RADIONUCLIDE INVENTORY AND DOSE RATE

for the

PATHFINDER ATOMIC POWER PLANT REACTOR PACKAGE

Prepared for

NORTHERN STATES POWER COMPANY

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EXECUTIVE SUMMARY

An activation analysis was performed for the Pathfinder Atomic Power Plant reactor vessel and internals in support of the Pathfinder Decommissioning Project. The results indicate that approximately 476 curies of neutron activation products, mainly Co60 and Ni63, are present within the reactor vessel and internals. The maximum curie density in any single reactor internal occurred in the boiler shroud, where the specific curie content was estimated to be 0.248 millicuries per gram.

The internal contamination ("crud") layer of the vessel and internals wetted surfaces contains approximately 95 millicuries, mainly Co60 and Ni63.

The external dose rate from the vessel package was calculated to be 6.8 mR per hour at two meters from the vessel at the reactor core midplane. This dose rate is based on 2 inches of carbon steel shielding on the vessel exterior, extending from five feet above the core upper elevation to three feet below the core lower elevation. This calculated dose rate also assumes an average packing density of the gravel present in the reactor vessel of 75% of the maximum.

The results of these analyses show that the Pathfinder reactor vessel and internals can be shipped intact as a single package without exceeding the LSA limits on specific curie content or US DOT external package dose rate.

1. PURPOSE

This report details the calculations performed to support and provide data for the Pathfinder Atomic Power Plant decommissioning plan. They consist of a neutron activation analysis of the reactor vessel and internals, estimation of internal surfaces contamination levels, and estimation of dose rates from the package as currently envisioned for shipping.

The neutron activation calculations have been performed using the ORIGEN2 [1] computer code, which was obtained through Oak Ridge National Laboratory's Radiation Shielding Information Center. The calculations determining the total curies based upon the ORIGEN2 specific curie values (curies per gram) were performed using the Lotus 1-2-3 version 2.01 [2].

The estimate of the primary system surface contamination was made using manual estimates of vessel and vessel internals surface areas, coupled with the Battelle estimates of specific surface contamination levels in the feedwater and main steam systems [3].

The calculation of the external exposure rates from the Pathfinder vessel package were performed using the Microshield code version 3.12 [4]. A variety of calculations were performed to bracket the possible amounts of gravel between the more highly activated portions of the reactor internals and the exterior of the package.

2. APPROACH

The activation analysis has been performed using ORIGEN2. Input to the code included material compositions, the Pathfinder operating history and neutron fluxes. Wherever possible, data obtained through NSP [5,6,7] has been employed. The balance of the input data was extracted from the available literature and is referenced as such. Conservative assumptions were made and justified wherever actual plant data was not available.

The estimate of the primary system surface contamination has been made using manual estimates of vessel and vessel internals surface areas, coupled with the Battelle estimates of specific surface contamination levels in the feedwater and main steam systems [3].

For the shielding analysis, cylindrical source geometry was used as the input model to the Microshield code. Multiple concentric cylindrical regions were used to model the vessel and internals. The activation analysis results from ORIGEN2 were used as a source term for the vessel and internals.

3. PATHFINDER OPERATING HISTORY

The Pathfinder Atomic Power Plant operating history has been extracted from data provided by Northern States Power. An available Pathfinder Six-Month Operating Report indicated that Pathfinder had its initial criticality on March 24, 1964. The plant's final shutdown occurred, due to a condenser tube failure, on September 16, 1967. The total core burnup was 16,635 megawatt(thermal)-days [5].

The Pathfinder Atomic Power Plant Safeguards Report [6] and subsequent correspondence [8] indicates the core design 100% power level to be 199.6 megawatts-thermal, at a core design average neutron flux of 3.5 E + 13 neutrons/cm^2-second.

Since most of the power operation occurred towards the end of the plant's life, for the purposes of this analysis it was conservatively assumed that the plant operated at 100% power for 87.6 days, until September 16, 1967.

4. MATERIAL COMPOSITION

Three material compositions were used in this analysis - Type 304 stainless steel, carbon steel and Zircaloy-2. There are other materials used in the construction of the components in this analysis. However, from the research performed, there does not appear to be any component of significant mass manufactured from a material other than the three analyzed here, which would significantly affect the results of this study.

In some of the material composition tables included below it may be noticed that some rather conspicuous elements are missing. As an example, in 304 SS, carbon and oxygen are missing from the table. The source of some of this data [9] did not include certain elements because their activation would not contribute significantly to the long-lived isotopes of interest in a decommissioning study. Annotations have been made in the footnotes to the tables regarding the lack of certain isotopes, and their typical concentrations in the material have been provided.

4.1 Stainless Steel Type 304 [9]

With the exception of the boiler boxes, all reactor vessel internals and the reactor vessel cladding are assumed to be manufactured from Type 304 stainless steel. The composition of this steel for use as input to the ORIGEN2 activation code is listed below.

Element	ppm or %	Element	ppm or %
Li	0.13	Y	5
N	452	Zr	10
Na	9.7	Nb	89
Al	100	Mo	2.60%
Cl	70	Ag	2
K	3	Sb	12.3
Ca	19	Cs	0.3
Sc	0.03	Ba	500
Ti	600	La	0.2
V	456	Ce	371
Cr	18.4%	Sm	0.1
Mn	1.53%	Eu	0.02
Fe	70.6%	Tb	0.47
Co	1414	Dy	1
Ni	10.0%	Ho	1
Cu	3080	Yb	2
Zn	457	Lu	0.8
Ga	129	Hf	2
As	194	W	186
Se	35	Pb	67
Br	2	Th	1
Rb	10	U	2
Sr	0.2		

Notes: No material certifications are available for the Pathfinder vessel internals; the elemental composition of 304 stainless steel above was taken from NUREG/CR-3474 [9]

Carbon is not included in this composition, but normally exists in Type 304 stainless steel at a maximum level of approximately 800 ppm. The creation of C^{14} from the $N^{14}(n,p)C^{14}$ reaction dominates the $C^{12}(n,\gamma)(n,\gamma)C^{14}$ reaction by several orders of magnitude.

The reactor vessel cladding may contain up to 0.8% niobium (columbium) [10]

4.2 Carbon Steel [9]

The reactor vessel shell is manufactured from carbon steel. The composition of this steel for use as input to the ORIGEN2 activation code is listed below.

Element	ppm or %	Element	ppm or %
Li	0.30	Y	20
N	84	Zr	10
Na	23	Nb	18.8
Al	33	Mo	0.56%
Cl	40	Ag	2
K	12	Sb	11
Ca	14	Cs	0.2
Sc	0.26	Ba	273
Ti	2	La	0.1
V	80	Ce	1
Cr	0.17%	Sm	0.017
Mn	1.02%	Eu	0.031
Fe	98.0%	Tb	0.45
Co	122	Dy	-
Ni	0.66%	Ho	0.8
Cu	1274	Yb	1
Zn	100	Lu	0.2
Ga	80	Hf	0.21
As	532	Ta	0.13
Se	0.7	W	5.5
Br	0.85	Pb	820
Rb	48	Th	0.18
Sr	0.15	U	0.20

Notes: No material certifications are available for the Pathfinder vessel and internals; the elemental composition of carbon steel above was taken from NUREG/CR-3474 [9].

Carbon is not included in this composition, but normally exists in carbon steel at a maximum level of approximately 3000 ppm. The creation of C^{14} from the $N^{14}(n,p)C^{14}$ reaction dominates the $C^{12}(n,\gamma)(n,\gamma)C^{14}$ reaction by several orders of magnitude.

4.3 Zircaloy-2 [11]

The boiler boxes surrounding the boiler fuel in the reactor are manufactured from Zircaloy-2. The composition of this metal for use as input to the ORIGEN2 activation code is listed below.

Element	ppm or %	Element	ppm or %
H	13	Fe	0.15%
B	0.33	Co	10
C	120	Ni	500
N	80	Cu	20
O	950	Zr	98.0%
Al	24	Nb	120
S	35	Cd	0.25
Ti	20	Sn	1.6%
V	20	Hf	78
Cr	0.1%	W	20
Mn	20	U	0.2

Notes: The elemental composition of Zircaloy-2 above was taken from PNL-6046 [10].

5. DISCUSSION OF THE POINT ACTIVATION ANALYSIS CALCULATIONS

The point activation calculation of materials at the Pathfinder Atomic Power Plant was divided into two categories:

1. Materials located within the radius of the core boundary.

2. Materials located outside the radius of the core boundary.

For materials located within the core boundary, the ORIGEN2 BWR-U cross section library was chosen. This library contains one-group energy spectrum-averaged neutron cross sections, which best represent the neutron energy spectrum within the core. For materials located outside the core boundary, the ORIGEN2 thermal cross section library - which contains only thermal cross sections at 68 °F. - was used.

A review of the information available on the thermal and fast neutron fluxes as a function of radial distance from the core boundary at Pathfinder indicated a high degree of spectrum thermalization beyond the core boundary, through and beyond the pressure vessel. Typically, more recent light water reactor (LWR) designs have pressure vessels two to three times the thickness of the Pathfinder vessel. While the large LWR's and Pathfinder both see significant thermalization in the plenum region just beyond the core boundary, the thick pressure vessel of the new, large LWR's significantly hardens the neutron flux energy spectrum. At Pathfinder, the neutron spectrum remains relatively well-thermalized beyond the outer wall of the pressure vessel.

Generally, the region inside the core boundary of typical light water reactors has an average fast/thermal neutron flux ratio on the order of 8:1. Outside the core boundary at Pathfinder, the fast/thermal neutron flux ratio was usually less than 1:5. Using in-core cross sections (the ORIGEN2 BWR-U library) would not be representative of the neutron spectrum, and would underestimate the activation of materials beyond the core boundary.

Use of the thermal cross section libraries (the ORIGEN2 thermal library) for radial regions beyond the core boundary requires several factors to be taken into account:

1. The thermal cross section libraries contains cross section data for neutrons at room temperature (2200 m/second, or 68 °F). The curie content results calculated by ORIGEN2 must be temperature-corrected for regional temperatures outside the core boundary.

2. Certain radionuclides in an activation analysis of reactor materials are products of fast neutron reactions only. There is only one radionuclide produced which has a significant impact on curie content and radiation levels - Mn^{54}. Manganese-54 is the product of the $Fe^{54}(n,p)Mn^{54}$ reaction, which a has significant cross section only above 1 MeV.

Since all of the radionuclides of interest in an activation analysis of reactor materials (with the exception of Mn^{54}) have temperature-corrected thermal cross sections which are greater than or nearly equal to the epithermal cross sections, the use of the thermal cross section library in conjunction with the total neutron flux will produce conservative results. In the case of Mn^{54}

the short half-life of the radioisotope (312.5 days) and the long decay time since shutdown (more than 20 years) imply that neglecting this isotope will not seriously impact the final results.

5.1 Activation Within the Core Boundary

Using ORIGEN2 and the BWR-U cross section library, point activation analyses were performed for Type 304 stainless steel and Zircaloy-2. A neutron flux of 3.50 E+13 n/cm^2-second was used as input. The results were decayed to June 1, 1989 within the ORIGEN2 runs. Additional decay to January 1, 1990 was performed exterior to ORIGEN2 with Lotus 1-2-3 during the mass determination and total curie estimates.

5.2 Activation Radially Beyond the Core Boundary

The ORIGEN2 thermal cross section library was used in the point activation analyses of materials radially beyond the core boundary. Neutron fluxes for locations beyond the core boundary (at the core midplane) through the reactor vessel wall were taken from Reference 6. The fast and thermal fluxes from the reference figure were totaled, and the total used as input to ORIGEN2. The radial core midplane neutron fluxes are tabulated below.

Radial Location	Total flux (n/cm^2-sec)
Core boundary	3.50 E+13
Boiler baffle	1.16 E+13
Steam separators	1.07 E+12
Reactor vessel inner wall	3.30 E+10
Reactor vessel outer wall	2.50 E+09

See Figure 5.1 for depiction of assumed axial flux profile.

For components located between the radial locations at which point activation analyses were performed, a logarithmic average of the ORIGEN2-calculated specific curie content results was used. Two such averages were computed and used. The first was at the location of the boiler shroud at a radius of 100.33 cm. The second was at the radial midpoint of the region from the core edge to the inner wall of the reactor vessel, an average radius of 127.6 cm. Point activation analyses were performed for Type 304 stainless steel and carbon steel. The results were decayed to June 1, 1989 internal to the ORIGEN2 code; additional decay to January 1, 1990 was performed with Lotus 1-2-3 during the mass determination and total curie estimates.

5.3 Activation Axially Beyond the Core Boundary

In the absence of axial flux maps for Pathfinder in regions above and below the core axial boundaries, flux reduction scaling factors were employed. For each 30 centimeter segment above and below the core, the total flux was conservatively reduced only by a factor of 10. In addition, for the regions axially above and below the core, point activation calculations were made with the thermal cross section libraries. For above and below the active core region, specific curie content results were multiplied by the axial flux reduction factors to obtain corrected results.

See Figure 5.2 for depiction of assumed radial flux profile.

5.4 Neutron Activation Model

A model was developed for the radionuclide estimation of the Pathfinder vessel and internals; in general the features of the model matched the actual Pathfinder vessel and internals layout with the following exceptions:

- The reactor vessel lower head curvature was ignored; a straight, vertical wall was assumed to run the entire length of the model.

- Material more than 90 centimeters above the core or below the core was not included in the model.

- Neutron fluxes were identified for specific regions of the vessel and internals, i.e. the reactor core, the core boundary, the steam separator region, the vessel inner wall, and the vessel outer wall. Within each of these regions specific curie contents (curies per gram) were calculated using ORIGEN2 for each material present in the region. No effort was made to identify peaks or depressions in the local neutron flux levels and to incorporate these local flux disturbances into the activation model.

- For the purpose of this estimate, the concrete bioshield was not considered in the activation analysis.

Figures 5.3 and 5.4 detail the neutron activation model used for the Pathfinder activation analysis.

FIGURE 5.1

PATHFINDER ATOMIC POWER PLANT
ASSUMED AXIAL FLUX

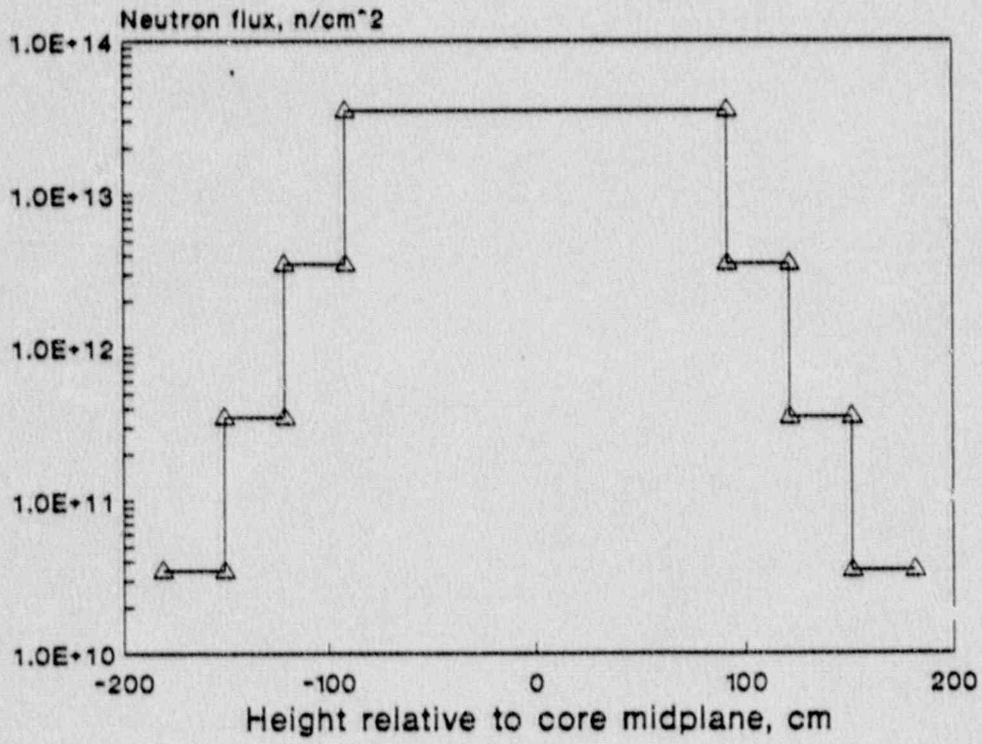


FIGURE 5.2

PATHFINDER ATOMIC POWER PLANT
ASSUMED RADIAL FLUX

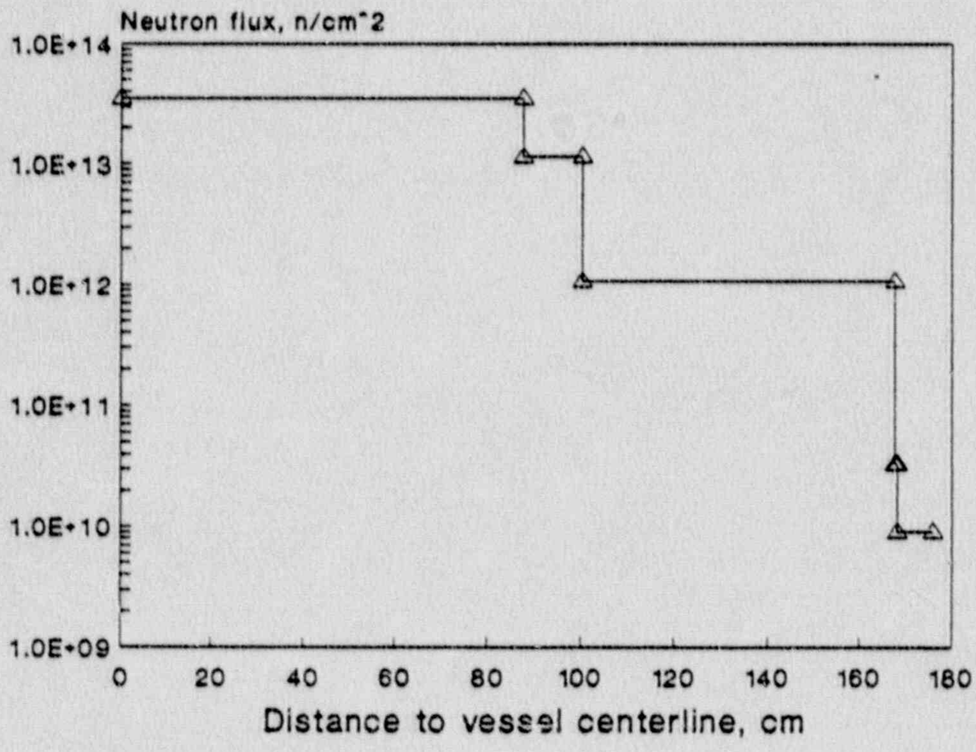


FIGURE 5.3

PATHFINDER ATOMIC POWER PLANT
NEUTRON ACTIVATION MODEL
AXIAL PROFILE

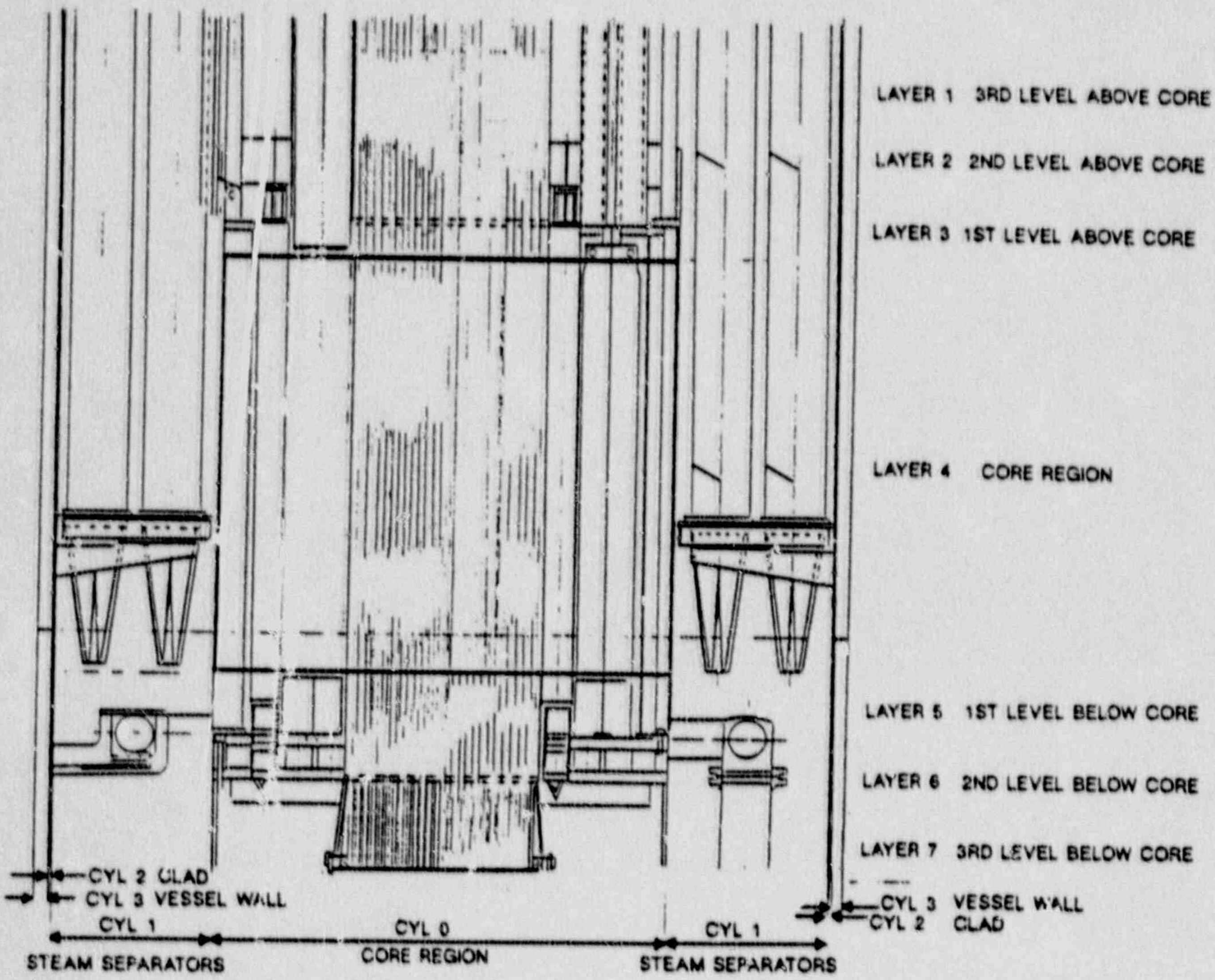
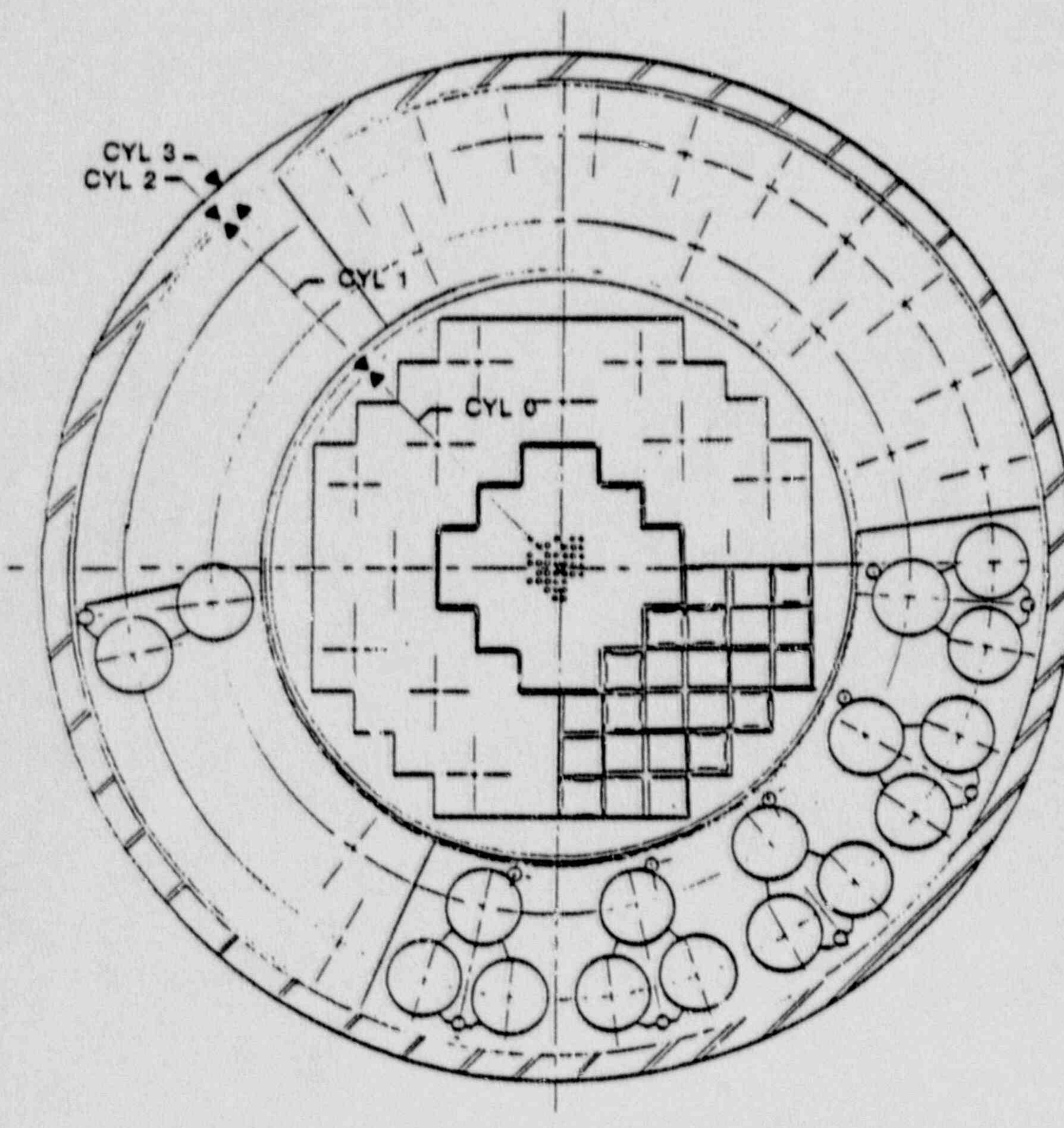


FIGURE 5.4

PATHFINDER ATOMIC POWER PLANT
NEUTRON ACTIVATION MODEL
RADIAL PROFILE



6. COMPONENT DIMENSIONS AND MATERIALS

The Pathfinder reactor was a unique concept in early nuclear design, incorporating nuclear superheating of steam at the center of the reactor core. To achieve this superheating the reactor core was more complicated than current LWR designs, necessitating some unusual components, or components different from those in standard LWR designs. This section describes each component within the vessel package at Pathfinder. Unless stated otherwise, all components are Type 304 stainless steel.

It is important to remember that many of these components fall within two or more regions of the neutron activation model, and as such no single curie per gram value can be allocated to each component. Also, portions of the vessel internals which lay outside the neutron activation model were not considered in the model.

6.1 Superheater fuel element insulating tubes

Each fuel element in the superheater region of the reactor core was contained within an inner and outer insulating tube. The superheater fuel elements themselves were tube shaped, with a central flow path for the superheated steam. The insulating tubes surrounded the fuel element tube, providing additional flow paths for the steam to travel from the top of the reactor vessel through the superheater region and exiting from the vessel bottom. Water for neutron moderation surrounded the outside of the insulating tubes. The tubes run the entire length of the activation model. There are 468 sets of inner and outer superheater fuel element insulating tubes in the Pathfinder vessel internals. Fifty-two of the 468 fuel element/insulating tube sets also contained a superheater control rod.

6.2 Superheater baffle

The superheater baffle is a structural support for the superheater fuel elements as well as a flow baffle separating the water in the boiler section of the reactor core from the water surrounding the superheater fuel elements. It is 0.25 thick inch stainless steel and runs the entire length of the activation model.

6.3 Superheater support plate

The superheater support plate lies at the bottom of the superheater fuel elements, providing support and alignment of the elements. It is stainless steel and curved such that portions of the curved plate would lie outside the activation model; however all portions of the support plate were assumed to lie within the activation model.

6.4 Superheater control rods

The superheater control rods are solid stainless steel of approximately 0.79 inches diameter. Four clusters of 13 control rods are within the superheater fuel element insulating tubes.

6.5 Boiler fuel boxes

Each boiler fuel element was individually contained within a Zircaloy-2 shroud to prevent cross-flow of water through the fuel assembly. The bottoms of the fuel boxes are manufactured from Type 304 stainless steel. There are 48 boiler fuel boxes, together containing 96 boiler fuel assemblies. There are 16 fuel boxes which contain 4 fuel assemblies apiece, and 32 fuel boxes which contain a single fuel assembly.

6.6 Boiler shroud

The boiler shroud is approximately 0.25 inch thick and surrounds the boiler fuel elements, separating the boiler reactor core section from the steam separator region of the vessel. It provides a flow baffle from the upflow through the boiler core region, and the down flow of the steam separator region.

6.7 Boiler fuel element holddown structure

The boiler fuel element holddown structure provides alignment of the boiler fuel assemblies, maintaining inter-assembly spacing for both fuel alignment and movement of the boiler control rods. The bottom of the holddown structure is an alignment grid to contain the fuel assemblies tops; the holddown structure also compresses the fuel assemblies lower nozzle springs, thereby providing both vertical and lateral alignment. The holddown structure also houses and provides alignment for the boiler control rod guide tubes.

6.8 Boiler CR guide tubes and remaining structure

This is basically the balance of the holddown structure above the lower fuel alignment grid; this section provides the rigidity necessary to compress the boiler fuel element lower nozzle springs and maintain the fuel alignment, both vertically and laterally. There are 16 boiler control rod guide tubes integral with the holddown structure.

6.9 Boiler element poison shims

Each boiler element boiler fuel box has indentations on each of it's four sides for the addition of a poison shim for use during initial core startup for control of excess fuel reactivity. It is estimated that 40 poison shims are present in the Pathfinder vessel at this time.

6.10 Boiler control blades

There are 16 cruciform-shaped control blades for the boiler fuel. Each blade is manufactured from borated steel; for the purpose of the activation analysis the boron present in the steel was ignored. The control blades entered from the top of the reactor core.

The six-month operation summaries for Pathfinder indicate several different rod bank heights for the boiler control blades were used during the core physics testing. For the activation analysis, a uniform rod bank height of 36 inches (one half out of core) was used. The 36 inches within the core was irradiated at full core flux, each 30 cm segment above the core was irradiated at 10% of the lower layers value, i.e. 10%, 1%, and 0.1% of full core flux.

6.11 Instrumentation tubing and sample holders

Three 0.75 inch outside diameter stainless steel instrument tubes run from the bottom to the top of the reactor core; in addition there are 12 small and 3 large sample holders at the elevation of the core. Without further information these items were combined into one item and assumed irradiated at the full core flux.

6.12 Boiler grid plate

The boiler grid plate provides lateral alignment for the boiler fuel elements as well as providing support for the fuel elements. The grid plate consists of two separate plates connected by bored-out pipes which surround the fuel element lower nozzles.

6.13 Steam separators and support shelves

The steam separators lie outside the core region at the same elevation as the core. There are 44 separators, grouped in sets of three; these are individually supported by three steam separator support shelves attached to the reactor vessel wall. Suction at the bottom of the reactor vessel draws water through the steam separator lower nozzle, which in turn draws water horizontally through the inlet nozzle in the side of the steam separator. The swirling action of the water separates the entrained steam which exits out the top of the separator.

Portions of the steam separator nozzles failed towards the end of operation of the Pathfinder reactor; these pieces were collected for examination, then returned to the vessel prior to final closure at the end of life.

6.14 Feedwater ring and supports

The feedwater ring is located at the bottom of the reactor vessel, beneath the steam separator support shelves. It is a ring header, oval in cross-section, which is perforated with holes to allow feedwater to be introduced into the lower plenum of the vessel. There the water mixes with water drawn through the steam separators prior to removal by the recirculation pumps and re-injection into the boiler section of the reactor core.

6.15 Reactor vessel cladding

The one quarter inch thick vessel cladding is made of SA 240 Type 304L stainless steel. As in the vessel shell, the cladding runs the entire vertical length of the activation model.

6.16 Reactor vessel base metal

The three inch thick outer wall of the reactor vessel is manufactured of SA212 Grade B carbon steel; it runs the entire vertical length of the activation model. The lower head of the vessel actually would lie within the model; but for simplicity the curvature of the lower head has been ignored, and the walls assumed to continue as a cylindrical shell to the bottom of the model.

