Welding Machines

14.2 QUALITY ASSURANCE PROGRAM DEVELOPMENT

W. W. Johnston, Jr. M. H. Cooper C. S. Lisser

Under the procedures and guidelines of Quality Assurance for ORNL in general, and the Instrumentation and Controls Division in particular, the Standards Laboratory is an active participant in quality assurance programs. In addition to the maintenance and calibration of metrology standards and measurement devices, we prepare and supervise the enforcement of procedures and recall schedules in cooperation with the divisional QA coordinator. These services are offered to all divisions of ORNL where a need exists.

At the request of the Plant and Equipment Division, procedures were written, measurement instruments and standards of temperature and electricity obtained, and calibrations performed on welding equipment providing traceability to National Standards. This traceability was one of the factors that resulted in the award to the Laboratory of ASME Certificates of Authorization to perform work in accordance with the ASME Boiler and Pressure Vessel Code.

The Metals and Ceramics Division Mechanical Properties Group has also requested a project to provide a similar traceability of temperature and force measurements in creep and tensile testing laboratories. Measurement standards have been made available for the initial calibration, and procedures for recall schedules are being written.

14.3 RDT STANDARDS

C. S. Lisser J. A. Russell, Jr.

The AEC Division of Reactor Research and Development (RRD) has shifted its standards program emphasis from the production of additional standards toward a program of updating and keeping current with their use experience the standards written to date. More of the RRD effort is being put into supporting work by national technical societies in producing consensus standards.

Support of this work has been mainly in the guidance of the Instrument Society of America's Control Centers standards committee and in liaison work with the Scientific Apparatus Makers Association. We have also served as reviewers of draft standards for RRD, ASTM, ISA, and IEEE.

During the year we went through several draft and review stages in order to prepare amendments to the following RDT standards:

C2-1 "Determination of Insulation Compaction in Ceramic Insulated Conductors"

C7-7 "Thermocouple Materials, Platinum and Platinum–10% Rhodium Wires, Noninsulated, Reference, and Standard Grades"

C15-3T "Current Pulse Preamplifier for Use with Fission Counters"

We also prepared for RRD approval a draft of RDT C6-2, "Differential Pressure Transmitter, Pneumatic or Electric Output Signal," which was adapted from an earlier, pneumatic signals only, version of a differential-pressure transmitter standard.

To date, we have written 25 RDT instrumentation standards, six of which have been amended.

14.4 INTRODUCTORY PROGRAMMING COURSE FOR PDP-8/E COMPUTER

A. F. Johnson, Jr. R. K. Adams C. D. Martin, Jr.

An introductory programming course for the Digital Equipment Corporation PDP-8/E computer was conducted to familiarize instrument engineers and technologists with a basic minicomputer. Although some of the students will be directly involved in programming, most will be dealing with computers in other aspects, such as maintenance. The course was given in two sections: an assembly language portion consisting of 20 hr of instruction and a high-level language portion consisting of 10 hr of instruction based on the FOCAL language to familiarize the students with engineering problem-solving methods. The students were able to get "hands on" experience with the minicomputer, using computer systems undergoing checkout in the laboratory.

14.5 INTENSIVE RECRUITING PROGRAM

R. K. Adams L. H. Thacker

In the course of the intensive recruiting program carried out during the 1974 calendar year, we have scanned literally thousands of college placement bureau resumes and applications. From these sources we selected over 100 candidates for personal interviews and offered positions to 61 professional and 4 weekly candidates. All 4 weekly candidates accepted and are on the job. We have 29 acceptances (one offer remains outstanding) and 31 rejections of offers to professionals. Nineteen of the new professional staff have reported, and the remaining nine are scheduled to arrive before November 1, 1974.

The recruiting effort is continuing at a slower pace in an effort to find very specific talents to fill specifically identified positions.

Professional Awards, Achievements, Offices, and Memberships in Professional Groups Held by Instrumentation and Controls Division Personnel

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

H. A. Metz: Member

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

W. W. Johnston, Jr.: Member of ANSI Committee C-96, Thermocouples

D. J. Knowles: Alternate Member with F. W. Manning of Committee N-42, Nuclear Instrumentation

J. W. Krewson: Member of Subcommittee, Liquid Level, under Committee B-88, Calibration of Instruments

C. S. Lisser: Member of U.S. Technical Advisory Group for International Electrotechnical Commission, Technical Committee 65

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

C. J. Borkowski: Fellow

J. B. Bullock: Member of ANS Computer Standards Working Committee 4.3-2

E. P. Epler: Fellow

F. W. Manning: Member of Subcommittee ANS-16, Nuclear Instruments Standards Committee

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

M. B. Herskovitz: Member of Committee E-40, Technical Aspects of Products Liability Litigation

W. W. Johnston, Jr.: Member of Committee E-20, Temperature Measurement; Chairman of Subcommittee, Resistance Thermometers; member of subcommittees and sections under Committee E20.04, Thermocouples

R. L. Shepard: Chairman of Subcommittee, Acoustical Thermometry, under Committee E-20, Temperature Measurement; member of subcommittees and sections under Committee E20.04, Thermocouples

BURST REACTOR EXPERIMENT REVIEW

J. T. Mihalczo: Chairman

ENGINEERING FOUNDATION CONFERENCE ON PROCESS DESIGN, OPERATION, AND CONTROL FOR SAFETY AND RELIABILITY, JULY 1974, HENNIKER, N.H.

