ANNUAL OPERATING REPORT FOR LICENSE R-74
TO THE UNITED STATES NUCLEAR REGULATORY COMMISSION

FOR

FISCAL YEAR 1980-1981

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UNIVERSITY OF WISCONSIN

REACTOR LABORATORY

ANNUAL REPORT

A. SUMMARY OF OPERATIONS

1. Instructional Use - UW-Madison Formal Classes

Three Nuclear Engineering Department classes make use of the reactor. The 39 students enrolled in NE 231 participated in a two-hour laboratory session to introduce students to reactor behavior characteristics. Twelve hours of reactor operating time were devoted to this session. NE 427 had an enrollment of 21 during the two semesters it was offered. Several of NE 427 experiments use materials that are activated in the reactor, while the experiment entitled "Radiation Survey" requires that Students make measurements of radiation levels in and around the Reactor Laboratory. Since the irradiations for the students and the radiation survey take place during normal isotope production runs, no reactor time was devoted exclusively to NE 427. The enrollment in NE 428 was 16 as it was offered in both semesters. A total of 94 operating hours was devoted to the three experiments (("Critical Experiment", "Control Element Calibration", and "Pulsing") which require exclusive use of the reactor. Each of these experiments was repeated four times during the year. Other laboratory sessions make use of material that has been irradiated in the reactor ("Fast Neutron Flux Measurements by Threshold Foil Techniques" and "Resonance Absorption"). These latter two experiments were repeated eight times during the semester.

Individual one to two-hour sessions in the Reactor Laboratory are also held for other departments ranging from Integrated Liberal Studies to Physics.

2. Reactor Sharing Program

Work on determination of common origin of archaeological artifacts was continued by the group (three staff members and two graduate students) from the University of Minnesota. The Neutron Activation Analysis Service determines trace element composition in samples of copper, bronze, and pottery.

Classes from the University of Wisconsin-Platteville (1 professor and 7 students), the University of Wisconsin-Eau Claire (1 professor and 6 students), and Beloit College (1 professor and 7 students) attended a four-hour laboratory session on reactor operating characteristics. One professor and

3 students from Carroll College came to the laboratory for a four-hour laboratory on Neutron Activation Analysis.

3. Utility Personnel Training

A group of six operator trainees from the Kewaunee Nuclear Plant attended our two-week Research Reactor Training Program. This program reinforces training in reactor physics and operation and gives laboratory experience in health physics and instrumentation as part of the overall training program for the nuclear plant.

4. Sample Irradiation and Neutron Activation Analysis Services

The number of samples irradiated during the year was 7641. There were 901 separate irradiations which collectively took 418 irradiation-space hours of use. Although 755 of the irradiations were of less than 15 minutes duration, the remaining samples required 17,788 sample hours of irradiation. Most of the samples were irradiated and subsequently counted at the laboratory as part of the Neutron Activation Analysis Service effort and are noted (NAA) in the listing of user groups below.

Biochemistry. (NAA) 134 samples, 98 less than 15 minutes, 73 sample hours.

Professor W. W. Cleland, J. V. Schloss, and 1 graduate student. Evaluation of metal contamination in commercially available preparations of adenosine triphosphate (ATP). Supported by NIH.

Chemistry. (NAA) 43 samples, 37 less than 15 minutes, 6 sample hours.

Professor Wright and 2 students. Measure trace element concentration in CaF_2 crystals. Supported by NSF.

(NAA) 50 samples, 25 sample hours.

Professor Record and 2 students. Study of binding of sodium ions to nucleic acids. Supported by NSF

Chemical Engineering. (NAA) 16 samples, all less than 15 minutes.

1 student. Measurement of amount of catalyst deposited on alumina. Support unknown.

Civil and Environmental Engineering. (NAA) 311 samples, 112 less than 15 minutes, 199 sample hours.

Professor Boyle and 2 students. Measurement of heavy metals in cupola dust. Supported by American Foundrymen's Society.

Consolidated Cigar Corporation. (NAA) 81 samples, 81 sample hours.

Measurement of bromine levels in tobacco.

Dairy Science. (NAA) 4,857 samples, 14,571 sample hours.

