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THE UNIVERSITY OF WISCONSIN
NUCLEAR REACTOR LABORATORY
MADISON, WISCONSIN

ANNUAL REPORT

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DEPARTMENT OF NUCLEAR ENGINEERING

FISCAL YEAR 1976-1977

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ANNUAL REPORT

A. SUMMARY OF OPERATIONS

1. Instructional Use (Exclusive of Reactor Sharing Program)

The Nuclear Engineering 421 Laboratory was replaced during the year with two separate laboratory courses -- NE 427 and NE 428.

NE 427 had a total enrollment of 51 students during the fiscal year. The initial offering of NE 427 was the summer of 1976. The experiments in NE 427 use foils which have been activated in the reactor for counting experiments. The principal use of the reactor by NE 427, however, is in one experiment entitled "Radiation Survey" in which students determine the radiation levels in and around the Reactor Laboratory by the use of portable instrumentation.

NE 428 was offered for the first time during the Spring Semester, with an enrollment of 34 students. Extensive exclusive use of the reactor is made in several of the experiments in NE 428 so that the "Critical Experiment", "Control Element Calibration Experiment", and "Pulsing Experiment" were repeated six times for the NE 428 students. In addition, an experiment on "Fast Neutron Flux Measurements by Threshold Foil Techniques" was repeated twelve times during the year, as was the "Resonance Absorption Experiment", which also required activation of foils under special conditions.

Enrollment in NE 231 was 62. The "Reactor Operation Demonstration Experiment" was performed six times for this class as a two-hour experiment. This reactor operation demonstration is used for other groups as a demonstration to acquaint students with reactor kinetic behavior at a very basic level.

NE 602, a special topics inter-session course on Power Reactor Instrumentation and Control, had an enrollment of 9. The reactor was used for demonstrations of gamma discrimination methods in nuclear reactors and of typical process instruments.

At least one session in the Reactor Laboratory was included in courses of the Departments of Minerals and Metals Engineering (22 students), Environmental and Civil Engineering (8 students), Biochemistry (70 students), and Physics (25 students).

A Workshop for High School Science Teachers (sponsored by ERDA) with 40 participants included a 3-hour reactor operation demonstration similar to that used in the NE 231 course.

As in the past, formal tours have brought large numbers of elementary and high school students to visit our laboratory.

Finally, during the year, the Engineering Exposition brought approximately 13,000 visitors to the Engineering Campus, most of whom also toured the Reactor Laboratory.

2. Reactor Sharing Program

(The information in this section is an abstract of reports (COO-2144-12 and COO-2144-13.)

Institutions using the reactor under the Reactor Sharing Program are listed below along with a brief description of the activity in which they engaged, and the number of staff and students involved. Total participation included 8 colleges and universities, 11 professorial staff members, and 69 students. As in the past, almost all of the effort involved teaching of undergraduate level students.

Carroll College. (1 professor and 3 students) Neutron activation analysis laboratory session.

Edgewood College. (1 staff and 4 students) An elementary education major Science class visited the laboratory for familiarization with reactors and nuclear power.

Milwaukee School of Engineering. (1 professor and 12 students) Demonstration of reactor operation characteristics.

University of Minnesota-Duluth. (2 staff members and 2 graduate students) A continuation of work on identification of copper artifacts by multi-element instrumental neutron activation analysis.

University of Wisconsin-Eau Claire. (1 staff member and 6 students) Neutron activation analysis laboratory session.

University of Wisconsin-Oshkosh. (2 staff members and 10 students) Reactor familiarization and neutron activation analysis laboratory session.

University of Wisconsin-Parkside. (2 staff members and 8 students) Students participated in a control rod calibration laboratory session.

University of Wisconsin-Stevens Point. (1 staff member and 24 students) Students participated in the Reactor Operation Demonstration and familiarization with use of the multi-channel analyzers for high resolution gamma spectroscopy.