N. J. Ackermann, Jr., Speaker

R. K. Adams: Cochairman and Member of Steering Committee

J. L. Anderson, Discusser

S. J. Ditto, Discusser

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

S. J. Ditto: Member of Nuclear Power Engineering Committee of the Power Engineering Society; Member of Subcommittee SC-6, Safety Related Systems

J. H. Holladay: Director, Oak Ridge Section

J. L. Lovvorn: Director and Chairman, Educational Activities Committee, Oak Ridge Section

H. J. Metz: Liaison Member, IEEE Industry Applications Society, Industrial Control Systems Subcommittee

Paul Rubel: Member of Subcommittee SC-5, Risk Assessment and Public Acceptance on Nuclear Power Standards of Nuclear Science Group and Power Group

INSTRUMENTATION AND CONTROLS DIVISION COMMITTEES

C. C. Hall: Vacuum Tubes, ORNL Stores Stock Advisory Committee

J. L. Lovvorn: Division Maintenance, Information Committee; Semiconductors, ORNL Stores Stock Advisory Committee; Operational Amplifiers, ORNL Stores Stock Advisory Committee

J. A. Russell: Batteries, ORNL Stores Stock Advisory Committee; Division Design and Drafting Standards Committee

INSTRUMENT SOCIETY OF AMERICA

R. K. Adams: Fellow

C. S. Lisser: Chairman, Control Centers Committee SP-60

J. A. Russell: Chairman, Oak Ridge Section Awards Committee

R. L. Shepard: Editor, *Temperature – Its Measurement and Control in Science and Industry,* Vol. 4, Part 1, Section 111: Omnibus Thermometry: Instrument Society of America, Pittsburgh (1972)

INTERNATIONAL SOLAR ENERGY SOCIETY

H. J. Metz: Member, U.S. Section, International

NATIONAL CONFERENCE OF STANDARDS LABORATORIES

R. L. Anderson: ORNL Delegate

NATIONAL COUNCIL ON RADIATION PROTECTION AND UNITS

F. H. Clark: Consultant

ORNL REVIEW COMMITTEES

J. L. Anderson: Neutron Physics Division Safety Review Committee
J. B. Bullock: Reactor Operations Subcommittee
B. G. Eads: Accelerator and Source Safety
B. C. Duggins: Reactor Operations
B. Lieberman: Radioactive Operations
L. C. Oakes: Member, RERC (ORNL Reactor Experiment Review Committee)
V. K. Paré: ORR Subcommittee of Reactor Operations Review Committee (RORC)
J. A. Russell: Accelerator and Source Safety
W. H. Sides: Reactor Operations
H. N. Wilson: Electrical Safety

SOCIETY FOR NUCLEAR MEDICINE

F. H. Clark: Member, Computer Standards Committee
J. W. Woody: Member, Computer Standards Committee

TENNESSEE SOCIETY OF PROFESSIONAL ENGINEERS

T. M. Gayle: PE
H. J. Metz: PE
J. A. Russell: PE and member, Engineer of the Year Committee

UNIVERSITY AWARDS

N. J. Ackermann, Jr., 1974 Distinguished Alumnus Award, University of Tennessee, College of Engineering

USAEC NIM-CAMAC COMMITTEE

H. W. Hill: Member, Subcommittee of Analog Signals
G. A. Holt: Member, Executive Committee
J. W. Woody: Member, NIM Committee

U.S. NAVY

H. E. Cochran, Commander: Executive Officer of Research Company 6-3 of the U.S. Naval Reserve

Publications

Some of the publications listed below were prepared jointly with members of other divisions and with consultants and other nonemployees. Their affiliations are footnoted.

Allen, J. W.,[1] J. C. Robinson,[2] and N. J. Ackermann, Jr., "Sensitivity Analysis of the Inverse Kinetics Rod-Drop Technique," *Trans. Am. Nucl. Soc.* **17**, 477–78 (November 1973).

Allen, J. W.,[1] J. C. Robinson,[2] and N. J. Ackermann, Jr., "Statistical Errors in Subcritical Reactivity Inferred from Inverse Kinetic Rod-Drop Measurements Using the Three Point Method," *Nucl. Technol.* **22**, 315–22 (June 1974).

Ball, S. J., N. E. Clapp, Jr., and J. G. Delene,[3] "Nuclear Desalination Plant Control Studies," *Proc. 4th Int. Symp. on Fresh Water from the Sea* (2), 429–38 (1973).

Borkowski, C. J., and T. V. Blalock,[4] "A New Method of Johnson Noise Thermometry," *Rev. Sci. Instrum.* **45**(2), 151–62 (February 1974).

Borkowski, C. J., and M. K. Kopp, "Applications of Position-Sensitive Proportional Counters to Neutron and X-Ray Scattering Experiments," *J. Appl. Crystallogr.* **7**, 116 (April 1974).

Booth, R. S., S. V. Kaye,[5] and P. S. Rohwer,[5] "A Systems Analysis Methodology for Predicting Dose to Man from a Radioactively Contaminated Terrestrial Environment," *Proc. Third Natl. Symp. Radioecology, May 10–12, 1971, Oak Ridge, Tenn.*, CONF-710501, pp. 877–93.

Booth, R. S., M. K. Kopp, G. L. Timm,[6] and J. E. Swander,[7] *Unfolding Spatial Images from a Position-Sensitive Proportional Neutron Counter*, ORNL-TM-4547 (June 1974).