Professors Jorgensen and Satter, 1 post doctoral fellow, and 13 students. Use of stable tracers in feed to determine digestability, rumen turnover, and rate of passage in dairy cattle. Supported by USDA, Industry Grants, Hatch Fund.

Forest Products Laboratory. (NAA) 41 samples, 34 less than 15 minutes, 17 sample hours.

Staff member Kirk and 1 post doctoral fellow. Determination of metal ion content of paper mill sludge. Supported by USDA.

Geology. (NAA) 103 sample, 170 sample hours.

Professor Craddock and 2 students. Trace element anlysis of Keweenawan volcanic rocks of Northwest Wisconsin. Supported by Wisconsin Geological Survey.

Globe Union. (NAA) 166 samples, 318 sample hours.

Analysis of lead metal and oxide for impurities.

University of Illinois. (NAA) 134 samples, 264 sample hours.

Professor Crooker. Stable tracer techniques in cattle feed utilization.

Limnology. (NAA) 133 samples, 6 less than 15 minutes, 127 sample hours.

Professor Magnuson and 1 student. Measure sodium and potassium levels in fish (Perca flavescens) exposed to low pH stress. Supported by NSF.

Madison Metropolitan Sewage District. (NAA) 7 samples, 14 sample hours.

Measure heavy metal content of agricultural products grown on sludge-treated soils.

University of Maryland. (NAA) 204 samples, 612 sample hours.

Professor Erdman. Stable tracer techniques in cattle feed utilization.

Mechanical Engineering. (NAA) 158 samples, 852 less than 15 minutes, 146 sample hours.

Professor Ragland, 1 additional staff member, and 3 students. Measurement of trace elements in fly ash, bottom ash, and fuel when burning refuse-derived fuels. Supported by EPA.

University of Minnesota-Duluth. (NAA) 292 samples, 584 sample hours.

Professor Rapp continued his studies of trace element characteristization of artifacts.

Nuclear Medicine. 101 samples, 24 less than 15 minutes, 101 sample hours.

Professor Gatley, 1 additional staff member, and 4 students. Development of Flourine-18 compounds for positron-emission tomography. Supported by National Cancer Institute, UW Medical School, and Graduate School.

Nuclear Engineering. 36 samples, 26 less than 15 minutes, 15 sample hours.

Professor Vogelsang and 1 student. Study of tritium production in thermonuclear reactors. Supported by Wis. Elec. Utilities Research Foundation.

NE 427. 95 samples, 65 less than 15 minutes, 24 sample hours.

NE 428. 60 samples, 24 less than 15 minutes, 71 sample hours.

Irradiation in support of laboratory instruction.

Reactor Laboratory. 223 samples, 47 less than 15 minutes, 56 sample hours.

Irradiation for calibrations and standard development of NAA service.

Soils. 52 samples, 104 sample hours.

Professor Helmke and 2 students. Analysis of soils and rocks to understand the behavior of elements in natural systems. Supported by EPA, College of Agriculture and Life Sciences.

(NAA) 75 samples, 39 less than 15 minutes, 72 sample hours.

Professor Schulte, 1 additional staff member, and 2 students. Determination of lime potential of fly ash applied to cropland. Supported by Wisconsin Power and Light Company.

Water Chemistry. (NAA) 197 samples, 111 less than 15 minutes, 98 sample hours.

Professors Andren and Chesters, 1 post doctoral fellow and 1 student.

Study of bromine and chlorine emissions of coal-fired power plants. Supported by EPA.

University of Wisconsin-Milwaukee. (NAA) 72 samples, 144 sample hours.

Studies of distribution of uranium and thorium in Wisconsin rock formations. Supported by Graduate School.

A. 5. <u>Changes in Personnel, Facility, and Procedures</u>

Changes reportable under 10 CFR 50.59 are indicated in Section E of this report.

There were several changes in personnel during the year and these are detailed in Section E of this report.

6. Results of Surveillance Tests

Surveillance tests and inspections during the year revealed no safety-related defects. Operating personnel performance evaluations under the Operator Proficiency Maintenance Program showed no deficiencies on written or oral examinations.

Core excess reactivity increased from 3.82% ρ to 3.88% ρ during the year. The increase is expected for a FLIP core.

