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ANALYSIS OF NRC DATA

ON NUCLEAR POWER PLANT WORKER EXPOSURES TO RADIATION

by Fred Millar and Bob Alvarez
September 1, 1981

Increases in Worker Exposures: "An All-Time High"

The most recent data compiled by the U.S. Nuclear Regulatory Commission (NRC) reveals an alarming increase of 33% in the average radiation exposures to the total workforce in U.S. nuclear power plants between 1979 and 1980. While the total number of commercial operating nuclear power plants in 1980 rose by only one new plant, from 67 to 68, the total worker radiation exposures for all operating nuclear plants increased from 39,759 person-rems in 1979 to 53,797 person-rems in 1980, an increase of 35%.* "The average yearly exposure for all commercial nuclear reactors," according to the latest NRC report, dated May 28, 1981, "is at an all-time high of 791 person-rems per reactor."

The big 1980 increase was no flash in the pan. Nuclear plant worker radiation doses have been rising steeply for the last three years. The 1979 average dose of 593 person-rems per reactor was itself a 20% rise from the year before. In addition, the 1979-1980 rise of 35% in total collective dose followed a similar rise of 25% between 1978-1979. The data thus provide persuasive refutation to comments by industry and NRC officials who have repeatedly suggested that some particular problem in the nuclear reactors has been given a "one-shot" fix requiring extraordinary radiation doses to workers, but that similar steep increases will not continue to occur.

NRC collects data annually from nuclear plant operators in two different ways. Data from the most recent reports show that the long-range trend in

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* When radiation doses are measured for large populations, like reactor workers, the unit person-rem is used. This measure is also used in estimating the risk of dying from radiation-induced cancer. Person-rems are derived by multiplying the total number of people exposed times their average dose in rems. Or it can be the actual sum of all doses received. For example, 10,000 person-rems is a dose received by 5,000 people exposed to 2 rems each; or by 10,000 people exposed to one rem.

U.S. nuclear reactor radiation exposures to their workforce has been a rise of 400% over ten years, from an average of less than 200 person-rems per reactor in 1969 to nearly 800 person-rems per reactor in 1980.

This high level of total worker exposures was not anticipated by those who have had to calculate the possible costs and benefits of nuclear power generation.

As we shall see below, the consequences of the large increases in terms of future cancers, deaths, and genetic damage are extremely serious. The continued exposures at unanticipated high levels confront the NRC with a clear problem in terms of its regulatory responsibility for health and safety.

The Results of Worker Radiation Exposures: Cancers, Deaths, Genetic Damage

The long-term implications of the steep-rise in workers' total radiation exposure are sobering, given the recent scientific estimates on the risks of low-level radiation exposure. Even the most conservative estimates give reason for grave concern.

In the case of reactor workers a total of 53,797 person-rems were accumulated in 1980, representing a 33 percent increase over the 39,759 person-rems accumulated in 1979. The new NRC documents analyzed here do not have a breakdown of how many workers were exposed or their individual exposures.

Cancers which have been shown to be initiated by radiation include leukemia, bone marrow, pancreas, lung, large intestine, thyroid, liver and breast. Scientists' estimates of the risk of dying from radiation-induced cancer vary widely, as the table on the next page suggests.

In terms of the risk of genetic damage, the risks to workers' children and future generations are significant. According to the National Academy of Sciences BEIR I and III reports, if 50,000 person-rems accumulate each year among reactor workers for 20 years, there will be as many as 3,000 excess human heredity disorders for every 100,000 progeny. Taking these estimates further and assuming that in ten generations no intermarriage with like-damaged individuals takes place, the 50,000 person-rems of radiation would

ESTIMATES OF RADIATION-INDUCED CANCER DEATHS FOR 1980 REACTOR WORKERS*

BEIR I (1972)	2-4 cancer deaths	50-80 mil. person-rems[(a)]
BEIR III (1979)	3-15 cancer deaths	70-353 per mil. person-rems[(a)]
BEIR III (1980)	3-10 cancer deaths	77-226 per mil. person-rems[(a)]
UNSCEAR (1977)	5 cancer deaths	100 per mil. person-rems[(b)]
Radford (1981)	10-30 cancer deaths	200-600 per mil. person-rems[(c)]
Gofman (1977)	200 cancer deaths	3771 per mil. person-rems[(d)]
Morgan (1979)	350 cancer deaths	7000 per mil. person-rems[(e)]

* The 53,797 person-rems reported by the NRC has been rounded off to 50,000

a) National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR Committee), reports for 1972, 1979 and 1980.

b) United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1977.

c) Radford, E., Science, August 7, 1981.

d) Gofman, J.W., Health Physics, July 1981.

e) Morgan, K.Z., Bulletin of Atomic Scientists, September 1979. (Morgan's estimates, unlike the above, are based on the Hanford data of Mancuso, Stewart, and Kneale, published in Health Physics, November 1977).

ultimately produce as many as 1.5 million living children with heredity disorders and 4,600 recognized miscarriages in excess of the normal number.

