

ASSESSMENT AND CONTROL OF  
FETAL EXPOSURE

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October 1991

Presented at the  
30th Hanford Symposium on Health  
and the Environment  
October 29 - November 1, 1991  
Richland, Washington

**MASTER**

Work supported by  
the U.S. Department of Energy  
under Contract DE-AC06-76RLO 1830

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## ABSTRACT

The assessment and control of fetal exposure to radiation in the workplace is an issue that is complicated by both biological and political/social ramifications. Because it is more sensitive to radiation, the risk to the embryo/fetus from radiological exposures is greater than the risk to adult radiation workers. As a result of the dramatic increase in the number of women employed as radiation workers during the past 10 years, many facilities using radioactive materials have instituted fetal protection programs with special requirements for female radiation workers. It is necessary, however, to ensure that any fetal protection program be developed in such a way as to be nondiscriminatory because Title VII of the Civil Rights Act prohibits discrimination on the basis of sex, and the Pregnancy Discrimination Act prohibits discrimination based on conditions of pregnancy. In addition, a recent Supreme Court ruling indicated that employers may not bar women of childbearing age from certain jobs because of potential risk to their fetuses.

The Pacific Northwest Laboratory, at the request of the DOE, has initiated a study whose purpose is to balance the political/social and the biological ramifications associated with occupational protection of the developing embryo/fetus. Several considerations are involved in properly balancing these factors. These considerations include appropriate methods of declaring the pregnancy, training workers, controlling the dose to the embryo/fetus, measuring and calculating the

dose to the embryo/fetus, and recording the pertinent information.

Alternative strategies for handling these factors while ensuring maximum protection of the embryo/fetus and the rights and responsibilities of employees and employers are discussed.

## INTRODUCTION

The assessment and control of fetal exposure in the workplace is an issue that is complicated by both biological and political/social ramifications. The biological aspects of the issue as they are currently understood have been addressed by the Committee on the Biological Effects of Ionizing Radiation (BEIR V)<sup>(1)</sup> and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).<sup>(2)</sup> As a result, advisory groups such as the International Commission of Radiological Protection (ICRP)<sup>(3)</sup> and the National Council on Radiation Protection and Measurements (NCRP)<sup>(4, 5)</sup> have recommended lower radiation dose limits for the embryo/fetus of pregnant radiation workers than they have for the radiation workers themselves. The recommendations of advisory groups such as the ICRP and NCRP were promulgated as regulations by Federal agencies.<sup>(6)</sup> Thus, as a result of the higher relative risk to the embryo/fetus, facilities that have radiation workers are placed in a position where it is important to protect the embryo/fetus, while not discriminating against the rights of the worker.

The social and technical aspects of this situation are addressed in this report. The relative radiosensitivity of the embryo/fetus is discussed, and the recommendations and regulations governing dose to the embryo/fetus are given. A quantification of the number of workers that

are affected by these regulations is also provided. A discussion is then given of the Federal laws that relate to discrimination issues, and the results of the recent Supreme Court ruling on the Johnson Controls case are described. Finally, considerations that should be made in order to provide effective control and assessment of fetal exposure are provided.

### RADIOSENSITIVITY

The BEIR V report<sup>(1)</sup> indicates that the consequences of irradiation of a fetus during the period of major organogenesis may include teratogenic effects on various organs (including mental retardation) and cancer. The data from the BEIR V report indicate that the prevalence of mental retardation appears to increase with dose in a manner consistent with a linear, non-threshold dose-response (when all cases of mental retardation for fetuses irradiated between 8 and 15 weeks after conception are considered). However, the BEIR V report states that analysis of the new DS86 dosimetry system suggests a threshold may exist in the range of 20 to 40 rad (0.2 to 0.4 Gy) for the period between 8 and 15 weeks. A second period of sensitivity (with a risk factor approximately 4 times less than the first) occurs from weeks 16 through 25. There is stronger evidence of a threshold effect during this period. Epidemiological studies of Japanese survivors of the atomic bomb and of children exposed to prenatal x-ray examinations also suggest a susceptibility to radiation-induced cancer that is relatively high during prenatal life.

### REGULATIONS AND RECOMMENDATIONS

Because of the increased susceptibility of the embryo/fetus to radiation, Federal agencies limit the dose received by an embryo/fetus of a female occupational worker. The Department of Energy, in Order 5480.11<sup>(7)</sup> gives 0.5 rem (0.005 sievert) as the limit for the annual dose equivalent received by an unborn child from the period of conception to birth (the entire gestational period) as a result of occupational exposure of a female worker who has notified her employer in writing that she is pregnant.

In the revision of 10 CFR 20<sup>(8)</sup> the Nuclear Regulatory Commission also provides a limit of 0.5 rem (0.005 sievert) to an embryo/fetus during the entire pregnancy, for the occupational exposure of a declared pregnant worker.

Other agencies have also recommended limits on the occupational dose to the embryo/fetus. The National Council on Radiation Protection and Measurements in Reports No. 53<sup>(4)</sup> and No. 91<sup>(5)</sup> recommends a total dose equivalent limit of 0.5 rem (0.005 sievert) for the embryo/fetus. The NCRP in Report 91 states that "it is implied in the NCRP's recommendations that women who are capable of becoming pregnant should not be exposed to radiation environments in which the uterus could receive a dose equivalent in excess of the total fetal limit, 5 mSv (0.5 rem), before a pregnancy becomes known. Therefore, special attention is required to ensure that if exposures are received occupationally,

they are distributed uniformly with time so that the embryo-fetus does not receive more than its limit before pregnancy is known." Further, NCRP 91 indicates that the dose equivalent to the embryo/fetus, rather than the maternal dose equivalent, should be the basis for implementation of the recommended limits for the embryo/fetus.