6.17 Gravel

The plant records indicate that approximately 66 cubic yards of pea gravel, weighing 214,000 pounds, were placed in the vessel after unloading of the fuel took place; this was done at the recommendation of the Atomic Energy Commission. The estimated void in the vessel after subtracting the volume occupied by the internals is approximately 75.6 cubic yards. This indicates an average packing fraction of approximately 87.3%. There will no doubt be local variations on this packing fraction. In addition, the void of 75.6 cubic yards does not consider the volume of piping beneath the vessel, and some of the gravel probably went through the core region and fell into these pipes.

7. ACTIVATION ANALYSIS RESULTS

7.1 Specific curie contents

The ORIGEN2 outputs provided the following curie per gram contents for the following regions and materials:

Region	Material	Ci/gram
Core (full flux)	304 SS	2.01E-4
Core (full flux)	Zirc-2	1.74E-6
Core (thermal flux)	304 SS	2.94E-5
Boiler Shroud	304 SS	2.48E-4*
Steam Separators	304 SS	5.66E-6
Vessel cladding	304 SS	1.09E-6
Vessel wall (average)	SA212 CS	7.54E-8

* The increase in the curie per gram value for the boiler shroud relative to the in-core values is the result of the conservative assumption that the neutron flux is totally thermalized at this point.

The specific curie content of any individual portion of any component, except the boiler core shroud, within the activation analysis model meets the current definition of LSA waste, i.e. less than 0.3 millicuries per gram. The boiler core shroud, due to the conservative assumption of full thermalization of the flux, exceeds 0.3 millicuries per gram for the section of the shroud immediately adjacent to the reactor core. If the upper and lower sections of the shroud, which are irradiated at 10% of the flux level of the core region, are weight averaged with the central portion, the average millicurie per gram decreases to 0.248, which then meets the definition of LSA waste.

7.2 Curie contents by component

The results of the neutron activation analysis is presented in Table 7.1, and shows the radionuclides by component.

The reactor vessel cladding may contain up to 0.8% niobium [10]. At this level, the amount of Nb^{94} present in the vessel cladding will be approximately 190 μCi. At a weight of approximately 4,240 pounds of stainless steel cladding in the activation analysis model, this equals a concentration of 0.00078 μCi Nb^{94} per cubic centimeter. The limit for Class A waste is 0.02 μCi Nb^{94} per cubic centimeter; therefore the concentration in the vessel cladding in the activation analysis model region alone is only 3.9% of the limit and will not present a problem for disposal.

TABLE 7.1

ESTIMATED RADIONUCLIDE INVENTORY IN THE REACTOR VESSEL AND INTERNALS AS OF JANUARY 1990

Component	H3	C14	Fe55	Co60	Ni59	Ni63	Nb94	Tc99	Eu152	Eu154	Others	Total Curies
Superheater baffle	0.08	0.03	4.58	34.40	0.19	21.97	***	***	0.02	***	***	61.3
Superheater fuel insul. tubes	0.15	0.06	8.77	65.92	0.35	42.11	***	***	0.05	***	***	117.4
Superheater support plate	***	***	***	***	***	***	***	***	***	***	***	<0.01
Superheater control rods	***	***	0.04	0.32	***	0.21	***	***	***	***	***	0.6
Boiler fuel boxes	0.01	0.03	0.84	7.19	0.04	4.35	***	***	***	***	0.86	13.3
Boiler shroud	0.15	0.06	9.59	51.61	0.39	46.84	***	***	***	***	0.01	108.6
Boiler hold down structure	0.01	***	0.61	4.58	0.02	2.93	***	***	***	***	***	8.1
Boiler CR tubes/remain. struct.	***	***	0.49	3.69	0.02	2.36	***	***	***	***	0.01	6.6
Boiler element poison shims	0.03	0.01	1.88	14.14	0.08	9.03	***	***	0.01	***	***	25.2
Boiler control blades	0.11	0.04	6.39	48.03	0.26	30.68	***	***	0.03	***	***	85.5
Instrumentation/sample holders	***	***	0.48	3.58	0.02	2.29	***	***	***	***	0.01	6.4
Boiler grid plate	0.04	0.02	2.52	18.96	0.10	12.11	***	***	0.01	***	***	33.8
[illegible] separators & supports	***	***	0.54	2.93	0.02	2.66	***	***	***	***	0.01	6.2
[illegible]ter ring & supports	***	***	0.15	0.83	***	0.75	***	***	***	***	0.01	1.7
Vessel cladding	***	***	0.06	0.34	***	0.31	***	***	***	***	***	0.7
Vessel	***	***	0.41	0.14	***	0.09	***	***	***	***	***	0.6
Total by isotope (curies)	0.59	0.25	37.36	256.66	1.49	178.68	<0.01	<0.01	0.13	<0.01	0.93	476.1
Percent of total by isotope	0.12%	0.05%	7.85%	53.91%	0.31%	37.53%	<0.01%	<0.01%	0.03%	<0.01%	0.19%	

8. PRIMARY SYSTEM SURFACE CONTAMINATION

8.1 Methodology

An estimate was prepared to determine the total amount of radioactivity present in the surface contamination ("crud") layer on the wetted area of the reactor vessel interior and internals. A surface area for the vessel interior was calculated using dimensioned drawings. The surface area for the vessel internals proved impossible to accurately determine with the available drawings. An assumption was made as to the average thickness of the internals structural components; using this, and with the calculated and/or stated weight of each internals component, the total surface area can be estimated.

8.2 Surface areas

Calculations were performed to determine the wetted internal surface area of the reactor vessel and internals. The total estimated interior surface area of the reactor vessel is approximately 660 square feet. Using the weights stated on the drawings provided by NSP for all internal components, an effective surface area for the internals was calculated. For an average thickness of one-quarter inch, the 44,600 pounds of the internals equates to approximately 8,660 square feet. The total of both areas, converted to square centimeters, yields an affected surface area of 8.67E+6 square centimeters.

8.3 Source terms

In 1980, Battelle Pacific Northwest Laboratories took samples throughout the Pathfinder Plant. There were three samples taken in the feedwater system; these were used as being representative of the type of interior contamination within the reactor vessel [3]. PNL data, when decayed to January 1, 1990, yields the following surface contamination levels:

Radionuclide	pCi/cm^2
Na22	<0.0077
Fe55	109
Ni59	15
Co60	5965
Ni63	4882
Nb94	<0.25
Ag108m	<0.09
Sb125	<0.01
Sn126	<0.06
Cs134	<0.002
Cs137	<0.06
Eu152	<0.2
Eu154	<0.45
Eu155	<0.04
Ho166m	<9.55
Ra228	<0.3
Pu238	<0.00093
Pu239	<0.0039

8.4 Results

Using the total surface areas for the wetted portion of the reactor vessel and internals, and the areal curie density of each radionuclide measured by Battelle, total curies for each radionuclide was determined.

Radionuclide	**Total curies**	**% of Total**
Fe55	9.45E-4	1.0
Ni59	1.30E-4	0.14
Co60	5.17E-2	54.4
Ni63	4.23E-2	44.5

All radionuclides with a total activity of less than 0.1 millicurie (i.e. <1.0E-4 curies) have been ignored. The total estimate of surface contamination radionuclides within the Pathfinder reactor vessel is 95 millicuries.

9. PATHFINDER VESSEL PACKAGE DOSE ESTIMATES

9.1 Method of Calculation

Using the total curies per component estimated with the Lotus 1-2-3 spreadsheet and the geometry of the internals, the dose rate was estimated for a point external to the vessel. Given the multiple layers of sources represented by the concentric nature of the internals arrangement in the Pathfinder vessel, many different runs were necessary, since each source is also a shield for other sources in the internals. All dose rate models used cylindrical sources with cylindrical shields.

In addition to the self-shielding and shielding provided by the internals components and vessel, the gravel added at shutdown serves as an effective shield. However, the density of the gravel undoubtedly varies throughout the region of the neutron activation model. With 66 cubic yards placed into a free void of 75.6 cubic yards, the average gravel packing factor is 87.3% of the theoretical maximum. The maximum density is estimated to be 120 pounds per cubic foot (1.92 grams per cubic centimeter), based upon 214,000 pounds weight of the 66 cubic yards. Since this is similar to the density and composition of concrete, the shielding parameters for concrete were used in the Microshield problems.

Two dose points were considered. The first was at 1 centimeter distance from the vessel outer wall at the core midplane. This determines the maximum contact dose rate and can be readily compared to the measured doses that NSP collected in May of 1989. The second dose point is on the same plane as the first, the core midplane, but is two meters from the edge of the shielded package. The package in this case includes the impact absorbing material and carbon steel shield which will surround the vessel for shipment. The impact absorbing material, together with any radiation shielding, will add approximately ten inches to the radius of the vessel package. This second dose point corresponds to the measuring point necessary to meet the U.S. Department of Transportation (US DOT) regulations.

In addition to the direct dose estimate from the core height region of the vessel internals and vessel wall, the regions above and below the core region are also neutron activated and must be considered in the dose rate. Calculations were performed which indicated, in the most conservative case (no shielding), that the total dose rate at two meters from the package side increased approximately 15% above the dose calculated for the core region. Rather than calculating a dose rate for each shield thickness for the regions above and below the core, the dose rate from the core midsection was increased by 15% to account for the contributions of the regions above and below the core.

See Table 9.1 for measured dose rates on the side of the Pathfinder vessel as of May 1989.

9.2 Results of Analysis

The unshielded dose rate at the core midplane on contact with reactor vessel, assuming a 75% gravel packing factor, is estimated by the activation analysis model to be approximately 254 mR per hour.

With the equivalent of two inches of steel shielding, and assuming a gravel packing factor of 75%, the external radiation exposure rate at the core midplane 2 meters from the exterior of the impact absorbing shell will be 6.8 mR per hour. The dose rate at 1 centimeter from the exterior of the impact absorbing shell (i.e. contact dose rate) at the core midplane will be 24.9 mR per hour. These dose estimates meet the US DOT requirements for external dose rates.

See Figure 9.1 for a depiction of vessel package radiation exposure rates versus the percentage of gravel in the interior void spaces at 1 centimeter from the vessel outer wall. Figure 9.2 shows a depiction of the vessel package radiation exposure rates versus the percentage of gravel in the interior void spaces for three shield thicknesses, as well as unshielded, at a distance of 2 meters from the package.

9.3 Discussion

Given the uncertainties present as to the actual configuration of the gravel within the vessel interior, the best that can be stated about the results shown in section 9.2 is that the measured dose rates alongside the vessel exterior are reasonably close to those estimated with the assumption of 75% gravel packing factor (without external shielding). Since the lowest core midplane dose rate is on the east side of the vessel package and is approximately 40% less than the dose rate estimate of 254 mR per hour, one approach might be to use this as a bench mark and adjust all dose rates accordingly. This would compensate for the built-in conservatism in the activation analysis model. For the purpose of the shield design, this was not done, the recommended shielding thickness is based solely upon the ORIGEN2 activation analysis and Microshield dose model.

The shield thickness of two inches obviously runs the full length of the core region. The shield should also run five feet above and three feet below the core region as well. The five feet above will encompass the 100 mR per hour peak on the west side of the vessel, which occurs approximately 2 feet above the top of the core. With the five additional feet of shielding above the core, all dose rates measured on the side of the vessel above this point meet US DOT limits. For the section below the core, the three foot length is based more upon mechanical considerations than dose limits, as the support feet for the vessel can serve as attachment points for the lower portion of the radiation shield. Based upon the dose readings in Table 9.1, a two foot length would be sufficient to meet US DOT radiation limits; but the three foot length will be easier to implement.

The hot spot shown on the northwest section of the vessel, as listed in Table 9.1 is probably a region of gravel with a packing factor lower than average. If this is the case, the grouting operation will almost certainly close this void region and lower the dose rates. Since the grouting will be performed prior to vessel lift, this will be determined prior to the loss of shielding around the vessel now presently provided by the bioshield. The grouting of the vessel will reduce the dose rate to that comparable for the remaining sections of the reactor vessel package at the same elevation.

The decommissioning crew should be prepared for the possibility that the dose rates will be greater than those estimated to be present with the recommended two inches of steel shielding. If this occurs it is likely to be on a limited basis, most probably one or two small areas. Additional steel shielding will then have to be used to further reduce the radiation levels to meet 10 mR/hour at 2 meters from the package.

9.4 Recommendations

The project should plan for the fabrication and use of a two inch thick steel shield surrounding the reactor vessel, starting at three feet below the bottom of the core, and ending five feet above the top of the core. The two inch thickness can include any additional steel to be placed around these regions, such as the impact absorbing material.

The vessel interior should be grouted to reduce the possibility of voids or "windows," which would allow excessive radiation leakage.

If the opportunity occurs, additional characterization would be invaluable in reducing the uncertainties with this hot-spot region on the northwest side of the vessel. Detailed geometry studies would help assess the extent of void assumed to be present.

TABLE 9.1

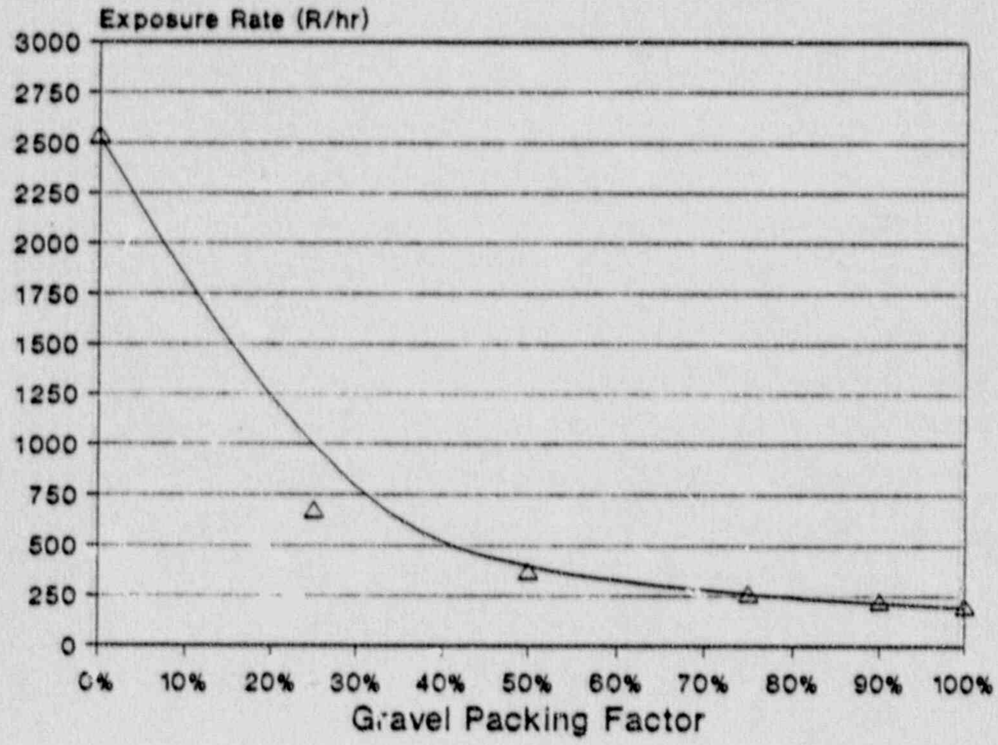
PATHFINDER MEASURED RADIATION LEVELS
AS OF MAY 1989

Elevation (MSL)	South mR/hr	West mR/hr	North mR/hr	East mR/hr
1285	1.75	2	5	1.8
1286	3	8	5	2.2
1287	9	27	20	7
1288	33	80	225	30
1289	90	175	450	150
1290	45	75	140	80
1291	17	85	35	22
1292	15	90	18	15
1293	9	95	10	10
1294	6	100	7	5
1295	3	75	3.8	3.2
1296	1.8	35	2.8	2
1297	1.5	8	2.2	1.5
1298	1.7	2.2	1.5	1.6
1299	1.7	1.2	1.5	.9
1300	.5	.7	.8	.5
1301	.3	.7	.5	.4
1302	.3	1.5	.25	.25
1303	--	3	.3	1.8
1304	--	7	--	--
1305	--	.2	--	--

The highest observed dose rate was 600 mR/hour at elevation 1289.5 elevation, on the north-west side of the vessel.

FIGURE 9.1

PATHFINDER VESSEL PACKAGE
GRAVEL PACKING % vs EXPOSURE RATE
CONTACT DOSE

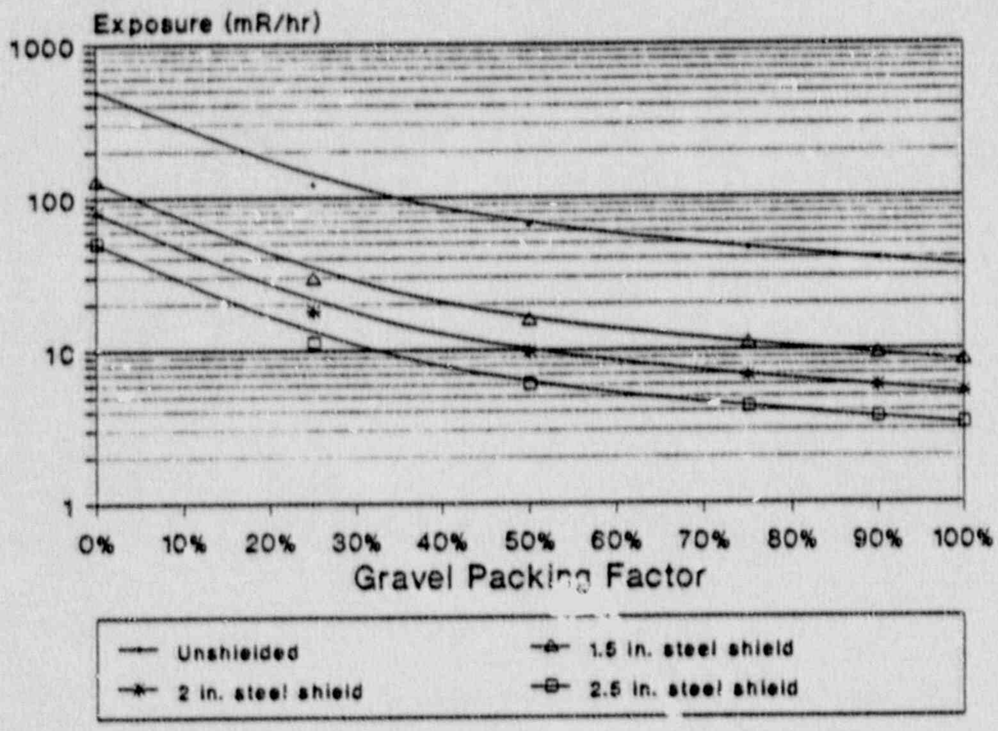


Shield Thickness	Gravel Packing Factor, %					
	0	25	50	75	90	100
Dose rate (mR/hr)	2529	665.6	364.4	253.5	214.3	194.3

Dose rate is measured at a point 1 centimeter from the vessel outer surface directly adjacent with the reactor core midplane.

FIGURE 9.2

PATHFINDER VESSEL PACKAGE
GRAVEL PACKING % vs EXPOSURE RATE
DOSE AT 2 METERS



Shield Thickness	0	25	50	75	90	100
			Gravel Packing Factor, %			
Dose rate (mR/hr)						
0.0 inch	498.2	120.2	65.49	45.98	39.08	35.56
1.5 inch	128.1	29.04	15.73	11.03	9.377	8.54
2.0 inch	80.18	18.04	9.768	6.845	5.825	5.303
2.5 inch	49.97	11.16	6.041	4.234	3.603	3.282

Dose rate is measured at a point 2 meters from the vessel package directly adjacent with the reactor core midplane. Values include an additional 15% for the portions of the activated reactor core above and below the active fuel section.

10. REFERENCES

1. ORNL/TM-7175, "A User's Manual For The ORIGEN2 Computer Code", Croff, A.G., Oak Ridge National Laboratory, July 1980.

2. Part Number 12020, "Reference Manual", Software Version 2.01, Lotus Development Corporation, Cambridge, MA 1985.

3. PNL-4326, "Residual Radionuclide Distribution and Inventory at the Pathfinder Generating Plant", Robertson, D.E., et. al., Table 3.2, Pacific Northwest Laboratory, June 1982.

4. Microshield 3 Reference Manual, Software Version 3.12, Grove Engineering, Inc. Rockville, MD 1988.

5. NSP 6801, "Pathfinder Atomic Power Plant - Six Month Operating Report No. 4 - Nov. 19, 1967 to May 19, 1968", Northern States Power Company, June 1968.

6. ACNP-5905, "Pathfinder Atomic Power Plant - Safeguards Report, Part II License Application." Northern States Power Company, October 1960.

7. Op. cit., ACNP-5905, Figure 4.4.

8. Letter NSLTG-89-110, Kuroyama to LaGuardia dated September 1, 1989, with attachment Page iii of ACNP-5905, "Pathfinder Atomic Power Plant - Safeguards Report, Part II License Application." Northern States Power Company, January 1962.

9. NUREG/CR-3474, "Long-Lived Activation Products in Reactor Materials", Evans, J.C., Pacific Northwest Laboratory, August 1984.

10. ACNP-62025, "Pathfinder Atomic Power Plant - Reactor Vessel Materials, Fabrication and Inspection", Patterson,J F. and Potochnik, J.F., Page A-147, Allis-Chalmers Manufacturing Company, December 1, 1962.

11. PNL-6046, "Spent Fuel Disassembly Hardware and Other Non-Fuel Bearing Components: Characterization, Disposal Cost Estimates, and Proposed Repository Acceptance Requirements", Luksic, A.T., et. al., Pacific Northwest Laboratory, October 1986.

APPENDIX A

ORIGEN2 INPUT AND OUTPUT DESCRIPTION

APPENDIX A

ORIGEN2 INPUT AND OUTPUT DESCRIPTION

The calculation of neutron-induced activity in the Pathfinder pressure vessel and internals was performed using a PC version of the point neutron activation and depletion code ORIGEN2. This version of the code was originally obtained from the Oak Ridge National Laboratory (ORNL) as ORIGEN2-PC Version 1.00, and recompiled under Microsoft's FORTRAN 4.01 optimizing compiler. After recompilation, the code was verified using the sample problem given in the ORNL-provided manual.

Some of the problem-specific data required as input for ORIGEN2 include the following:

1. Material compositions.
2. Neutron flux exposure histogram.
3. Total neutron flux (or specific power level).
4. One-group neutron cross-section libraries, decay libraries and photon libraries.

Material compositions for the materials analyzed in this activation analysis were taken from the available literature. Material certifications for the Pathfinder reactor vessel and internals were unavailable and/or did not contain trace element data.

Based upon plant data, the Pathfinder plant operated for 16,635 MWd (thermal). Some discrepancies were encountered in the review of plant data regarding the plant's thermal output at 100% rated power. Early plant documents indicate a core design thermal output of 190 MWt, and a core design flux of 5.0 E+13 neutrons/cm^2-sec. However, subsequent correspondence stated a thermal output of 199.6 MWt, and a design flux of 3.5 E+13 neutrons/cm^2-sec over the life of the plant.

For input files used to analyze the activation of materials in the reactor core and at the reactor core boundary, a core average total flux of 5.0 E+13 was used. After verification of the actual average core flux from the Pathfinder staff, the results generated by ORIGEN2 were scaled linearly down to correspond to the 3.5 E+13 level, for the core and core boundary regions. This scaling was performed in the Lotus 1-2-3 spreadsheet, as given in Appendix B. All fluxes beyond the core boundary were used as given in the Pathfinder plant documents.

The total exposure (16,635 MWd) was used to provide the exposure time input necessary for ORIGEN2. To calculate the total effective full power days, the core design thermal output value of 190 MWt was used. This provided a conservative result of 87.6 effective full power days. Additionally, it was conservatively assumed that all of this exposure occurred immediately prior to plant shutdown.

The ORIGEN2 libraries were used as the source of neutron cross sections, photon information and decay data. For all calculations of neutron activation inside the reactor core, the ORIGEN2 BWR-U neutron cross section library was employed. For calculations of neutron activation outside the reactor core, the ORIGEN2 thermal library was used. The decay library used was the ORIGEN2-provided library. The H_2O bremsstrahlung photon library was used; however, the choice of photon libraries has no impact on the results of concern in this analysis.

Figure A-1 contains a sample input file, and Figure A-2 a portion of the output file for the activation of stainless steel at the core boundary. This problem required a material composition for stainless steel and the thermal neutron cross section library as input.

FIGURE A-1
ORIGEN2 SAMPLE INPUT

```
  -1
  -1
  -1
*
*    CALCULATION OF ACTIVATION AND DEPLETION IN THE PATHFINDER ATOMIC POWER
*    PLANT INTERNALS, VESSEL, AND BIOLOGICAL SHIELD.
*
*    THE PATHFINDER ATOMIC POWER PLANT HAD ITS INITIAL CRITICALITY ON
*    MARCH 24, 1964.  THE PLANT'S FINAL SHUTDOWN OCCURRED, DUE TO A CONDENSER
*    TUBE FAILURE, ON SEPTEMBER 16, 1967.  THE TOTAL CORE BURNUP AT THAT TIME
*    WAS 16635 MWD.  THE CORE DESIGN POWER IS 190 MWt.  SINCE MOST OF THE
*    POWER OPERATION OCCURRED AT THE END OF THE PLANT'S LIFE, WE WILL
*    CONSERVATIVELY ASSUME THE PLANT OPERATED AT 100% POWER FOR 87.553 DAYS,
*    UNTIL SEPTEMBER 16, 1964.
*
*    USE DEFAULT FRACTIONAL RECOVERY VALUES, AS GIVEN BY FIRST THREE
*    RECORDS OF THIS FILE.
*
*    PROVIDE A TITLE FOR THE PROBLEM.
*
 TIT    PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*
*    STORAGE VECTOR DEFINITIONS.
*
*         -1 = STAINLESS STEEL.
*
*    READ THERMAL CROSS SECTION LIBRARY AND PUT DATA ON UNIT 9.
*
 LIB    0  1  2  3  201  202  203  9  0  0  1  0
*
*    READ H2O-BREMSSTRAHLUNG PHOTON LIBRARY.  PUT DATA ON UNIT 10.
*
 PHO    101  102  103  10
*
*    READ STAINLESS STEEL COMPOSITION.
*
 INP    -1  1  4*0
*
*              $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*              $                                                  $
*              $    ACTIVATION AND DEPLETION CALCULATION.         $
*              $                                                  $
*              $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

FIGURE A-1

ORIGEN2 SAMPLE INPUT
(CONTINUED)

```
*
*   PREPARE FOR ACTIVATION.
*
BAS    THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
*
*   MOVE MATERIAL COMPOSITION TO OUTPUT VECTOR 1.
*
MOV    -1  1  0  1.0
*
*   FLUX EXPOSURE OF MATERIAL OF INTEREST.
*
BUP
IRF     87.553  5.0GE13  1  2  4  2
BUP
*
*           $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*           $                                          $
*           $    DECAY OF THE IRRADIATED MATERIAL.     $
*           $                                          $
*           $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*
*   PREPARE FOR THE DECAY CALCULATION.
*
*   DECAY THE ACTIVATED MATERIAL OF INTEREST OUT TO JUNE 1, 1989.
*
DEC    7929.0  2  3  4  1
*
*   PROVIDE HEADINGS FOR THE COLUMNS.
*
HED    1  *  STARTUP
HED    2  * SHUTDOWN
HED    3  *1-JUN-1989
*
*   PRINT THE NUCLIDE AND CURIE TABLES ONLY, IN GRAMS, FOR THE MATERIAL
*   OF INTEREST.
*
OPTL    6*8  5  17*8
OPTA   24*8
OPTF   24*8
OUT    3  1  0  0
END
```

FIGURE A-1

ORIGEN2 SAMPLE INPUT
(CONTINUED)

```
*
*    MATERIAL COMPOSITION.
*
  4  030000  1.30E-7  070000  4.52E-4  110000  9.70E-6  130000  1.00E-4
  4  170000  7.00E-5  190000  3.00E-6  200000  1.90E-5  210000  3.00E-8
  4  220000  6.00E-4  230000  4.56E-4  240000  1.84E-1  250000  1.53E-2
  4  260000  7.06E-1  270000  1.41E-3  280000  1.00E-1  290000  3.08E-3
  4  300000  4.57E-4  310000  1.29E-4  330000  1.94E-4  340000  3.50E-5
  4  350000  2.00E-6  370000  1.00E-5  380000  2.00E-7  390000  5.00E-6
  4  400000  1.00E-5  410000  8.90E-5  420000  2.60E-2  470000  2.00E-6
  4  510000  1.23E-5  550000  3.00E-7  560000  5.00E-4  570000  2.00E-7
  4  580000  3.71E-4  620000  1.00E-7  630000  2.00E-8  650000  4.70E-7
  4  660000  1.00E-6  670000  1.00E-6  700000  2.00E-6  710000  8.00E-7
  4  720000  2.00E-6  740000  1.86E-4  820000  6.70E-5  900000  1.00E-6
  4  920000  2.00E-6  0        0.0
  0
```

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT

1 OUTPUT UNIT = 6 PAGE 13

PATHFINDER ACTIVATION ANALYSIS. CURIES PER GRAM OF MATERIAL.

ACTIVATION PRODUCTS

POWER= 0.00000E+00 MW, BURNUP= 0.00000E+00 MWD, FLUX= 5.00E+13 N/CM**2-SEC

0 7 NUCLIDE TABLE: RADIOACTIVITY, CURIES

THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.

	STARTUP	SHUTDOWN	1-JUN-1989
H 1	0.000E+00	0.000E+00	0.000E+00
H 2	0.000E+00	0.000E+00	0.000E+00
H 3	0.000E+00	1.215E-05	3.593E-06
H 4	0.000E+00	2.050E-12	0.000E+00
HE 3	0.000E+00	0.000E+00	0.000E+00
HE 4	0.000E+00	0.000E+00	0.000E+00
HE 6	0.000E+00	0.000E+00	0.000E+00
LI 6	0.000E+00	0.000E+00	0.000E+00
LI 7	0.000E+00	0.000E+00	0.000E+00
LI 8	0.000E+00	5.231E-07	0.000E+00
BE 8	0.000E+00	5.231E-07	0.000E+00
BE 9	0.000E+00	0.000E+00	0.000E+00
BE 10	0.000E+00	0.000E+00	0.000E+00
BE 11	0.000E+00	0.000E+00	0.000E+00
B 10	0.000E+00	0.000E+00	0.000E+00
B 11	0.000E+00	0.000E+00	0.000E+00
B 12	0.000E+00	0.000E+00	0.000E+00
C 12	0.000E+00	0.000E+00	0.000E+00
C 13	0.000E+00	0.000E+00	0.000E+00
C 14	0.000E+00	1.374E-06	1.370E-06
C 15	0.000E+00	1.792E-11	0.000E+00
N 13	0.000E+00	0.000E+00	0.000E+00
N 14	0.000E+00	0.000E+00	0.000E+00
N 15	0.000E+00	0.000E+00	0.000E+00
N 16	0.000E+00	2.326E-09	0.000E+00
O 16	0.000E+00	0.000E+00	0.000E+00
O 17	0.000E+00	0.000E+00	0.000E+00
O 18	0.000E+00	0.000E+00	0.000E+00
O 19	0.000E+00	0.000E+00	0.000E+00
F 19	0.000E+00	0.000E+00	0.000E+00
F 20	0.000E+00	0.000E+00	0.000E+00
NE 20	0.000E+00	0.000E+00	0.000E+00
NE 21	0.000E+00	0.000E+00	0.000E+00
NE 22	0.000E+00	0.000E+00	0.000E+00
NE 23	0.000E+00	0.000E+00	0.000E+00
NA 22	0.000E+00	0.000E+00	0.000E+00
NA 23	0.000E+00	0.000E+00	0.000E+00
NA 24	0.000E+00	1.819E-04	0.000E+00
NA 24M	0.000E+00	1.373E-04	0.000E+00
NA 25	0.000E+00	0.000E+00	0.000E+00
MG 24	0.000E+00	0.000E+00	0.000E+00
MG 25	0.000E+00	0.000E+00	0.000E+00
MG 26	0.000E+00	0.000E+00	0.000E+00
MG 27	0.000E+00	5.807E-19	0.000E+00
MG 28	0.000E+00	9.512E-28	0.000E+00
AL 27	0.000E+00	0.000E+00	0.000E+00
AL 28	0.000E+00	6.935E-04	0.000E+00
AL 29	0.000E+00	0.000E+00	0.000E+00
AL 30	0.000E+00	0.000E+00	0.000E+00
SI 28	0.000E+00	0.000E+00	0.000E+00
SI 29	0.000E+00	0.000E+00	0.000E+00
SI 30	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