Bullock, J. B., J. T. Mihalczo, and M. V. Mathis, "IKRD Measurements with a Mockup of CRBR Shield," *Trans. Am. Nucl. Soc.* **18**, 347 (June 1974).

Burtis, C. A.,[8] W. F. Johnson, and J. B. Overton,[9] "Automated Loading of Discrete, Microliter Volumes of Liquids into a Miniature Fast Analyzer," *Anal. Chem.* **46**(6), 786–89 (May 1974).

Burtis, C. A.,[8] W. F. Johnson, J. B. Overton,[9] T. O. Tiffany,[8] and J. C. Mailen,[9] "Optimization and Analytical Applications of the Techniques of Dynamic Introduction of Liquids into the Centrifugal Analyzer," *Clin. Chem.* **20**(8), 932–41 (1974).

Burtis, C. A.,[8] W. F. Johnson, T. O. Tiffany,[8] and C. D. Scott,[8] "Techniques for Loading Liquids into the Rotor of the Miniature Centrifugal Fast Analyzer," *Clin. Chem.* **20**(7), 866 (1974).

Churchich, Margarita K.,[10] J. E. Mott,[10] J. C. Robinson,[2] and K. R. Piety,[1] "Real Time Analyzer for Inverse Kinetics Rod Drop Experiments," *IEEE Nucl. Sci. Symp.* **21**(1), 771–75 (1973).

Clark, F. H., R. S. Booth, and H. A. Vanderploeg,[5] *User's Manual for MODSOV, a Terminal Operated Program, Solving the Linear Matrix Equation* $\dot{x} = A\,x + k$, ORNL-TM-4404 (January 1974).

Davidson, J. B., "Fly's Eye: A Counting Camera for Thermal Neutrons," *J. Appl. Cyrstallogr.* **7**, 356–66 (1974).

Davidson, J. B., S. A. Werner,[11] and A. S. Arrott,[12] "Neutron Microscopy of Spin Density Wave Domains in Chromium," pp. 396–400 in *AIP Conf. Proc., No. 18, Part 1, Magnetism and Magnetic Materials – 1973,* American Institute of Physics, New York, 1974.

De Lorenzo, J. T., W. T. Clay, and G. C. Guerrant, "Differential Current Pulse Preamplifier for Fission Counter," *IEEE Trans. Nucl. Sci.* **21**(1), 757–62 (February 1974).

De Lorenzo, J. T., E. J. Kennedy,[4] and C. H. Tucker, "Low-Power Hybrid IC Electrometer Amplifiers," *Dig. Government Microcircuit Appliance Conference (GOMAC), Univ. of Colorado,* pp. 222–23 (June 1974).

Flanagan, G. F.,[13] D. B. Simpson,[13] D. L. Selby,[14] and J. T. Mihalczo, "Transplant Calculations for Reactivity Measurements in Subcritical Configurations of the FFTF Engineering Mockup Core," *Trans. Am. Nucl. Soc.* **18**, 268 (June 1974).

Fry, D. N., R. C. Kryter, and J. C. Robinson,[2] *Analysis of Neutron-Density Oscillations Resulting from Core Barrel Motion in the Palisades Nuclear Power Plant,* ORNL-TM-4570 (May 1974).

Fry, D. N., R. C. Kryter, and J. C. Robinson,[2] "On-Site Noise Diagnostics at Palisades Nuclear Power Station," Paper 27 in *Proc., Power Plant Dynamics, Control and Testing, An Applications Symposium, Knoxville, Tenn., Oct. 8–10, 1973,* CONF-731021.

Gonzalez, R. C.,[2] and J. T. Tou,[15] *Pattern Recognition Principles,* Addison-Wesley, Reading, Mass. 1974.

Gonzalez, R. C.,[2] D. N. Fry, and R. C. Kryter, "Results in the Application of Pattern Recognition Methods to Nuclear Reactor Core Component Surveillance," *IEEE Trans. Nucl. Sci.* **21**(1), 750–56 (February 1974).

Hagen, E. W. (ed.), "Control and Instrumentation," *Nucl. Saf.* **14**(5), 461–69 (September–October 1973); **14**(6), 605–17 (November–December 1973); **15**(1), 15–29, (January–February (1974); **15**(2), 151–62 (March–April 1974); **15**(3), 292–94 (May–June 1974); **15**(4), 409–22 (July–August 1974).

Hagen, E. W., and T. W. Kerlin,[2] "IAEA International Symposiums on Nuclear Power-Plant Control and Instrumentation," *Nucl. Saf.* **15**(1), 15–29 (January–February 1974).

Hall, C. C., *Description of Facility, and Contamination Alarm Systems Installed in the Intermediate and High Level Waste Evaporator, Bldg. 2531,* ORNL-TM-4317 (November 1973).

Hancher, C. W.,[9] L. H. Thacker, and E. F. Phares,[16] "A Fiber-Optic Retroreflective Turbidimeter for Continuously Monitoring Cell Concentration During Fermentation," *Biotechnol. Bioeng.* **16**, 475–84 (1974).

Kopp, M. K., *Report of Foreign Travel to Madrid, Spain; Munchen, Heidelberg, and Julich, Germany; Grenoble, France; Geneva, Switzerland; and Harwell, U.K., Aug. 8–Sept. 17, 1973,* Internal Memorandum.