"Used-up Workers" Outpace Electricity Production

Are the huge increases in nuclear plant worker exposures matched by increases in electricity produced? Not by a long shot. Data from an NRC study released in March 1981 (NUREG-0713) show that during the period 1969-1979, the number of U.S. operating reactors increased 950%, from 7 to 67 reactors. Total doses to workers, however, rose four times as fast, nearly 3200%, from 1247 person-rems in 1969 to 39,759 person-rems in 1979. Total electricity generated during the period did not keep pace with worker exposures; the former rose 2321%, from 1289 megawatt-years in 1969 to 29,920 megawatt-years in 1979.

Nuclear plants each have "used up" more and more radiation workers; the average number of radiation workers exposed in a single nuclear plant in 1969 was 145, whereas in 1979 the average was 1010 workers exposed, a rise of 696%.

The reported average dose for individual workers, which is regulated by the NRC, has been kept well within regulatory limits, in fact has ranged from a high of 1.03 rems in 1969 to .73 rems in 1979. This level has been accomplished, however, by the using up of a total of 64,073 radiation workers in U.S. nuclear plants in 1979 compared with 744 in 1969, a rise of 8600 %. The total amount of radiation to the workforce is not regulated by the NRC or any other agency, unlike the amount of a nuclear plant's radiation releases to the environment, which is regulated by limits set by U.S. EPA.

Even so, official estimates of average radiation doses to individual workers have over time been proven seriously below the actual experience of nuclear workers. In 1972 the EPA predicted that the greatest increase in occupational radiation exposures would not be from the rapidly expanding medical applications, but from industrial uses, particularly nuclear power plants. EPA suggested that the average annual dose to individual reactor workers by the year 2000 would not exceed .225 rem. By 1979 the NRC reported the average annaul individual exposure to be .680 rems, more than three times the EPA prediction for the end of the century.

What Explains the Recent Large Worker Radiation Exposure Increases?

There is no one answer, but some educated guesses can be made. In the first place, NRC data reveals that one major type of nuclear reactor is much hotter overall for its workers than the other major type.

Boiling-water reactors (BWRs) exposed their workforce in 1980 to nearly double the average yearly exposures compared with pressurized-water reactors (PWRs). The 1979-1980 increase in average exposures per boiling-water reactor was 55%, from 733 to 1136, while the pressurized water reactor increase was 13%, from 510 to 578 person-rems. Understanding the exposure differences requires a closer look at what is going on at the 68 operating U.S. commercial reactors: many BWRs have needed several specific major repair jobs requiring workforce exposures to many person-rems of radiation.

Some Plants Are "Hotter" Than Others: Frequent Repairs Needed

"It should be noted," stated a 1981 NRC report, "that there are significant differences in nuclear plant designs, even between plants of a given type." Some individual plants have been much "hotter" in radiation exposures (in person-rems) for their workers than others. The hottest of 30 pressurized water reactors (and their 1979/1980 exposure totals) were: San Onofre (150/2400), Surry (1800/1950), Robinson (1200/1850), Connecticut Yankee (1150/1350), Haddam Neck and Turkey Point (830/820). The hottest of 18 boiling-water reactors (and their 1979/1980 exposure totals) were: Pilgrim (1000/3650), Quad Cities (1100/2400), Millstone (1800/2160), Fitzpatrick (850/2050), Brunswick (1300/1950), and Oyster Creek (470/1730).

In all of the hottest PWRs with the exception of Connecticut Yankee, abnormally high 1979 and 1980 radiation exposures can almost certainly be attributed to the expensive, lengthy, and extraordinary inspection and repair operations required by the premature corrosion and leakage of the radioactive steam generators, a generic problem which also afflicts nearly all PWRs in the U.S. and Europe. The replacement of only one plant's failed steam generators, at the two Surry reactors in Virginia, cost hundreds of workers in 1978-79 a total of over 2000 person-rems.

The other "hottest" PWRs have undergone similar costly large scale repairs or the leaks in their extremely radioactive steam generator tubes have been frequently "plugged" at great cost in worker exposures. Recently developed remote "robot" equipment may soon be able to reduce worker exposures somewhat in the major repair jobs which many nuclear plants will eventually have to undergo, but repair techniques developed in the lab for steam generator problems have not always worked in actual on-site repair operations (e.g., tube welding in the 1980-81 San Onofre "sleeving").

Major repairs on such failed components and safety-related modifications required by NRC have clearly assumed a greater and greater importance for exposures to nuclear workers. One category of NRC worker exposure data, "Special Maintenance", accounted for only 19% of the annual collective radiation dose in 1975, but has doubled to around 40% in recent years. NRC does not, however, require nuclear utilities to submit detailed regular reports on which specific repair or maintenance jobs led to large worker exposures.