```
1                                                              OUTPUT UNIT = 6                       PAGE   14

   * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                          ACTIVATION PRODUCTS
   POWER= 0.00000E+00 MW.  BURNUP= 0.00000E+00 MWD.  FLUX= 5.00E+13 N/CM**2-SEC
0                  7 NUCLIDE TABLE:  RADIOACTIVITY, CURIES
                            THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
```

	STARTUP	SHUTDOWN	1-JUN-1989
SI 31	0.000E+00	3.186E-17	0.000E+00
SI 32	0.000E+00	0.000E+00	0.000E+00
P 31	0.000E+00	0.000E+00	0.000E+00
P 32	0.000E+00	9.270E-08	0.000E+00
P 33	0.000E+00	2.186E-18	0.000E+00
P 34	0.000E+00	0.000E+00	0.000E+00
S 32	0.000E+00	0.000E+00	0.000E+00
S 33	0.000E+00	0.000E+00	0.000E+00
S 34	0.000E+00	0.000E+00	0.000E+00
S 35	0.000E+00	2.952E-04	0.000E+00
S 36	0.000E+00	0.000E+00	0.000E+00
S 37	0.000E+00	3.076E-11	0.000E+00
CL 35	0.000E+00	0.000E+00	0.000E+00
CL 36	0.000E+00	2.859E-08	2.859E-08
CL 37	0.000E+00	0.000E+00	0.000E+00
CL 38	0.000E+00	1.665E-04	0.000E+00
CL 38M	0.000E+00	1.946E-06	0.000E+00
AR 36	0.000E+00	0.000E+00	0.000E+00
AR 37	0.000E+00	7.677E-07	0.000E+00
AR 38	0.000E+00	0.000E+00	0.000E+00
AR 39	0.000E+00	1.444E-11	1.365E-11
AR 40	0.000E+00	0.000E+00	0.000E+00
AR 41	0.000E+00	3.221E-11	0.000E+00
AR 42	0.000E+00	1.430E-20	9.267E-21
K 39	0.000E+00	0.000E+00	0.000E+00
K 40	2.571E-15	1.724E-14	1.724E-14
K 41	0.000E+00	0.000E+00	0.000E+00
K 42	0.000E+00	6.129E-06	9.267E-21
K 43	0.000E+00	0.000E+00	0.000E+00
K 44	0.000E+00	0.000E+00	0.000E+00
CA 40	0.000E+00	0.000E+00	0.000E+00
CA 41	0.000E+00	3.067E-10	3.066E-10
CA 42	0.000E+00	0.000E+00	0.000E+00
CA 43	0.000E+00	0.000E+00	0.000E+00
CA 44	0.000E+00	0.000E+00	0.000E+00
CA 45	0.000E+00	2.505E-06	5.652E-21
CA 46	0.000E+00	0.000E+00	0.000E+00
CA 47	0.000E+00	9.445E-09	0.000E+00
CA 48	0.000E+00	0.000E+00	0.000E+00
CA 49	0.000E+00	8.056E-07	0.000E+00
SC 45	0.000E+00	0.000E+00	0.000E+00
SC 46	0.000E+00	7.363E-06	0.000E+00
SC 46M	0.000E+00	5.164E-06	0.000E+00
SC 47	0.000E+00	4.021E-08	0.000E+00
SC 48	0.000E+00	0.000E+00	0.000E+00
SC 49	0.000E+00	8.056E-07	0.000E+00
SC 50	0.000E+00	0.000E+00	0.000E+00
TI 46	0.000E+00	0.000E+00	0.000E+00
TI 47	0.000E+00	0.000E+00	0.000E+00
TI 48	0.000E+00	0.000E+00	0.000E+00
TI 49	0.000E+00	0.000E+00	0.000E+00
TI 50	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

```
1                                                              OUTPUT UNIT = 6                         PAGE  15

    * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                ACTIVATION PRODUCTS
    POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
0                   7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                              THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
```

	STARTUP	SHUTDOWN	1-JUN-1989
TI 51	0.000E+00	9.496E-05	0.000E+00
V 49	0.000E+00	0.000E+00	0.000E+00
V 50	1.999E-19	1.946E-19	1.946E-19
V 51	0.000E+00	0.000E+00	0.000E+00
V 52	0.000E+00	3.755E-02	0.000E+00
V 53	0.000E+00	0.000E+00	0.000E+00
V 54	0.000E+00	0.000E+00	0.000E+00
CR 50	0.000E+00	0.000E+00	0.000E+00
CR 51	0.000E+00	1.760E+00	0.000E+00
CR 52	0.000E+00	0.000E+00	0.000E+00
CR 53	0.000E+00	0.000E+00	0.000E+00
CR 54	0.000E+00	0.000E+00	0.000E+00
CR 55	0.000E+00	2.512E-02	0.000E+00
MN 54	0.000E+00	0.000E+00	0.000E+00
MN 55	0.000E+00	0.000E+00	0.000E+00
MN 56	0.000E+00	2.997E+00	0.000E+00
MN 57	0.000E+00	0.000E+00	0.000E+00
MN 58	0.000E+00	0.000E+00	0.000E+00
FE 54	0.000E+00	0.000E+00	0.000E+00
FE 55	0.000E+00	8.320E-02	2.550E-04
FE 56	0.000E+00	0.000E+00	0.000E+00
FE 57	0.000E+00	0.000E+00	0.000E+00
FE 58	0.000E+00	0.000E+00	0.000E+00
FE 59	0.000E+00	2.549E-02	0.000E+00
CO 58M	0.000E+00	0.000E+00	0.000E+00
CO 58	0.000E+00	0.000E+00	0.000E+00
CO 59	0.000E+00	0.000E+00	0.000E+00
CO 60	0.000E+00	2.215E-02	1.274E-03
CO 60M	0.000E+00	3.838E-01	0.000E+00
CO 61	0.000E+00	5.324E-04	0.000E+00
CO 62	0.000E+00	0.000E+00	0.000E+00
NI 58	0.000E+00	0.000E+00	0.000E+00
NI 59	0.000E+00	8.855E-06	8.853E-06
NI 60	0.000E+00	0.000E+00	0.000E+00
NI 61	0.000E+00	0.000E+00	0.000E+00
NI 62	0.000E+00	0.000E+00	0.000E+00
NI 63	0.000E+00	1.266E-03	1.075E-03
NI 64	0.000E+00	0.000E+00	0.000E+00
NI 65	0.000E+00	1.862E-02	0.000E+00
NI 66	0.000E+00	2.993E-07	0.000E+00
CU 62	0.000E+00	0.000E+00	0.000E+00
CU 63	0.000E+00	0.000E+00	0.000E+00
CU 64	0.000E+00	1.225E-01	0.000E+00
CU 65	0.000E+00	0.000E+00	0.000E+00
CU 66	0.000E+00	2.834E-02	0.000E+00
CU 67	0.000E+00	7.849E-08	0.000E+00
ZN 63	0.000E+00	0.000E+00	0.000E+00
ZN 64	0.000E+00	0.000E+00	0.000E+00
ZN 65	0.000E+00	4.761E-04	7.763E-14
ZN 66	0.000E+00	0.000E+00	0.000E+00
ZN 67	0.000E+00	0.000E+00	0.000E+00
ZN 68	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

1 OUTPUT UNIT = 6 PAGE 16

* PATHFINDER ACTIVATION ANALYSIS. CURIES PER GRAM OF MATERIAL.

* ACTIVATION PRODUCTS

POWER= 0.00000E+00 MW, BURNUP= 0.00000E+00 MWD, FLUX= 5.00E+13 N/CM**2-SEC

0 7 NUCLIDE TABLE: RADIOACTIVITY, CURIES

THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINL?SS STEEL.

	STARTUP	SHUTDOWN	1-JUL-1989
ZN 69	0.000E+00	1.144E-03	0.000E+00
ZN 69M	0.000E+00	7.690E-05	0.000E+00
ZN 70	0.000E+00	0.000E+00	0.000E+00
ZN 71	0.000E+00	2.925E-06	0.000E+00
ZN 71M	0.000E+00	3.066E-07	0.000E+00
GA 69	0.000E+00	0.000E+00	0.000E+00
GA 70	0.000E+00	1.519E-03	0.000E+00
GA 71	0.000E+00	0.000E+00	0.000E+00
GA 72	0.000E+00	2.913E-03	0.000E+00
GA 72M	0.000E+00	9.001E-05	0.000E+00
GE 70	0.000E+00	0.000E+00	0.000E+00
GE 71	0.000E+00	1.589E-06	0.000E+00
GE 71M	0.000E+00	1.607E-07	0.000E+00
GE 72	0.000E+00	0.000E+00	0.000E+00
GE 73	0.000E+00	0.000E+00	0.000E+00
GE 74	0.000E+00	0.000E+00	0.000E+00
GE 75	0.000E+00	1.464E-13	0.000E+00
GE 75M	0.000E+00	5.467E-14	0.000E+00
GE 76	0.000E+00	0.000E+00	0.000E+00
GE 77	0.000E+00	0.000E+00	0.000E+00
GE 77M	0.000E+00	0.000E+00	0.000E+00
AS 75	0.000E+00	0.000E+00	0.000E+00
AS 76	0.000E+00	9.041E-03	0.000E+00
AS 77	0.000E+00	0.000E+00	0.000E+00
SE 74	0.000E+00	0.000E+00	0.000E+00
SE 75	0.000E+00	6.387E-05	7.588E-25
SE 76	0.000E+00	0.000E+00	0.000E+00
SE 77	0.000E+00	0.000E+00	0.000E+00
SE 77M	0.000E+00	7.312E-04	0.000E+00
SE 78	0.000E+00	0.000E+00	0.000E+00
SE 79	0.000E+00	8.679E-11	8.677E-11
SE 79M	0.000E+00	2.809E-05	0.000E+00
SE 80	0.000E+00	0.000E+00	0.000E+00
SE 81	0.000E+00	1.094E-04	0.000E+00
SE 81M	0.000E+00	1.435E-05	0.000E+00
SE 82	0.000E+00	0.000E+00	0.000E+00
SE 83	0.000E+00	1.293E-06	0.000E+00
SE 83M	0.000E+00	1.924E-07	0.000E+00
BR 79	0.000E+00	0.000E+00	0.000E+00
BR 80	0.000E+00	1.141E-04	0.000E+00
BR 80M	0.000E+00	2.672E-05	0.000E+00
BR 81	0.000E+00	0.000E+00	0.000E+00
BR 82	0.000E+00	2.650E-03	0.000E+00
BR 82M	0.000E+00	2.447E-05	0.000E+00
BR 83	0.000E+00	1.485E-06	0.000E+00
KR 78	0.000E+00	0.000E+00	0.000E+00
KR 79	0.000E+00	0.000E+00	0.000E+00
KR 79M	0.000E+00	0.000E+00	0.000E+00
KR 80	0.000E+00	0.000E+00	0.000E+00
KR 81	0.000E+00	2.194E-13	2.193E-13
KR 81M	0.000E+00	1.798E-07	0.000E+00
KR 82	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

```
1                                                          OUTPUT UNIT = 6                         PAGE   17
    * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                   ACTIVATION PRODUCTS
    POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
0                      7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                                 THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
              STARTUP   SHUTDOWN  1-JUN-1989
 KR 83       0.000E+00 0.000E+00 0.000E+00
 KR 83M      0.000E+00 1.663E-06 0.000E+00
 KR 84       0.000E+00 0.000E+00 0.000E+00
 KR 85       0.000E+00 7.012E-15 1.728E-15
 KR 85M      0.000E+00 2.047E-12 0.000E+00
 KR 86       0.0[illegible]E+00 0.000E+00 0.000E+00
 KR 87       0.000E+00 1.597E-21 0.000E+00
 KR 88       0.000E+00 3.164E-25 0.000E+00
 RB 85       0.000E+00 0.000E+00 0.000E+00
 RB 86       0.000E+00 3.037E-05 0.000E+00
 RB 86M      0.000E+00 3.433E-06 0.000E+00
 RB 87       2.477E-13 2.477E-13 2.477E-13
 RB 88       0.000E+00 3.178E-06 0.000E+00
 RB 89       0.000E+00 2.448E-13 0.000E+00
 SR 84       0.000E+00 0.000E+00 0.000E+00
 SR 85       0.000E+00 4.628E-09 0.000E+00
 SR 85M      0.000E+00 5.716E-09 0.000E+00
 SR 86       0.000E+00 0.000E+00 0.000E+00
 SR 87       0.000E+00 0.000E+00 0.000E+00
 SR 87M      0.000E+00 1.605E-07 0.000E+00
 SR 88       0.000E+00 0.000E+00 0.000E+00
 SR 89       0.000E+00 6.224E-09 0.00[illegible]E+00
 SR 90       0.000E+00 2.799E-15 1.670E-15
 SR 91       0.000E+00 1.670E-16 0.000E+00
 SR 93       0.000E+00 0.000E+00 0.000E+00
  Y 89       0.000E+00 0.000E+00 0.0[illegible]E+00
  Y 89M      0.000E+00 0.000E+00 0.000E+00
  Y 90       0.000E+00 5.851E-05 1.[illegible]E-15
  Y 90M      0.000E+00 4.572E-08 0.[illegible]E+00
  Y 91       0.000E+00 3.901E-09 0.000E+00
  Y 92       0.000E+00 1.992E-12 0.000E+00
  Y 93       0.000E[illegible]00 0.000E+00 0.000E+00
  Y 94       0.000E+00 0.000E+00 0.000E+00
  Y 96       0.000E+00 0.000E+00 0.000E+00
 ZR 89       0.000E+00 0.000E+00 0.000E+00
 ZR 90       0.000E+00 0.000E+00 0.000E+00
 ZR 91       0.000E+00 0.000E+00 0.000E+00
 ZR 92       0.000E+00 0.000E+00 0.000E+00
 ZR 93       0.000E+00 4.303E-13 4.303E-13
 ZR 94       0.000E+00 0.000E+00 0.000E+00
 ZR 95       0.000E+00 5.322E-07 0.000E+00
 ZR 96       0.000E+00 0.000E+00 0.000E+00
 ZR 97       0.000E+00 4.244E-08 0.000E+00
 NB 91       0.000E+00 0.000E+00 0.000E+00
 NB 92       0.000E+00 0.000E+00 0.000E+00
 NB 93       0.000E+00 0.000E+00 0.000E+00
 NB 93M      0.000E+00 2.447E-15 2.744E-13
 NB 94       0.000E+00 7.312E-09 7.306E-09
 NB 95       0.000E+00 2.717E-06 0.000E+00
 NB 95M      0.000E+00 3.726E-04 0.000E+00
 NB 96       0.000E+00 4.167E-09 0.000E+00
 NB 97       0.000E+00 4.244E-08 0.000E+00
```

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

```
1                                                          OUTPUT UNIT = 6                    PAGE   18

    * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
 *                                                                         ACTIVATION PRODUCTS
    POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
 0                      7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                               THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
                 STARTUP   SHUTDOWN  1-JUN-1989
  NB 97M      0.000E+00 4.016E-06 0.000E+00
  NB 98       0.000E+00 0.000E+00 0.000E+00
  NB100       0.000E+00 0.000E+00 0.000E+00
  MO 92       0.000E+00 0.000E+00 0.000E+00
  MO 93M      0.000E+00 3.957E-0[illegible] 0.000E+00
  MO 93       0.000E+00 7.898E-0[illegible] 7.866E-06
  MO 94       0.000E+00 0.000E+00 0.000E+00
  MO 95       0.000E+00 0.000E+00 0.000E+00
  MO 96       0.000E+00 0.000E+00 0.[illegible]E+00
  MO 97       0.000E+00 0.000E+00 0.000E+00
  MO 98       0.000E+00 0.000E+00 0.000E+00
  MO 99       0.000E+00 6.9[illegible]8E-03 1.000E+00
  MO100       0.000E+00 0.000E+00 [illegible].000E+00
  MO101       0.000E+00 4.211E-0[illegible] [illegible].000E+00
  TC 97       0.000E+00 0.000E+00 [illegible].000E+00
  TC 97M      0.000E+00 0.000E+00 0.000E+00
  TC 98       0.000E+00 0.000E+00 0.000E+00
  TC 99       0.000E+00 6.381E-10 6.685E-10
  TC100       0.000E+00 5.879E-06 0.000E+00
  TC101       0.000E+00 4.211E-03 0.000E+00
  RU 96       0.000E+00 0.000E+00 0.000E+00
  RU 97       0.000E+00 0.000E+00 0.000E+00
  RU 98       0.000E+00 0.000E+00 0.000E+00
  RU 99       0.000E+00 0.000E+00 0.000E+00
  RU100       0.000E+00 0.000E+00 0.000E+00
  RU101       0.000E+00 0.000E+00 0.000E+00
  RU102       0.000E+00 0.000E+00 0.000E+00
  RU103       0.000E+00 4.423E-10 0.000E+00
  RU104       0.000E+00 0.000E+00 0.000E+00
  RU105       0.000E+00 1.102E-19 0.000E+00
  RU106       0.000E+00 0.000E+00 0.000E+00
  RU107       0.000E+00 0.000E+00 0.000E+00
  RH102       0.000E+00 0.000E+00 0.000E+00
  RH103       0.000E+00 0.000E+00 0.000E+00
  RH104       0.000E+00 6.578E-13 0.000E+00
  RH104M      0.000E+00 4.820E-14 0.000E+00
  RH105       0.000E+00 7.977E-19 0.000E+00
  RH105M      0.000E+00 3.086E-20 0.000E+00
  RH106       0.000E+00 8.277E-20 0.000E+00
  RH106M      0.000E+00 3.443E-20 0.000E+00
  RH107       0.000E+00 0.000E+00 0.000E+00
  PD102       0.000E+00 0.000E+00 0.000E+00
  PD103       0.000E+00 0.000E+00 0.000E+00
  PD104       0.000E+00 0.000E+00 0.000E+00
  PD105       0.000E+00 0.000E+00 0.000E+00
  PD106       0.000E+00 0.000E+00 0.000E+00
  PD107       0.000E+00 0.000E+00 0.000E+00
  PD107M      0.000E+00 0.000E+00 0.000E+00
  PD108       0.000E+00 0.000E+00 0.000E+00
  PD109       0.000E+00 2.878E-04 0.000E+00
  PD109M      0.000E+00 4.721E-10 0.000E+00
  PD110       0.000E+00 0.000E+00 0.000E+00
```

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

```
1                                                        OUTPUT UNIT = 6                          PAGE   19
    * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                    ACTIVATION PRODUCTS
    POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
0                    7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                          THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
```

	STARTUP	SHUTDOWN	1-JUN-1989
PD111	0.000E+00	1.540E-10	0.000E+00
PD111M	0.000E+00	1.442E-11	0.000E+00
AG106	0.000E+00	0.000E+00	0.000E+00
AG107	0.000E+00	0.000E+00	0.000E+00
AG108	0.000E+00	2.636E-04	2.405E-09
AG108M	0.000E+00	3.042E-08	2.702E-08
AG109	0.000E+00	0.000E+00	0.000E+00
AG109M	0.000E+00	3.503E-08	4.491E-14
AG110	0.000E+00	6.242E-04	2.507E-17
AG110M	0.000E+00	6.718E-06	1.885E-15
AG111	0.000E+00	1.716E-06	0.000E+00
AG111M	0.000E+00	8.581E-07	0.000E+00
AG112	0.000E+00	7.390E-10	0.000E+00
CD106	0.000E+00	0.000E+00	0.000E+00
CD107	0.000E+00	0.000E+00	0.000E+00
CD108	0.000E+00	0.000E+00	0.000E+00
CD109	0.000E+00	6.258E-09	4.491E-14
CD110	0.000E+00	0.000E+00	0.000E+00
CD111	0.000E+00	0.000E+00	0.000E+00
CD111M	0.000E+00	2.406E-08	0.000E+00
CD112	0.000E+00	0.000E+00	0.000E+00
CD113	0.000E+00	0.000E+00	0.000E+00
CD114	0.000E+00	0.000E+00	0.000E+00
CD115	0.000E+00	1.395E-16	0.000E+00
CD115M	0.000E+00	3.422E-18	0.000E+00
CD116	0.000E+00	0.000E+00	0.000E+00
CD117	0.000E+00	0.000E+00	0.000E+00
CD117M	0.000E+00	0.000E+00	0.000E+00
CD119	0.000E+00	0.000E+00	0.000E+00
CD121	0.000E+00	0.000E+00	0.000E+00
IN113	0.000E+00	0.000E+00	0.000E+00
IN113M	0.000E+00	0.000E+00	0.000E+00
IN114	0.000E+00	0.000E+00	0.000E+00
IN114M	0.000E+00	0.000E+00	0.000E+00
IN115	0.000E+00	2.542E-34	1.090E-33
IN116	0.000E+00	1.301E-20	0.000E+00
IN116M	0.000E+00	4.539E-20	0.000E+00
IN117	0.000E+00	0.000E+00	0.000E+00
IN117M	0.000E+00	0.000E+00	0.000E+00
IN118	0.000E+00	0.000E+00	0.000E+00
IN119	0.000E+00	0.000E+00	0.000E+00
IN119M	0.000E+00	0.000E+00	0.000E+00
IN120	0.000E+00	0.000E+00	0.000E+00
IN120M	0.000E+00	0.000E+00	0.000E+00
IN121	0.000E+00	0.000E+00	0.000E+00
SN112	0.000E+00	0.000E+00	0.000E+00
SN1[illegible]	0.000E+00	0.000E+00	0.000E+00
SN1[illegible]	0.000E+00	0.000E+00	0.000E+00
SN1[illegible]	0.000E+00	0.000E+00	0.000E+00
SN1[illegible]	0.000E+00	0.000E+00	0.000E+00
SN116	0.000E+00	0.000E+00	0.000E+00
SN117	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