3. Sample Irradiations and Neutron Activation Analysis Services

During the year, 5,277 samples were irradiated. 1,291 of these irradiations were of 15 minutes or less duration, while the remainder accumulated 12,304 sample hours of irradiation. The listing below indicates the university department or other organization for which the samples were irradiated, the numbers of staff and students involved, a very brief description of the research program and, where known, the organization sponsoring the research. The paranthetical expression (NAA) with the entry indicates work done by the UWNR Neutron Activation Analysis Service.

Biophysics. (NAA) 80 samples, 80 sample hours.

Professor Anderegg and 1 graduate student. Study of cesium content of polio viruses. Supported by NIH.

Chemistry Department. (NAA) 69 samples, 75 sample hours.

Professor J. Wright and 6 graduate students. Development of ultra trace methods of analysis using chemical steps followed by neutron activation analysis. Supported by NSF.

Civil and Environmental Engineering. (NAA) 19 samples, 7 less than 15 minutes, 72 sample hours. Professor Andren, 1 additional staff member, 7 graduate students. Study of trace elements in air and water suspended particulate matter and in sediments. Supported by Sea Grant and Environmental Protection Agency.

Dairy Science. (NAA) 1,317 samples, 4,350 sample hours. Professor L. Satter, 1 additional staff member, 2 students. Use of rare earth stable tracers in study of feed constituent utilization in dairy cattle. Supported by Industrial Grant.

Department of Natural Resources. (State of Wisconsin) (NAA) 218 samples, 16 less than 15 minutes, 694 sample hours. Measurement of trace elements in fish, sludges, and sediments as part of overall environmental surveillance program.

Food Science Department. (NAA) 9 samples less than 15 minutes.

Professor Amundson and 1 graduate student. Comparison of fermentation processes for preparing single celled proteins.

Department of Geology and Geophysics. (NAA) 18 samples less than 15 minute irradiation. Professor Brewer. Measurement of sodium, manganese and potassium content of rock samples.

Geology/UIR. (NAA) 410 samples, 206 less than 15 minutes, 612 sample hours. J. Larsen and 1 additional staff member. Neutron activation analysis of vegetation to detect minerals as a prospecting tool. Support by Graduate School and St. Joseph's Explorations of Toronto, Canada.

Globe-Union, Inc., Milwaukee, Wisconsin. (NAA) 247 samples, 210 less than 15 minutes, 37 sample hours. Analysis of impurity levels in feed materials for quality control group within corporate structure; establish content of standard lead samples for use in routine laboratory analysis.

Madison Metropolitan Sewage District. (NAA) 11 samples, 34 sample hours. Development of methods to measure metal content of sewage sludges for routine surveillance program.

Department of Medicine. 2 samples, 1 less than 15 minutes, 2 sample hours. Activation of materials for Professors Azen and Updike, plus one graduate student. Attempt to label phosphorous 32 content of chromatographic films for use in autoradiography and preparation of tracer material for use in measuring catalytic behavior in trans-membrane catalysis of H_2O_2 . Support by National Institutes of Health.

Milwaukee County Medical Examiners Office. (NAA) 8 samples, 4 less than 15 minutes, 6 sample hours. Assist in determining cause of illness in death of a child who died in a Milwaukee Area hospital.

Minerals & Metals Engineering. (NAA) 13 samples, 6.5 sample hours. Professor R. Boom and 1 graduate student. Determination of compositions of superconducting alloys. Supported by NSF, ERDA, and WEURF.

University of Minnesota-Duluth. (NAA) 599 samples, 915.5 sample hours. Professor Rapp, 1 additional staff member and 4 students. Continuation of program to determine origin in past metallurgical treatment of metallic artifacts. Supported by Reactor Sharing Program of USERDA.

University of Minnesota. (NAA) 23 samples, 23 sample hours. Professor Sawkins and 1 graduate student. Assay of metal content of rocks.