NRC officials can only guess, therefore, about what factors account for the large increases in worker radiation doses that numerous nuclear plants of both types are experiencing. The 1981 NRC report <u>NUREG-0731</u> says:

> Usually, when a plant reports a large annual collective dose, and a large man-rems to megawatt-year ratio as well, it indicates that extensive maintenance or modifications were undertaken during the year. Also, numerous plants reported increases in their collective doses as a result of the actions that the NRC required operating reactors to take because of the Three Mile Island 2 accident and NRC's concern for seismic design deficiencies in safety-related piping. And again in 1978, several PWRs reported substantial collective doses associated with the inspection and repair of steam generator tubes. Some major activities at BWRs that accounted for a portion of the 1979 collective dose were inspection and maintenance of shock suppressors, and maintenance and repair of various valves.

Several NRC officials, however, report that safety-related modifications required from the "lessons learned" at Three Mile Island have not yet begun at most nuclear plants, so that these NRC requirements are <u>not</u> yet a significant explanation for increased worker doses. (In general, older nuclear plants are hotter for their workers because more of the reactor piping and other equipment has been irradiated during operation. But the recent

NRC data does not allow an analysis of exactly how much hotter the older plants are.)

The "ALARA" Philosophy

Without an absolute regulatory limit on total exposures to their nuclear workers, the nuclear industry is constrained only by what is termed the "ALARA" philosophy. "As low as reasonably achievable" radiation exposure to workers is the goal towards which NRC pushes the nuclear utilities. Despite ten years of nuclear reactor experience, however, the nuclear industry has not improved its ability to reduce the total worker radiation exposures measured against the amounts of electricity produced. The average ratio over the eleven-year period 1969-1979 has hovered around a level of 1.3 person-rems per megawatt-year. The 1979 figure was 1.3, up from a ten-year low in 1978 of 1.0 person-rems per reactor year. Some NRC officials say that the "more progressive" nuclear plants are compiling books on history of various repair jobs in different plants, in order to learn how worker exposures can be reduced.

The key question is obvious: what does "reasonably achievable" mean? Shielding workers from radiation can be a very expensive problem for nuclear management. The NRC has not required nuclear utilities to report how much money they are spending to reduce worker exposures to "ALARA", nor has NRC made a rule as to how much a utility is required to spend in order to reduce a given amount of such exposures. Rather than strict cost-benefit analysis, utilities use "common-sense" approaches as to what works to reduce exposures, according to NRC. NRC does not, moreover, independently monitor the accuracy of utility-reported radiation exposures, although a more vigorous NRC effort in this area is being contemplated.

A significant number of nuclear plant workers are transient workers, about 3200 each year who worked at from two to nine different nuclear facilities during 1977, 1978 and 1979. Only a small number of nuclear workers (27 in 1977, 9 in 1978, 21 in 1979) received reported exposures above the allowed quarterly limits. NRC has only "limited" data on the "career doses" of nuclear workers, since it collects data only for employees "terminating" with a nuclear plant, not for ongoing workers.

Those NRC officials charged with maintaining worker radiation exposures "ALARA" seem to feel beleaguered by the recent onrush of high radiation-impact demands in nuclear plant operation. And the future looks grim: a NIOSH report prepared by health physicist David Scott, dated March 30, 1980, suggests that the trend of increasing person-rem exposure will be dramatic. Scott projects current trends and calculates that within the next 7 years 105,000 reactor workers may annually be receiving measurable radiation doses.

How Much Radiation, And For Whom?

Early estimates of how much total radiation nuclear plant workers would get were very low. NRC officials now report that their most recent Environmental Impact Statements for newly-licensed nuclear plants contain much higher estimates of future worker exposures, reflecting the regrettable experience of recent years.

How much total radiation exposure to a workforce should be tolerated in the centralized production of electricity? This seems to be a question no one has asked in any effective way. Nuclear plant managers report that their main question is whether they can keep the plant operating. Recent repair operations such as the Surry steam generator replacement operation, requiring hundreds of workers and record levels of total exposure (2020 person-rems for this one repair operation, despite elaborate dose-reduction techniques), seem to indicate that total worker exposures are not considered to have any foreseeable limit from the utilities' current cost-benefit perspective. A possible limit on the numbers of some skilled craftspeople might be the most compelling factor in this area.

As long as major repair operations are required for flaws in highly radioactive nuclear reactor piping and other components, "nothing much can be done" to reduce total workforce exposures to previously anticipated levels, according to NRC officials.

Finally, just one of the dilemmas in nuclear power safety is that when nuclear plants implement measures to control radiation released to the public and the environment surrounding the plant, more radioactive material is kept inside the plant, thus to some extent shifting the radiation burden to nuclear plant workers. This is not, however, a major contributor to the workers' overall exposures, the majority of which is from increased radioactivity in permanent nuclear plant components.