B. OPERATING STATISTICS AND FUEL EXPOSURE

Operating Period	Startups	Critical Hours	MW Hours	Pulses
FY 80-81	196	714.18	602.31	33
Total Present I23-R12 FLIP Core	---	1630.88	1161.88	107
TOTAL - TRIGA Cores	2583	8813.66	6301.66	1468

C. EMERGENCY SHUTDOWNS AND INADVERTENT SCRAMS

There were no emergency shutdowns during the year. There were 19 inadvertent shutdowns distributed as indicated below.

5 trainee operator error trips:

11/21/80, 6/2/81.
Excessive control element withdrawal resulted in period trip.

5/14/81, 5/15/81/ 6/8/81.
Picoammeter range switches operated improperly, resulting in picoammeter trip.

8 instrument noise sensitivity trips:

3/5/81, 4/4/81, 5/12/81, 5/13/81, 5/21/81, 5/26/81, 6/2/81, 6/15/81.

Log N-Period channel relay scrams from switching transient upon moving control blades, rundown switch, or deliberate dropping of transient rod. Several of these trips had no upscale movement of Log N or period trace, but all took place after the new Log N amplifier was installed. The relay scram function in the new instrument employs a solid-state relay (triac actuated by photo diode and photo transistor). The solid state relay is much faster acting than the previous mechanical relay and is more sensitive to electronic noise. Solder joints and connectors have been checked, but it has not been possible to duplicate the trip conditions while diagnostic instrumentation is attached. In all cases, the trip bistable has not actuated, so a filter will be installed at the solid-state relay input to eliminate the spurious trips.

1 period trip:

1/22/81. Period faster than actual period due to improper compensation of Log N CIC.

1 trip due to loss of electrical service to Reactor Laboratory: 1/20/81.

1 trip due to core inlet temperature recorder:

8/28/80. When recorder access door was closed after a check of paper supply, the slidewire cover fell off, shorted the slidewire, and caused upscale movement of pen to the 130°F trip point.

1 trip - fuel temperature meter:

4/21/81. Intermittent upscale meter movement due to intermittent open thermocouple; did not recur after thermocouple connector was resoldered.

1 trip from high pool water level:

6/10/81. Due to high wet bulb temperature, pool water temperature reached 107°F. The resulting expansion caused a high pool level trip.

1 trip from Hig. Voltage Monitor:

6/30/81. High voltage monitor setpoint drifted up to high voltage and caused a trip. A semiconductor in the monitor had changed characteristics and eventually failed while the reactor was shut down.

D. MAINTENANCE OPERATIONS

The Log N-Period Amplifier was replaced with a new unit and successfully tested to meet performance specifications on 6 January 1981.

Fuel thermocouple number 41T showed intermittent shorts while the reactor was at power on 12 February 1981. It was disconnected from the fuel temperature meter and number 41C was connected in its place.

Modifications to the pool drain line are reported under Section E of this report.

During an upgrading of the building fire alarm system, smoke detectors and manual fire alarms were added to the Reactor Laboratory and associated laboratories and shops. A replacement High Voltage Power Supply for the console was approved by the Reactor Safety Committee on 27 May 1981.

E. CHANGES IN THE FACILITY OR PROCEDURES REPORTABLE UNDER 10 CFR 50.59

Modifications to the reactor pool drain line were performed during the annaul maintenance shutdown (27 December 1980). Pages 2-30, 2-31, and 6-16 of the Safety Analysis Report are appended to this report. The original piping configuration had the demineralizer discharge into the pool through a 2-inch line which bypassed the 8-inch pipe loop (equipped with a siphon breaker). A drain valve was provided off this 2-inch line.

The 2-inch line was plugged with two expanded aluminum plugs in the portion of the pipe inside the concrete shield. The drain valve was removed, the 2-inch pipe was capped, and the demineralizer discharge to the pool was re-routed through the 8-inch pipe loop. With the new arrangement, no break in any pipe can result in draining the pool to a level which would uncover the core.

Personnel changes. On 12 January 1981, R. J. Cashwell was appointed Reactor Director and S. M. Matusewic was appointed Reactor Supervisor. Mr. H. O. Nelson received his degree and left the university for employment with Northern States Power Company. Mr. G. C. Penn was added to the staff as an operator trainee.