State of Minnesota, Environmental Quality Council--Copper-Nickel Project. (NAA) 185 samples, 95 less than 15 minutes, 129 sample hours. Trace element neutron activation analysis of rocks, soils, plant tissues, sediments, air particulates, and waters in order to determine environmental consequences of mining operations.

Nuclear Engineering Department. 511 samples, 231 less than 15 minutes, 791.9 sample hours. Irradiations for NE 427 included 234 samples, 118 less than 15 minutes and 205.2 sample hours. Irradiations for NE 428 included 92 samples, 37 less than 15 minutes, 95.33 sample hours. The remaining 185 samples, 76 less than 15 minutes, 491.33 sample hours were samples irradiated by the Reactor Laboratory staff for instrument calibrations or investigation of feasibility of various neutron activation analysis projects.

Pharmacy Department. (NAA) 24 samples, 28 sample hours. Professor Peterson and 1 student. Determination if dithiodiuret increases the urinary excretion of zinc and iron. Supported by NIEHS.

Department of Physics. (NAA) 11 samples, 22 sample hours. Professor W. Yen and 1 graduate student. Correlation of optical properties of antiferromagnetic insulators with elemental compositions. Supported by NSF.

Reactor Sharing Program. 13 samples less than 15 minutes. Joint irradiations for neutron activation analysis demonstrations for visiting Reactor Sharing Program classes. Supported by ERDA.

Soil Science Department/Chemistry. 1,226 samples, 458 less than 15 minutes, 4,131.5 sample hours. Professor P. Helmke and 5 graduate students. Neutron activation analysis of rocks, soils, and biological materials; production of radio tracers. Supported by EPA, Cooperative State Research Service (Hatch Act), Wisconsin Power & Light, Madison Gas & Electric, Wisconsin Public Service Corporation (IES), and ERDA.

Wisconsin State Historical Society. (NAA) 4 samples, 8 sample hours. Determine authenticity of copper needle artifacts found in State archeological excavations.

University of Wisconsin-Green Bay. 22 samples, 4 less than 15 minutes, 27 sample hours. Professor Norman and 1 student. NAA of sediment samples to determine environmental impact.

University of Wisconsin-Oshkosh. (NAA) 27 samples, 40.5 sample hours. Professor Propp. Determine fundamental composition of sewage sludge samples. Supported by Duncan Foundation Grant.

WARF Institute. (NAA) 123 samples, 19 less than 15 minutes, 138 sample hours. Neutron activation analysis service for measurement of various elements in rocks, soils, and leaves; measurement of chlorine level in toxathene.

Zoology Department. (NAA) 89 samples, 89 sample hours. Professor W. Burns and 1 graduate student. Study of mercury inventory of fur-bearing animals on the Wisconsin River Water Shed. Supported by WARF and Graduate School.

4. Changes in Personnel, Facility, and Procedures.

Personnel Changes

There were no changes in operating personnel during the year.

Facility Changes

The startup channel for the reactor was replaced in July 1976 with a newly-designed, solid state version functionally equivalent to the previous unit, but incorporating a preamplifier mounted on top of fission chamber detector. The fuel temperature meters, one of which is connected to the reactor safety system to give reactor trips on high fuel temperature, were modified to conform to the manufacturer's recommendations for removing sensitivity to electronic noise picked up on the AC power line. The modification consists of a filter network to prevent noise pulses from giving trip actuation. The pneumatic tube control circuitry was modified to allow blower turnon only from the control console and to allow blower turnoff from either the control console or at the normal operating position for the pneumatic tube. An additional lighted flashing sign panel was added to the emergency evacuation alarm system in the hallway connecting the ground floor level of the Engineering Research Building and the Mechanical Engineering Building from the Thermosciences Laboratory. This change was made as a result of installations of partitions within the Thermosciences Laboratory which might have prevented an individual entering the Mechanical Engineering Building from observing the flashing signs indicating a condition existed warranting evacuation.