Resources

Our brief analysis of occupational radiation exposures is not a comprehensive survey of the problem. The following resources contain valuable data and analysis that complement this EPI study.

NUREG - 0713, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors, 1979: Annual Report." B.G. Brooks, Office of Management and Program Analysis, U.S. Nuclear Regulatory Commission. Latest in a series of annual reports including plant-by-plant data (1978 version was NUREG-0594). Available for about $5.00 from National Technical Information Service, Springfield, VA 22161.

"Preliminary LWR Exposure Data for 1980", Memo from Charles Hinson, Radiological Assessment Branch to William E. Kreger, Assistant Director for Radiation Protection, U.S. Nuclear Regulatory Commission, dated May 28, 1981. 10 pp. with charts showing historical trends. Xerox available from Environmental Policy Center, 317 Pennsylvania Avenue, S.E., Washington, D.C. 20003.

"A Review of Radiation Protection Principles and Practices and the Potential for Worker Exposure to Radiation: A Research Report for the National Institute for Occupational Safety and Health", David M. Scott, Health Physicist, Rockville, Md., March 30, 1980. 122 pp. An excellent discussion, especially of the Three-Mile Island accident's implications for worker exposures. Good critique of current federal regulatory activity.

"Atomic Worker's Guide to the Most Unsafe Atomic Power Plants in 1977". Public Citizen Health Research Group, Dr. Sidney Wolfe, Dept. 411, 2000 P Street, N.W., Washington, D.C. 20036, (202)872-0320. $2.00 each. Somewhat dated, but a valuable discussion of the overall situation which goes beyond this brief analysis. 23 pp.

"Plutonium and the Workplace: An Assessment of Health and Safety Procedures For Workers at the Kerr/McGee Plutonium Fuel Fabrication Facility," by Kitty Tucker and Elli Walters, March 1979, p. 103. A detailed analysis of utilizing official documents and worker interviews of worker health and safety at a commercial plutonium fuel fabrication facility. A timely report in the face of renewed support by the Reagan Administration for the commercial development of plutonium fuels. Available from the Environmental Policy Institute.

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MEMORANDUM FOR: R. Wayne Houston, Assistant Director for Radiation Protection, DSI

FROM: Frank J. Congel, Chief
Radiological Assessment Branch, DSI

SUBJECT: PRELIMINARY LWR OCCUPATIONAL DOSE DATA FOR 1981

Attached is a preliminary compilation and analysis of occupational radiation doses reported from 70 light water cooled nuclear reactors (LWRs) for the year 1981. The information in this memorandum was derived from reports submitted to the Commission in accordance with 10 CFR Part 20.407. Two PWR units, Arkansas 2 and North Anna 2, completed their first full year of commercial operation in 1981 and are included in this year's summary for the first time. In addition, this summary includes four units (Dresden 1, Humboldt Bay, Indian Point 1, and Three Mile Island 2) that are currently shutdown for an indefinite period of time. These units have been retained in this summary since they are still licensed and dose is still accumulate to maintain them.

The total collective dose reported for 1981 was 54,555 person-rems, an increase of 1.3 percent over the 1980 figure of 53,797 person-rems. This total gives an averag of 779 person-rems per unit, which is slightly lower than the 791 person-rems per unit reported for 1980. This leveling off of the average person-rems per unit follows two years of increases during which the average dose per unit rose from 497 person-rems in 1978 to 791 person-rems in 1980.

In 1981 the average dose for PWR units was 656 person-rems, a 13% increase over the 1980 average of 578 person-rems. The 1981 average BWR dose of 988 person-rems per unit is a 13% decrease from the 1980 average of 1136 person-rems. Seventeen plants reported collective dose reductions 30% or more. Six of these seventeen pla reported 1981 doses per unit that were less than half of their 1980 doses. None of these six plants had a major refueling outage in 1981. For the eighth consecutive year, the average annual dose per unit for BWR's remained higher than the PWR avera Figure 1 shows the trends in average yearly LWR doses from 1969 to 1981. Figure 2 breaks these doses down to BWR and PWR units for the same time period. Table 1 presents the computed person-rems accumulated at each LWR plant in 1981. Figures 3 4a and 4b give the total doses reported for each plant from 1979 thru 1981.

In an effort to obtain background information on the collective dose reported by the plants, the staff had informal telephone conversations with the radiation prote staff at several plants. Attention was given to plants whose reported collective doses had shown significant changes, either increasing or decreasing, between 1980 and 1981. We asked the licensees' staff to identify the major dose intensive jobs performed at their plants in 1981. The licensees' staff were also asked to identif

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a cause for the significant change in dose accumulated at their plants.