Kopp, M. K., G. L. Timm,[6] and J. E. Swander,[7] *Unfolding Spatial Image from a Position-Sensitive Proportional Neutron Counter,* ORNL-TM-4547 (June 1974).

Kryter, R. C., D. N. Fry, and R. C. Gonzalez,[2] "Application of Pattern Recognition Methods to Reactor Core Component Surveillance," *Trans. Am. Nucl. Soc.* **17**, 379–80 (November 1973).

Mihalczo, J. T., J. E. Mott,[10] M. Churchich,[10] M. V. Mathis, J. C. Robinson,[2] and N. J. Ackermann, Jr., "A Digital On-Line Reactivity Analysis System," *Trans. Am. Nucl. Soc.* **17**, 445 (November 1973).

Mihalczo, J. T., V. K. Paré, M. V. Mathis, and N. J. Ackermann, Jr., "Noise Analysis at Delayed Criticality for a Mockup of the FFTF," *Trans. Am. Nucl. Soc.* **17**, 454 (November 1973).

Mihalczo, J. T., V. K. Paré, M. V. Mathis, and F. Shahrokhi,[1] "Breakfrequency Noise Analysis Measurements for Subcritical Configurations of the FFTF Engineering Mockup Core," *Trans. Am. Nucl. Soc.* **18**, 346 (June 1974).

Mihalczo, J. T., M. V. Mathis, V. K. Paré, and J. W. Allen,[1] "IKRD Measurements for Subcritical Configurations of the FFTF Engineering Mockup Core," *Trans. Am. Nucl. Soc.* **18**, 345 (June 1974).

Mihalczo, J. T., M. V. Mathis, and V. K. Paré, "Source Multiplication Measurements with a Mockup of the Fast Test Reactor," *Trans. Am. Nucl. Soc.* **18**, 344 (June 1974).

Mihalczo, J. T., "The Use of Californium-252 as a Randomly Pulsed Neutron Source for Prompt-Neutron Decay Measurements," *Nucl. Sci. Eng.* **53**, 393–414 (1974).

Mook, H. A.,[17] F. W. Snodgrass, and D. D. Bates, "A Magnetically Pulsed Neutron Time-of-Flight Spectrometer for Inelastic Scattering," *Nucl. Inst.* **116**, 205–16 (April 1974).

Park, R. A.,[18] et al., "A Generalized Model for Simulating Lake Ecosystems," *Simulation* **23**(2), 33–50 (August 1974).

Paré, V. K., R. C. Kryter, and J. T. Mihalczo, "Experience with a Digital Noise Analysis System in Subcriticality Measurements on a Mockup of the FFTF," *IEEE Trans. Nucl. Sci.* **21**(1), 767–70 (February 1974).

Robinson, J. C.,[2] J. W. Allen,[1] and J. T. Mihalczo, "Adequacy of LLFM Detector for IKRD Application in the FTR," *Trans. Am. Nucl. Soc.* **17**, 446–47 (November 1973).

Robinson, J. C.,[2] and J. E. Mott,[10] "Nuclear Power Plant Noise Monitoring," *Trans. Am. Nucl. Soc.* **17**, 376–77 (November 1973).

Rochelle, J. M., "A Simple Differential Discriminator," *Nucl. Inst. Meth.* **113**, 315–16 (1973).

Rochelle, J. M., and E. J. Kennedy,[4] "Miniaturized Logarithmic Count-Rate Circuit," *Rev. Sci. Instrum.* **44**(11), 1638–42 (November 1973).

Rochelle, J. M., and C. C. Coutant,[5] *Temperature Sensitive Ultrasonic Fish Tag, Q-5099,* ORNL-TM-4438 (December 1973).

Rochelle, J. M., "Design of Gateable Transmitter for Acoustic Telemetering Tags," *IEEE Trans. Biomed. Eng.* **21**(1), 63–66 (January 1974).

Rochelle, J. M., *An Analysis of Gas Breakdown Integrating Ionization Chambers,* ORNL-TM-4574 (March 1974).

Rochelle, J. M., and C. C. Coutant,[5] "Ultrasonic Tag for Extended Temperature Monitoring From Small Fish," *Underwater Telemetry Newsletter Tracking Aquatic Animals* **4**(1), 1–7 (August 1974).

Scott, C. D.,[9] C. A. Burtis,[8] W. F. Johnson, L. H. Thacker, and T. O. Tiffany,[8] "A Small Portable Centrifugal Fast Analyzer System," *Clin. Chem.* **20**(8), 1003–8 (1974).

Shahrokhi, F.,[1] J. C. Robinson,[2] J. T. Mihalczo, and N. J. Ackermann, Jr., *The State of the Art in Non-Destructive Assay and Application to LMFBR Aqueous Fuel Reprocessing Plant,* ORNL-TM-4586 (1974).

Sides, W. H., Jr., and J. B. Bullock, *Inverse Kinetics Measurements Using the SRM Detector Signal at Quad Cities Unit 2,* ORNL-TM-4191 (September 1973).

Stone, R. S., "LOCA Modeling on the Hybrid Computer," CONF-730304 (1974).

Sulouff, M. D.,[19] and E. W. Hagen, "The 16th Annual ISA Power Instrumentation Symposium: Challenges for Power Instrumentation," *Nucl. Safety* **15**(4), 417–22 (July–August 1974).

Tiffany, T. O.,[8] N. E. Lee,[9] W. F. Johnson, and C. D. Scott,[9] "Automated Plasma, Red Blood Cell, and Hemolysate Preparation," *Clin. Chem.* **20**(7), 866 (1974).