```
1                                                             OUTPUT UNIT = 6                          PAGE   20
   * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                  ACTIVATION PRODUCTS
   POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
0                     7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                                 THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
              STARTUP   SHUTDOWN  1-JUN-1969
 SN117M     0.000E+00 0.000E+00 0.000E+00
 SN118      0.000E+00 0.000E+00 0.000E+00
 SN119      0.000E+00 0.000E+00 0.000E+00
 SN119M     0.000E+00 0.000E+00 0.000E+00
 SN120      0.000E+00 0.000E+00 0.000E+00
 SN121      0.000E+00 0.000E+00 0.000E+00
 SN121M     0.000E+00 0.000E+00 0.000E+00
 SN122      0.000E+00 0.000E+00 0.000E+00
 SN123      0.000E+00 9.285E-11 3.082E-29
 SN123M     0.000E+00 2.540E-12 0.000E+00
 SN124      0.000E+00 0.000E+00 0.000E+00
 SN125      0.000E+00 0.000E+00 0.000E+00
 SN125M     0.000E+00 0.000E+00 0.000E+00
 SB121      0.000E+00 0.000E+00 0.000E+00
 SB122      0.000E+00 2.939E-04 0.000E+00
 SB122M     0.000E+00 2.586E-06 0.000E+00
 SB123      0.000E+00 0.000E+00 0.000E+00
 SB124      0.000E+00 9.617E-05 0.000E+00
 SB124M     0.000E+00 3.787E-07 0.000E+00
 SB125      0.000E+00 8.026E-09 3.511E-11
 SB126      0.000E+00 3.163E-11 0.000E+00
 SB126M     0.000E+00 3.947E-11 0.000E+00
 TE120      0.000E+00 0.000E+00 0.000E+00
 TE121      0.000E+00 0.000E+00 0.000E+00
 TE121M     0.000E+00 0.000E+00 0.000E+00
 TE122      0.000E+00 0.000E+00 0.000E+00
 TE123      0.000E+00 1.530E-21 2.336E-21
 TE123M     0.000E+00 2.461E-08 2.797E-28
 TE124      0.000E+00 0.000E+00 0.000E+00
 TE125      0.000E+00 0.000E+00 0.000E+00
 TE125M     0.000E+00 7.896E-10 8.566E-12
 TE126      0.000E+00 0.000E+00 0.000E+00
 TE127      0.000E+00 1.052E-14 0.000E+00
 TE127M     0.000E+00 1.846E-16 0.000E+00
 TE128      0.000E+00 0.000E+00 0.000E+00
 TE129      0.000E+00 0.000E+00 0.000E+00
 TE129M     0.000E+00 0.000E+00 0.000E+00
 TE130      0.000E+00 0.000E+00 0.000E+00
 TE131      0.000E+00 0.000E+00 0.000E+00
 TE131M     0.000E+00 0.000E+00 0.000E+00
  I125      0.000E+00 [illegible] 0.000E+00
  I126      0.000E+00 0.000E+00 0.000E+00
  I127      0.000E+00 0.000E+00 0.000E+00
  I128      0.000E+00 5.789E-18 0.000E+00
  I129      0.000E+00 0.000E+00 0.000E+00
  I130      0.000E+00 0.000E+00 0.000E+00
  I130M     0.000E+00 0.000E+00 0.000E+00
  I131      0.000E+00 0.000E+00 0.000E+00
  I132      0.000E+00 0.000E+00 0.000E+00
 XE124      0.000E+00 0.000E+00 0.000E+00
 XE125      0.000E+00 0.000E+00 0.000E+00
 XE125M     0.000E+00 0.000E+00 0.000E+00
```

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

1 OUTPUT UNIT = 6 PAGE 21

* PATHFINDER ACTIVATION ANALYSIS. CURIES PER GRAM OF MATERIAL.

* ACTIVATION PRODUCTS

POWER= 0.00000E+00 MW, BURNUP= 0.00000E+00 MWD, FLUX= 5.00E+13 N/CM**2-SEC

0 7 NUCLIDE TABLE: RADIOACTIVITY, CURIES

THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.

	STARTUP	SHUTDOWN	1-JUN-1989
XE126	0.000E+00	0.000E+00	0.000E+00
XE127	0.000E+00	0.000E+00	0.000E+00
XE127m	0.000E+00	0.000E+00	0.000E+00
XE128	0.000E+00	0.000E+00	0.000E+00
XE129	0.000E+00	0.000E+00	0.000E+00
XE129m	0.000E+00	1.582E-22	0.000E+00
XE130	0.000E+00	0.000E+00	0.000E+00
XE131	0.000E+00	0.000E+00	0.000E+00
XE131m	0.000E+00	0.000E+00	0.000E+00
XE132	0.000E+00	0.000E+00	0.000E+00
XE133	0.000E+00	5.129E-11	0.000E+00
XE133m	0.000E+00	3.350E-12	0.000E+00
XE134	0.000E+00	0.000E+00	0.000E+00
XE135	0.000E+00	9.793E-19	0.000E+00
XE135m	0.000E+00	8.525E-20	0.000E+00
XE136	0.000E+00	0.000E+00	0.000E+00
XE137	0.000E+00	8.163E-23	0.000E+00
CS131	0.000E+00	4.279E-05	0.000E+00
CS132	0.000E+00	0.000E+00	0.000E+00
CS133	0.000E+00	0.000E+00	0.000E+00
CS134	0.000E+00	3.945E-06	2.672E-09
CS134m	0.000E+00	4.541E-06	0.000E+00
CS135	0.000E+00	9.620E-14	9.620E-14
CS136	0.000E+00	2.916E-09	0.000E+00
CS137	0.000E+00	5.002E-16	3.059E-16
CS138	0.000E+00	3.758E-18	0.000E+00
BA130	0.000E+00	0.000E+00	0.000E+00
BA131	0.000E+00	4.355E-05	0.000E+00
BA131m	0.000E+00	8.105E-06	0.000E+00
BA132	0.000E+00	0.000E+00	0.000E+00
BA133	0.000E+00	4.159E-07	1.027E-07
BA133m	0.000E+00	2.008E-06	0.000E+00
BA134	0.000E+00	0.000E+00	0.000E+00
BA135	0.000E+00	0.000E+00	0.000E+00
BA135m	0.000E+00	1.122E-05	0.000E+00
BA136	0.000E+00	0.000E+00	0.000E+00
BA136m	0.000E+00	2.713E-06	0.000E+00
BA137	0.000E+00	0.000E+00	0.000E+00
BA137m	0.000E+00	2.344E-06	2.866E-16
BA138	0.000E+00	0.000E+00	0.000E+00
BA139	0.000E+00	7.435E-04	0.000E+00
BA140	0.000E+00	1.581E-09	0.000E+00
BA141	0.000E+00	2.016E-[illegible]	0.000E+00
LA137	0.000E+00	8.132E-11	8.206E-11
LA138	3.393E-18	3.179E-18	3.179E-18
LA139	0.000E+00	0.000E+00	0.000E+00
LA140	0.000E+00	1.303E-05	0.000E+00
LA141	0.000E+00	3.676E-10	0.000E+00
CE136	0.000E+00	0.000E+00	0.000E+00
CE137	0.000E+00	2.955E-05	0.000E+00
CE137m	0.000E+00	3.877E-06	0.000E+00
CE138	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

1 OUTPUT UNIT = 8 PAGE 22

* PATHFINDER ACTIVATION ANALYSIS. CURIES PER GRAM OF MATERIAL.

* ACTIVATION PRODUCTS

POWER= 0.00000E+00 MW, BURNUP= 0.00000E+00 MWD, FLUX= 5.00E+13 N/CM**2-SEC

0 7 NUCLIDE TABLE: RADIOACTIVITY, CURIES

THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.

	STARTUP	SHUTDOWN	1-JUN-1989
CE139	0.000E+00	2.141E-06	9.687E-24
CE139M	0.000E+00	8.102E-08	0.000E+00
CE140	0.000E+00	0.000E+00	0.000E+00
CE141	0.000E+00	9.151E-04	0.000E+00
CE142	9.994E-13	9.990E-13	9.990E-13
CE143	0.000E+00	2.267E-04	0.000E+00
CE144	0.000E+00	2.190E-09	8.782E-18
CE145	0.000E+00	3.879E-12	0.000E+00
PR141	0.000E+00	0.000E+00	0.000E+00
PR142	0.000E+00	2.573E-06	0.000E+00
PR142M	0.000E+00	8.728E-07	0.000E+00
PR143	0.000E+00	2.175E-04	0.000E+00
PR144	0.000E+00	1.638E-06	8.677E-18
PR145	0.000E+00	3.879E-12	0.000E+00
ND142	0.000E+00	0.000E+00	0.000E+00
ND143	0.000E+00	0.000E+00	0.000E+00
ND144	0.000E+00	7.822E-22	7.831E-22
ND145	0.000E+00	0.000E+00	0.000E+00
ND146	0.000E+00	0.000E+00	0.000E+00
ND147	0.000E+00	1.168E-13	0.000E+00
ND148	0.000E+00	0.000E+00	0.000E+00
ND149	0.000E+00	0.000E+00	0.000E+00
ND150	0.000E+00	0.000E+00	0.000E+00
ND151	0.000E+00	0.000E+00	0.000E+00
PM145	0.000E+00	9.123E-12	4.853E-11
PM147	0.000E+00	5.579E-15	2.243E-17
PM148	0.000E+00	2.216E-14	0.000E+00
PM148M	0.000E+00	4.251E-16	0.000E+00
PM149	0.000E+00	3.817E-15	0.000E+00
PM150	0.000E+00	7.366E-17	0.000E+00
PM151	0.000E+00	0.000E+00	0.000E+00
PM152	0.000E+00	0.000E+00	0.000E+00
SM144	0.000E+00	0.000E+00	0.000E+00
SM145	0.000E+00	1.881E-09	1.800E-16
SM146	0.000E+00	5.395E-19	5.395E-19
SM147	3.355E-16	3.274E-16	3.274E-16
SM148	3.350E-21	3.461E-21	3.461E-21
SM149	3.307E-21	1.832E-25	1.832E-25
SM150	0.000E+00	0.000E+00	0.000E+00
SM151	0.000E+00	3.700E-09	3.130E-09
SM152	0.000E+00	0.000E+00	0.000E+00
SM153	0.000E+00	2.922E-05	0.000E+00
SM154	0.000E+00	0.000E+00	0.000E+00
SM155	0.000E+00	6.713E-07	0.000E+00
EU151	0.000E+00	0.000E+00	0.000E+00
EU152	0.000E+00	5.451E-07	1.803E-07
EU152M	0.000E+00	5.335E-06	0.000E+00
EU153	0.000E+00	0.000E+00	0.000E+00
EU154	0.000E+00	3.670E-07	6.200E-08
EU155	0.000E+00	1.287E-07	6.192E-09
EU156	0.000E+00	4.026E-06	0.000E+00
GD152	0.000E+00	3.869E-20	5.153E-20

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

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1                                                          OUTPUT UNIT =  6                              PAGE   23

   * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                    ACTIVATION PRODUCTS
   POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
0                   7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                                   THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
               STARTUP  SHUTDOWN 1-JUN-1989
 GD153       0.000E+00 2.023E-06 2.776E-16
 GD154       0.000E+00 0.000E+00 0.000E+00
 GD155M      0.000E+00 3.506E-12 0.000E+00
 GD155       0.000E+00 0.000E+00 0.000E+00
 GD156       0.000E+00 0.000E+00 0.000E+00
 GD157       0.000E+00 0.000E+00 0.000E+00
 GD158       0.000E+00 0.000E+00 0.000E+00
 GD159       0.000E+00 4.768E-05 0.000E+00
 GD160       0.000E+00 0.000E+00 0.000E+00
 GD161       0.000E+00 7.156E-15 0.000E+00
 GD162       0.000E+00 3.552E-18 0.000E+00
 TB157       0.000E+00 1.03[illegible]E-10 9.374E-11
 TB159       0.000E+00 0.000E+00 0.000E+00
 TB160       0.000E+00 3.187E-05 0.000E+00
 TB161       0.000E+00 7.539E-06 0.000E+00
 TB162       0.000E+00 1.144E-10 0.000E+00
 DY156       0.000E+00 0.000E+00 0.000E+00
 DY157       0.000E+00 9.304E-08 0.000E+00
 DY158       0.000E+00 0.000E+00 0.000E+00
 DY159       0.000E+00 7.562E-06 2.010E-24
 DY160       0.000E+00 0.000E+00 0.000E+00
 DY161       0.000E+00 0.000E+00 0.000E+00
 DY162       0.000E+00 0.000E+00 0.000E+00
 DY163       0.000E+00 0.000E+00 0.000E+00
 DY164       0.000E+00 0.000E+00 0.000E+00
 DY165       0.000E+00 1.547E-03 0.000E+00
 DY165M      0.000E+00 9.278E-04 0.000E+00
 DY166       0.000E+00 3.681E-06 0.000E+00
 HO163       0.000E+00 0.000E+00 0.000E+00
 HO165       0.000E+00 0.000E+00 0.000E+00
 HO166       0.000E+00 3.641E-04 0.000E+00
 HO166M      0.000E+00 2.617E-09 2.564E-09
 ER162       0.000E+00 0.000E+00 0.000E+00
 ER163       0.000E+00 0.000E+00 0.000E+00
 ER164       0.000E+00 0.000E+00 0.000E+00
 ER165       0.000E+00 1.366E-11 0.000E+00
 ER166       0.000E+00 0.000E+00 0.000E+00
 ER167       0.000E+00 0.000E+00 0.000E+00
 ER167M      0.000E+00 1.915E-06 0.000E+00
 ER168       0.000E+00 0.000E+00 0.000E+00
 ER169       0.000E+00 1.458E-10 0.000E+00
 ER170       0.000E+00 0.000E+00 0.000E+00
 ER171       0.000E+00 5.875E-11 0.000E+00
 ER172       0.000E+00 3.212E-14 0.000E+00
 TM169       0.000E+00 0.000E+00 0.000E+00
 TM170       0.000E+00 1.093E-07 2.995E-26
 TM170M      0.000E+00 4.861E-08 0.000E+00
 TM171       0.000E+00 2.098E-10 8.264E-14
 TM172       0.000E+00 2.269E-10 0.000E+00
 TM173       0.000E+00 1.009E-10 0.000E+00
 YB168       0.000E+00 0.000E+00 0.000E+00
 YB169       0.000E+00 1.767E-05 0.000E+00
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FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

1 OUTPUT UNIT = 6 PAGE 24

* PATHFINDER ACTIVATION ANALYSIS. CURIES PER GRAM OF MATERIAL.

* ACTIVATION PRODUCTS

POWER= 0.00000E+00 MW, BURNUP= 0.00000E+00 MWD, FLUX= 5.00E+13 N/CM**2-SEC

0 7 NUCLIDE TABLE: RADIOACTIVITY, CURIES

THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.

	STARTUP	SHUTDOWN	1-JUN-1989
YB170	0.000E+00	0.000E+00	0.000E+00
YB171	0.000E+00	0.000E+00	0.000E+00
YB172	0.000E+00	6.000E+00	0.000E+00
YB173	0.000E+00	0.000E+00	0.000E+00
YB174	0.000E+00	0.000E+00	0.000E+00
YB175	0.000E+00	1.864E-04	0.000E+00
YB175M	0.000E+00	1.339E-04	0.000E+00
YB176	0.000E+00	0.000E+00	0.000E+00
YB177	0.000E+00	2.843E-06	0.000E+00
LU175	0.000E+00	0.000E+00	0.000E+00
LU176	1.417E-15	7.378E-16	7.378E-16
LU176M	0.000E+00	6.003E-05	0.000E+00
LU177	0.000E+00	1.171E-04	1.422E-23
LU177M	0.000E+00	1.550E-07	6.163E-23
HF174	0.000E+00	0.000E+00	0.000E+00
HF175	0.000E+00	3.035E-06	0.000E+00
HF176	0.000E+00	0.000E+00	0.000E+00
HF177	0.000E+00	0.000E+00	0.000E+00
HF178	0.000E+00	0.000E+00	0.000E+00
HF178M	0.000E+00	1.678E-06	0.000E+00
HF179	0.000E+00	0.000E+00	0.000E+00
HF179M	0.000E+00	1.364E-04	0.000E+00
HF180	0.000E+00	0.000E+00	0.000E+00
HF180M	0.000E+00	4.494E-07	0.000E+00
HF181	0.000E+00	3.064E-05	0.000E+00
HF182	0.000E+00	3.684E-15	3.684E-15
TA180	0.000E+00	0.000E+00	0.000E+00
TA181	0.000E+00	0.000E+00	0.000E+00
TA182	0.000E+00	1.436E-04	3.684E-15
TA182M	0.000E+00	7.645E-11	0.000E+00
TA183	0.000E+00	8.440E-08	0.000E+00
W180	0.000E+00	0.000E+00	0.000E+00
W181	0.000E+00	1.475E-06	2.965E-26
W182	0.000E+00	0.000E+00	0.000E+00
W183M	0.000E+00	1.067E-04	0.000E+00
W183	0.000E+00	0.000E+00	0.000E+00
W184	0.000E+00	0.000E+00	0.000E+00
W185	0.000E+00	2.524E-04	0.000E+00
W185M	0.000E+00	5.011E-07	0.000E+00
W186	0.000E+00	0.000E+00	0.000E+00
W187	0.000E+00	4.774E-03	0.000E+00
W188	0.000E+00	2.010E-06	0.000E+00
W189	0.000E+00	5.066E-26	0.000E+00
RE185	0.000E+00	0.000E+00	0.000E+00
RE186	0.000E+00	5.967E-06	0.000E+00
RE187	0.000E+00	2.848E-14	2.896E-14
RE188	0.000E+00	2.419E-04	0.000E+00
RE188M	0.000E+00	2.348E-04	0.000E+00
RE189	0.000E+00	2.133E-09	0.000E+00
OS184	0.000E+00	0.000E+00	0.000E+00
OS185	0.000E+00	0.000E+00	0.000E+00
OS186	0.000E+00	0.000E+00	0.000E+00

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

1 OUTPUT UNIT = 6 PAGE 25

* PATHFINDER ACTIVATION ANALYSIS. CURIES PER GRAM OF MATERIAL.

* ACTIVATION PRODUCTS

POWER= 0.00000E+00 MW, BURNUP= 0.00000E+00 MWD, FLUX= 5.00E+13 N/CM**2-SEC

0 7 NUCLIDE TABLE: RADIOACTIVITY, CURIES

THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.

	STARTUP	SHUTDOWN	1-JUN-1969
OS187	0.000E+00	0.000E+00	0.000E+00
OS188	0.000E+00	0.000E+00	0.000E+00
OS189	0.000E+00	0.000E+00	0.000E+00
OS190	0.000E+00	0.000E+00	0.000E+00
OS190M	0.000E+00	6.362E-15	0.000E+00
OS191	0.000E+00	3.267E-13	0.000E+00
OS191M	0.000E+00	4.948E-13	0.000E+00
OS192	0.000E+00	0.000E+00	0.000E+00
OS193	0.000E+00	9.939E-21	0.000E+00
OS194	0.000E+00	0.000E+00	0.000E+00
IR191	0.000E+00	0.000E+00	0.000E+00
IR192	0.000E+00	2.064E-15	6.779E-22
IR192M	0.000E+00	8.772E-22	8.772E-22
IR193	0.000E+00	0.000E+00	0.000E+00
IR194	0.000E+00	5.873E-16	0.000E+00
IR194M	0.000E+00	3.096E-19	0.000E+00
PT190	0.000E+00	0.000E+00	0.000E+00
PT191	0.000E+00	0.000E+00	0.000E+00
PT192	0.000E+00	0.000E+00	0.000E+00
PT193	0.000E+00	4.361E-23	4.881E-23
PT193M	0.000E+00	2.210E-19	0.000E+00
PT194	0.000E+00	0.000E+00	0.000E+00
PT195	0.000E+00	0.000E+00	0.000E+00
PT195M	0.000E+00	2.476E-23	0.000E+00
PT196	0.000E+00	0.000E+00	0.000E+00
PT197	0.000E+00	0.000E+00	0.000E+00
PT197M	0.000E+00	0.000E+00	0.000E+00
PT198	0.000E+00	0.000E+00	0.000E+00
PT199	0.000E+00	0.000E+00	0.000E+00
PT199M	0.000E+00	0.000E+00	0.000E+00
AU197	0.000E+00	0.000E+00	0.000E+00
AU198	0.000E+00	0.000E+00	0.000E+00
AU199	0.000E+00	0.000E+00	0.000E+00
AU200	0.000E+00	0.000E+00	0.000E+00
HG196	0.000E+00	0.000E+00	0.000E+00
HG197	0.000E+00	0.000E+00	0.000E+00
HG197M	0.000E+00	0.000E+00	0.000E+00
HG198	0.000E+00	0.000E+00	0.000E+00
HG199	0.000E+00	0.000E+00	0.000E+00
HG199M	0.000E+00	0.000E+00	0.000E+00
HG200	0.000E+00	0.000E+00	0.000E+00
HG201	0.000E+00	0.000E+00	0.000E+00
HG202	0.000E+00	0.000E+00	0.000E+00
HG203	0.000E+00	0.000E+00	0.000E+00
HG204	0.000E+00	0.000E+00	0.000E+00
HG205	0.000E+00	0.000E+00	0.000E+00
TL203	0.000E+00	0.000E+00	0.000E+00
TL204	0.000E+00	0.000E+00	0.000E+00
TL205	0.000E+00	0.000E+00	0.000E+00
TL206	0.000E+00	2.649E-19	9.810E-21
PB204	1.156E-20	1.156E-20	1.156E-20
PB205	0.000E+00	1.349E-14	1.349E-14

FIGURE A-2

PARTIAL ORIGEN2 SAMPLE OUTPUT
(CONTINUED)

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1                                                        OUTPUT UNIT =  6                          PAGE   26

     * PATHFINDER ACTIVATION ANALYSIS.  CURIES PER GRAM OF MATERIAL.
*                                                                                    ACTIVATION PRODUCTS
     POWER= 0.00000E+00 MW,  BURNUP= 0.00000E+00 MWD,  FLUX= 5.00E+13 N/CM**2-SEC
0                     7 NUCLIDE TABLE:  RADIOACTIVITY,  CURIES
                              THERMAL XSEC - FLUX AT CORE BOUNDARY - STAINLESS STEEL.
                STARTUP  SHUTDOWN 1-JUN-1989
 PB206       0.000E+00 0.000E+00 0.000E+00
 PB207       0.000E+00 0.000E+00 0.000E+00
 PB208       0.000E+00 0.000E+00 0.000E+00
 PB209       0.000E+00 6.718E-08 0.000E+00
 BI208       0.000E+00 0.000E+00 0.000E+00
 BI209       0.000E+00 0.000E+00 0.000E+00
 BI210       0.000E+00 4.827E-13 0.000E+00
 BI210M      0.000E+00 9.850E-21 9.849E-21
 BI211       0.000E+00 8.142E-19 0.000E+00
 PO210       0.000E+00 8.430E-14 3.940E-23
 PO211       0.000E+00 2.184E-18 0.000E+00
 PO211M      0.000E+00 3.638E-20 0.000E+00
 TOTAL       1.251E-12 5.555E+00 2.619E-03
0                                        CUMULATIVE TABLE TOTALS

 AP+FP       1.251E-12 5.555E+00 2.619E-03
 ACT+FP      0.000E+00 0.000E+00 0.000E+00
 AP+ACT+FP   1.251E-12 5.555E+00 2.619E-03
```

APPENDIX B

PATHFINDER CURIE ESTIMATE SPREADSHEET

APPENDIX B

PATHFINDER CURIE ESTIMATE SPREADSHEET

Using the curie per gram source terms for 1 June 1989 calculated for the various materials as typically shown in Appendix A, a Lotus 1-2-3 spreadsheet was constructed to perform the disparate tasks necessary to determine the total curie contents of the vessel package and individual components as of 1 January 1990. These tasks are:

- Further decay of the curie/gram source terms to 1 January 1990 (the spreadsheet shown has already decayed these values from 1 June 1989 to 1 January 1990; therefore the decay factor for all radionuclides is shown as 1.00
- Calculation of logarithmic averages for various regions and constructing a set of radionuclides appropriate for this average
- Determination of individual weights of materials in each region of the neutron activation model
- Calculation of curie contents by isotope in each component in each region of the activation model
- Summation of curie contents by isotope of each component
- Summation of curie contents by isotope for entire vessel package
- Summation of curie contents for entire package and determination of relative contribution by isotope

The regions referred to in the spreadsheet are those shown in the neutron activation model as described in Section 5 and depicted in Figures 5.3 and 5.4. Region numbering begins with the central cylinder, uppermost layer. Region numbers increase with decreasing elevation until the bottom of the central cylinder (region 7), then begins again with region 8 at the top of the first concentric ring around the core.

FIGURE B-1
PATHFINDER CURIE ESTIMATE SPREADSHEET
UPPER LEFT SECTION

NOTES: 1) All dimensions are CGS units unless otherwise noted
2) Top and bottom boundaries are relative to core midplane
3) Radii are based upon reactor vessel/core centerline
4) Material within the core region (region 4 only) are modeled on a standard ORIGEN2 BWR neutron flux spectrum.
5) Material outside the core region (regions 1-3 & 5-20) are modeled on thermal neutron spectrum only.
Standard thermal cross-sections assume 0.025 ev neutron energies; for reactor operating temperatures a correction factor to the average neutron velocity's absorption cross-section must be applied to the ORIGEN2 results.
Materials external to the reactor vessel are assumed to be at room temperature of 6C deg. F

MATERIAL DENSITIES (GM/CM^3):

Stainless steel 304L	7.90
Zircaloy-2	6.57
Carbon steel A212	7.8S

GEOMETRY/MATERIAL AXIAL FLUX REDUCTION FACTORS:

From core avg to	third layer above core	1.000E-03
	second layer above core	1.000E-02
	first layer above core	1.000E-01
	first layer below core	1.000E-01
	second layer below core	1.000E-02
	third layer below core	1.000E-03

THERMAL NEUTRON CROSS-SECTION CORRECTION FACTORS:

0.025 ev neutron temperature: 65.00 deg. F =	293.00 K
Core operating temperature: 489.00 deg. F =	526.89 K
Cross-section compared to 293 K =	66.09%
Vessel wall avg temperature: 400.00 deg. F =	477.44 K
Cross-section compared to 293 K =	69.47%

Input isotopic decay date: 01-jan-90
Proposed shipping date: 01-jan-90

Cyl. No.	Cylinder n/cm^2	ORIGEN2/IBM MICRO VERSION * RADIONUCLIDE SOURCE TERMS (Ci/GM):	H3	C14	K40	Ca41	Fe55	Co60	Ni59	Ni63	Zn65	Sr90	Zr93	Nb93m	Nb94	Tc99
0	3.50E+13	Core region stainless steel 304L	2.50E-07	9.82E-08	3.46E-15	1.27E-11	1.50E-05	1.13E-04	6.00E-07	7.22E-05	3.82E-15	5.30E-17	0.00	0.00	1.96E-09	4.06E-09
0	3.50E+13	Core region Zircaloy-2	2.19E-13	1.74E-08	0.00E+00	0.00E+00	3.23E-08	8.00E-07	3.01E-09	3.61E-07	8.90E-21	8.96E-13	0.00	0.00	2.59E-09	6.18E-17
	3.50E+13	Core bndry SS 304L (boiler shroud)	3.40E-07	1.37E-07	1.72E-15	1.88E-11	2.19E-05	1.18E-04	8.05E-07	1.07E-04	4.23E-15	1.65E-16	0.00	0.00	7.30E-10	7.00E-11
	3.50E+13	Core bndry SS 304L (except shroud)	4.12E-08	1.62E-08	2.04E-16	2.21E-12	2.60E-06	1.40E-05	1.05E-07	1.27E-05	5.01E-16	1.95E-17	0.00	0.00	8.65E-11	8.29E-12
1	1.07E+12	- Log average for region	8.60E-09	3.11E-09	5.90E-16	4.29E-13	4.98E-07	2.69E-06	2.03E-08	2.44E-06	9.59E-17	0.00E+00	9.78E-16	6.24E-16	1.66E-11	1.59E-12
2	3.30E+10	Vessel clad stainless steel 304L	1.80E-09	5.98E-10	1.71E-15	8.32E-14	9.57E-08	5.18E-07	3.94E-09	4.70E-07	1.04E-17	1.14E-21	0.00	0.00	3.20E-12	3.06E-13
	3.30E+10	Inner vessel wall carbon steel A212	4.15E-09	1.11E-10	6.82E-15	6.13E-14	1.33E-07	4.49E-08	2.60E-10	3.10E-08	4.02E-18	8.58E-22	0.00	0.00	6.75E-13	6.59E-14
3	9.08E+09	- Log average for region	1.24E-10	3.76E-11	8.37E-15	2.63E-14	4.85E-08	1.58E-08	8.01E-11	1.05E-08	1.43E-18	0.00E+00	6.36E-17	4.29E-17	2.29E-13	2.23E-14
	2.50E-09	Outer vessel wall carbon steel A212	3.71E-12	1.27E-11	1.03E-14	1.13E-14	1.77E-08	5.55E-09	2.98E-11	3.57E-09	8.47E-19	0.00E+00	2.15E-17	1.37E-17	7.74E-14	7.55E-15
		Isotope half-life, years	12.35	5730.00	1.28E+09	0.0548	2.685	5.272	15130	100.10	0.6681	28.82	1,530,000	13.6	20320	214500
		Additional decay factor against Ci/gm values listed below	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00 (secular equilibrium)	1.00	1.00

* Note that the input Ci/gm values have been adjusted in another spreadsheet for decay, thermal, radial and component averaging corrections.

Region No.	Cylinder	Cylinder description	Outer Radius	Inner Radius	Layer	Layer Description	Boundary @Top	Boundary @Bottom	Region Volume	Region Material	Axial Factor	Region contents
1	0	Core region	87.63	0.00	1	3rd layer above core	181.44	151.44	723,730	SS 304	1.00E-03	Superheater baffle
												Boiler control blades
												Control rod guide tubes
												Superheater control rods
												Superheater fuel element tubes
2					2	2nd layer above core	151.44	121.44	723,730	SS 304	1.00E-02	Superheater baffle
												Boiler control blades
												Control rod guide tubes
												Superheater control rods
												Superheater fuel element tubes
3					3	1st layer above core	121.44	91.44	723,730	Zircaloy	1.00E-01	4 element boiler boxes
										-		Single element boiler boxes
										SS 304		Superheater baffle
										-		Boiler control blades
										-		Control rod guide tubes
										-		Boiler element hold down structure
												Superheater control rods
										-		Superheater fuel element tubes
4					4	Reactor Core	91.44	-91.44	4,411,860	Zircaloy	1.00E+00	4 element boiler boxes
										-		Single element boiler boxes
										SS 304		Superheater baffle
										-		Instrumentation & sample holders
										-		Superheater fuel element tubes
										-		Boiler control blades
										-		Boiler element poison shims

FIGURE B-1
PATHFINDER CURIE ESTIMATE SPREADSHEET
LOWER LEFT SECTION

Region No	Cylinder	Cylinder description	Outer Radius	Inner Radius	Layer	Layer Description	Boundary @Top	Boundary @Bottom	Region Volume	Region Material	Axial Factor	Region contents
5					5	1st layer below core	-91.44	-121.44	723.730	Zircaloy	1.00E-01	4 element boiler box
										-		Single element boiler box
										SS 304		4 element boiler box bottom
										-		Single element boiler box bottom
										-		Superheater baffle
										-		Superheater fuel element tubes
										-		Boiler grid plate
6					6	2nd layer below core	-121.44	-151.44	723.730	SS 304	1.00E-02	Superheater baffle
												Superheater fuel element tubes
7					7	3rd layer below core	-151.44	-181.44	723.730	SS 304	1.00E-03	Superheater baffle
												Superheater support plate
												Superheater fuel element tubes
8	1	Steam separator region	167.64	87.63	1	3rd layer above core	181.44	151.44	1,924.931	SS 304	1.00E-03	Boiler baffle
												Steam separators
9					2	2nd layer above core	151.44	121.44	1,924.931	SS 304	1.00E-02	Boiler baffle
												St[illegible]m separators
10					3	1st layer above core	121.44	91.44	1,924.931	SS 304	1.00E+00	[illegible] baffle **
												S[illegible]m separators
11					4	Reactar Core Level	91.44	-91.44	11,734.380	SS 304	1.00E+00	Boiler baffle
												Steam separators
												Steam separator nozzles
												Steam separators shell
12					5	1st layer below core	-91.44	-121.44	1,924.931	SS 304	1.60E+00	Boiler baffle **
												Feedwater ring w/supports
13					6	2nd layer below core	-121.44	-151.44	1,924.931	SS 304	1.00E-02	(empty region)
14					7	3rd layer below core	-151.44	-181.44	1,924.931	SS 304	1.00E-03	(empty region)
15	2	Vessel cladding region	168.28	167.64	1	3rd layer above core	181.44	151.44	20,104	SS 304	1.00E-03	Vessel cladding
16					2	2nd layer above core	151.44	121.44	20,104	SS 304	1.00E-02	Vessel cladding
17					3	1st layer above core	121.44	91.44	20,104	SS 304	1.00E-01	Vessel cladding
18					4	Reactor Core Level	91.44	-91.44	122,552	SS 304	1.00E+00	Vessel cladding
19					5	1st layer below core	-91.44	-121.44	20,104	SS 304	1.00E-01	Vessel cladding
20					6	2nd layer below core	-121.44	-151.44	20,104	SS 304	1.00E-02	Vessel cladding
21					7	3rd layer below core	-151.44	-181.44	20,104	SS 304	1.00E-03	Vessel cladding
22	3	Vessel wall region	173.10	168.28	1	3rd layer above core	181.44	151.44	247,172	CS A212	1.00E-03	Vessel wall
23					2	2nd layer above core	151.44	121.44	247,172	CS A212	1.00E-02	Vessel wall
24					3	1st layer above core	121.44	91.44	247,172	CS A212	1.00E-01	Vessel wall
25					4	Reactor Core Level	91.44	-91.44	1,506,760	CS A212	1.00E+00	Vessel wall
26					5	1st layer below core	-91.44	-121.44	247,172	CS A212	1.00E-01	Vessel wall
27					6	2nd layer below core	-121.44	-151.44	247,172	CS A212	1.00E-02	Vessel wall
28					7	3rd layer below core	-151.44	-181.44	247,172	CS A212	1.00E-03	Vessel wall

TOTAL FOR VESSEL PACKAGE
Isotopic percentage of total

** Boiler baffle above and below core does not have a flux reduction factor due to the use of homogenized Ci/gm source term.

SUMMARY OF CURIES BY COMPONENT:	Tot model Weight, lb	model vs Total Wt.	H3	C14	K40	Ca41	Fe55	Co60	Ni59	Ni63	Zn65	Sr90	Zr95	Nb93m
Superheater baffle	1,300.72	11	7.87E-02	2.99E-02	9.61E-10	3.86E-06	4.58E+00	3.44E+01	1.05E-01	2.30E+01	1.16E-09	1.64E-11	8.38E-08	5.34E-08
Superheater fuel insul. tubes (inner & outer)	2,4[illegible]2.71	11	1.51E-01	5.74E-02	1.84E-09	7.39E-06	8.77E+00	6.59E+01	3.55E-01	4.21E+01	2.23E-09	3.14E-11	1.61E-07	1.02E-07
Superheater support plate	45.98	79.99%	3.56E-06	1.36E-06	4.35E-14	1.75E-10	2.07E-04	1.56E-03	8.30E-06	9.95E-04	5.26E-14	7.41E-16	3.79E-12	2.42E-12
Superheater control rods	275.52	25.63%	7.41E-04	2.02E-04	9.06E-12	3.63E-08	4.31E-02	3.24E-01	1.74E-03	2.07E-0[illegible]	1.10E-11	1.54E-13	7.09E-10	5.03E-10
Boiler fuel boxes	7,664.14	100.00%	1.35E-02	3.37E-02	1.64E-10	6.60E-07	8.35E-01	7.19E+00	3.66E-02	4.35E+00	1.99E-10	7.47E-06	1.14E-02	7.23E-03
Boiler shroud	1,460.00	100.00%	1.92E-01	5.99E-02	7.54E-10	8.16E-06	9.59E+00	5.16E+01	3.07E-01	4.60E+01	1.05E-09	7.20E-11	1.00E-08	1.20E-08
Boiler element hold down structure	1,352.39	11	1.05E-02	3.99E-03	1.28E-10	5.14E-07	6.09E-01	4.58E+00	2.46E-02	2.53E+00	1.55E-10	2.18E-12	1.12E-09	7.11E-09
Boiler CR guide tubes & remaining structure	2,942.83	61.36%	8.43E-03	3.21E-03	1.03E-10	4.14E-07	4.91E-01	3.69E+00	1.98E-02	2.38E+00	1.25E-10	1.76E-12	8.98E-09	5.73E-09
Boiler element poison shims	276.00	100.00%	3.24E-02	1.23E-02	3.95E-10	1.59E-06	1.88E+00	1.41E+01	7.61E-02	9.03E+00	4.78E-10	6.73E-12	3.45E-08	2.20E-08
Boiler control blades	1,816.18	69.21%	1.10E-01	4.18E-02	1.34E-09	5.39E-06	6.39E+00	4.80E+01	2.58E-01	3.07E+01	1.62E-09	2.29E-11	1.17E-07	7.46E-08
Instrumentation tubing & sample holders	69.85	103.47%	8.19E-03	3.12E-03	1.00E-10	4.01E-07	4.76E-01	3.58E+00	1.93E-02	2.29E+00	1.21E-10	1.70E-12	8.72E-09	5.56E-09
Boiler grid plate	5,600.00	100.00%	4.34E-02	1.65E-02	5.30E-10	2.13E-06	2.52E+00	1.90E+01	1.02E-01	1.21E+01	6.41E-10	9.03E-12	4.62E-08	2.95E-08
Steam separators & supports	4,636.08	61.94%	9.30E-03	3.40E-03	6.43E-10	4.67E-07	5.43E-0[illegible]	2.93E+00	2.22E-02	2.66E+00	1.05E-10	0.00E+00	1.07E-09	6.80E-10
Feedwater ring & supports	1,027.00	100.00%	2.65E-03	9.59E-04	1.02E-10	1.32E-07	1.53E-0[illegible]	8.20E-01	6.25E-0[illegible]	[illegible].92E-01	2.05E-11	0.00E+00	3.01E-10	1.92E-10
Vessel cladding	4,235.23	11	1.19E-03	3.96E-04	1.13E-09	5.92E-08	6.34E-02	3.4[illegible]E-01	2.81E-0[illegible]	[illegible].12E-01	1.22E-11	7.59E-16	1.25E-10	7.94E-11
Vessel	52,005.84	[illegible]8.93%	1.06E-03	3.32E-04	7.16E-08	2.25E-07	4.15E-01	1.[illegible]E-01	7.53E-[illegible]	9.01E-02	1.58E-11	0.00E+00	5.44E-10	3.47E-10
Totals	87,200.47	46.65%	0.62	0.27	0.00	0.00	37.36	256.66	1.50	178.68	0.00	0.00	0.01	0.01
Percent of total by isotope	n/a	n/a	0.13%	0.06%	0.00%	0.00%	7.85%	53.90%	0.31%	37.53%	0.00%	0.00%	0.00%	0.00%

FIGURE B-1
PATHFINDER CURIE ESTIMATE SPREADSHEET
UPPER CENTER SECTION

Component	Weight (lbs)
Superheater baffle	4,800.00
Superheater fuel insul. tubes (inner & outer)	11
Superheater support plate	11
Superheater control rods	1,075.00
Boiler fuel boxes	7,664.00
Boiler shroud	1,460.00
Boiler element hold down structure & guide tub	7,000.00
Boiler element poison shims	276.00
Boiler control blades	2,824.00
Instrumentation tubing & sample holders	67.50
Boiler grid plate	5,600.00
Steam separators & supports	7,465.00
Feedwater ring & supports	1,037.00
Steam dryer assembly	3,490.00
Vessel & cladding	144,458.00
Total weight of internals & vessel	194,934.50

Cyl. No.	Cylinder n/cm^2	ORIGEN2/IBM MICRO VERSION RADIONUCLIDE SOURCE TERMS (Ci/GM):	Sn121m	Sb125	Te125m	Cs137	Eu152	Eu154	Total Ci/gm
0	3.50E+13	Core region stainless steel 304L	0.00	0.00	0.00	3.17E-18	8.18E-08	9.21E-09	2.01E-04
0	3.50E+13	Core region Zircaloy-2	0.00	0.00	0.00	0.00E+00	0.00E+00	0.30E+00	1.74E-06
	3.50E+13	Core bndry SS 304L (boiler shroud)	0.00	0.00	0.00	2.99E-17	1.75E-08	6.08E-09	2.48E-04
	3.50E+13	Core bndry SS 304L (except shroud)	0.00	0.00	0.00	3.54E-18	2.07E-09	7.21E-10	2.94E-05
1	1.07E+12	- Log average for region	0.00E+00	1.77E-15	4.36E-16	0.00E+00	1.03E-09	1.47E-10	5.66E-06
2	3.30E+10	Vessel clad stainless steel 304L	0.00	0.00	0.00	0.00E+00	5.13E-10	3.01E-11	1.09E-06
	3.30E+10	Inner vessel wall carbon steel A212	0.00	0.00	0.00	0.00E+00	7.96E-10	4.67E-11	2.14E-07
3	9.08E+09	- Log average for region	0.00E+00	7.68E-19	1.92E-19	0.00E+00	2.74E-10	1.62E-11	7.54E-08
	2.50E+09	Outer vessel wall carbon steel A212	0.00E+00	7.56E-20	1.92E-20	0.00E+00	9.42E-11	5.61E-12	2.70E-08
		Isotope half-life, years	55	2.71	0.159	30.17	13.23	8.59	
		Additional decay factor against Ci/gm values listed below	1.00	1.00	1.00 (secular equilibrium)	1.00	1.00	1.00	