On the basis of these calls, no item could be singled out as a cause for the significantly increased doses. Each plant contacted implements its own method for categorizing plant activities. Although correlating these activities to trends in dose is difficult, some similarities in the responses can be seen. For BWR's the licensees' staff stated that torus modifications contributed significantly to their 1981 doses. Other plants, both BWRs and PWRs, singled out in-service inspections a plant modification (such as pipe hangars, snubbers, fire protection, and post-accid sampling) as significant contributors. The staff at most PWRs also stated that an increasing amount of steam generator work (including eddy current testing and tube plugging) contributed to their dose increases.

The most frequent reason given for the observed decreases in dose from 1980 to 1981 was that the plant did not have a major refueling or maintenance outage in 1981. One individual contacted did state that this particular plant had finished NRC-mandated plant modifications in 1980, resulting in lower 1981 doses. Several of the licensees' staff members, whose plants had no refueling ou' e in 1981, said they anticipated increases in 1982 doses since they still have s. eral major modificatio and inspections (such as the torus mods and pipe hangar inspections) to complete.

This information was completed by R. Pedersen and C. Hinson, RPS, RAB.

Frank J. Congel

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Radiological Assessment Branch
Division of Systems Integration

Attachment:
As Stated

TABLE 1

PLANT NAME	TYPE	AGE	20.407 (AG 1.16)
Arkansas I, II (N)	P	7, 1	1102 (890)
Beaver Valley I	P	5	229 (146)
Big Rock Point	B	13	160* (134)
Brown's Ferry I, II, III	B	7, 6, 4	2469 ( )
Brunswick I, II	B	6, 4	2729 (2558)
Calvert Cliffs I, II	P	6, 4	607 (538)
Cook I, II	P	6, 3	656 (609)
Cooper Station	B	7	579 (594)
Crystal River III	P	4	408 (362)
Davis Besse I	P	4	68 (85)
Dresden I, II, III	B	21, 11, 10	2802 (2302)
Duane Arnold	B	6	790 (839)
Farley I	P	4	512 (497)
FitzPatrick	B	6	1425 (1369)
Fort Calhoun I	P	8	458 (450)
Ginna	P	11	655 (614)
Haddam Neck (Connecticut Yankee)	P	13	1089 (1073)
Hatch I + II	B	6, 2	1337 (1294)
Humboldt Bay	B	18	9 ( )
Indian Point I, II	P	19, 8	2731 (2633)
Indian Point III	P	5	371 (405)
Kewaunee	P	7	141 (127)
LaCrosse	B	12	123 (116)
Maine Yankee	P	9	424 (281)
Millstone I	B	10	1496 (1399)
Millstone II	P	6	531 (497)
Monticello	B	10	1042 (991)
Nine Mile Pt	B	12	1592 (1588)
North Anna I, II (N)	P	3, 1	680 (777)
Oconee I, II, III	P	8, 7, 7	1302 (1384)
[illegible]	P	12	917 ([illegible])

PLANT NAME	TYPE	AGE
Palisades	P	10
Peach Bottom II, III	B	7, 7
Pilgrim	B	9
Point Beach I, II	P	11, 9
Prairie Island I, II	P	8, 7
Quad Cities I, II	B	8, 8
Rancho Seco I	P	6
Robinson II	P	10
Salem I	P	4
San Onofre I	P	13
St. Lucie I	P	5
Surry I, II	P	9, 8
Three Mile Island I, II	P	7, 3
Trojan	P	5
Turkey Point III, IV	P	7, 8
Vermont Yankee	B	9
Yankee Rowe	P	15
Zion I, II	P	8, 7

REACTOR TYPE	NO.	20.407 TOTAL PERSON-REMS	2C A PERS
PWR	44	28865	
BWR	26	25690	
LWR	70	54555	

FIGURE 1

AVERAGE PERSON - REMS per YEAR
(LWR's)