Procedure Changes. Several minor wording changes were made in maintenance procedures in order to implement an improved quality assurance program which would satisfy the requirements of Standard ANS 15.8. An Emergency Plan was prepared and approved by the Reactor Safety Committee and changes in the format of several Emergency Procedures, primarily UWNR Nos. 151 and 153, were made in order to reflect the adoption of the overall emergency plan as UWNR 006. Procedure UWNR 162, which concerns pH control in the secondary cooling system, was modified to reflect current use of city water rather than lake water in the secondary cooling system. The change indicates that pH treatment is not necessary if the pH range of the makeup water to the cooling tower sump is in the range of 6.5 to 8.5.

5. Results of Surveillance Tests

Surveillance tests and inspections during the year revealed no problems in safety-related systems.

The surface roughness noted on FLIP fuel element #7422 during the previous fuel bow and elongation measurements was carefully observed, and there was an apparent decrease in surface roughening with the additional time of exposure to pool water.

Surveillance of licensed operator performance under the Operator Proficiency Maintenance Program showed no deficiencies.

B. OPERATING STATISTICS AND FUEL EXPOSURE

	<u>Startups</u>	<u>Critical Hours</u>	<u>MW Hours</u>	<u>Pulses</u>
FY 76-77	121	469.20	380.06	59
Total on TRIGA Core	1790	6254.84	4571.46	1209

Total energy output during the year was 15.8 MW days, and the total exposure since converting to TRIGA fuel is 190.5 MW days.

The fuel exposure since loading the mixed FLIP-TRIGA core is 822.46 MW hours or 34.27 MW days.

Core excess reactivity decreased by 0.13% during the year.

C. EMERGENCY SHUTDOWNS AND INADVERTENT SCRAMS

There were no emergency shutdowns during the year. There were four inadvertent Scrams distributed as indicated below.

On 23 July 1976, 13 September 1976, 3 November 1976, and 23 November 1976, Relay Scrams occurred which were attributed to the fuel temperature indicator (19M1). In all of these cases there was no increase in power level nor reactivity change which could have caused the fuel temperature increase to the trip point. Several attempts were made to resolder the thermocouples to their connectors since the symptoms observed were indicative of a momentary open in the thermocouple circuit which would give a trip due to the upscale burnout feature built into the instrument. Tests showed that a momentary (1 millisecond) opening of the thermocouple circuit would result in a trip. Since this same sort of problem had occurred in the previous year seven different times, the instrument manufacturer was contacted about the problem. The instrument manufacturer pointed out that since our instruments had been manufactured, the instrument design had been changed to incorporate a resistance-capacitance filter to prevent noise pulses on the AC power line from causing actuation of the alarm function in the meters. The Reactor Safety Committee approved a request for reactor modification based on the manufacturer's recommendation, and the modification was performed at the Annual Maintenance Shutdown. No recurrence of the problem has been noted.

In addition to the inadvertent shutdowns, there were two occasions during the year when the reactor could not be started up as scheduled due to an instrument failure which was detected during the prestartup checklist. On 5 November 1976, the balancing motor in the gaseous air monitor recorder failed and delayed the startup until the deficiency could be repaired. On 12 November 1976, the startup was delayed because of the failure of a diode in the startup channel power supply.

D. MAINTENANCE OPERATIONS

Ordinary preventative maintenance was performed on the equipment throughout the period and resulted in acceptable performance for all instrumentation. All non-routine preventative maintenance was either a facility change, as covered in item A.4. of this report, or in item C. above, detailing the corrective maintenance required to replace a burned out motor and defective Zener diode.

The replacement startup channel has given outstanding service except for the single diode failure mentioned above. A complete spare channel for this instrument is available.

E. CHANGES IN THE FACILITY OR PROCEDURES PURSUANT TO SECTION 50.59 OF 10 CFR PART 50

There were none.

F. RADIOACTIVE WASTE DISPOSAL

1. Solid Waste

No solid waste was shipped offsite during the year.

2. Liquid Waste

Table 1 shows the record of liquid waste disposal during the fiscal year.