Region No.	Cylinder	Cylinder description	Outer Radius	Unit Volume	Quantity	Mat'l vol in region	Ci H3	Ci C14	K40	Ci Ca41	Ci Fe55	Ci Co60	Ci Ni59	Ci Ni63	Ci Zn65	Ci Sr90	Ci Zr95
1	0	Core region	87.63	6.17E-03	1	6174.18	8.33E-06	3.17E-06	1.02E-13	4.08E-10	4.85E-04	3.64E-03	1.96E-05	2.33E-03	1.23E-13	1.73E-15	8.07E-12
				1.08E-03	16	17241.93	2.33E-05	8.85E-06	2.84E-13	1.14E-09	1.35E-03	1.02E-02	5.47E-05	6.90E-03	3.44E-13	4.84E-15	2.48E-11
				3.52E-03	16	56322.56	7.60E-05	2.89E-05	9.28E-13	3.73E-09	4.42E-03	3.32E-02	1.79E-04	2.12E-02	1.12E-12	1.58E-14	8.09E-11
				9.14E-01	65	5938.53	8.01E-06	3.05E-06	9.79E-14	3.93E-10	4.66E-04	3.50E-03	1.88E-05	2.24E-03	1.18E-13	1.67E-15	8.53E-12
				2.53E-01	468	11832.29	1.60E-05	6.08E-06	1.95E-13	7.83E-10	9.29E-04	6.98E-03	3.76E-05	4.46E-03	2.36E-13	3.32E-15	1.70E-11
2				6.17E-03	1	6174.18	8.33E-05	3.17E-05	1.02E-12	4.08E-09	4.85E-03	3.64E-02	1.96E-04	2.33E-02	1.23E-12	1.73E-14	8.07E-11
				1.08E-03	16	17241.93	2.33E-04	8.85E-05	2.84E-12	1.14E-08	1.35E-02	1.02E-01	5.47E-04	6.90E-02	3.44E-12	4.84E-14	2.48E-10
				3.52E-03	16	56322.56	7.60E-04	2.89E-04	9.28E-12	3.73E-08	4.42E-02	3.32E-01	1.79E-03	2.12E-01	1.12E-11	1.58E-13	8.09E-10
				7.60E-01	65	4940.40	6.67E-05	2.54E-05	8.14E-13	3.27E-09	3.88E-03	2.91E-02	1.57E-04	1.86E-02	9.85E-13	1.39E-14	7.10E-11
				2.53E-01	468	11832.29	1.50E-04	6.08E-05	1.95E-12	7.83E-09	9.29E-03	6.98E-02	3.76E-04	4.46E-02	2.36E-12	3.32E-14	1.70E-10
3				1.86E+05	16	29777.06	3.34E-03	1.27E-03	4.08E-11	1.64E-07	1.94E-01	1.46E+00	7.86E-03	9.33E-01	4.94E-11	6.95E-13	3.96E-09
				4.62E-02	32	14774.50	1.66E-03	6.31E-04	2.03E-11	8.13E-08	9.64E-02	7.25E-01	3.90E-03	4.63E-01	2.45E-11	3.45E-13	1.77E-09
				6.17E-03	1	6174.18	8.33E-04	3.17E-04	1.02E-11	4.08E-08	4.85E-02	3.64E-01	1.96E-03	2.33E-01	1.23E-11	1.73E-13	8.07E-10
				1.08E-03	16	17241.93	2.33E-03	8.85E-04	2.84E-11	1.14E-07	1.35E-01	1.02E+00	5.47E-03	6.90E-01	3.44E-11	4.84E-13	2.48E-09
				3.52E-03	16	56322.56	7.60E-03	2.89E-03	9.28E-11	3.73E-07	4.42E-01	3.32E+00	1.79E-02	2.12E+00	1.12E-10	1.58E-12	8.09E-09
				7.76E-04	1	77649.94	1.05E-02	3.99E-03	1.28E-10	5.14E-07	6.09E-01	4.58E+00	2.46E-02	2.93E+00	1.55E-10	2.18E-12	1.12E-08
				7.60E-01	65	4940.40	6.67E-04	2.54E-04	8.14E-12	3.27E-08	3.88E-02	2.91E-01	1.57E-03	1.86E-01	9.85E-12	1.39E-13	7.10E-10
				2.53E-01	468	11832.29	1.60E-03	6.08E-04	1.95E-11	7.83E-08	9.29E-02	6.98E-01	3.76E-03	4.46E-01	2.36E-11	3.32E-13	1.70E-09
4				1.58E+04	16	252229.35	2.40E-07	1.91E-02	0.00E+00	0.00E+00	3.53E-02	8.77E-01	3.30E-03	3.95E-01	9.75E-15	9.81E-07	7.59E-03
				3.91E-03	32	125148.68	1.19E-07	9.47E-03	0.00E+00	0.00E+00	1.75E-02	4.35E-01	1.64E-03	1.96E-01	4.84E-15	4.87E-07	3.77E-03
				3.76E-04	1	37637.80	7.68E-02	2.92E-02	9.39E-10	3.77E-06	4.47E+00	3.36E+01	1.81E-01	2.15E+01	1.14E-09	1.60E-11	8.18E-08
				4.01E-03	1	4010.29	8.19E-03	3.12E-03	1.00E-10	4.01E-07	4.76E-01	3.58E+00	1.93E-02	2.29E+00	1.21E-10	1.70E-12	8.72E-09
				1.54E-02	468	72129.66	1.47E-01	5.60E-02	1.80E-09	7.22E-06	8.57E+00	6.44E+01	3.46E-01	4.11E+01	2.18E-09	3.06E-11	1.57E-07
				3.28E-03	16	52553.41	1.07E-01	4.08E-02	1.31E-09	5.26E-06	6.24E+00	4.69E+01	2.52E-01	3.00E+01	1.59E-09	2.23E-11	1.14E-07
				3.96E-02	40	15847.02	3.24E-02	1.23E-02	3.95E-10	1.59E-06	1.88E+00	1.41E+01	7.61E-02	9.03E+00	4.78E-10	6.73E-12	3.45E-08

FIGURE B-1
PATHFINDER CURIE ESTIMATE SPREADSHEET
LOWER CENTER SECTION

Region No.	Cylinder	Cylinder description	Outer Radius	Unit Volume	Quantity	Mat'l vol in region	Ci H3	Ci C14	K40	Ci Ca41	Ci Fe55	Ci Co60	Ci Ni59	Ci Ni63	Ci Zn63	Ci Sr90	Ci Zr93
5				1.86E-03	16	29777.06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
				4.62E+02	32	14774.50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
				2.73E-03	15	43671.74	5.09E-03	2.24E-03	7.20E-11	2.09E-07	3.43E-01	2.58E+00	1.39E-02	1.65E+00	8.71E-11	1.23E-12	6.28E-09
				5.93E-02	32	18976.82	2.56E-03	9.74E-04	3.33E-11	1.26E-07	1.49E-01	1.12E+00	6.02E-03	7.15E-01	3.78E-11	5.33E-13	2.73E-09
				6.17E-03	1	6174.18	8.33E-04	3.17E-04	1.02E-11	4.08E-08	4.85E-02	3.64E-01	1.96E-03	2.33E-01	1.23E-11	1.73E-13	8.87E-10
				2.53E+01	468	11832.29	1.60E-03	6.08E-04	1.95E-11	7.83E-08	9.29E-02	6.98E-01	3.76E-03	4.46E-01	2.36E-11	3.32E-13	1.70E-09
				3.22E-05	1	321533.03	4.34E-02	1.65E-02	5.30E-10	2.13E-06	2.52E+00	1.90E+01	1.02E-01	1.21E+01	6.41E-10	9.03E-12	4.62E-08
6				6.17E-03	1	6174.18	8.33E-05	3.17E-05	1.02E-12	4.08E-09	4.85E-03	3.64E-02	1.96E-04	2.33E-02	1.23E-12	1.73E-14	8.87E-11
				2.53E+01	468	11832.29	1.60E-04	6.08E-05	1.95E-12	7.83E-09	9.29E-03	6.98E-02	3.76E-04	4.46E-02	2.36E-12	3.32E-14	1.70E-10
7				6.17E-03	1	6174.18	8.33E-06	3.17E-06	1.02E-13	4.08E-10	4.85E-04	3.64E-03	1.96E-05	2.33E-03	1.23E-13	1.73E-15	8.87E-12
				2.64E-03	1	2640.18	3.56E-06	1.36E-06	4.35E-14	1.75E-10	2.07E-04	1.56E-03	8.38E-06	9.95E-04	5.26E-14	7.41E-16	3.79E-12
				2.53E-01	468	11832.29	1.60E-05	6.08E-06	1.95E-13	7.83E-10	9.29E-04	6.98E-03	3.76E-05	4.46E-03	2.36E-13	3.32E-15	1.70E-11
8	1	Steam separator region	167.64	none	0	0.00											
				6.56E-02	44	28944.16	1.30E-06	4.69E-07	8.09E-14	6.46E-11	7.50E-05	4.05E-04	3.05E-06	3.68E-04	1.44E-14	0.00E+00	1.47E-13
9				none	0	0.00											
				6.56E-02	44	28844.16	1.30E-05	4.69E-06	8.09E-13	6.46E-10	7.50E-04	4.05E-03	3.06E-05	3.68E-03	1.44E-13	0.00E+00	1.47E-12
10				1.77E-04	1	17684.36	3.21E-02	1.26E-02	1.59E-10	1.72E-06	2.02E+00	1.09E+01	8.17E-02	9.88E+00	3.90E-10	1.52E-11	3.97E-09
				6.56E-02	44	28844.16	1.30E-03	4.69E-04	8.09E-11	6.46E-08	7.50E-02	4.05E-01	3.06E-03	3.68E-01	1.44E-11	0.00E+00	1.47E-10
11				5.15E-04	1	51502.83	9.35E-02	3.68E-02	4.63E-10	5.01E-06	5.89E+00	3.17E+01	2.38E-01	2.88E+01	1.14E-09	4.43E-11	1.16E-08
				2.66E-03	44	117222.68	5.26E-03	1.91E-03	3.61E-10	2.62E-07	3.05E-01	1.65E+00	1.24E-02	1.49E+00	5.07E-11	0.00E+00	5.99E-10
				8.04E-02	44	35372.30	1.59E-03	5.75E-04	1.09E-10	7.92E-08	9.20E-02	4.97E-01	3.75E-03	4.51E-01	1.77E-11	0.00E+00	1.81E-10
				2.71E-04	1	27060.97	1.22E-03	4.40E-04	8.34E-11	[illegible]	7.04E-02	3.80E-01	2.87E-03	3.45E-01	1.36E-11	0.00E+00	1.38E-10
12				1.46E+04	1	14641.27	2.66E-02	1.05E-02	1.32E-10	1.43E-06	1.68E+00	9.01E+00	6.76E-02	8.18E+00	3.23E-10	1.26E-11	3.29E-09
				5.90E-04	1	50967.01	2.65E-03	9.59E-04	1.82E-10	1.32E-07	1.53E-01	8.28E-01	6.26E-03	7.52E-01	[illegible]	0.00E+00	3.01E-10
13				none	0	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14				none	0	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	2	Vessel cladding region	168.28	20.104	1	20.104	1.09E-07	6.27E-08	1.79E-13	8.73E-12	1.00E-05	5.44E-05	4.14E-07	4.94E-05	1.93E-15	1.20E-19	1.97E-14
16				20.104	1	20.104	1.09E-06	6.27E-07	1.79E-12	8.73E-11	1.00E-04	5.44E-04	4.14E-06	4.94E-04	1.93E-14	1.20E-18	1.97E-13
17				20.104	1	20.104	1.09E-05	6.27E-06	1.79E-11	8.73E-10	1.00E-03	5.44E-03	4.14E-05	4.94E-03	1.93E-13	1.20E-17	1.97E-12
18				122.552	1	122.552	1.15E-03	3.83E-04	1.09E-09	5.32E-08	6.12E-02	3.32E-01	2.52E-03	3.01E-01	1.18E-11	7.32E-16	1.20E-10
19				20.104	1	20.104	1.09E-05	6.27E-06	1.79E-11	8.73E-10	1.00E-03	5.44E-03	4.14E-05	4.94E-03	1.93E-13	1.20E-17	1.97E-12
20				20.104	1	20.104	1.09E-06	6.27E-07	1.79E-12	8.73E-11	1.00E-04	5.44E-04	4.14E-06	4.94E-04	1.93E-14	1.20E-18	1.97E-13
21				20.104	1	20.104	1.09E-07	6.27E-08	1.79E-13	8.73E-12	1.00E-05	5.44E-05	4.14E-07	4.94E-05	1.93E-15	1.20E-19	1.97E-14
22	3	Vessel wall region	175.90	247.172	1	247.172	1.68E-07	5.09E-08	1.13E-11	3.56E-11	6.57E-05	2.14E-05	1.19E-07	1.43E-05	[illegible]	[illegible]	8.61E-14
23				247.172	1	247.172	1.68E-06	5.09E-07	1.13E-10	3.56E-10	6.57E-04	2.14E-04	1.19E-06	1.43E-04	[illegible]	[illegible]	8.61E-13
24				247.172	1	247.172	1.68E-05	5.09E-06	1.13E-09	3.56E-09	6.57E-03	2.14E-03	1.19E-05	1.43E-03	2.90E-13	0.00E+00	8.61E-12
25				1,506.760	1	1,506.760	1.02E-03	3.10E-04	6.91E-08	2.17E-07	4.00E-01	1.30E-01	7.27E-04	8.69E-02	1.52E-11	0.00E+00	5.25E-10
26				247.172	1	247.172	1.68E-05	5.09E-06	1.13E-09	3.56E-09	6.57E-03	2.14E-03	1.19E-05	1.43E-03	2.90E-13	0.00E+00	8.61E-12
27				247.172	1	247.172	1.68E-06	5.09E-07	1.13E-10	3.56E-10	6.57E-04	2.14E-04	1.19E-06	1.43E-04	2.90E-14	0.00E+00	8.61E-13
28				247.172	1	247.172	1.68E-07	5.09E-08	1.13E-11	3.56E-11	6.57E-05	2.14E-05	1.19E-07	1.43E-05	2.90E-15	0.00E+00	8.61E-14
		TOTAL FOR VESSEL PACKAGE					6.23E-01	2.67E-01	7.99E-08	3.14E-05	3.74E+01	2.57E+02	1.50E+00	1.79E+02	8.78E-09	1.47E-06	1.14E-02
		Isotopic percentage of total					0.13%	0.06%	0.00%	0.00%	7.05%	53.90%	0.31%	37.53%	0.00%	0.00%	0.00%

SUMMARY OF CURIES BY COMPONENT:	Nb94	Tc99	Sn121m	Sb125	Te125m	Cs137	Eu152	Eu154	Total Curies
Superheater baffle	5.97E-04	1.24E-03	0.00E+00	1.11E-06	2.74E-07	9.66E-13	2.49E-02	2.00E-03	61.27
Superheater fuel insul. tubes (inner & outer)	1.14E-03	2.37E-03	0.00E+00	2.12E-06	5.25E-07	1.85E-12	4.77E-02	5.38E-03	117.42
Superheater support plate	2.70E-08	5.60E-08	0.00E+00	5.02E-11	1.24E-11	4.37E-17	1.13E-06	1.27E-07	6.00
Superheater control rods	5.62E-06	1.16E-05	0.00E+00	1.04E-08	2.58E-09	9.10E-15	2.35E-04	2.64E-05	0.58
Boiler fuel boxes	4.35E-03	2.11E-04	3.54E-02	6.40E-01	1.58E-01	1.65E-13	4.26E-03	4.80E-04	13.32
Boiler shroud	3.19E-04	3.06E-05	0.00E+00	1.32E-06	3.27E-07	1.31E-11	7.65E-03	2.66E-03	108.65
Boiler element hold down structure	7.95E-05	1.65E-04	0.00E+00	1.48E-07	3.65E-08	1.29E-13	3.32E-03	3.73E-04	8.16
Boiler CR guide tubes & remaining structure	6.40E-05	1.33E-04	0.00E+00	1.19E-07	2.94E-08	1.04E-13	2.67E-03	3.01E-04	3.97
Boiler element poison shims	2.45E-04	5.08E-04	0.00E+00	4.56E-07	1.13E-07	3.97E-13	1.02E-02	1.15E-03	25.19
Boiler control blades	8.33E-04	1.73E-03	0.00E+00	1.55E-06	3.82E-07	1.35E-12	3.48E-02	3.92E-03	85.55
Instrumentation tubing & sample holders	6.21E-05	1.29E-04	0.00E+00	1.15E-07	2.85E-08	1.00E-13	2.59E-03	2.92E-04	6.37
Boiler grid plate	3.29E-04	6.82E-04	0.00E+00	6.11E-07	1.51E-07	5.33E-13	1.37E-02	1.55E-03	33.78
Steam separators & supports	1.81E-05	1.74E-06	0.00E+00	1.93E-09	4.76E-10	0.00E+00	1.12E-03	1.61E-04	6.18
Feedwater ring & supports	5.12E-06	4.90E-07	0.00E+00	5.44E-10	1.34E-10	0.00E+00	3.17E-04	4.53E-05	1.74
Vessel cladding	2.12E-06	2.03E-07	0.00E+00	5.78E-12	1.43E-12	0.00E+00	3.40E-04	2.00E-05	0.72
Vessel	1.96E-06	1.91E-07	0.00E+00	6.57E-12	1.64E-12	0.00E+00	2.34E-03	1.38E-04	0.64
Totals	0.01	0.01	0.04	0.64	0.16	0.00	0.16	0.02	476.14
Percent of total by isotope	0.00%	0.00%	0.01%	0.13%	0.03%	0.00%	0.03%	0.00%	OK

FIGURE B-1
PATHFINDER CURIE ESTIMATE SPREADSHEET
UPPER RIGHT SECTION

Region No.	Cylinder	Cylinder description	Outer Radius	Ci Nb93m	Ci Nb94	Ci Tc99	Ci Sn121m	Ci Sb125	Ci Te125m	Ci Cs137	Ci Eu152	Ci Eu154	Total Ci in region	Total % by region
1	0	Core region	87.63	5.66E-12	6.32E-08	1.31E-07	0.00E+00	1.17E-10	2.90E-11	1.02E-16	2.64E-06	2.97E-07	6.49E-03	0.00%
				1.58E-11	1.76E-07	3.65E-07	0.00E+00	3.28E-10	8.10E-11	2.86E-16	7.36E-06	8.29E-07	1.81E-02	0.00%
				5.16E-11	5.76E-07	1.19E-06	0.00E+00	1.07E-09	2.64E-10	9.33E-16	2.41E-05	2.71E-06	5.92E-02	0.01%
				5.44E-12	6.08E-08	1.26E-07	0.00E+00	1.13E-10	2.79E-11	9.83E-17	2.54E-06	2.86E-07	[illegible]	0.00%
				1.08E-11	1.21E-07	2.51E-07	0.00E+00	2.25E-10	5.56E-11	1.96E-16	5.05E-06	5.69E-07	1.24E-02	0.00%
2				5.66E-11	6.32E-07	1.31E-06	0.00E+00	1.17E-09	2.90E-10	1.02E-15	2.64E-05	2.97E-06	6.49E-02	0.01%
				1.58E-10	1.76E-06	3.65E-06	0.00E+00	3.28E-09	8.10E-10	2.86E-15	7.36E-05	8.29E-06	1.81E-01	0.04%
				5.16E-10	5.76E-06	1.19E-05	0.00E+00	1.07E-08	2.64E-09	9.33E-15	2.41E-04	2.71E-05	5.92E-01	0.13%
				4.53E-11	5.06E-07	1.05E-06	0.00E+00	9.39E-10	2.32E-10	8.18E-16	2.11E-05	2.38E-06	5.19E-02	0.01%
				1.08E-10	1.21E-06	2.51E-06	0.00E+00	2.25E-09	5.56E-10	1.96E-15	5.05E-05	5.69E-06	1.24E-01	0.03%
3				2.27E-09	2.53E-05	5.25E-05	0.00E+00	4.71E-08	1.15E-08	4.10E-14	1.06E-03	1.19E-04	2.60E+00	0.55%
				1.13E-09	1.26E-05	2.60E-05	0.00E+00	2.34E-08	5.77E-09	2.03E-14	5.25E-04	5.91E-05	1.29E+00	0.27%
				5.66E-10	6.32E-06	1.31E-05	0.00E+00	1.17E-08	2.90E-09	1.02E-14	2.64E-04	2.97E-05	6.49E-01	0.14%
				1.58E-09	1.76E-05	3.65E-05	0.00E+00	3.28E-08	8.10E-09	2.86E-14	7.36E-04	8.29E-05	1.81E+00	0.38%
				5.16E-09	5.76E-05	1.19E-04	0.00E+00	1.07E-07	2.64E-08	9.33E-14	2.41E-03	2.71E-04	5.92E+00	1.24%
				7.11E-09	7.95E-05	1.65E-04	0.00E+00	1.48E-07	3.65E-08	1.29E-13	3.32E-03	3.73E-04	8.16E+00	1.71%
				4.53E-10	5.06E-06	1.05E-05	0.00E+00	9.39E-09	2.32E-09	8.18E-15	2.11E-04	2.38E-05	5.19E-01	0.11%
				1.08E-09	1.21E-05	2.51E-05	0.00E+00	2.25E-08	5.56E-09	1.96E-14	5.05E-04	5.69E-05	1.24E+00	0.26%
4				4.83E-03	2.84E-03	6.77E-11	2.37E-02	4.28E-01	1.06E-01	0.00E+00	0.00E+00	0.00E+00	1.90E+00	0.40%
				2.40E-03	1.41E-03	3.36E-11	1.17E-02	2.12E-01	5.24E-02	0.00E+00	0.00E+00	0.00E+00	9.44E-01	0.20%
				5.22E-08	5.83E-04	1.21E-03	0.00E+00	1.08E-06	2.67E-07	9.43E-13	2.43E-02	2.74E-03	5.98E+01	12.57%
				9.56E-09	6.21E-05	1.29E-04	0.00E+00	1.15E-07	2.85E-08	1.00E-13	2.59E-03	2.92E-04	6.37E+00	1.34%
				1.00E-07	1.12E-03	2.31E-03	0.00E+00	2.07E-06	5.12E-07	1.81E-12	4.66E-02	5.25E-03	1.15E+02	24.08%
				7.29E-08	8.14E-04	1.69E-03	0.00E+00	1.51E-06	3.73E-07	1.32E-12	3.40E-02	3.82E-03	8.35E+01	17.55%
				2.20E-08	2.45E-04	5.08E-04	0.00E+00	4.56E-07	1.13E-07	3.97E-13	1.02E-02	1.15E-03	2.52E+01	5.29%

FIGURE B-1
PATHFINDER CURIE ESTIMATE SPREADSHEET
LOWER RIGHT SECTION

Region No.	Cylinder	Cylinder description	Outer Radius	Ci Nb93m	Ci Nb94	Ci Tc99	Ci Sn121m	Ci Sb125	Ci Te125m	Ci Cs137	Ci Eu152	Ci Eu154	Total Ci in region	Total % by region
5														
				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00%
				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00%
				4.00E-09	4.47E-05	9.26E-05	0.00E+00	8.30E-08	2.05E-08	7.23E-14	1.87E-03	2.10E-04	4.59E+00	0.96%
				1.74E-09	1.94E-05	4.02E-05	0.00E+00	3.61E-08	8.91E-09	3.14E-14	8.11E-04	9.13E-05	1.99E+00	0.42%
				5.66E-10	6.32E-06	1.31E-05	0.00E+00	1.17E-08	2.90E-09	1.02E-14	2.64E-04	2.97E-05	6.49E-01	0.14%
				1.08E-09	1.21E-05	2.51E-05	0.00E+00	2.25E-08	5.56E-09	1.96E-14	5.05E-04	5.69E-05	1.24E+00	0.26%
				2.95E-08	3.29E-04	6.82E-04	0.00E+00	6.11E-07	1.51E-07	5.33E-13	1.37E-02	1.55E-03	3.38E+01	7.09%
6				5.66E-11	6.32E-07	1.31E-06	0.00E+00	1.17E-09	2.90E-10	1.02E-15	2.64E-05	2.97E-06	6.49E-02	0.01%
7				1.08E-10	1.21E-06	2.51E-06	0.00E+00	2.25E-09	5.56E-10	1.96E-15	5.05E-03	5.69E-06	1.24E-01	0.03%
				5.66E-12	6.32E-08	1.31E-07	0.00E+00	1.17E-10	2.90E-11	1.02E-16	2.64E-06	2.97E-07	6.49E-03	0.00%
				2.42E-12	2.70E-08	5.60E-08	0.00E+00	5.02E-11	1.24E-11	4.37E-17	1.13E-06	1.27E-07	2.77E-03	0.00%
				1.08E-11	1.21E-07	2.51E-07	0.00E+00	2.25E-10	5.56E-11	1.96E-16	5.05E-06	5.69E-07	1.24E-02	0.00%
8	1	Steam separator region	167.84										2.00E+00	0.00%
				9.39E-14	2.50E-09	2.40E-10	0.00E+00	2.66E-13	6.57E-14	0.00E+00	1.55E-07	2.22E-08	8.53E-04	0.00%
9													0.00E+00	0.00%
				9.39E-13	2.50E-08	2.40E-09	0.00E+00	2.66E-12	6.57E-13	0.00E+00	1.55E-06	2.22E-07	8.53E-03	0.00%
10				2.53E-09	6.74E-05	6.46E-06	0.00E+00	2.79E-07	6.89E-08	2.76E-12	1.61E-03	5.62E-04	2.29E+01	4.81%
				9.39E-11	2.50E-06	2.40E-07	0.00E+00	2.66E-10	6.57E-11	0.00E+00	1.55E-04	2.22E-05	8.53E-01	0.18%
11				7.38E-09	1.96E-04	1.88E-05	0.00E+00	8.12E-07	2.01E-07	8.03E-12	4.70E-03	1.64E-03	6.68E+01	14.02%
				3.82E-10	1.02E-05	9.74E-07	0.00E+00	1.08E-09	2.67E-10	0.00E+00	6.31E-04	9.01E-05	3.47E+00	0.73%
				1.15E-10	3.07E-06	2.94E-07	0.00E+00	3.26E-10	8.06E-11	0.00E+00	1.90E-04	2.72E-05	1.05E+00	0.22%
				8.81E-11	2.35E-06	2.25E-07	0.00E+00	2.50E-10	6.16E-11	0.00E+00	1.46E-04	2.08E-05	8.00E-01	0.17%
12				2.10E-09	5.58E-05	5.35E-06	0.00E+00	2.31E-07	5.71E-08	2.28E-12	1.34E-03	4.65E-04	1.90E+01	3.99%
				1.92E-10	5.12E-06	4.90E-07	0.00E+00	5.44E-10	1.36E-10	0.00E+00	3.17E-04	4.53E-05	1.74E+00	0.37%
13				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00%
14				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.[illegible]E+02	0.00E+00	0.00E+00	0.03%
15	2	Vessel cladding region	163.28	1.26E-14	3.36E-10	3.21E-11	0.00E+00	9.15E-16	2.26E-16	0.00E+00	5.[illegible]E-08	3.16E-09	1.15E-04	0.00%
16				1.26E-13	3.36E-09	3.21E-10	0.00E+00	9.15E-15	2.26E-15	0.00E+00	5.39E-07	3.16E-08	1.15E-03	0.00%
17				1.26E-12	3.36E-08	3.21E-09	0.00E+00	9.15E-14	2.26E-14	0.00E+00	5.39E-06	3.16E-07	1.15E-02	0.00%
18				7.66E-11	2.05E-06	1.96E-07	0.00E+00	5.58E-12	1.38E-12	0.00E+00	3.29E-04	1.93E-05	6.98E-01	0.15%
19				1.26E-12	3.36E-08	3.21E-09	0.00E+00	9.15E-14	2.26E-14	0.00E+00	5.39E-06	3.16E-07	1.15E-02	0.00%
20				1.26E-13	3.36E-09	3.21E-10	0.00E+00	9.15E-15	2.26E-15	0.00E+00	5.39E-07	3.16E-08	1.15E-03	0.00%
21				1.26E-14	3.36E-10	3.21E-11	0.00E+00	9.15E-16	2.26E-16	0.00E+00	5.39E-08	3.16E-09	1.15E-04	0.00%
22	3	Vessel wall region	175.90	5.49E-14	3.10E-10	3.02E-11	0.00E+00	1.04E-15	2.60E-16	0.00E+00	3.71E-07	2.19E-09	1.02E-04	0.00%
23				5.49E-13	3.10E-09	3.02E-10	0.00E+00	1.04E-14	2.60E-15	0.00E+00	3.71E-06	2.19E-07	1.02E-03	0.00%
24				5.49E-12	3.10E-08	3.02E-09	0.00E+00	1.04E-13	2.60E-14	0.00E+00	3.71E-05	2.19E-06	1.02E-02	0.00%
25				3.35E-10	1.89E-06	1.84E-07	0.00E+00	6.34E-12	1.59E-12	0.00E+00	2.26E-03	1.34E-04	6.22E-01	0.13%
26				5.49E-12	3.10E-08	3.02E-09	0.00E+00	1.04E-13	2.60E-14	0.00E+00	3.71E-05	2.19E-06	1.02E-02	0.00%
27				5.49E-13	3.10E-09	3.02E-10	0.00E+00	1.04E-14	2.60E-15	0.00E+00	3.71E-06	2.19E-07	1.02E-03	0.00%
28				5.49E-14	3.10E-10	3.02E-11	0.00E+00	1.04E-15	2.60E-16	0.00E+00	3.71E-07	2.19E-08	1.02E-04	0.00%
				********	********	********	********	********	********	********	********	********	********	
		TOTAL FOR VESSEL PACKAGE		7.23E-03	8.05E-03	7.20E-03	3.54E-02	6.40E-01	1.58E-01	1.87E-11	1.56E-01	1.93E-02	4.76E+02	
		Isotopic percentage of total		0.00%	0.00%	0.00%	0.01%	0.13%	0.03%	0.00%	0.03%	0.00%		

APPENDIX C

MICROSHIELD INPUT AND OUTPUT DESCRIPTION

APPENDIX C

MICROSHIELD INPUT AND OUTPUT DESCRIPTION

MICROSHIELD Version 3.12 was used by TLG Engineering to perform the calculations required to estimate the shielding thickness for packaging the Pathfinder reactor vessel and internals. The computer code was verified and validated in-house using benchmark problems from ANSI 6.6.1 "Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plants".

An extensive number of calculations were made to determine the exposure rate two meters from the surface of the shipping package. For the purposes of this analysis, the vessel and its internals (the source region) were divided into four concentric regions and three axial regions as follows:

A. Concentric Regions
   1. Core region.
   2. Steam separator region.
   3. Vessel clad region.
   4. Vessel wall region.

B. Axial Regions
   1. Core height.
   2. One foot segment above the core.
   3. One foot segment below the core.

Exposure rate contributions were calculated for each of the twelve regions for various package shielding thicknesses and packing densities of gravel (concrete) in the vessel. Additionally, a calculation was made for various packing densities of gravel at the core centerline, one centimeter from the reactor vessel outer wall. This calculation was made in order to benchmark the shielding calculations to exposure rate measurements made at Pathfinder by the plant staff.

Figure C-1 is a MICROSHIELD calculation (input and output) for the exposure rate at two meters from the package surface due to the core region internals, for the height of the core, with twenty-five void percent gravel and a two inch thick carbon steel shield. The source term for the region, as for all regions, was taken from the curie spreadsheet as shown in Appendix B.

FIGURE C-1
MICROSHIELD SAMPLE PROBLEM

Microshield 3.12
================
(TLG Engineering - #141)

Page : 1 File Ref: ________
File : RXSHD101.MSH Date: __/__/__
Run date: October 3, 1989 By: ________
Run time: 9:07 a.m. Checked: ________

CASE: Core Region - Core Height - 25 v/O concrete - 2.0 in. shld.

GEOMETRY 7: Cylinder source from side - cylindrical shields

Distance to detector........................	X	403.2	cm.
Source length................................	L	182.880	"
Dose point height from base................	Y	91.440	"
Source cylinder radius......................	T1	87.630	"
Thickness of second shield..................	T2	79.375	"
Thickness of third shield...................	T3	0.640	"
Thickness of fourth shield..................	T4	7.620	"
Thickness of fifth shield...................	T5	5.080	"
Microshield inserted air gap................	air	222.855	"

Source Volume: 4.41186e+6 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Shield 4	Shield 5	Air gap
Air						.001220
Aluminum						
Carbon						
Concrete	1.5390	1.7280				
Hydrogen						
Iron	.32620	.15560	7.90	7.890	7.90	
Lead						
Lithium						
Nickel						
Tin						
Titanium						
Tungsten						
Urania						
Uranium						
Water						
Zirconium	.5620					

FIGURE C-1
MICROSHIELD SAMPLE PROBLEM
(continued)

Page 2 File: RXSH101.MSH

CASE: Core Region - Core Height - 25 v/O concrete - 2.0 in. shld

BUILDUP FACTOR: based on GP method
Using the characteristics of the materials in shield 5.