F. RADIOACTIVE WASTE DISPOSAL

1. Solid Waste

There was no solid waste transferred out of the laboratory during the year.

2. Liquid Waste

Table 1 shows liquid waste discharges during the fiscal year.

3. Particulate and Gaseous Radioactivity Released to the Atmosphere

Table 2 presents information on stack discharges during the year.

G. SUMMARY OF RADIATION EXPOSURES (1 July 1980 - 15 June 1981)

No significant exposure of personnel occurred due to operation of the reactor. For occupationally-exposed personnel: the highest annual whole body and skin doses were 220 mrem and 150 mrem respectively, while the highest extremity dose for the entire year was 110 mrem. For laboratory students, the highest annual whole body and skin doses were 90 mrem and 100 mrem respectively. No facility visitor received any measurable dose.

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.

The table below lists doses for persons continuously in the area for representative dosimeter readings.

Annual Dose Data-Environmental Monitors

Location	Average Dose Rate-mrem/week
Inside Wall of Reactor Laboratory	6.40 ± 1.64
Inside Reactor Laboratory Stack	3.37 ± .36
Highest Dose Outside Reactor Laboratory (Reactor Lab roof entrance window: Monitor adjacent to stone surface)	3.28 ± .97
Highest Dose in Occupied Nonrestricted area (third floor classroom facing away from Reactor Lab)	.92 ± .24
Average Dose in Occupied Nonrestricted Area	.76 ± .12
Average Dose in All Unrestricted Areas (29 Monitor Points)	1.01 ± .28

TABLE 1

LIQUID WASTE TO SANITARY SEWER

	7 JULY 80	21 AUG 80	27 AUG 80	30 DEC 80	3 APR 81	22 JUNE 81	TOTALS
TOTAL ACTIVITY DISCHARGED (Microcuries)	61.65	199.60	342.9	778.34	94.99	30.983	1508.46
LIQUID QUANTITY (Gallons)	1000.	950.	1050	1950.	1180.	900.	7030.
Ra^{226} - MPC USED - 4×10^{-7}							
AMOUNT (μCi)	--	1.76	--	--	--	--	1.76
CONC (μCi/ml)		4.89E-6					
Ru^{106} - MPC USED - 4×10^{-4}							
AMOUNT (μCi)	7.71	21.95	56.47	--	22.19	1.015	109.335
CONC (μCi/ml)	2.04E-6	6.11E-6	1.42E-5	--	4.98E-6	2.98E-7	
Co^{57} - MPC USED - 2×10^{-2}							
AMOUNT (μCi)	--	7.97	0.154	--	--	0.671	8.795
CONC (μCi/ml)		2.22E-6	7.79E-8			3.95E-7	
Co^{58} - MPC USED - 4×10^{-3}							
AMOUNT (μCi)	3.00	11.31	27.76	3.35	11.05		56.47
CONC (μCi/ml)	7.93E-6	3.15E-6	6.99E-6	4.55E-7	2.48E-6		
Co^{60} - MPC USED - 1×10^{-3}							
AMOUNT (μCi)	11.25	4.79	16.40	--	4.42	0.127	36.987
CONC (μCi/ml)	3.00E-6	1.33E-6	4.13E-6		9.91E-7	7.45E-8	
Zn^{65} - MPC USED - 3×10^{-3}							
AMOUNT (μCi)	--	78.25	183.1	21.37	36.92	21.75	341.39
CONC (μCi/ml)		2.18E-5	4.62E-5	2.90E-6	8.26E-6	6.39E-6	
Mn^{54} - MPC USED - 4×10^{-3}							
AMOUNT (μCi)	1.606	12.58	29.82	3.77	9.07		56.846
CONC (μCi/ml)	4.25E-7	3.50E-6	7.52E-6	5.12E-7	2.03E-6		
K^{40} - MPC USED - 9×10^{-5}							
AMOUNT (μCi)	6.63	--	--	--	--		6.63
CONC (μCi/ml)	1.75E-6						
Fe^{55} - MPC USED - 2×10^{-2}							
AMOUNT (μCi)	--	26.54	--	716.4	--	--	742.94
CONC (μCi/ml)		7.39E-6		1.94E-4			
Fe^{59} - MPC USED - 2×10^{-3}							
AMOUNT (μCi)	--	0.492	--	13.26	--	--	13.752
CONC (μCi/ml)		1.37E-7		3.60E-6			
Cr^{51} - MPC USED - 5×10^{-2}							
AMOUNT (μCi)	31.45	33.96	29.2	20.19	11.34	7.42	133.56
CONC (μCi/ml)	8.32E-6	9.46E-6	7.36E-6	2.74E-6	2.54E-6	2.18E-6	