Tiffany, T. O.,[8] J. M. Parella,[20] C. A. Burtis,[8] W. F. Johnson, and C. D. Scott[9] "Blood Grouping with a Miniature Centrifugal Fast Analyzer," *Clin. Chem.* **20**(8), 1043–54 (1974).

Tiffany, T. O.,[8] J. M. Parella,[20] W. F. Johnson, and C. A. Burtis,[8] "Specific Protein Analysis by Light-Scatter Measurement with a Miniature Centrifugal Fast Analyzer," *Clin. Chem.* **20**(8), 1055–61 (1974).

Warmack, R. E.,[21] and R. C. Gonzalez, "Linear Inequalities and Its Application to Pattern Recognition," *IEEE Trans. Comput.* **C-22**, 1065–75 (December 1973).

---

1. Graduate student, University of Tennessee, Knoxville (UTK).
2. Consultant, Dept. Nuclear Engineering, UTK.
3. Reactor Division.
4. Consultant, Dept. Electrical Engineering, UTK.
5. Environmental Sciences Division.
6. Summer participant (1973) from Kalamazoo College, Kalamazoo, Mich.
7. Deceased June 7, 1974.
8. MAN Program.
9. Chemical Technology Division.
10. Nuclear Engineering Dept., UTK.
11. Ford Motor Co., Dearborn, Michigan.
12. Simon Fraser University, Burnaby, B.C., Canada.
13. Neutron Physics Division.
14. Computer Sciences Division.
15. Director of Center for Information Research, University of Florida, Gainesville.
16. Biology Division.
17. Solid State Division.
18. Rensselaer Polytechnic Institute, Troy, N.Y.
19. Pittsburgh Power and Light Co.
20. Summer employee, 1973.
21. Atlantic Richland Oil Co., Dallas, Texas.

Papers Presented at Professional Meetings

Some of the papers listed below were prepared jointly with members of other divisions and with consultants and other nonemployees. Their affiliations are footnoted.

3rd International Conf. on Small Angle Scattering, Grenoble, France, Sept. 5, 1973

Borkowski, C. J., and M. K. Kopp, "Applications of Position-Sensitive Proportional Counters to Neutron and X-Ray Scattering Experiments."

4th International Symp. on Fresh Water from the Sea. Heidelberg, W. Germany, Sept. 9–14, 1973

Ball, S. J., N. E. Clapp, Jr., and J. G. Delene,[1] "Nuclear Desalination Plant Control Studies."

Conference on Machine Processing of Remotely Sensed Data, Purdue University, October, 1973

Gonzalez, R. C.,[2] and C. W. Skinner,[3] "On the Management and Processing of Earth Resources Information."

1973 Power Plant Dynamics, Control and Testing: An Applications Symposium, Hyatt Regency Hotel, Knoxville, Tenn., Oct., 8–11 (1973).

Fry, D. N., R. C. Kryter, and J. C. Robinson,[2] "On-Site Noise Diagnostics at Palisades Nuclear Power Station."

Gonzalez, R. C.,[2] "On the Application of Pattern Recognition Methods to Reactor Malfunction Diagnosis."

1973 Winter Meeting American Nuclear Society, San Francisco, Calif., Nov. 11–15, 1973

Kryter, R. C., D. N. Fry, and R. C. Gonzalez,[2] "Application of Pattern Recognition Methods to Reactor Core Component Surveillance."

Mihalczo, J. T., J. E. Mott,[4] M. Churchich,[4] M. V. Mathis, J. C. Robinson,[2] and N. J. Ackermann, Jr., "A Digital On-Line Reactivity Analysis System."

Robinson, J. C., J. W. Allen,[5] and J. T. Mihalczo, "Adequacy of the LLFM Detector for IKRD Application in the FTR."

Robinson, J. C.,[2] and J. E. Mott,[4] "Nuclear Power Plant Noise Monitoring."

19th Annual Conf. on Magnetism and Magnetic Materials, Boston, Nov. 13–16, 1973

Davidson, J. B., S. A. Werner,[6] and A. S. Arrott,[7] "Neutron Microscopy of Spin Density Wave Domains in Chromium."

1973 IEEE Nuclear Science Symp., San Francisco, Calif., Nov. 14–16, 1973

Allen, J. W.,[5] J. C. Robinson,[2] and N. J. Ackermann, Jr., "Sensitivity Analysis of the Inverse Kinetics Rod-Drop Technique."

Borkowski, C. J., and M. K. Kopp, "Recent Developments and New Applications of Position-Sensitive Proportional Counters Using RC Time Signal Encoding."

Churchich, Margarita K.,[4] J. E. Mott,[4] J. C. Robinson,[2] and K. R. Piety,[5] "Real Time Analyzer for Inverse Kinetics Rod Drop Experiments."

De Lorenzo, J. T., W. T. Clay, and G. C. Guerrant, "Differential Current Pulse Preamplifier for Fission Counters."

Gonzalez, R. C.,[2] D. N. Fry, and R. C. Kryter, "Results in the Application of Pattern Recognition Methods to Nuclear Reactor Core Component Surveillance."

Paré, V. K., R. C. Kryter, and J. T. Mihalczo, "Experience with a Digital Noise Analysis System in Subcriticality Measurements on a Mockup of the FFTF."