INTEGRATION PARAMETERS:

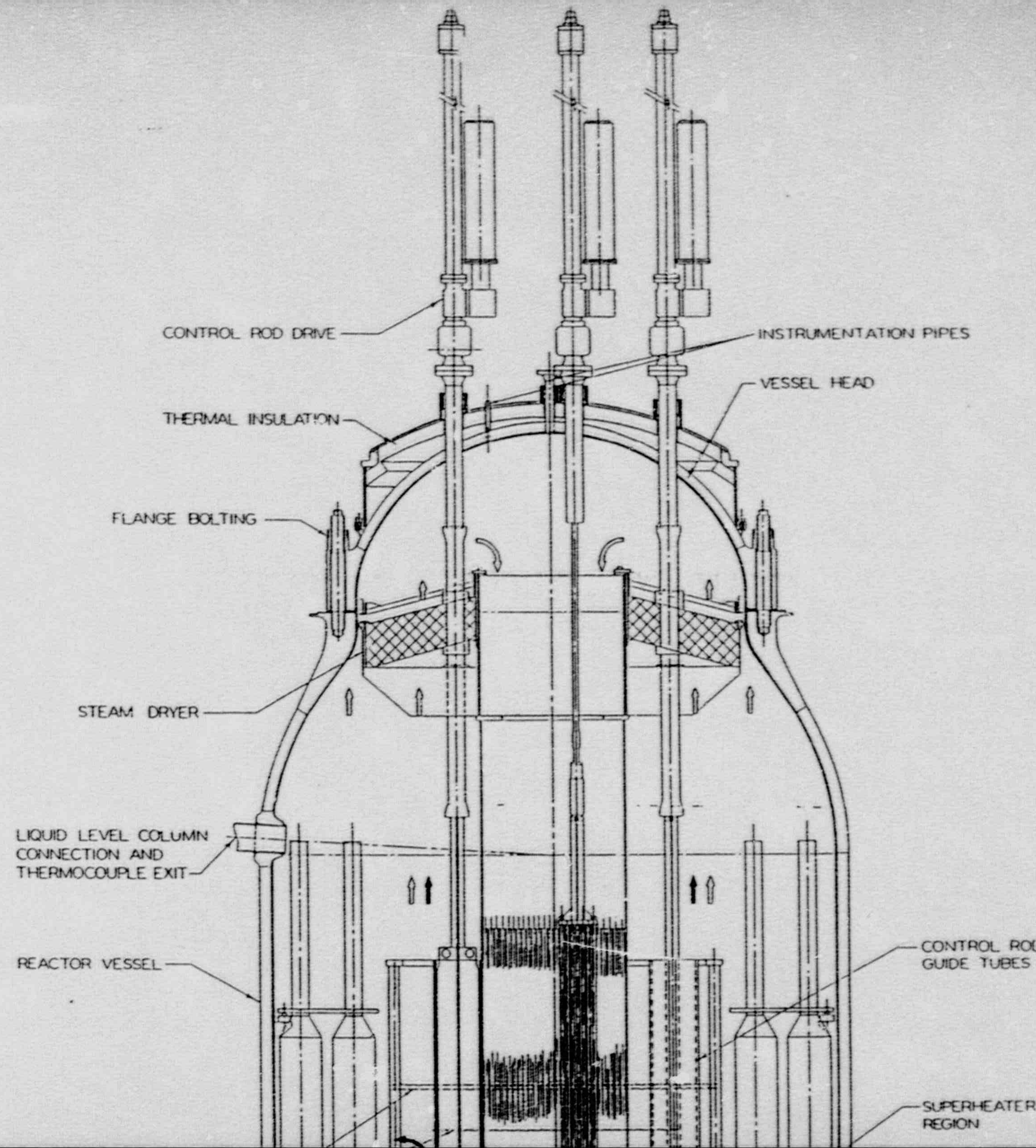
Number of lateral angle segments (Ntheta)..... 15
Number of azimuthal angle segments (Npsi)..... 15
Number of radial segments (Nradius)........... 15

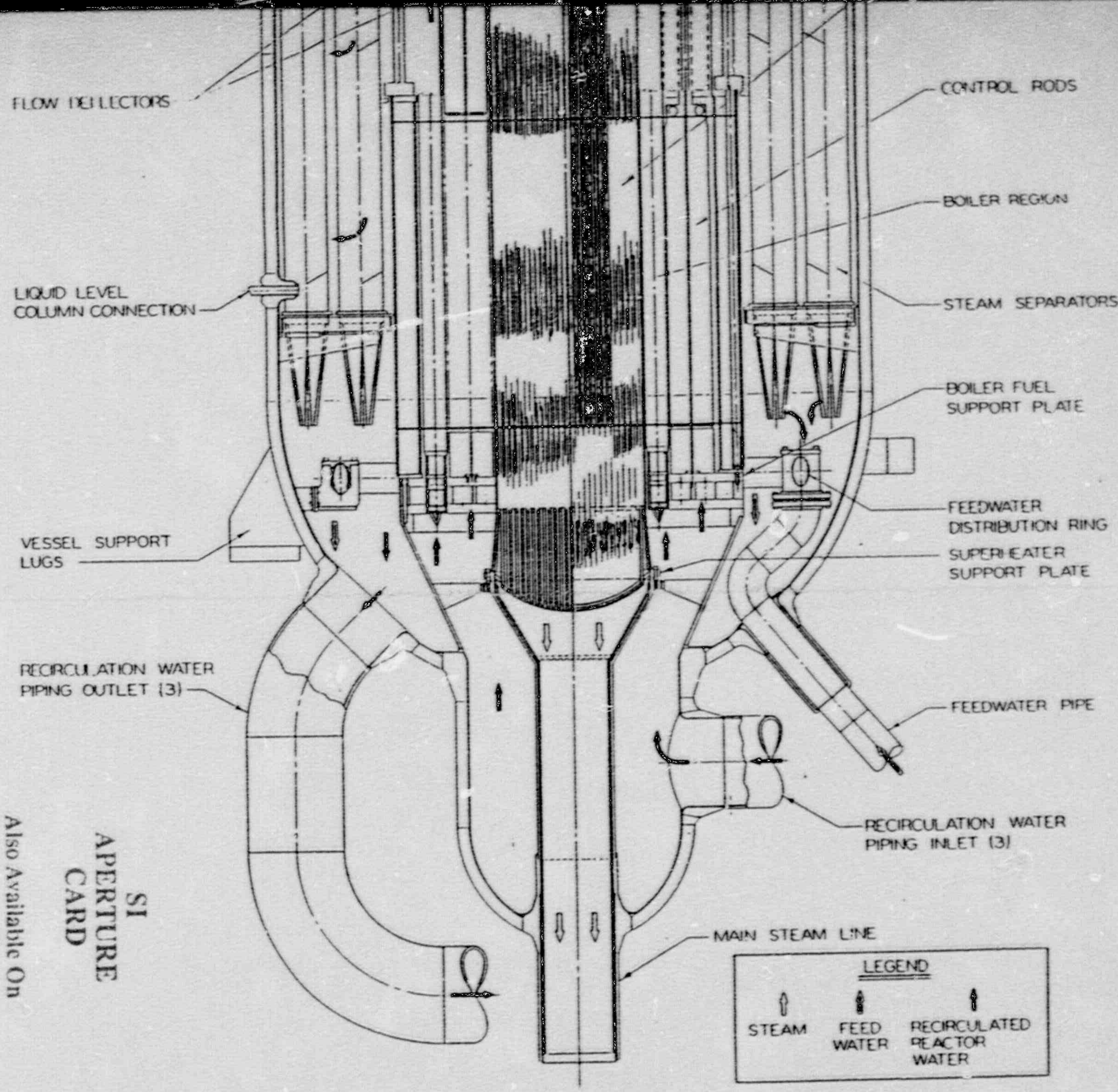
SOURCE NUCLIDES:

Co-60: 1.6390e+02 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.3359	6.064e+12	2.407e+00	4.344e-03
2	1.1797	6.064e+12	9.331e-01	1.734e-03
3	.6953	9.892e+08	1.815e-06	3.737e-09
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.213e+13	3.341e+00	6.078e-03


CONTROL ROD DRIVE
INSTRUMENTATION PIPES
VESSEL HEAD
THERMAL INSULATION
FLANGE BOLTING
STEAM DRYER
LIQUID LEVEL COLUMN
CONNECTION AND
THERMOCOUPLE EXIT
REACTOR VESSEL
CONTROL ROD
GUIDE TUBES
SUPERHEATER
REGION


FLOW DEFLECTORS
CONTROL RODS
BOILER REGION
LIQUID LEVEL COLUMN CONNECTION
STEAM SEPARATORS
BOILER FUEL SUPPORT PLATE
FEEDWATER DISTRIBUTION RING
VESSEL SUPPORT LUGS
SUPERHEATER SUPPORT PLATE
RECIRCULATION WATER PIPING OUTLET (3)
FEEDWATER PIPE
RECIRCULATION WATER PIPING INLET (3)
MAIN STEAM LINE
LEGEND
STEAM
FEED WATER
RECIRCULATED REACTOR WATER

ATTACHMENT 4

RESPIRATORY EQUIPMENT USE GUIDELINES

RESPIRATORY EQUIPMENT USE GUIDELINES

(Levels are in terms of DPM/100 cm^2, except for the last category)

	No Respiratory Protection	Protection Factor > 50	Protection Factor > 1,000
Removable contamination with no mechanism for raising airborne	< 100,000	100,000 to 10,000,000	> 10,000,000
Removable contamination with a mechanism for raising airborne	< 5,000	5,000 to 1,000,000	> 1,000,000
Fixed contamination with a mechanism for raising airborne	< 1,000	1,000 to 100,000	> 100,000

AIRBORNE CONCENTRATION	PROTECTION FACTOR SUGGESTED
0.25 MPC - 10 MPC	50
10 MPC - 100 MPC	1,000
Greater than 100 MPC	10,000

DISCUSSION

The above criteria are conservative guidelines, and it may be that a job could have conditions in excess of the specified levels, but not need protective equipment that meet the above range levels. As the job conditions approach the upper end of the ranges specified, the strength of the recommendation to require the appropriate respiratory protective equipment increases.

Keep in mind that engineering controls, such as process, containment, or ventilation techniques, or decontamination, must be used to the extent practical to lower airborne levels to limit or avoid use of respirators. In addition, in hot environments, or where waterproof clothing is specified, some type of supplied air should be specified, depending on job duration and worker fatigue.

ATTACHMENT 5

PROTECTIVE CLOTHING GUIDELINES

PROTECTIVE CLOTHING GUIDELINES

Protective Clothing Requirements are based primarily on the level of removable contamination in the job work area according to the following guidelines:

> NOTE: Anytime respiratory protection equipment is required a hood should be required.

> NOTE: If wet conditions may be encountered it may be appropriate to require a waterproof outer layer or parts of a waterproof outer layer in addition to the normal protective clothing requirements.

1. Class I Area ($\geq$ 500 dpm/100 cm^2 but < 100,000 dpm/100 cm^2)

   A. Coveralls (1 pair)
   B. Surgeon's cap or hood
   C. Plastic shoecover with rubber overshoes (rubbers) or cloth shoe covers
   D. Rubber gloves (with glove liners) or canvas gloves

   NOTE: The use of coveralls, surgeon's cap or hood may be exempted for work in which it is not expected that areas of the body other than the hands and/or feet may contact surfaces in the work area.

2. Class II Area ($\geq$ 10,000 dpm/100 cm^2 but < 100 dpm/100 cm^2)

   A. No personal outer clothing
   B. Coveralls
   C. Surgeon's cap or hood
   D. Plastic shoecover with rubber overshoes (rubber) or cloth shoe covers
   E. Rubber gloves with glove liners
   F. Taping of junctions

   NOTE: Items a,b,c, and f may be exempted for work in which it is not expected that areas of the body other than the hands and/or feet may contact surfaces in the work area.

3. Class III Area ($\geq$ 100,000 dpm/100 cm^2)

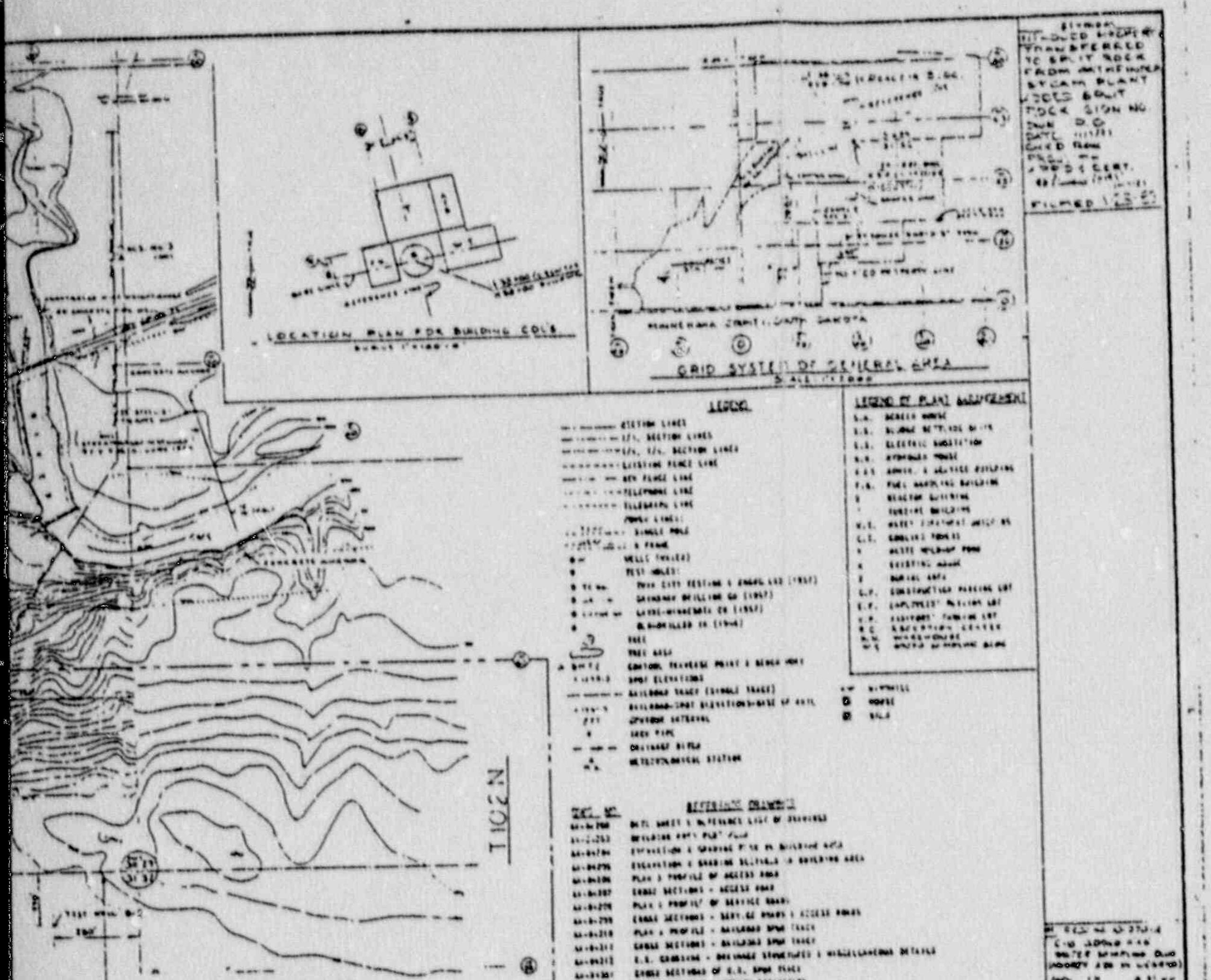
   A. No personal outer clothing
   B. 2 pair coveralls
   C. Hood
   D. Plastic shoecovers with rubber overshoes
   E. 2 pair rubber gloves with one pair glove liners
   F. Taping of junctions

   NOTE: Two pair of coveralls consists of any combination of cloth, paper, or plastic coveralls.

ATTACHMENT 6

REACTOR BUILDING AND FUEL HANDLING BUILDING DRAWINGS


HIGH FUEL OIL
STORAGE TANKS
R 48 W



SI
APERTURE
CARD

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Aperture Card

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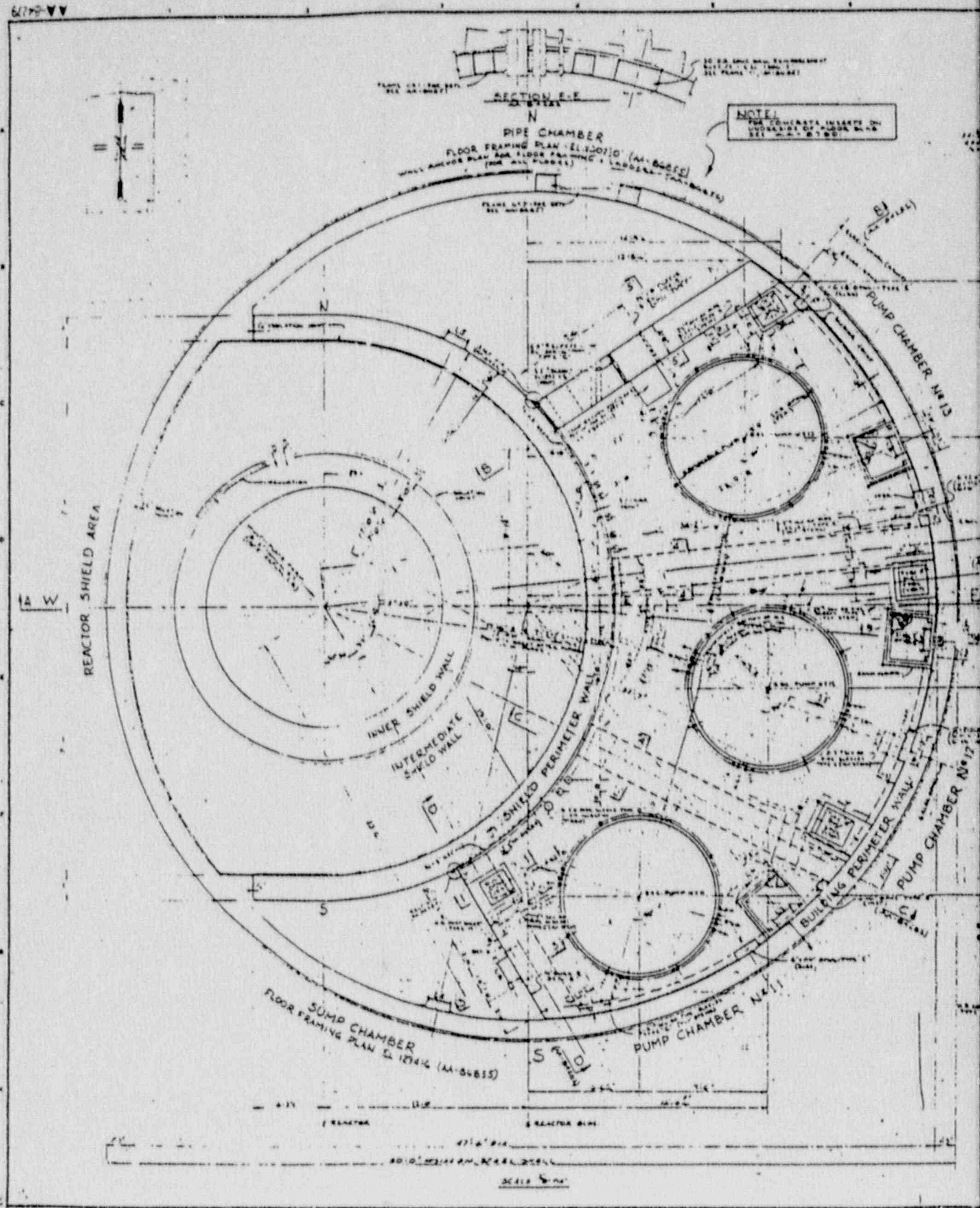
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NOTE
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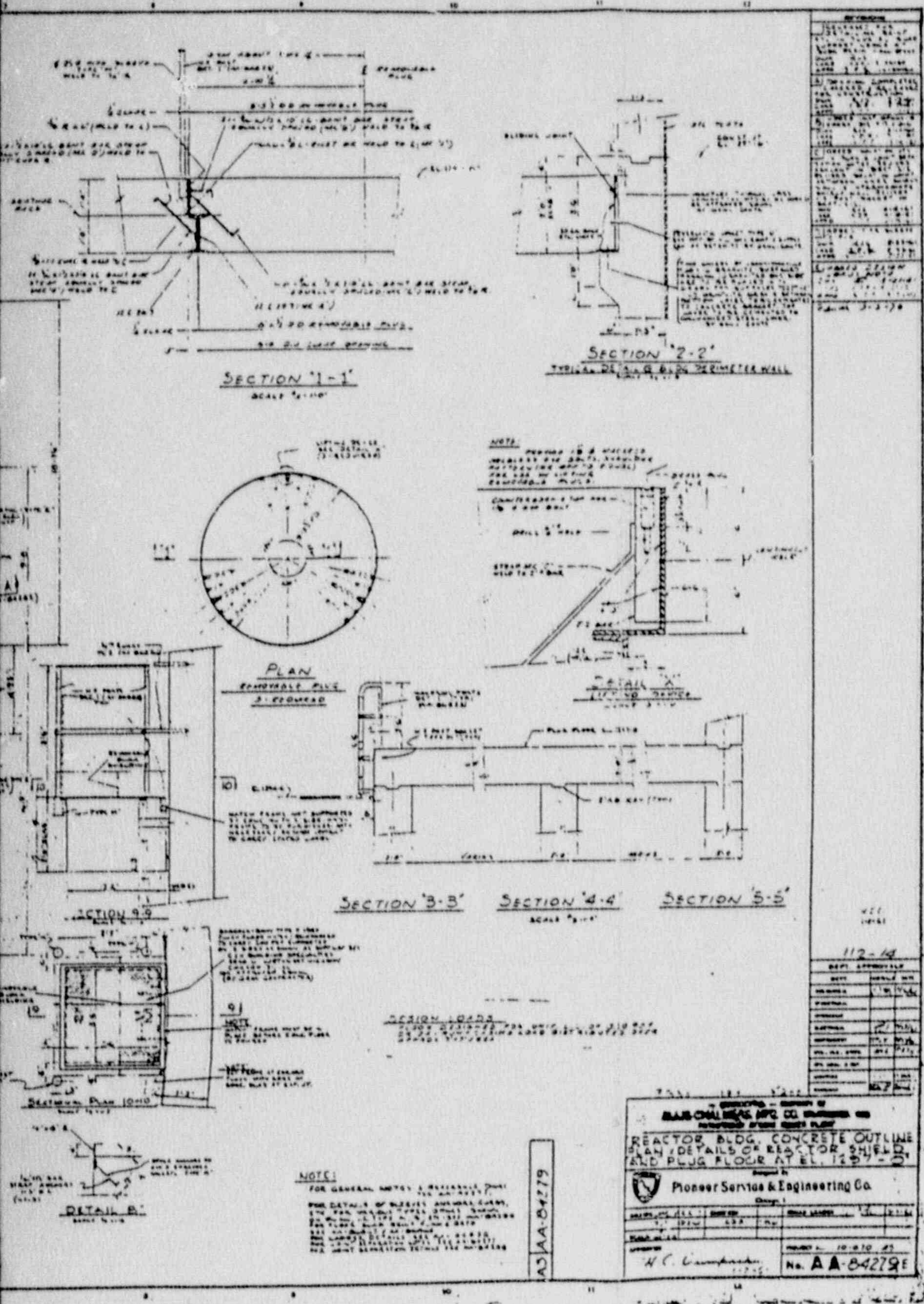
INNER SHIELD WALL
INTERMEDIATE SHIELD WALL
SHIELD PERIMETER WALL
BUILDING PERIMETER WALL
PUMP CHAMBER No 12
PUMP CHAMBER No 11
SUMP CHAMBER
S



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APERTURE
CARD

Also Available On
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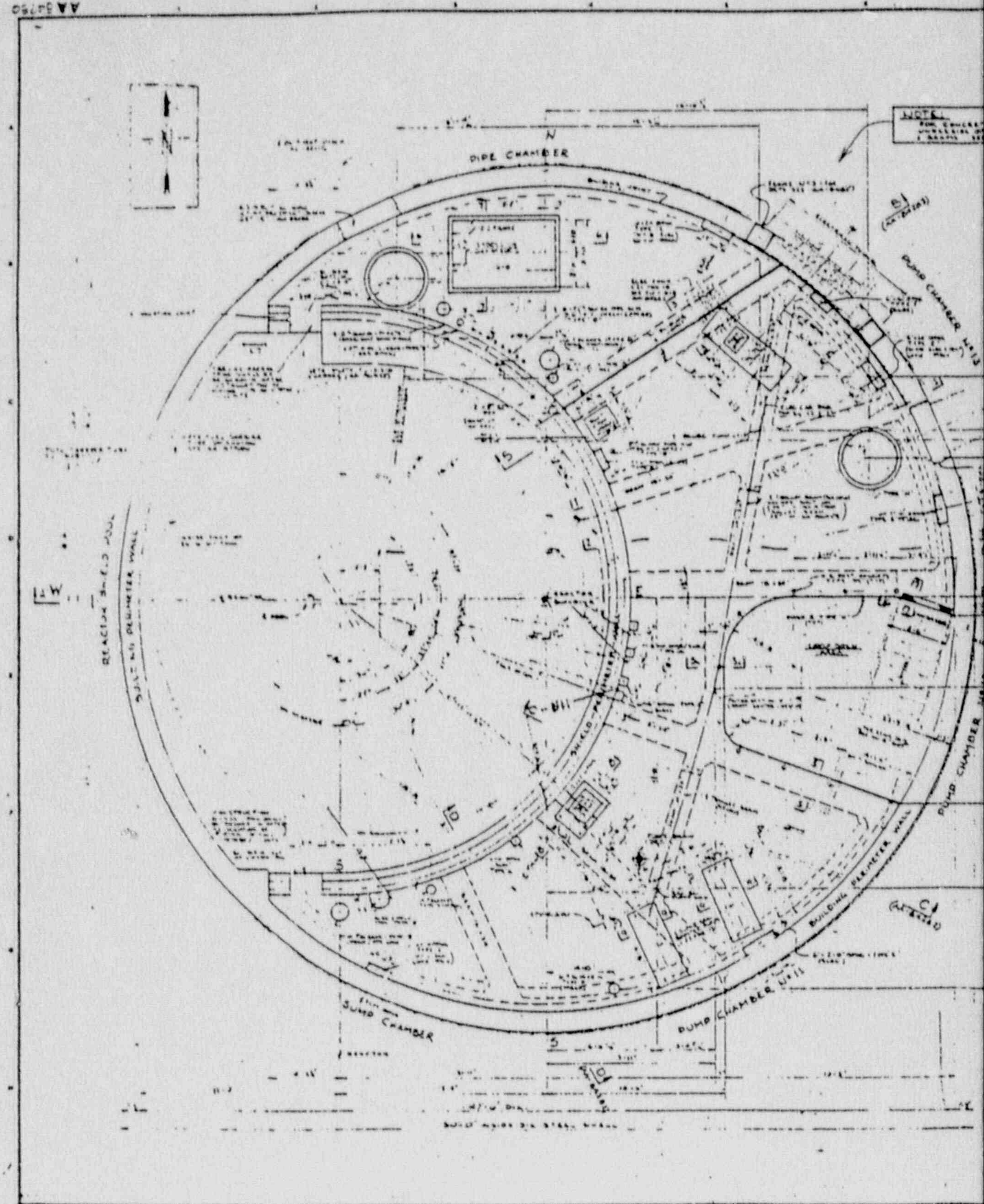
PIPE CHAMBER
N
W
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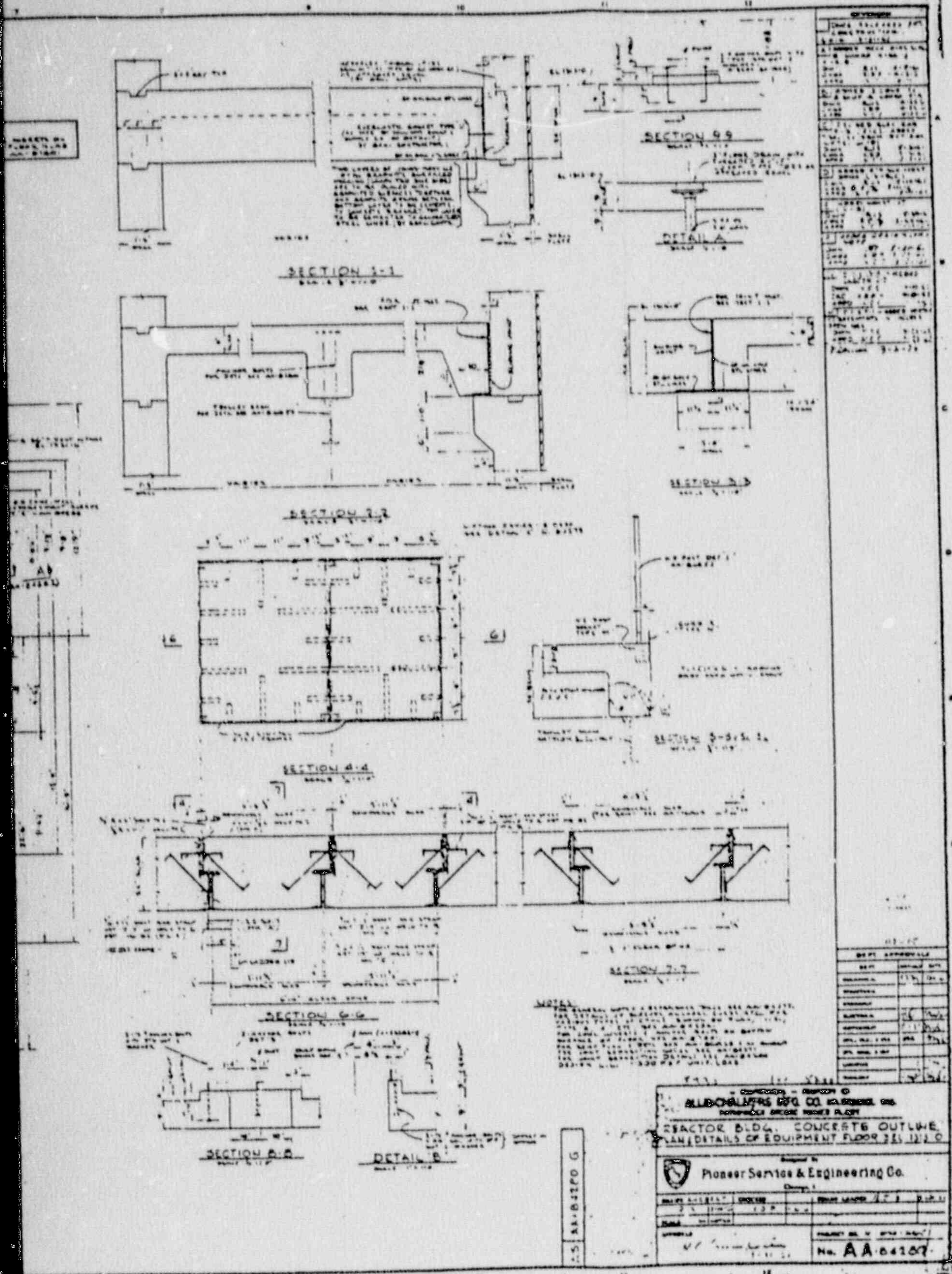
PUMP CHAMBER UNIT
C1