Average concentration at point of release to sewer = 5.68E-5 μCi/ml (includes natural radioactivity).

Average daily sewage flow for dilution = 2.37E-4 gallons

Average concentration after dilution = 4.61E-8 μCi/ml

TABLE 2

EFFLUENT FROM STACK

1. Particulate Activity

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

2. Gaseous Activity - All Argon 41

Month	Activity Discharged (Curies)	Maximum Instantaneous Concentration $\mu Ci/ml \times 10^{-6}$	Average Stack Concentration $\mu Ci/ml \times 10^{-8}$	MPC Used $\mu Ci/ml$
July	.1791	2.3	10.0	2.4×10^{-5}
August	.1426	3.1	7.68	
September	.2210	10.0	13.2	
October	.2876	6.4	15.0	
November	.1585	3.1	9.78	
December	.1541	5.8	8.32	
January '81	.2439	4.0	13.6	
February	.1418	3.5	8.76	
March	.1102	1.6	6.34	
April	.1003	1.2	5.80	
May	.0450	2.0	2.55	
June	.1067	1.4	6.15	
TOTAL	1.8908	1.0×10^{-5} Maximum	8.96×10^{-8}	

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

I. PUBLICATIONS AND PRESENTATIONS ON WORK BASED ON REACTOR USE

CHEMISTRY

Bleam, M. L., Anderson, C. F., Record, M. T. Jr., "Relative Binding Affinities of Monovalent Cations for Double-stranded DNA," Proc. Natl. Acad. Sci., USA 77, pp 3085-3089, 1980.

Bleam, M. L., PhD thesis, "NMR Studies of the Interactions of Small Cations with DNA," 1980.

DAIRY SCIENCE

Erdman, R.A., "Rumen Fractional Clearance Rates of Feed Ingredients Within Mixed Rations Fed Lactating Dairy Cows," Journal of Dairy Science, 64, Supplement 1, pp 129, 1981.

Prange, Robert, PhD thesis, "Kinetics of Digesta Passage in Lactating Dairy Cows," 1981.

Lu, C. D., et al, "Intake, Digestibility, and Rate of Passage of Silages and Hays from Wet Fractionation of Alfalfa," Journal of Dairy Science, 63, pp 2051-2059, 1980.

Lu, C. D., PhD thesis, "Wet Fractionation of Alfalfa: Utilization of Pressed Forage and Protein Concentrate by Ruminents," 1981.

Santini, F. J., PhD thesis, "Effect of Forage Particle Length on Performance of High Producing Cows,", 1981.

FOREST PRODUCTS LABORATORY

Eaton, D. C., Chang, H-M, and Kirk, T.K., "Decolorization of Kratt Bleach Plant Effluents Using Acidified Primary Sludge: the FPL/NCSUDAS Process." For submission to Tappi.

GEOLOGY AND GEOPHYSICS

Ali, H.A., PhD thesis, "Geology of Keweenawen Volcanic Rock in Grandview-Minors Area, NW Wisconsin," 1981.

NUCLEAR MEDICINE

Gatley, S. J., Shaughnessy, W. J., "Synthesis of 3-deoxy-3-fluoro-D-glucose from Reactor-produced F-18", Int. J. Appl. Radiat. Isotopes 31:339-341, 1980.

Shaughnessy, W. J., Gatley, S. J., Hichwa, R. D., Lieberman, L. M. and Nickles, R. J., "Aspects of the Production of F-18 2-deoxy-2-fluoro-D-glucose via $^{18}F_2$ With a Tandem Van de Groot Accelerator," Ibid 32:23-29, 1981.