3. Particulate and Gaseous Radioactivity Released to the Atmosphere

Table 2 presents information on stack activity discharged.

TABLE 1

LIQUID WASTE TO SANITARY SEWER

	<u>25 AUG 1976</u>	<u>11 NOV 1976</u>	<u>TOTAL</u>
TOTAL ACTIVITY DISCHARGED (MICROCURIES)	313.9	394	707.9
LIQUID QUANTITY (GALLONS)	1400.	1270	2670.
Ru^{106} - MPC USED - 4×10^{-4}			
AMOUNT (μCi)	47.5	77.7	125.2
CONC ($\mu Ci/ml$)	8.97×10^{-6}	1.62×10^{-5}	
Co^{60} - MPC USED - 1×10^{-3}			
AMOUNT (μCi)	4.5	5.5	10.0
CONC ($\mu Ci/ml$)	8.61×10^{-7}	1.15×10^{-6}	
Zn^{65} - MPC USED - 3×10^{-3}			
AMOUNT (μCi)	247.	250.	497.
CONC ($\mu Ci/ml$)	4.66×10^{-5}	1.44×10^{-5}	
Mn^{54} - MPC USED - 4×10^{-3}			
AMOUNT (μCi)	6.3	27.	33.3
CONC ($\mu Ci/ml$)	1.20×10^{-6}	5.56×10^{-6}	
Co^{58} - MPC USED - 4×10^{-3}			
AMOUNT (μCi)	8.6	31.1	39.7
CONC ($\mu Ci/ml$)	1.63×10^{-6}	6.5×10^{-6}	
Cr^{51} - MPC USED - 5×10^{-2}			
AMOUNT (μCi)	0.0	6.	6.
CONC ($\mu Ci/ml$)	0.0	1.2×10^{-6}	

Average concentration at point of release to sewer = 7.00×10^{-5} $\mu Ci/ml$ (includes natural radioactivity).

Average daily sewage flow for dilution = 2.37×10^4 gallons.

Average concentration after dilution = 2.16×10^{-8} $\mu Ci/ml$.

TABLE 2

EFFLUENT FROM STACK

1. Particulate Activity

There was no discharge of particulate activity in excess of background levels.

3. Gaseous Activity -- All Argon 41

<u>Month</u>	<u>Activity Discharged (Curies)</u>	<u>Maximum Instantaneous Concentration $\mu\text{Ci/ml} \times 10^{-6}$</u>	<u>Average Stack Concentration $\mu\text{Ci/ml} \times 10^{-8}$</u>	<u>MPC Used $\mu\text{Ci/ml}$</u>
July 7	0.0824	2.5	4.55	2.4×10^{-5}
August	0.1165	3.1	7.60	
September	0.1112	2.3	6.50	
October	0.2240	3.0	12.00	
November	0.2554	1.0	14.70	
December	0.1768	0.8	9.26	
January 7	0.1312	0.8	7.90	
February	0.1243	1.5	7.90	
March	0.1509	1.3	8.20	
April	0.1538	2.0	8.60	
May	0.1211	2.5	7.00	
June	<u>0.1236</u>	<u>3.0</u>	<u>7.12</u>	
TOTAL	1.7712	3.1×10^{-6} Maximum	8.44×10^{-8} Yearly Average	

The MPC value above is that calculated in the SAR to be equivalent to $3 \times 10^{-8} \mu\text{Ci/ml}$ in the area surrounding the laboratory.

G. SUMMARY OF RADIATION EXPOSURES

No significant exposure of personnel occurred due to operation of the reactor. For occupationally exposed personnel, the highest annual dose was only 4.8% of the quarterly dose limit (60 mrem whole body) while the highest extremity dose for the entire year was less than 2% of the permissible quarterly dose (210 mrem). No laboratory student or facility visitor received more than 5 mrem.

Routine radiation and contamination surveys of the facility revealed no areas of high exposure rates or contamination.