1974 Scientific Apparatus Makers Association, Houston, Tex., March 1974

Lisser, C. S., "AEC Procurement to RDT Instrumentation Standards."

1974 Microelectronics Symp., Sandia Laboratories, Albuquerque, N.M., Mar. 6–8, 1974

Kennedy, E. J.,[8] J. T. De Lorenzo, J. M. Rochelle, and C. H. Tucker, "Microelectronics Activities in the Instrumentation and Controls Division."

15th Annual Quality Control Clinic, Knoxville, Tenn. (Mar. 8–9, 1974)

Rubel, P., "The Fault Tree Jungle, and Other Dark Places."

6th Annual Symp. on Advanced Analytical Concepts for the Clinical Laboratory, Oak Ridge, Tenn., March 14–15, 1975

Burtis, C. A.,[9] W. F. Johnson, J. B. Overton,[10] T. O. Tiffany,[9] and J. C. Mailen,[10] "Optimization and Analytical Applications of the Technique of Dynamic Introduction of Liquids into the Centrifugal Analyzer."

Scott, C. D.,[10] C. A. Burtis,[9] W. F. Johnson, L. H. Thacker, and T. O. Tiffany,[9] "A Small Portable Centrifugal Fast Analyzer System."

Tiffany, T. O.,[9] J. M. Parella, C. A. Burtis, W. F. Johnson, and C. D. Scott,[10] "Blood Grouping with a Miniature Centrifugal Fast Analyzer."

Tiffany, T. O., J. M. Parella,[11] W. F. Johnson, and C. A. Burtis,[9] "Specific Protein Analysis by Light-Scatter Measurement with a Miniature Centrifugal Fast Analyzer."

12th Annual ACM Conf. Nashville, Tenn., April 1974

Gonzalez, R. C. "Tree Grammars and Their Application to Pattern Recognition."

1974 Symp. on Mineral Cycling in Southeastern Eco Systems, University of Georgia, Augusta (May 1–3, 1974)

Vanderploeg, H. A.,[12] R. S. Booth, and F. H. Clark, "A Specific Activity and Concentration Model Applied to Cesium Movement in an Oligotrophic Lake."

1974 IAEA Specialist's Meeting on In-Core Instrumentation and Failed-Fuel Detection and Location, Toronto, Canada, May 13–15, 1975

Kryter, R. C. "Development of the Delayed-Neutron Triangulation Technique for Locating Failed Fuel in LMFBR."

1974 Annual Meeting American Nuclear Society, Philadelphia, Pa., June 23–27, 1974

Bullock, J. B., J. T. Mihalczo, and M. V. Mathis, "IKRD Measurements with a Mockup of CRBR Shield."

Mihalczo, J. T., G. F. Flanagan,[13] D. B. Simpson,[13] and D. L. Selby,[14] "Transport Calculations for Reactivity Measurements in Subcritical Configurations."

1974 Government Micro-Circuits Applications Conf. (GOMAC) Univ. of Colorado, Boulder (June 25–27, 1974)

De Lorenzo, J. T., E. J. Kennedy,[8] and C. H. Tucker, "Low-Power Hybrid IC Electrometer for Amplifiers."

1974 Engineering Foundation Conf. on Process Design, Operation and Control for Safety and Reliability, Henniker, N.H., July 21–26, 1974

Ackermann, N. J., Jr., "Diagnostic Tools for Present and Future Applications to Plant Safety and Reliability."

2nd International Joint Conf. on Pattern Recognition, Copenhagen, Denmark, August 1974

Gonzalez, R. C., "Classification of Imperfect Syntactic Structures."

26th National Meeting of American Association of Clinical Chemists, Las Vegas, Nev., Aug. 18–20, 1974

Burtis, C. A.,[9] W. F. Johnson, T. O. Tiffany,[9] and C. D. Scott,[10] "Techniques for Loading Liquids into the Rotor of the Miniature Centrifugal Fast Analyzer."

Tiffany, T. O.,[9] N. E. Lee,[10] W. F. Johnson, and C. D. Scott,[10] "Automated Plasma, Red Blood Cell, and Hemolysate Preparation."

---

1. Reactor Division.
2. Consultant, Dept. Nuclear Engineering, University of Tennessee, Knoxville (UTK).
3. Computer Science Dept., North Carolina State University, Raliegh.
4. Dept. of Nuclear Engineering, UTK.
5. Graduate student, UTK.
6. Ford Motor Co., Dearborn, Mich.
7. Simon Fraser University, Burnaby, B.C., Canada.
8. Consultant, Dept. Electrical Engineering, UTK.
9. MAN Program.
10. Chemical Technology Division.
11. Summer employee, 1973.
12. Environmental Sciences Division.
13. Neutron Physics Division.
14. Computer Sciences Division.

Theses Completed

M. J. Roberts, "Transmission Line with Distributed Sources, and Some Applications in Active Filtering," University of Tennessee (March 1974).

J. M. Rochelle, "An Analysis of Gas Breakdown Integrating Ionization Chambers," University of Tennessee (March 1974). Also issued as ORNL-TM-4574.

Farshid Shahrokhi, "The State-of-Art in Nondestructive Assay Systems and Its Application to a LMFBR Aqueous Fuel Reprocessing Plant" (August 1974). Also issued as ORNL-TM-4586.

D. W. Wilson, "Dynamic Experiments for Heat Transfer and Mixing Studies in LMFBR Fuel Assemblies," University of Tennessee (June 1974). Also issued as ORNL-TM-4597.