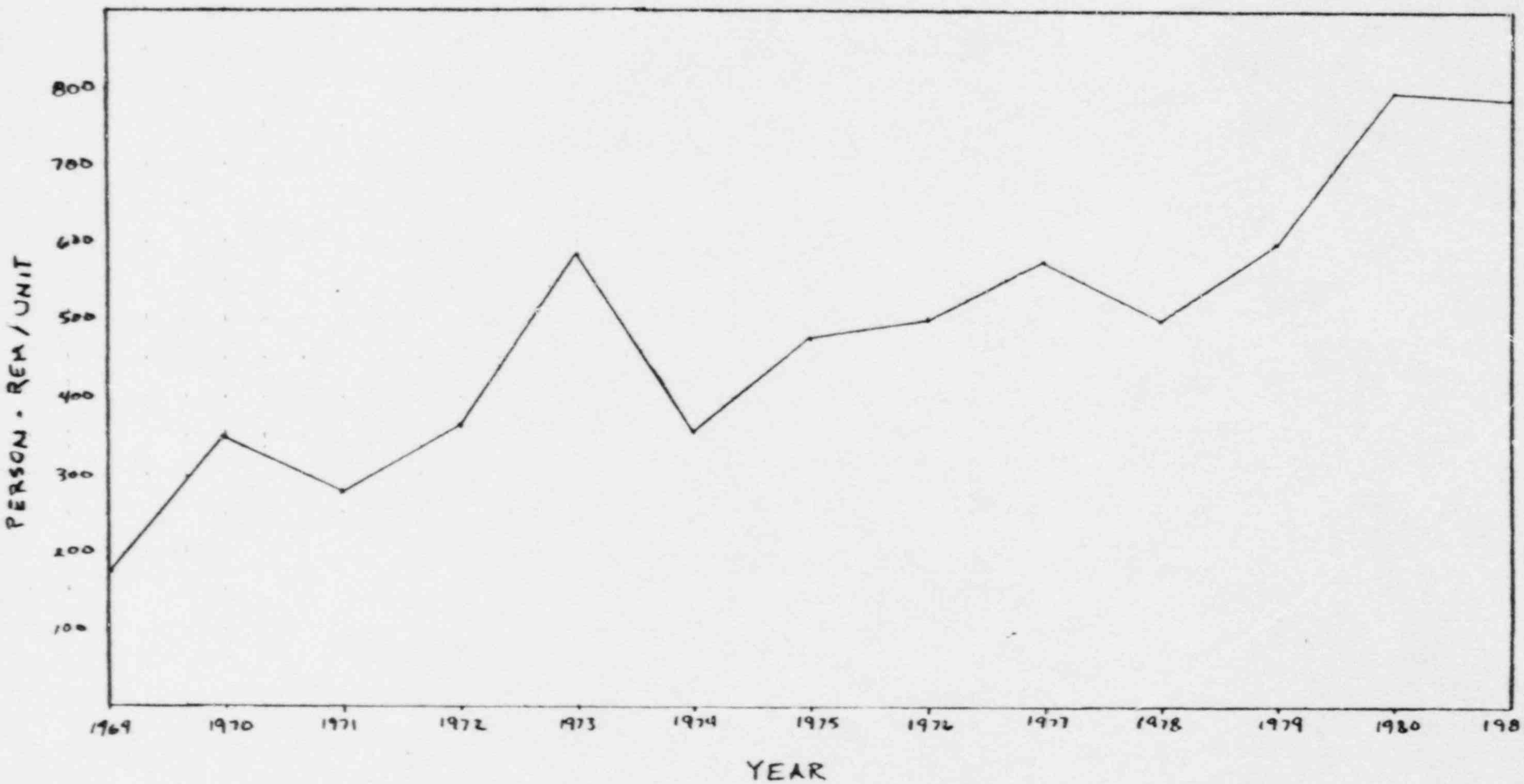
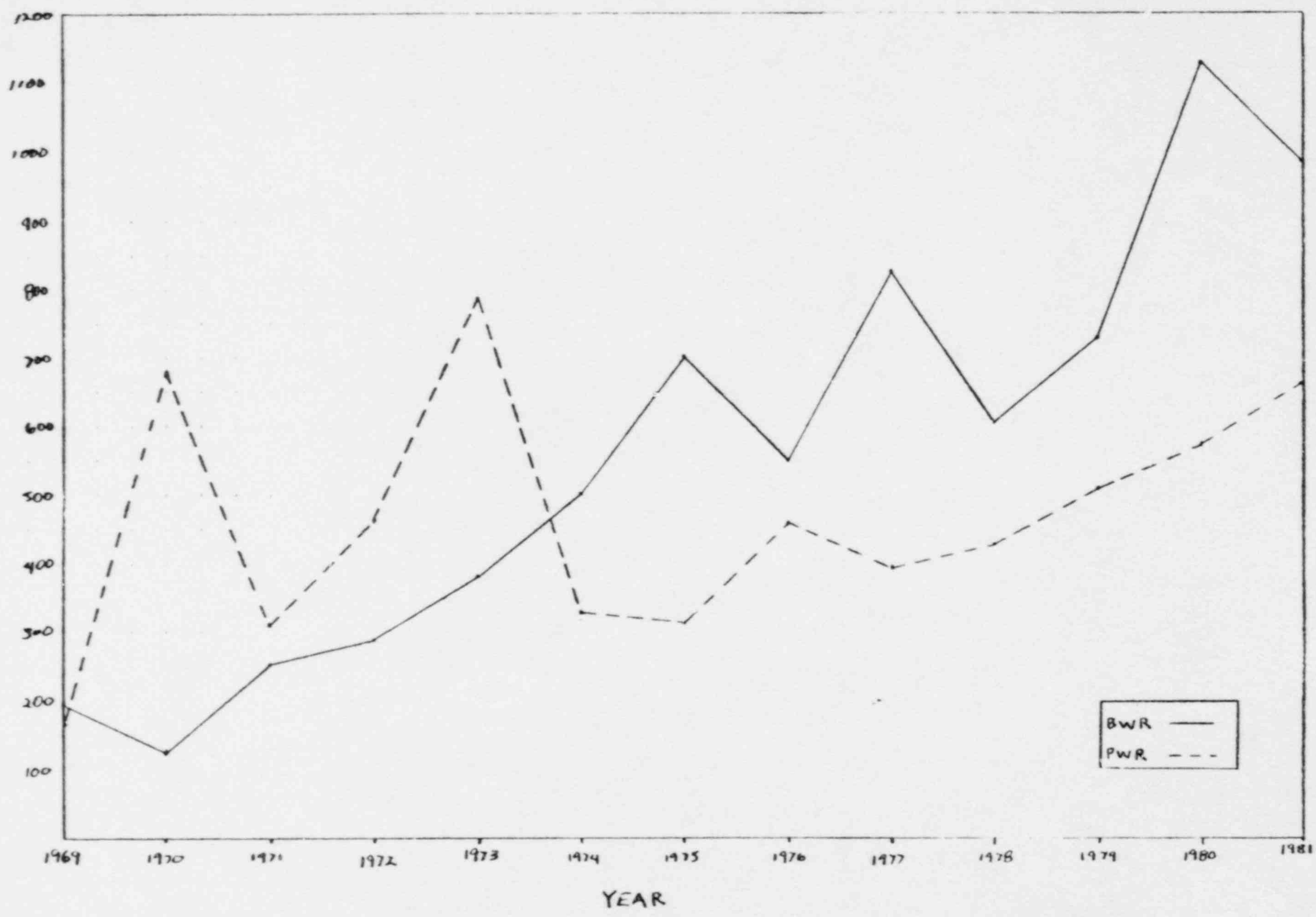