Gatley, S. J., Hichwa, R. D., Shaughnessy, W. J., Nickles, R. J., "F-18 Labeled Lower Fluoro Alkanes; Reactor-produced Gaseous Physiological Tracers," Ibid 32:211-214, 1981.

Nuclear Medicine (continued)

Holden, J. E., Gatley, S. J., Hichwa, R. D., Ip, W. R., Shaughnessy, W. J., Nickles, R. J., Polcyn, R. E., "Cerebral Blood Flow Using PET Measurements of Fluoromethane Kinetics," Journal of Nuc' ar Medicine, (In press).

Gatley, S. J., Shaughnessy, W. J., "Millicuries of F-18 Radiopharmaceuticals From a One Megawatt Research Reactor," Ibid, (Submi ted).

Gatley, S. J., Shaughnessy, W. J., "Nucleophilic Substitution with Fluoride: Effects of Solvent, Temperature, Ions Leaving Group and Water," Journal Labeled Comp. 18:24-25, 1981.

SOIL SCIENCE

Lim, C. H., Jackson, M. L., Koons, R. D., Helmke, P.A., "Kaolins. Sources of Differences in Cation-Exchange Capacities and Cesium Retention,", Clays and Clay Minerals 28:223-229, 1980.

Hanson, G. D., Helmke, P. A., "Properties and Potential Uses of Fly Ash and Flue Gas Desulfurization Sludge Stabilized by Pozzolanic Reactions", 3rd Ann. Madison Conf. Applied Research on Municipal and Industrial Waste, Madison, WI 1980.

Helmke, P. A., "Rock Alteration and Mineral Transformations," Symposium volume on basic research needs for managing nuclear wastes in geologic media. Nuclear Technol. J. 51:182-187, 1980.

DaSilva, F. A. F., M.S. thesis, "Trace Elements in the Clay-size Fraction from Alluvial Soils of Southwestern Wisconsin," 1980.

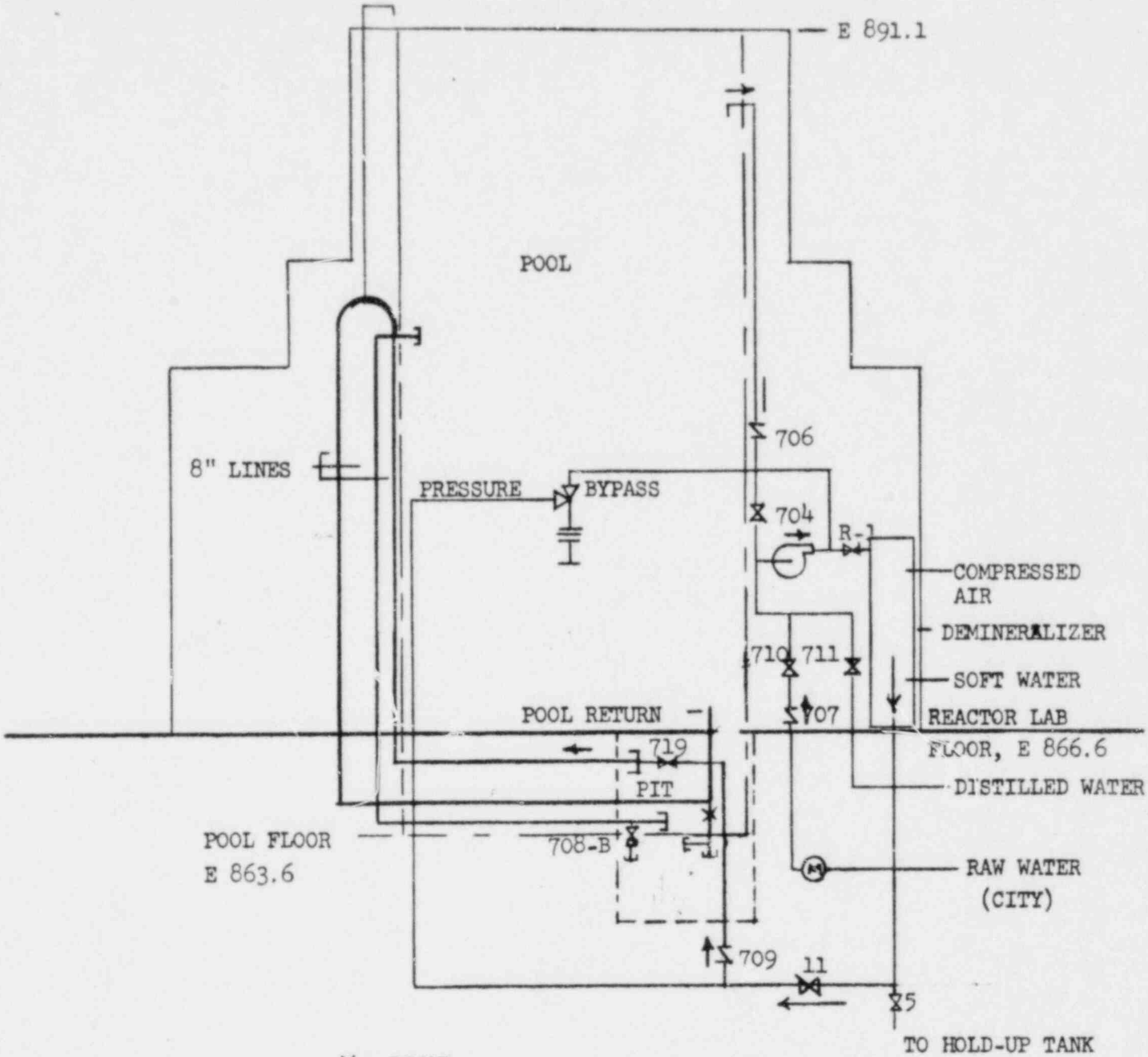
Wastes from regeneration of the demineralizer are discussed in the next section.