Patents

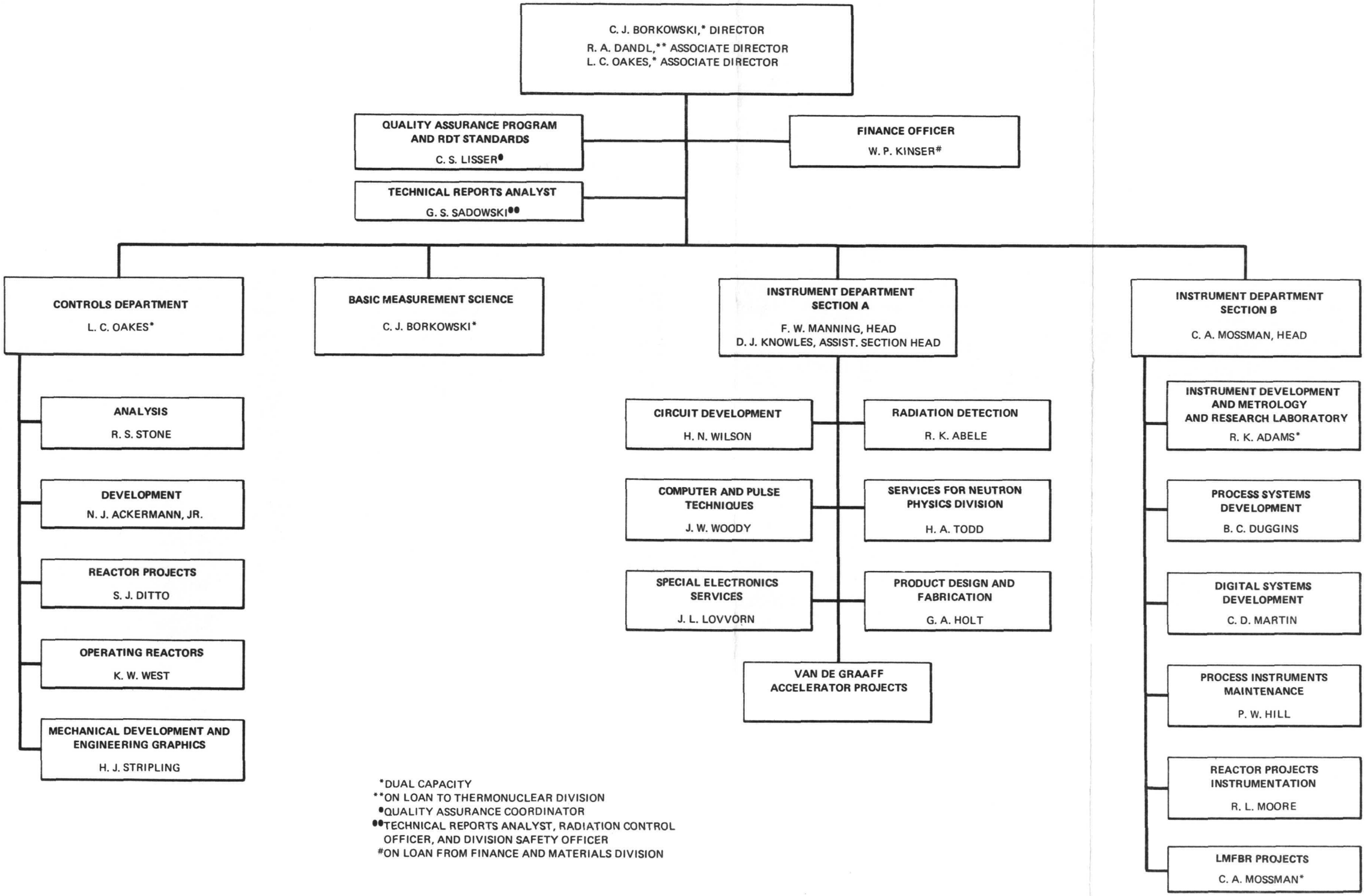
C. J. Borkowski and M. K. Kopp, "Proportional Counter Radiation Camera," U.S. Patent 3,786,270 (Jan. 15, 1975).

W. F. Johnson, "Automatic Photomultiplier Tube Voltage Controller," U.S. Patent 3,783,300 (Jan. 1, 1974).

W. F. Johnson, "Miniature Multistation Photometer Rotor Temperature Control," U.S. Patent 3,792,231 (Feb. 13, 1974).

N. G. Anderson, C. A. Burtis, W. F. Johnson, J. C. Mailer, and C. D. Scott, "Compact Dynamic Multistation Photometer Utilizing Disposable Cuvette Rotor," U.S. Patent 3,789,459 (Mar. 19, 1974).