FIGURE 2

AVERAGE PERSON-REMS per YEAR
(BWR's and PWR's)



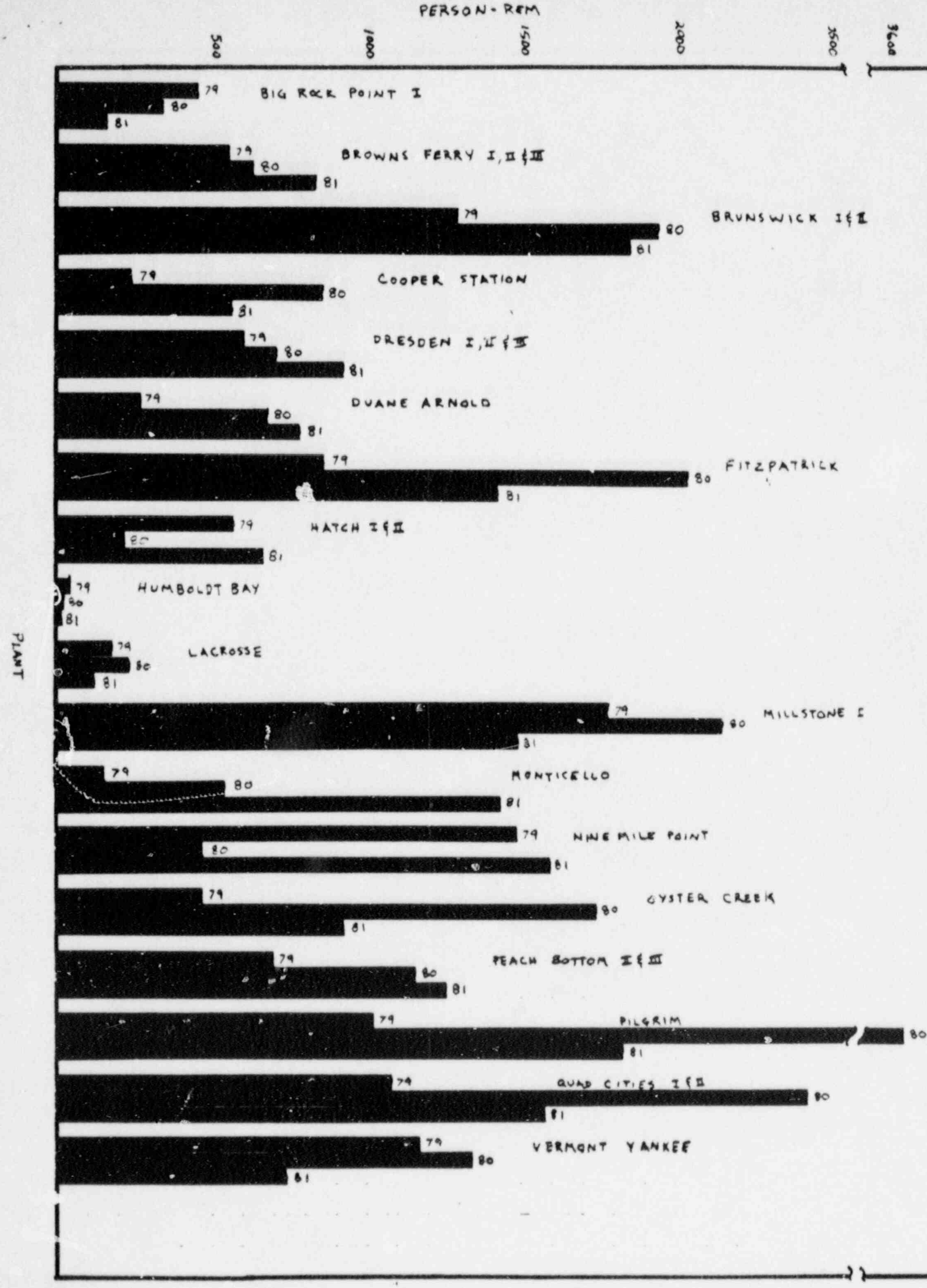


FIGURE 3 BWR PERSON-REMS/UNIT 1979-1981