H. RESULTS OF ENVIRONMENTAL SURVEYS

The environmental monitoring program at Wisconsin consists of thermoluminescent dosimeters (LiF TLD service from Eberline) located in the area surrounding the Reactor Laboratory. In addition, occasional checks are made with a high sensitivity (2 inch NaI detector) survey meter.

The outer stone facing of the Mechanical Engineering Building and masonry faces of other buildings give larger readings than does reactor operation, leading to some difficulty in interpretation of dosimeter data. A study is in progress to find dosimeter locations that will not place the dosimeters in close proximity to the building materials but which will give the same area coverage as the present distribution. The table below lists doses for persons continuously in the area for representative dosimeter readings.

Annual Dose Data-Environmental Monitors

mrem/year corrected for control background

<u>Location</u>	<u>Average Dose Rate/mrem/week</u>
Inside wall of Reactor Laboratory	3.95
Inside Reactor Laboratory Stack	0.59
Highest dose outside Reactor Laboratory (Laboratory Roof)	1.65
Highest Dose in Occupied Nonrestricted Area (third floor classroom facing away from Reactor Lab)	0.32
Average Dose in Occupied Nonrestricted Area	0.09
Average Dose in all Unrestricted Areas (29 Monitor Points)	0.29

I. PUBLICATIONS AND PRESENTATIONS ON WORK BASED ON REACTOR USE

Civil and Environmental Engineering, Water Chemistry Program

L. C. Bate, S. E. Lindberg, A. W. Andren, "Elemental Analysis of Water and Air Solids by Neutron Activation Analysis", Journal of Radioanalytical Chemistry, Vol. 32 pp 125-135. (1976)

Dairy Science

G. F. Hartnell and L. D. Satter, "Sm, La, and Ce as Particulate Markers in the Ruminant Gut", presented at the 69th Annual Meeting of the American Society of Animal Science, July 23-27, 1977.

Gary F. Hartnell: PhD Thesis, "The Significance and Measurement of Ingesta Turnover Rates Using Rare Earth Metals in Dairy Cattle".

Metallurgical and Mineral Engineering

R. W. Boom et al, "Wisconsin Superconductive Energy Storage Project, Vol. II", Jan. 1976.

R. W. Boom, et al, "Wisconsin Superconductive Energy Storage Project, 1976 Annual Report", May 1977.

K. T. Hartwig, F. J. Worzala, "Dilute Aluminum Alloys: Their Potential in Superconducting Devices", Proceedings of the Sixth International Cryogenic Engineering Conference, p 206, Grenoble France, May 1976.

K. T. Hartwig: PhD Thesis (1977) "A Study of Dilute Al-An and Al-Sb Alloys for Superconductor Stabilizer Applications".

Physics Department

William C. Egbert: PhD Thesis (1977), "Tricritical Magnetic Phase Diagrams of Ferrous Chloride Doped with Cadmium".

University-Industry Research Program

James A. Larsen, Manuscript in preparation.

Zoology Department

T. B. Sheffy: PhD Thesis (1977) "Mercury Burdens in Furbearers of the Wisconsin River Watershed".

Enrico Fermi Institute, University of Chicago

Roy S. Lewis, Jacques Gros, and Edward Anders, "Isotopic Anomalies of Noble Gases in Meteorites and Their Origins 2. Separated Minerals from Allende", Journal of Geophysical Research, Vol. 82, pp 779-792 (1977).

Geology Department, University of Minnesota-Duluth

George Rapp, Jr., Richard E. Jones, Strathmore R. B. Cooke, and Eiler Henrikson, "Analysis of the Metal Artifacts", Chapter II, Nichoria Vol. I: Site, Environs, Techniques, Edited by George Rapp, Jr. and Stanley E. Aschenbrenner, University of Minnesota Press (In press 1977).

George Rapp, Jr., Chapter "Trace Elements as a Guide to the Geographical Source of Tin Ore: Smelting Experiments", The Search for Ancient Tin, Edited by T. A. Wertime and J. Olin, Smithsonian Inst. Press (In press 1977).