INSTRUMENTATION AND CONTROLS



*DUAL CAPACITY
**ON LOAN TO THERMONUCLEAR DIVISION
•QUALITY ASSURANCE COORDINATOR
••TECHNICAL REPORTS ANALYST, RADIATION CONTROL OFFICER, AND DIVISION SAFETY OFFICER
#ON LOAN FROM FINANCE AND MATERIALS DIVISION

ORNL-5032
Dist. Category UC-37

INTERNAL DISTRIBUTION

1. Biology Library
2–4. Central Research Library
5. Laboratory Shift Supervisor
6. ORNL – Y-12 Technical Library Document Reference Section
7–255. Laboratory Records Department (I & C Division Distribution)
256. S. I. Auerbach
257. J. A. Auxier
258. M. Bender
259. T. V. Blalock (consultant)
260. C. J. Borkowski
261. F. R. Bruce
262. W. D. Burch
263. H. P. Carter
264. J. F. Clarke
265. T. E. Cole
266. W. B. Cottrell
267. J. A. Cox
268. F. L. Culler
269. D. M. Davis
270. W. H. Ellis (consultant)
271. E. P. Epler (consultant)
272. G. G. Fee
273. D. E. Ferguson
274. C. R. Fisher
275. A. P. Fraas
276. W. Fulkerson
277. R. C. Gonzalez (consultant)
278. J. M. Googe (consultant)
279. W. O. Harms
280. P. N. Haubenreich
281. R. F. Hibbs
282. G. R. Jasny
283. P. R. Kasten
284. N. N. Kaushall
285. O. L. Keller
286. G. G. Kelley
287. E. J. Kennedy (consultant)
288. T. W. Kerlin (consultant)
289. J.B.H. Kuper (consultant)
290. B. Lieberman
291. T. A. Lincoln
292. R. S. Livingston
293. D. A. Mack (consultant)
294. R. E. MacPherson
295. F. C. Maienschein
296. F. W. Manning
297. H. C. McCurdy
298. H. F. McDuffie
299. J. R. McGuffey
300. C. A. Mossman
301. J. E. Mott (consultant)
302. F. H. Neill
303. J. P. Nichols
304. L. C. Oakes
305. H. M. Paynter (consultant)
306. J. Pidkowicz
307. H. Postma
308–309. H. P. Raaen
310. M. E. Ramsey
311. C. R. Richmond
312. J. C. Robinson (consultant)
313. M. W. Rosenthal
314. L. G. Rubin (consultant)
315. R. F. Saxe (consultant)
316. C. D. Scott
317. H. E. Seagren
318. M. H. Schultz (consultant)
319. M. J. Skinner
320. P. H. Stelson
321. J. E. Storer
322. E. G. Struxness
323. J. A. Thie (consultant)
324. A. J. Thompson
325. D. B. Trauger
326. G. U. Ulrikson
327. J. R. Weir, Jr.
328. J. C. White
329. M. K. Wilkinson
330. C. E. Winters
331. A. Zucker

EXTERNAL DISTRIBUTION

332. N. F. Barr, Assistant Director for Special Programs, Division of Biomedical and Environmental Research, U.S. Energy Research and Development Administration, Washington, D.C. 20545

333. D. A. Bromley, Nuclear Structure Laboratory, Yale University, 51 Sachem Street, New Haven, Connecticut 06519
334. R. L. Butenhoff, Division of Biomedical and Environmental Research, U.S. Energy Research and Development Administration, Washington, D.C. 20545
335. R. L. Chase, Associated Universities, Inc., Brookhaven National Laboratory, Upton, New York 11973
336. E. H. Cooke-Yarborough, Head, Electronics and Applied Physics Division, Atomic Energy Research Establishment, Harwell, Berkshire, England
337. Louis Costrell, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234
338. J. W. Crawford, Assistant Director, Division of Reactor Research and Development, U.S. Energy Research and Development Administration, Washington, D.C. 20545
339. F. S. Goulding, University of California, Lawrence Berkeley Laboratory, Berkeley, California 94720
340. S. H. Hanauer, Technical Advisor to Director of Regulation, Office of Director of Regulation, U.S. Nuclear Regulatory Commission, Washington, D.C. 20545
341. R. Hofstadter, Physics Department, Stanford University, Palo Alto, California 94305
342. R. N. Keller, Chemistry Department, University of Colorado, Boulder, Colorado 80302
343–345. F. C. Legler, Division of Reactor Research and Development, U.S. Energy Research and Development Administration, Washington, D.C. 20545
346. G. L. Miller, Bell Telephone Laboratories, Murray Hill, New Jersey 07974
347. A. Pearson, Chalk River Nuclear Laboratories, Atomic Energy Canada, Ltd., Ontario, Canada
348. A. J. Pressesky, Acting Assistant Director for Engineering and Technology, Division of Reactor Research and Development, U.S. Energy Research and Development Administration, Washington, D.C. 20545
349. Velijko Radeka, Associated Universities, Inc., Brookhaven National Laboratory, Upton, New York 11973
350. R. W. Roberts, Assistant Administrator, Office of the Assistant Administrator for Nuclear Energy, U.S. Energy Research and Development Administration, Washington, D.C. 20545
351. D. P. Roux, Société Générale Pour l'Industrie 71 Avenue Louis-Cosai, 1216 Cointrin-Geneve, Switzerland
352–354. C. R. Siebentritt, Jr., PO(DC), Defense Civil Preparedness Agency, Washington, D.C. 20301
355. H. R. Wasson, Division of Biomedical and Environmental Research, Administration, Washington, D.C. 20545
356. R. W. Wood, Manager, Physical and Technological Programs, Division of Biomedical and Environmental Research, U.S. Energy Research and Development Administration, Washington, D.C. 20545
357. Research and Technical Support Division, Oak Ridge Operations, U.S. Energy Research and Development Administration
358. Patent Office, Oak Ridge Operations, U.S. Energy Research and Development Administration
359–532. Given distribution as shown in TID-4500 under recipients listed in Instruments category (25 copies – NTIS)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1976-748-189/4