SI
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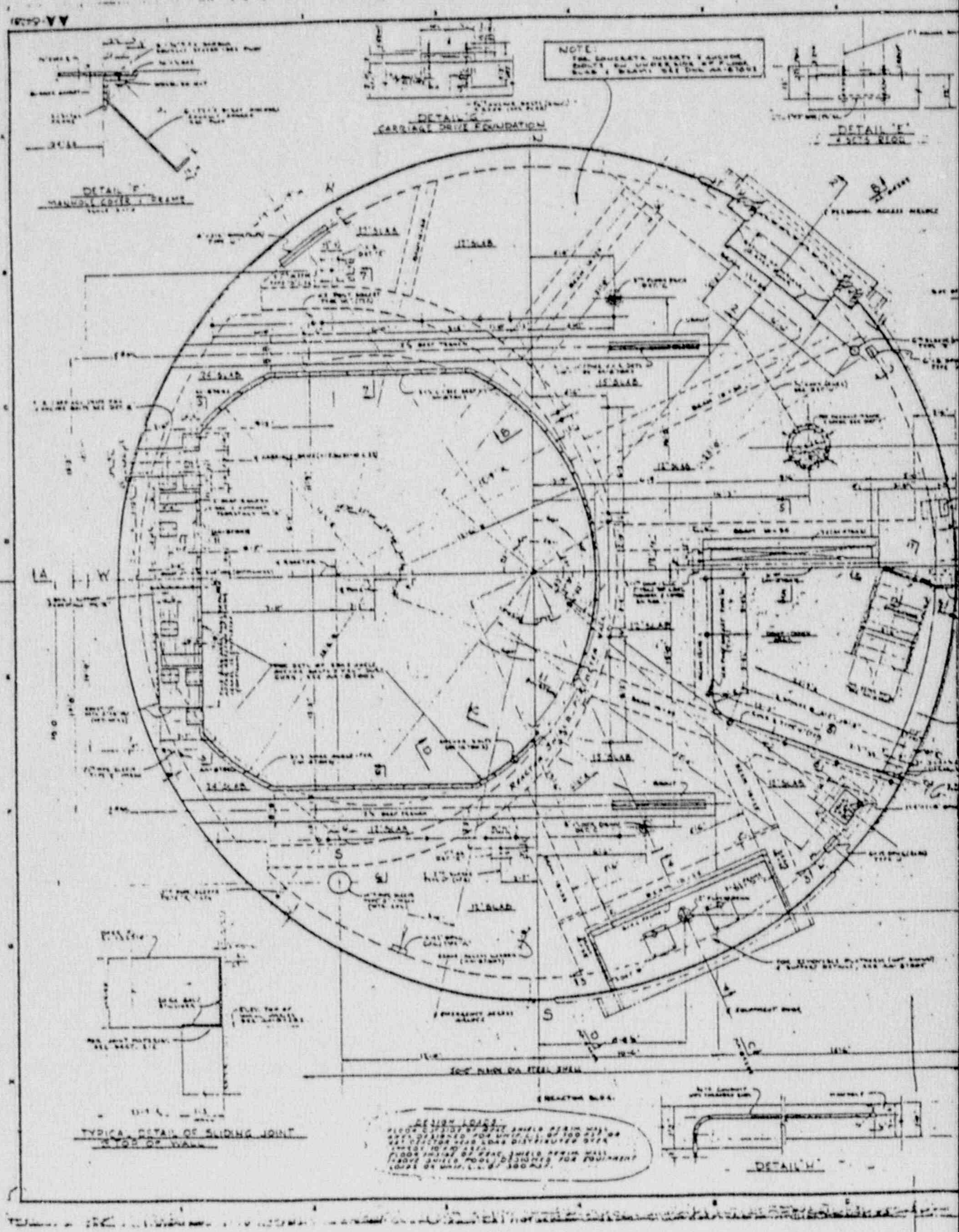
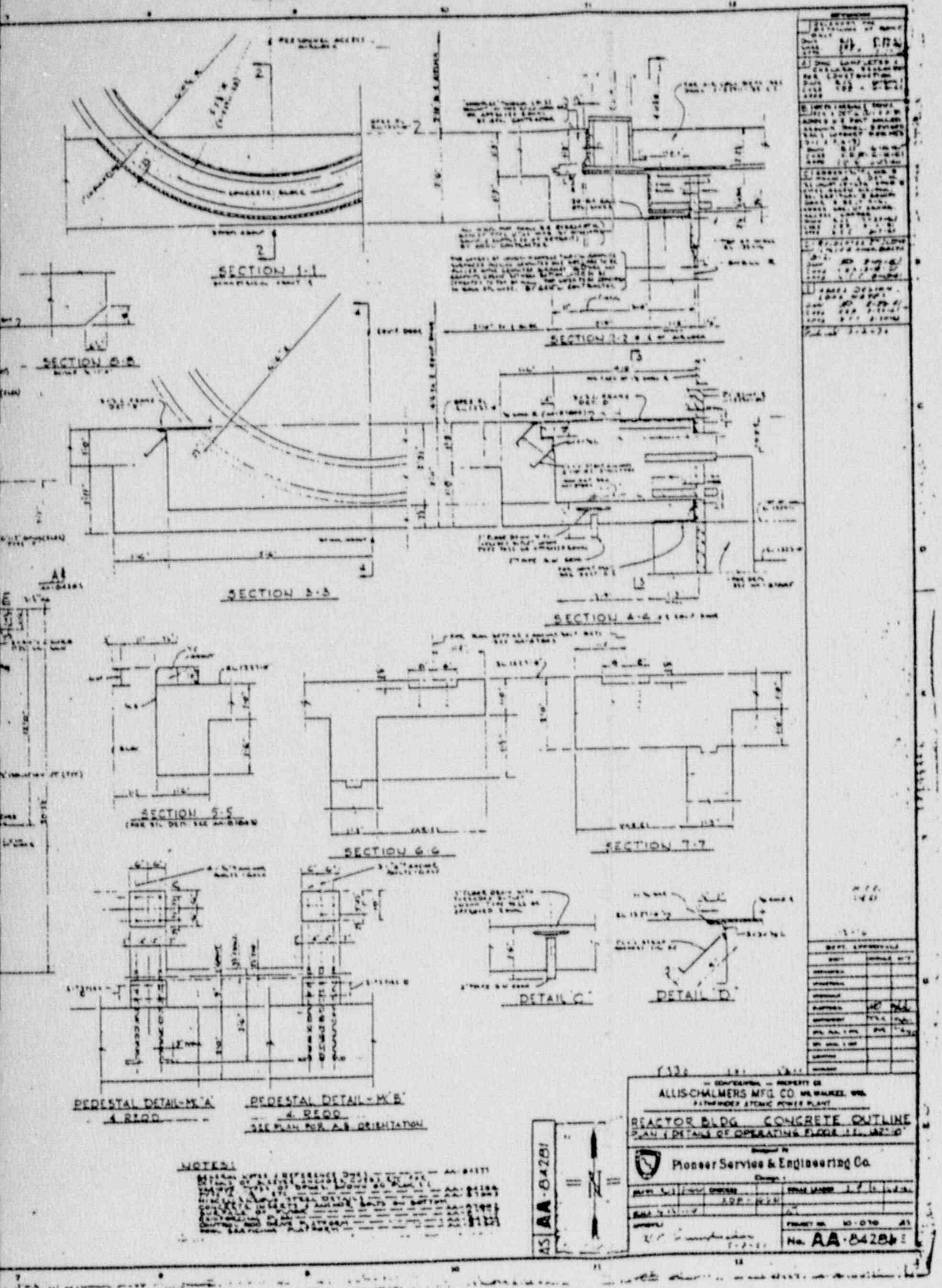


DETAIL 'F'
DETAIL 'G'
CARRIAGE DRIVE FOUNDATION
DETAIL 'E'
NOTE:
TYPICAL DETAIL OF SLIDING JOINT
DETAIL 'H'
DESIGN LOADS



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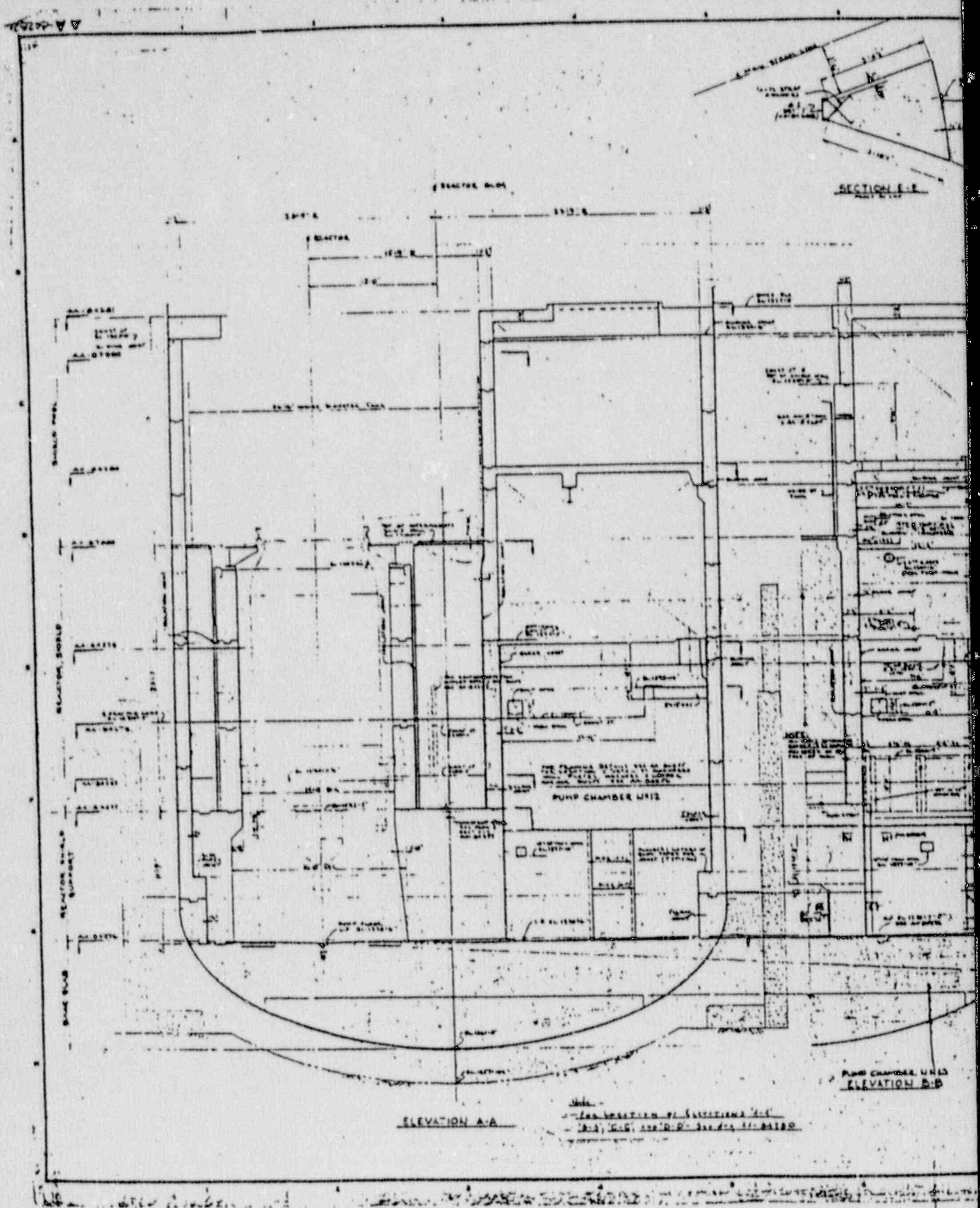
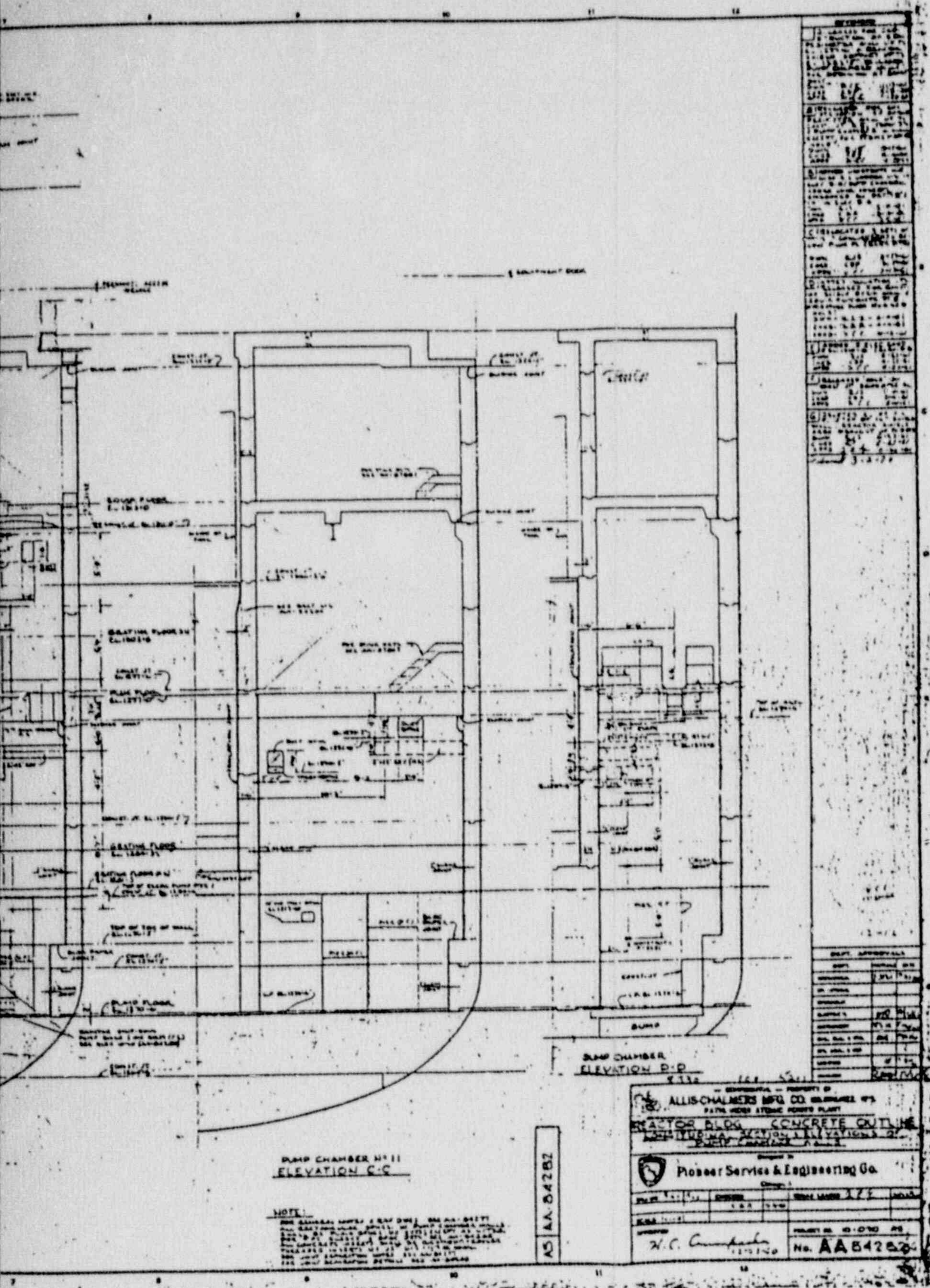


SECTION E-E
PUMP CHAMBER
ELEVATION A-A
ELEVATION B-B



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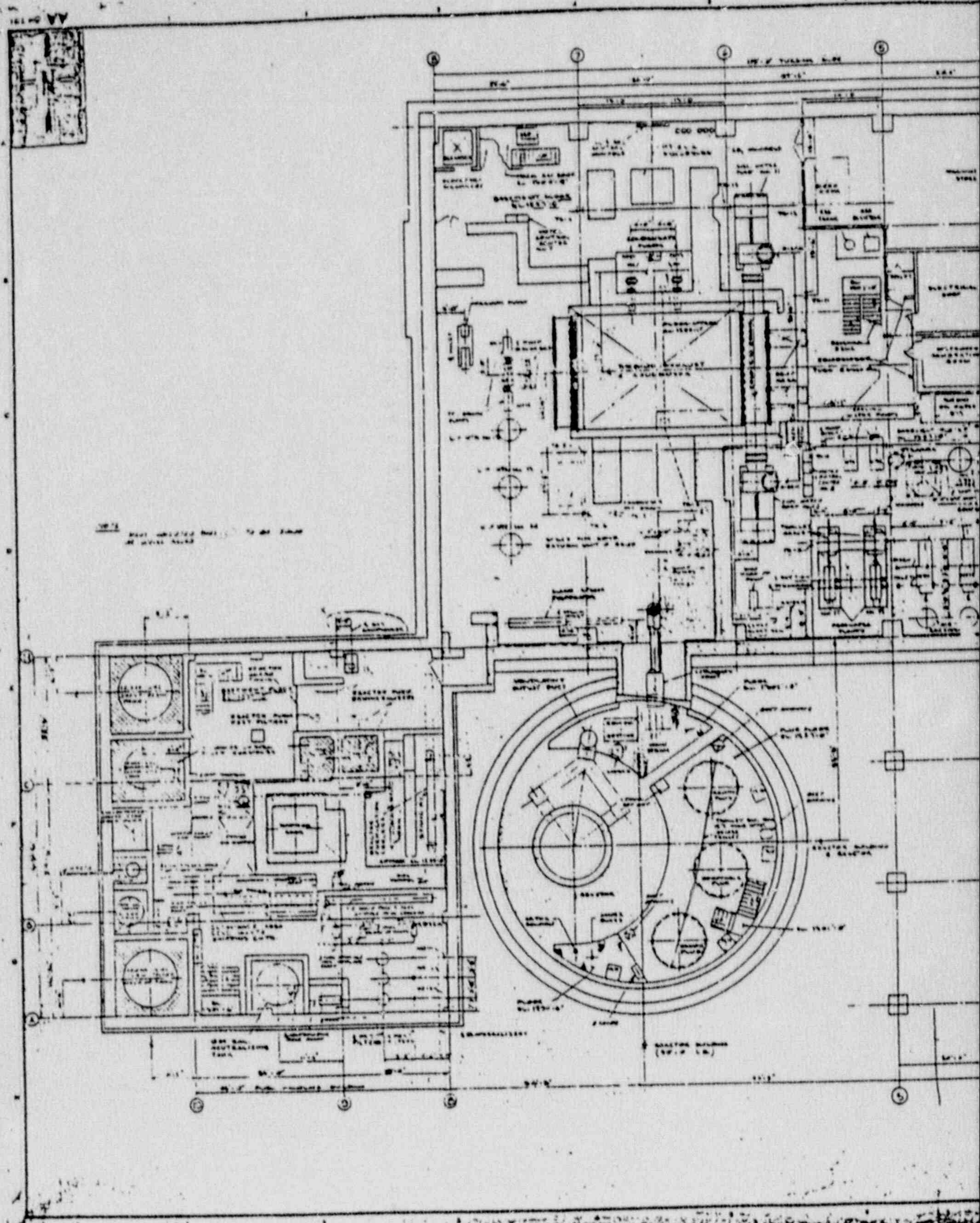

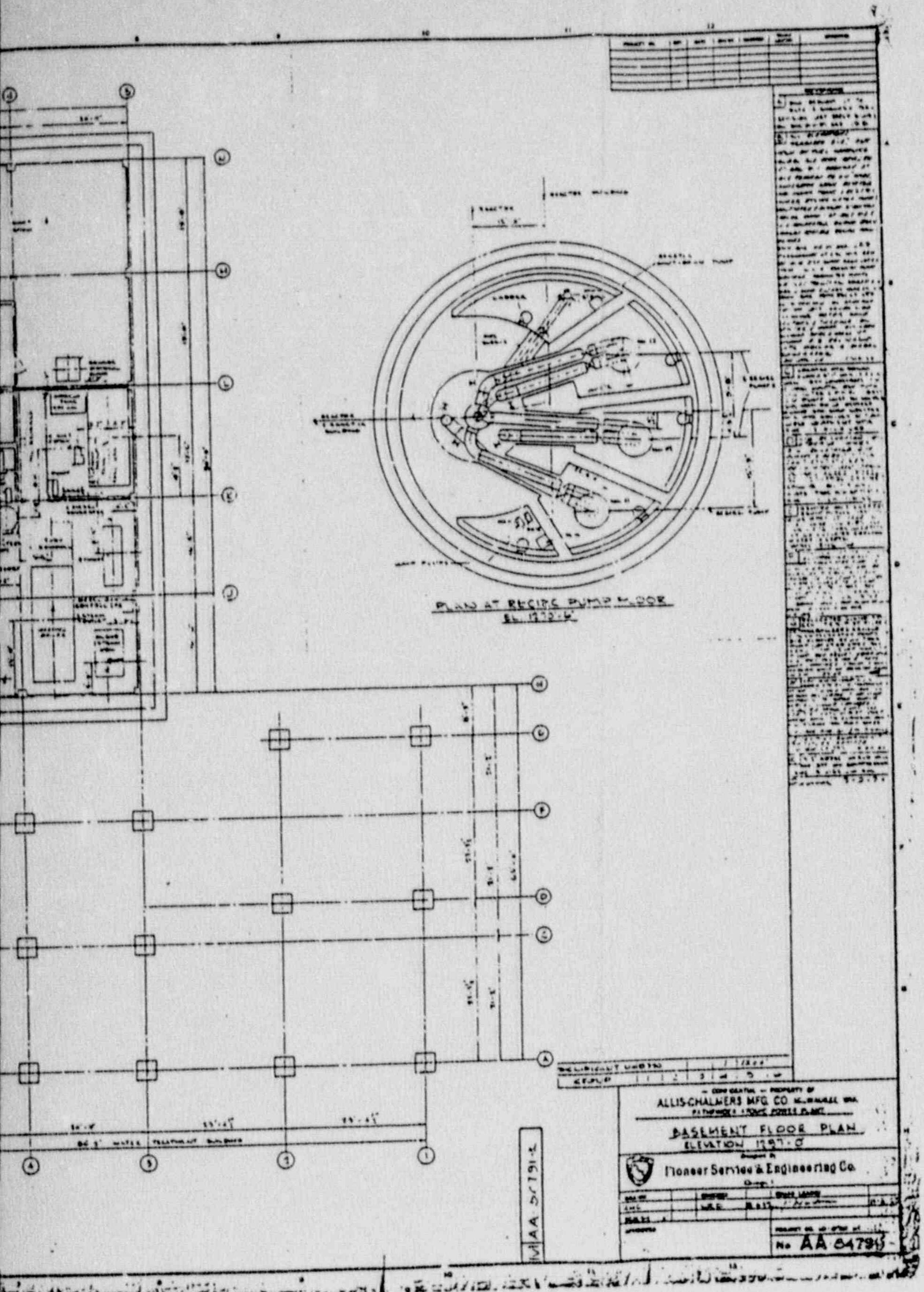

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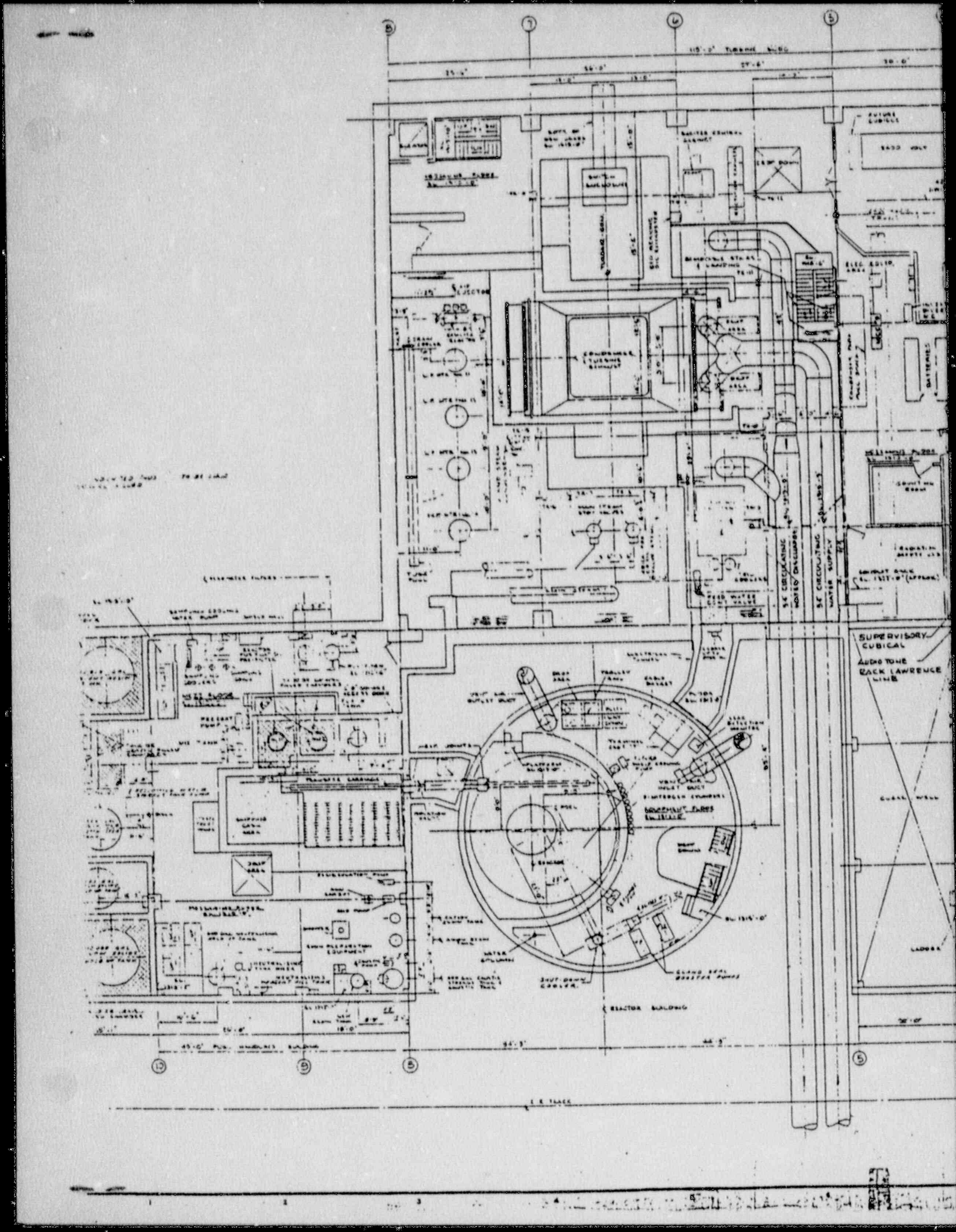
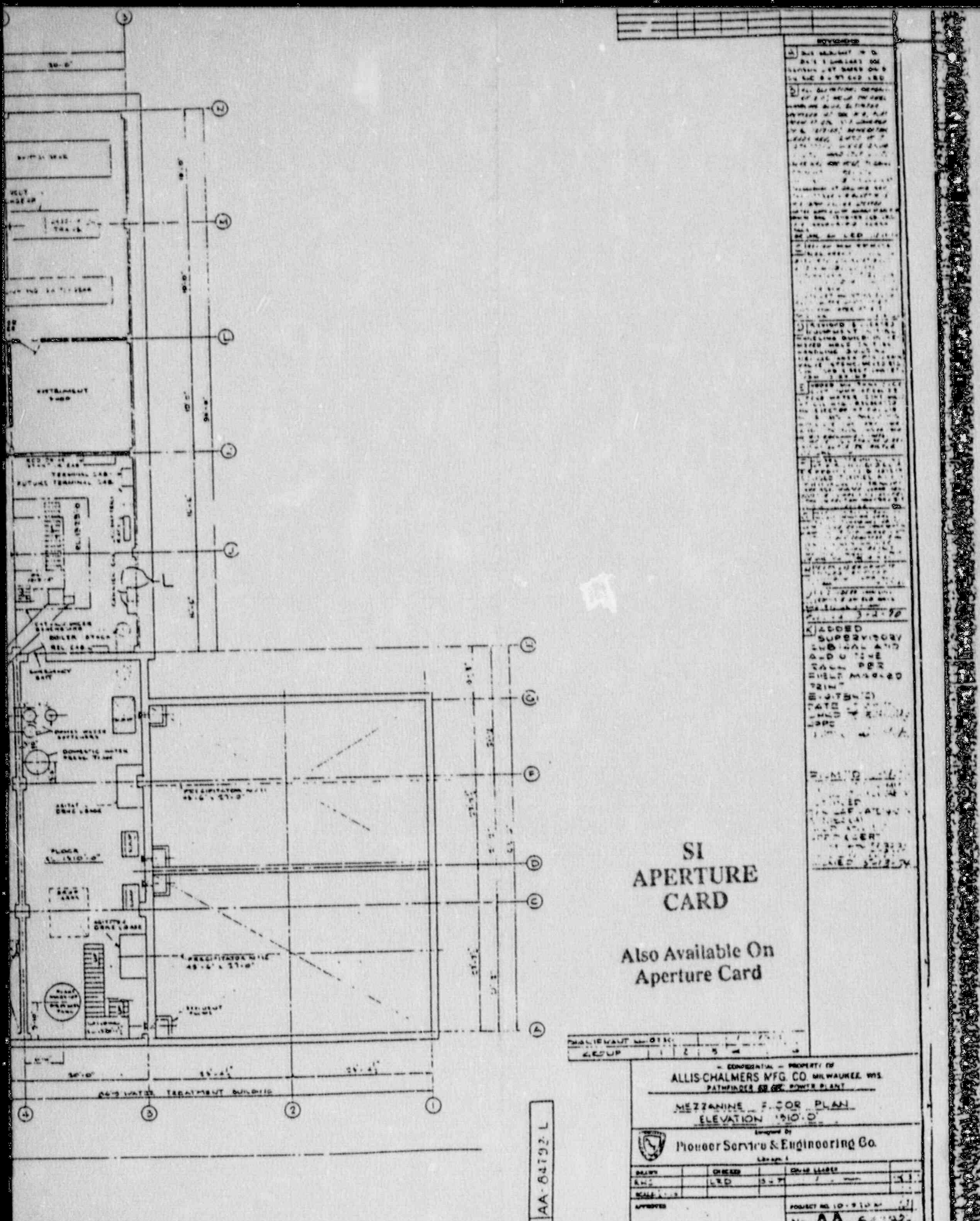