Flow from the demineralizer to the pool is through valve 11, check valve 709 which prevents back flow, and valve 719 into the 8 inch pipe loop and into the bottom of the grid box. The 8 inch line is equipped with a siphon breaker at the top of the pool so that rupture of the line at the demineralizer outlet or of the 8 inch line outside the shield cannot drain the pool to a level that will uncover the core. A second 8 inch line is flanged off on both ends. The 8 inch lines were originally installed to allow a forced-convection cooling mode, but the lines are used only as indicated above.

A two inch line whose rupture could have caused loss of pool water has been permanently plugged inside the concrete shield and is presently sealed off outside the shield. A pool drain line and valve have been eliminated.

Should valve numbers 5 (shown in both figures 17 and 18) be left open upon placing the system in its normal operating condition, as much as 400 gallons of pool water could be pumped to the holdup tank. No further loss of water would then occur, since check valve 709 will prevent reverse flow from the 8 inch pipe loop to the demineralizer.

All operations involving the make-up and clean-up systems are performed by written checklist-type procedures designed to prevent draining of the pool.



×- PLUG
t- CAP OR FLANGE

FIGURE 17

POOL MAKEUP AND CLEANUP SYSTEM

6.6 LOSS OF POOL WATER

Although there is little liklihood of complete loss of water from the reactor pool, an analysis is made to demonstrate that such loss will not damage reactor fuel.

6.6.1 Possible Means of Water Loss

The pool is contained within the thick reinforced concrete reactor shield which will maintain its integrity under the most severe earthquake that would be expected in this area.

A sheared and open beam port could drain the water level to mid-core height in about 400 seconds, but water would still be in contact with the fuel and would prevent excessive temperatures.

The 8-inch stainless steel pipes built into the pool walls for possible future use in a forced convection cooling system are flange sealed on the outer ends. In addition, one of these pipes has a loop and a siphon breaker extending well above the core so that a rupture cannot lower pool level below the core. The other pipe is flange sealed inside the pool and penetrates the shield wall well above the core. Rupture of either of these lines will not uncover the core.

Rupture of the piping in the demineralizer could cause only slight water loss due to location of the outlet lines from the pool and a check valve at the demineralizer outlet.

6.6.2 Radiation Levels Due to Unshielded Core

Calculations of radiation levels at various points in the Reactor Laboratory were made assuming operations at 1000 kW for an infinite time. Doses from direct and scattered radiation were considered, wit the scattered dose calculated for the case of a thick concrete ceiling nine (9) feet above the pool. Results of the calculations are given in Table 3.