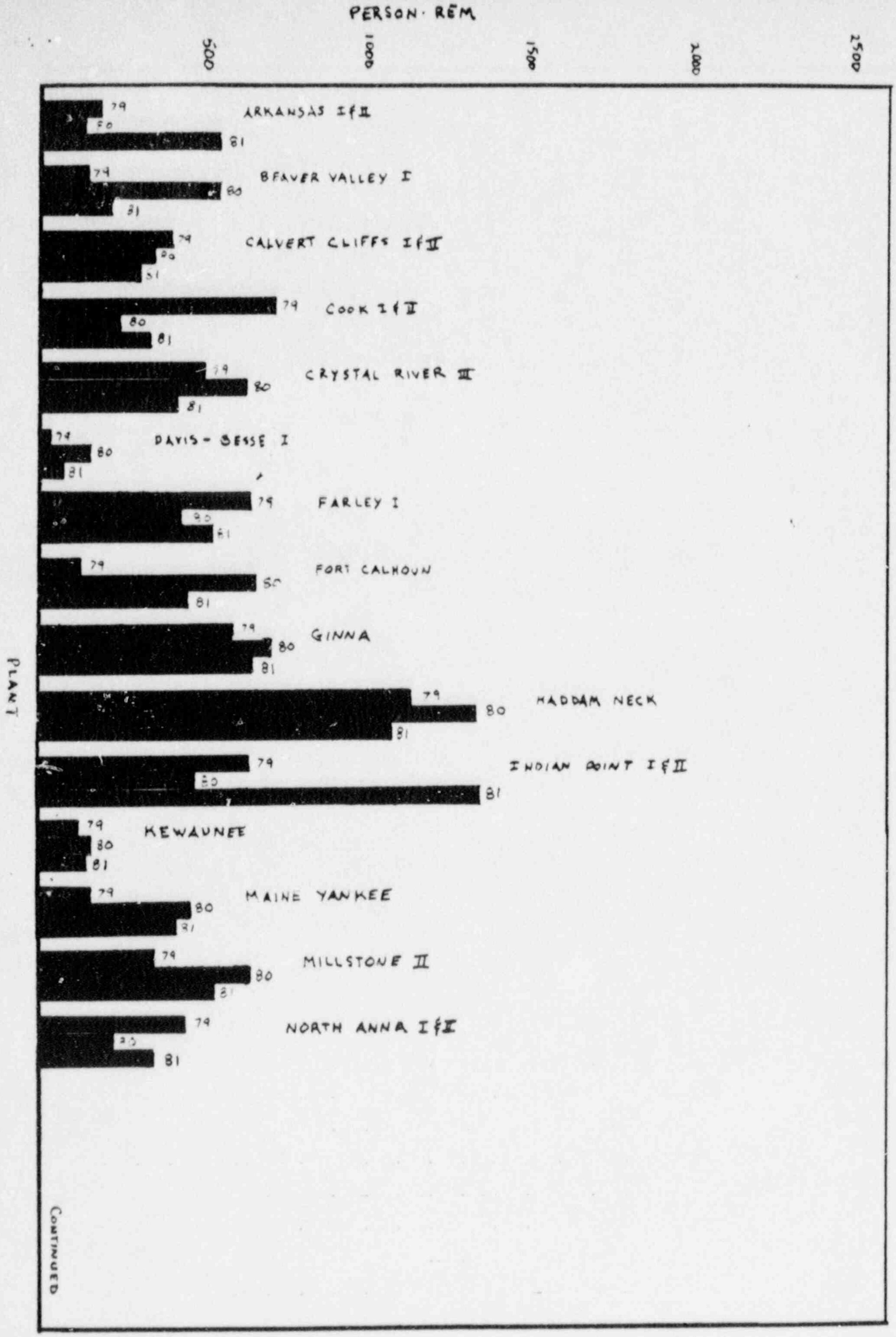


FIGURE 4a. PWR PERSON-REMS/UNIT 1979-1981

FIGURE 9b. PWR PERSON-REMS/UNIT 1979-1981