SUPERVISORY CUBICAL
AUDIO TONE RACK LAWRENCE LINE
5' CIRCULATING WATER SUPPLY
BATTERIES



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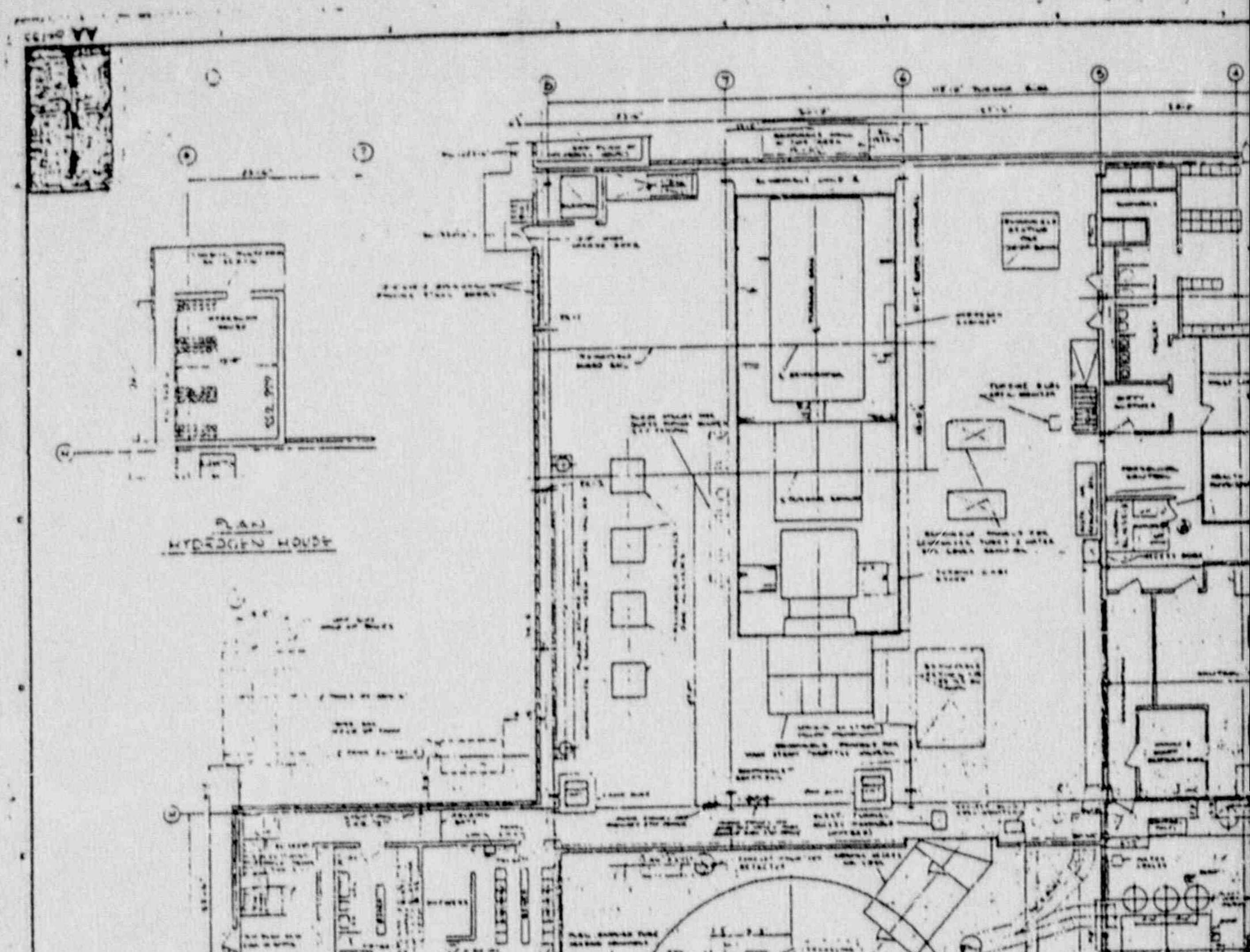
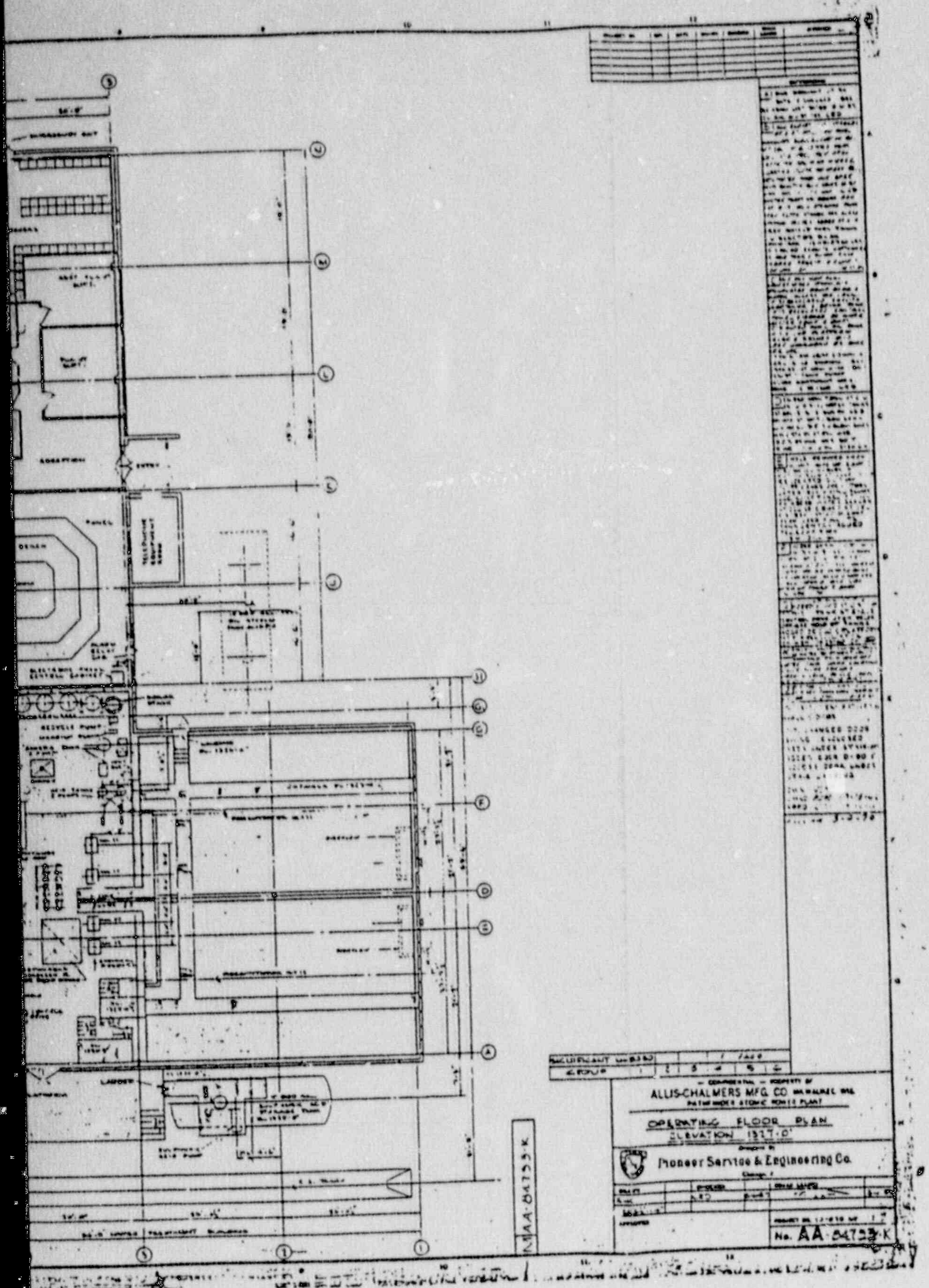

PLAN
HYDROGEN HOUSE



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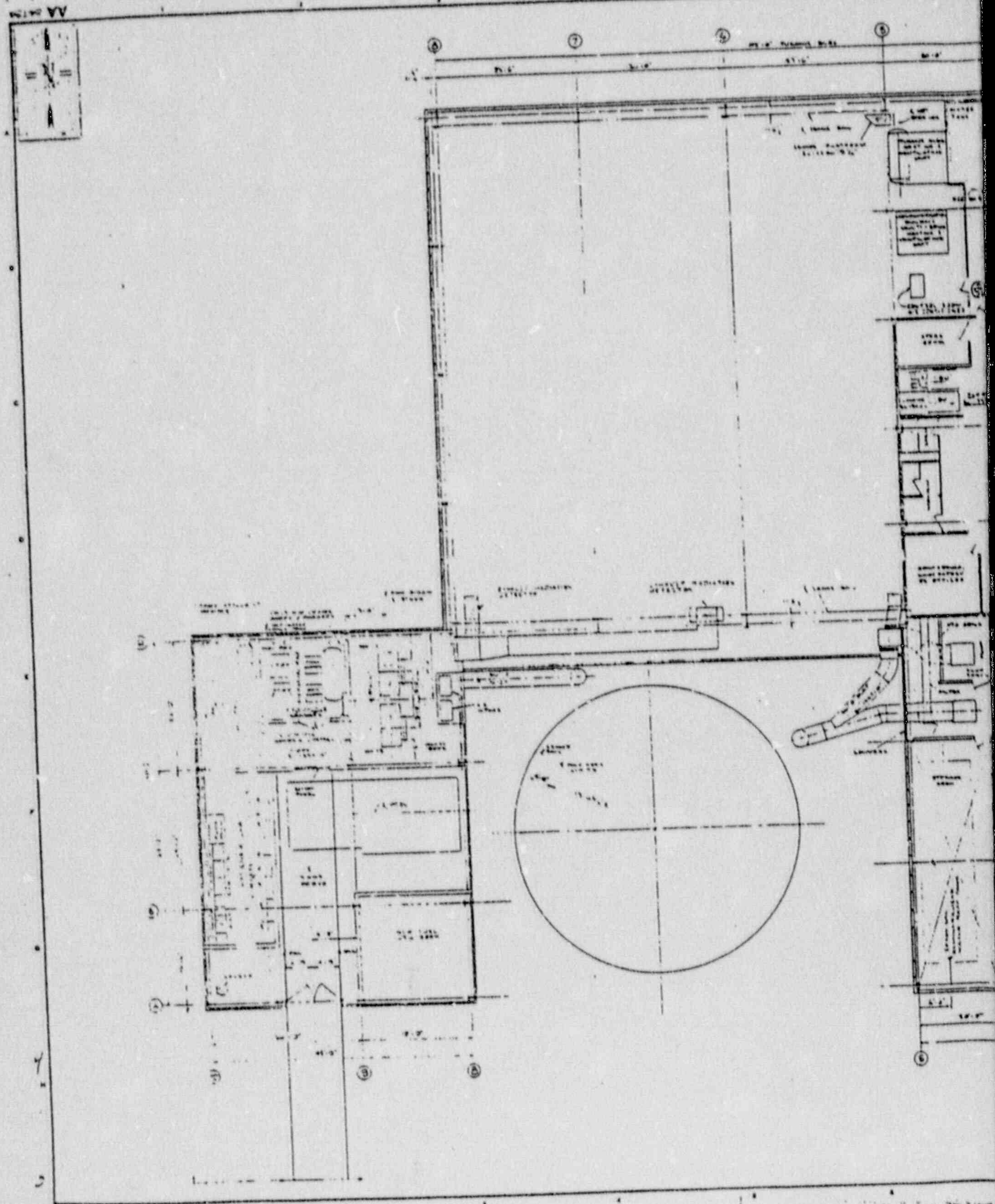

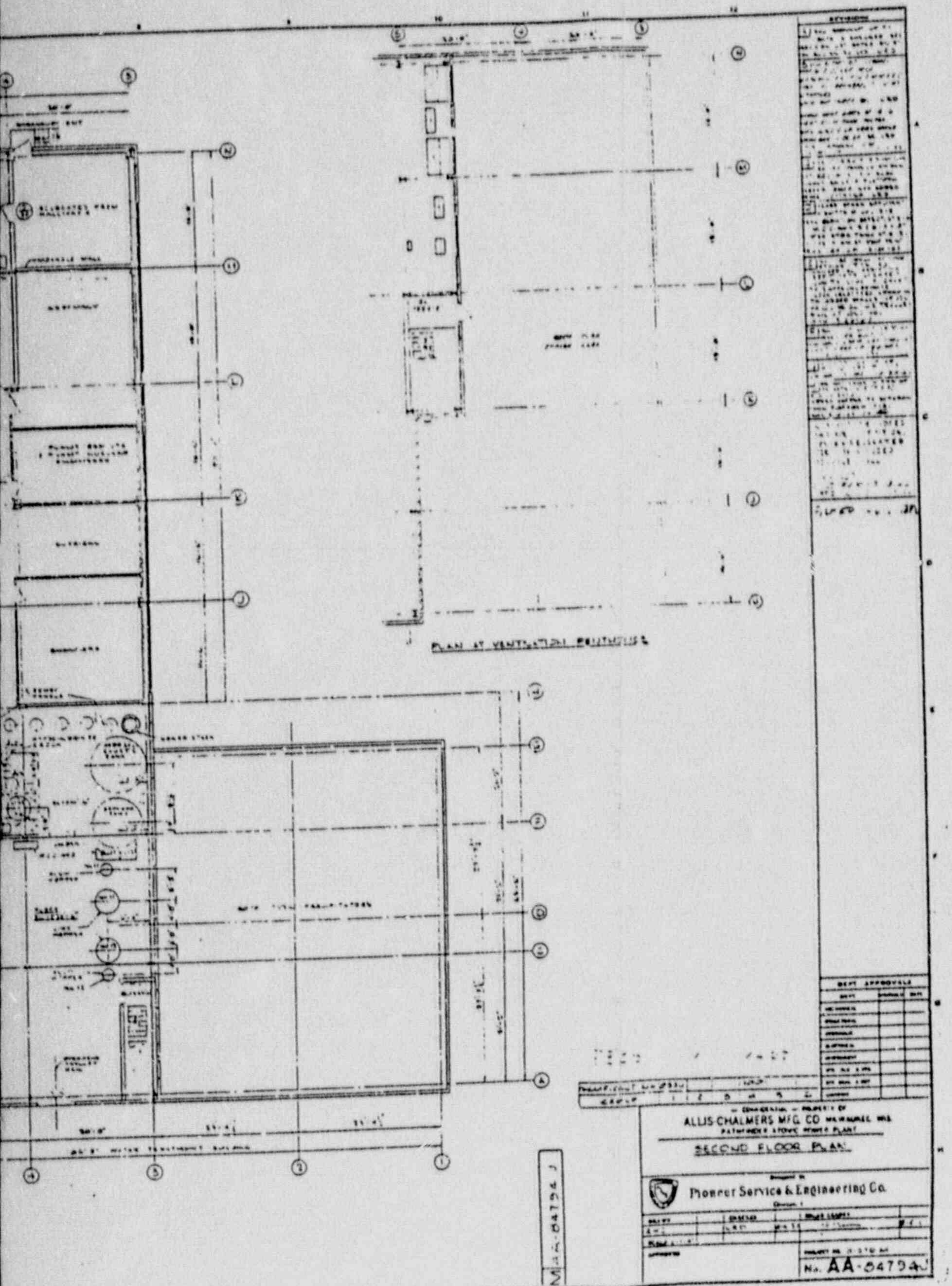

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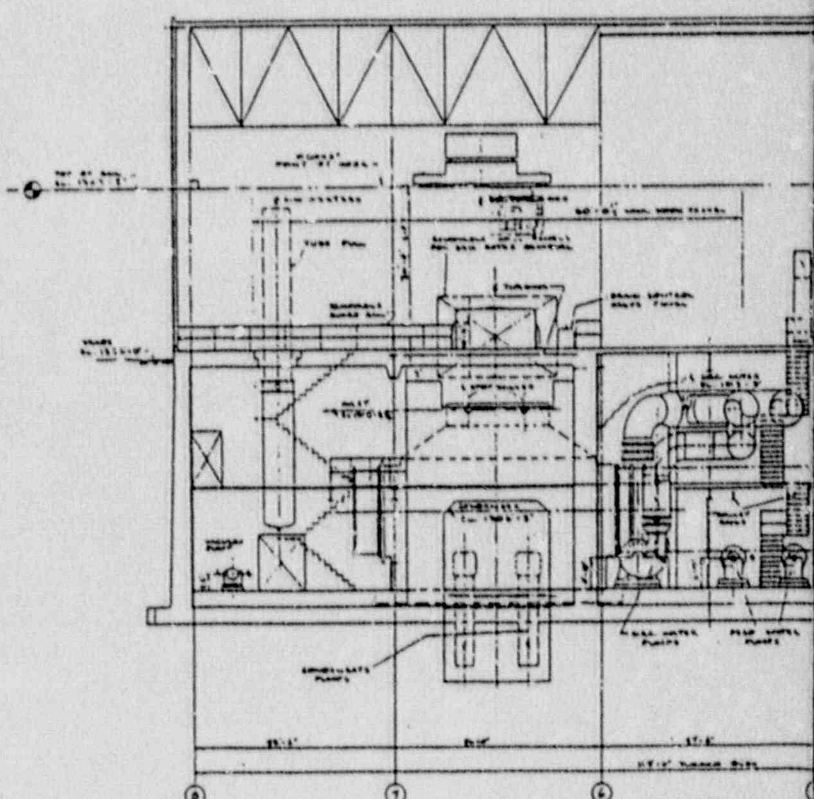

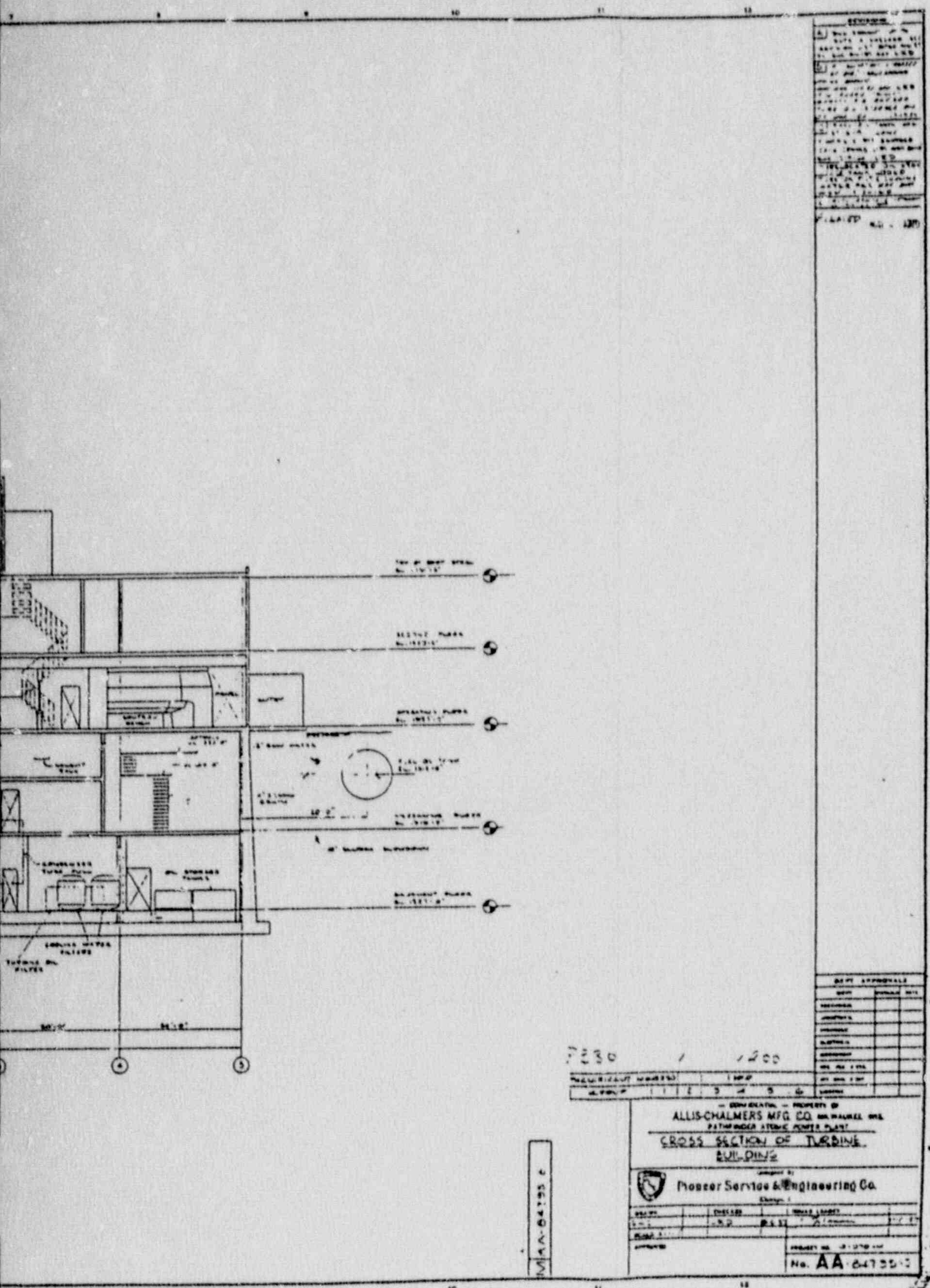

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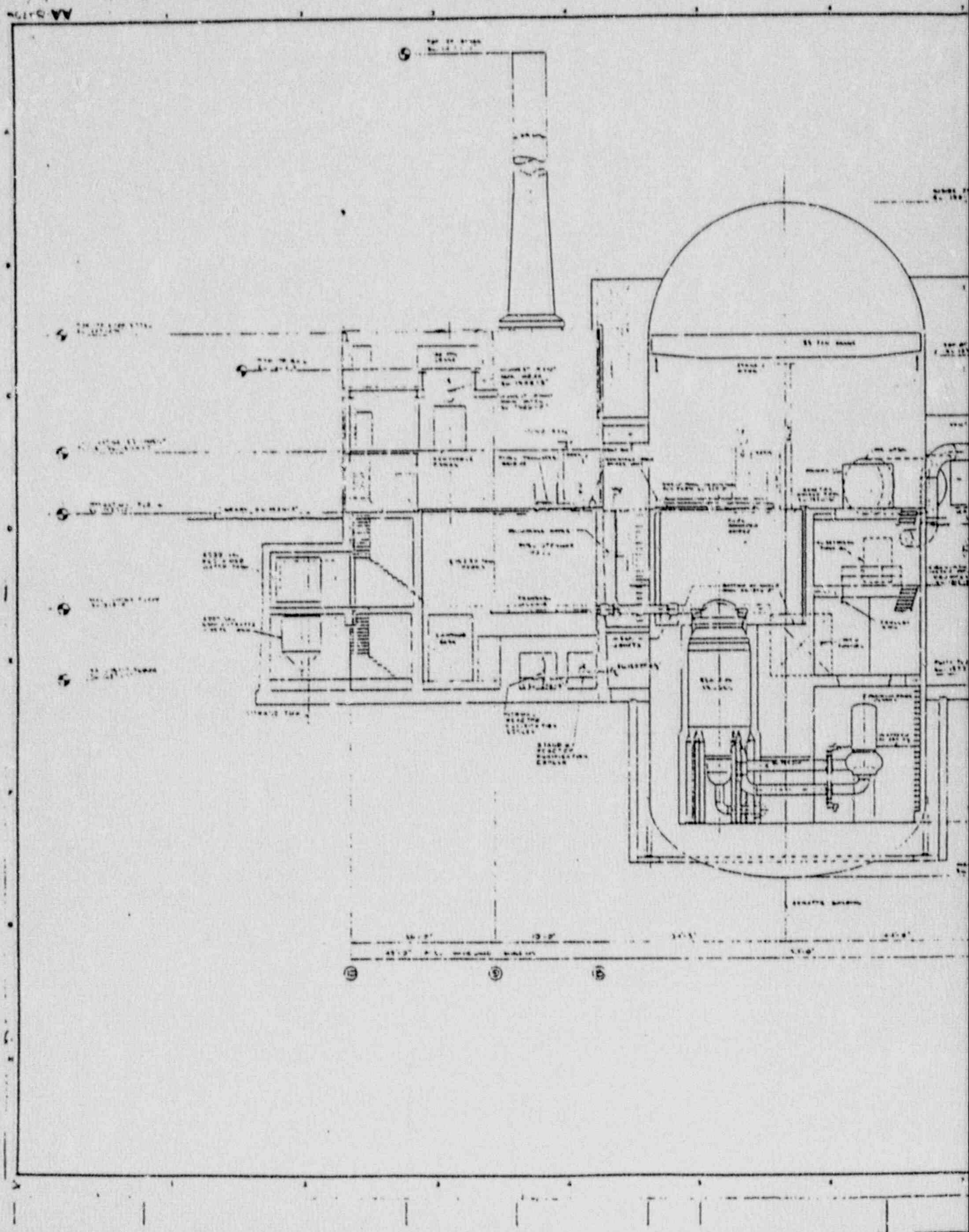

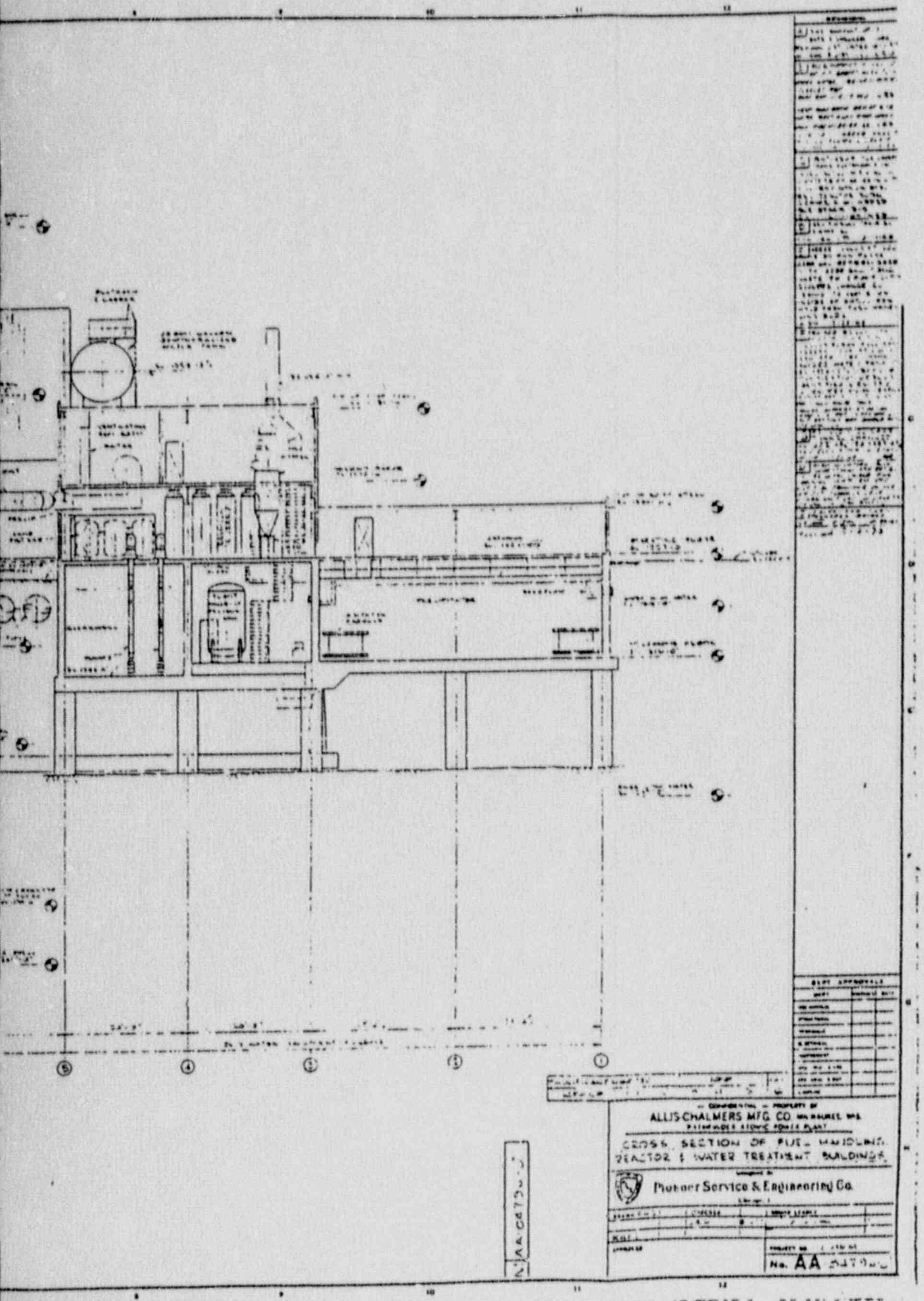

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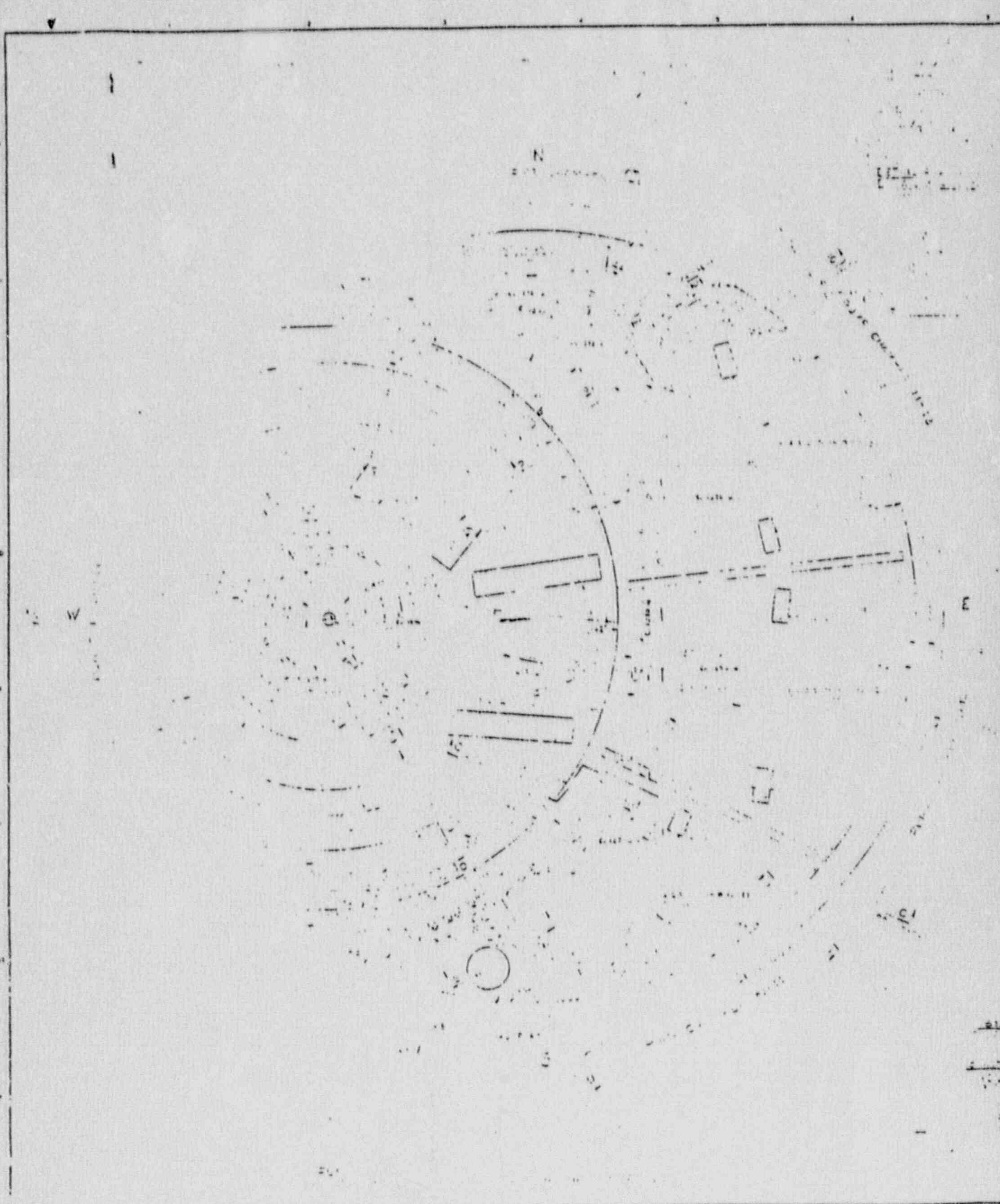
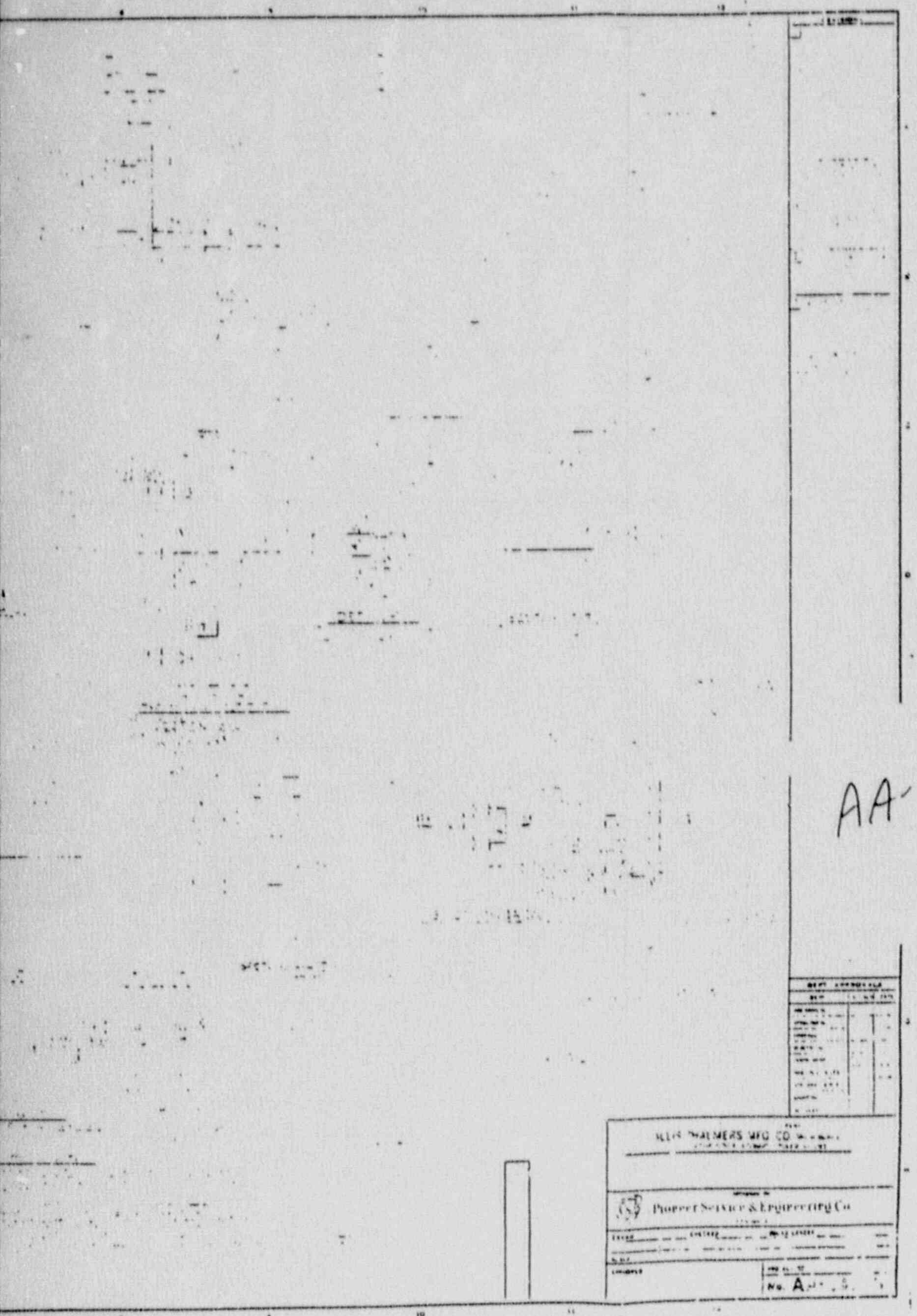

N
W

POOR ORIGINAL



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