More recently, the International Council on Radiological Protection (ICRP) in Report 60<sup>(3)</sup> recommends that once a pregnancy has been declared, the fetus should be protected by applying a supplementary equivalent-dose limit to the surface of the woman's abdomen (lower trunk) of 0.2 rem (0.002 sievert) during the remainder of the pregnancy, and by limiting intakes of radionuclides to about 1/20 of their annual limit on intake (ALI). The ICRP does not recommend a special occupational dose limit for women in general, but rather states that the basis for the control of the occupational exposure of women who are not pregnant is essentially the same as that for men.

#### NUMBER OF WORKERS AND DOSE RECEIVED

In order to determine the number of workers who could be affected by regulations for limiting dose to radiation workers who have declared their pregnancy, a review was conducted of the data reported annually to DOE.

The total population of radiation workers in DOE facilities in 1989 was 103,525. (This data has not yet been published.) This includes 3094

workers whose sex was not identified. Of the remaining 100,431 workers, 83,327 are male (83%) and 17,104 are female (17%). The average age of male and female workers lies within the 40-44 years category and 35-39 years category, respectively. Thus, female workers tend to be younger than their male counterparts. The total number of female radiation workers of childbearing age (assumed to be younger than 45 years of age) is 12,704, which is 12.5% of the total population of radiation workers and 75% of the total number of female radiation workers. Figure 1 shows the frequency distribution by age of male and female workers for the year 1989.

Figure 2 shows the frequency distribution of the total person-rem received by each category of worker (male and female) for the year 1989 as a function of age of the worker. For ages below 40 years, the female population received a larger fraction of the person-rem dose than they did for ages above 40 years. This result was not unexpected since the female population was shown to be younger than the male population.

Table I shows the distribution of radiation dose to DOE and DOE contractor employees. The female population received lower doses than their male counterparts, considering the female population as a whole. For the female population, more than 70% of the population received doses less than the measurable limit (which is based on the dosimeter used at each specific facility and thus varies between facilities); 30% received doses higher than the measurable limit; and less than 1%



received doses higher than 0.5 rem. These results changed slightly when only female workers of childbearing age are considered. The results (shown in Table II) indicate that 68% of the female workers of childbearing age received doses below the measurable limit and slightly greater than 1% received doses above 0.5 rem (0.005 sievert). The highest annual dose received by any female radiation worker during 1989 was less than 2.5 rem (0.25 sievert).

A survey conducted in 1990 of the number and frequency of pregnancies for female radiation workers at NRC-licensed power plants indicated that the number of women in the occupationally exposed work force at nuclear power plants has more than doubled from 4% to 8% of the work force over the previous ten years.<sup>(9)</sup> This represents an increase in real numbers from 5000 in 1980 to 17,000 in 1989. During this period, the number of pregnancies experienced by these radiation workers increased more than six-fold. During 1989, 197 pregnancies were reported from 37 different sites which included 68 reactor facilities (averaging approximately 5 pregnancies among female radiation workers per site).

### LITIGATION

Two Federal Laws have a bearing on fetal protection plans. They are Title VII of the Civil Rights Act and the Pregnancy Discrimination Act. Title VII<sup>(10)</sup> prohibits discrimination in the hiring, discharge, compensation, conditions, or privileges of employment because of an individual's race, color, religion, sex, or national origin. In 1978,

Congress amended Title VII to explicitly prohibit discrimination based on pregnancy. The amendment, known as the Pregnancy Discrimination Act states that "women affected by pregnancy, childbirth, or related medical conditions shall be treated the same for all employment-related purposes... as other persons not so affected but similar in their ability or inability to work."

Five court cases that relate to fetal protection policies have been decided. Two of the cases, *Zuniga v. Kleberg*<sup>(11)</sup> and *Hayes v. Shelby*,<sup>(12)</sup> involved hospital x-ray technicians and their exposure to radiation. A third case, *Wright v. Olin*,<sup>(13)</sup> involved chemical exposures. The two most recent cases, *Grant v. General Motors*<sup>(14)</sup> and *Automobile Workers v. Johnson Controls*,<sup>(15)</sup> involved exposure to lead. This latter case was elevated to the level of the Supreme Court after passing through District Court and Appeals Court. The Supreme Court gave their decision last March.

Johnson Controls uses lead in the manufacture of batteries. After 8 of its employees became pregnant while maintaining blood lead levels exceeding OSHA recommendations for workers "planning a family," Johnson Controls instituted a policy stating that "women who are pregnant or who are capable of bearing children will not be placed into jobs involving lead exposure or which could expose them to lead through the exercise of job bidding, bumping, transfer or promotion rights." The policy defined "women capable of bearing children" as all women except those whose

inability to bear children was medically documented. In 1984, a class action suit was filed. Among the individual plaintiffs were the following: a woman who had chosen to be sterilized in order to avoid losing her job; a 50-year-old divorcee who had suffered a loss in compensation when she was transferred out of a job that exposed her to lead; and a man who had requested and been denied a change in job location that would have lowered his exposure to lead because he and his wife were planning a family. (Lead is also considered a reproductive hazard for males.)

The Supreme Court concluded that "the language of both the BFOQ [Bona Fide Occupational Qualification] provision and the PDA [Pregnancy Discrimination Act] which amended it, as well as the legislative history and the case law, prohibit an employer from discriminating against a woman because of her capacity to become pregnant unless her reproductive potential prevents her from performing the duties of the job." The Supreme Court stated that "fertile women, as far as appears in the record, participate in the manufacture of batteries as efficiently as anyone else" and that "Title VII, as amended by the PDA, mandates that decisions about the welfare of future children be left to the parents who conceive, bear, support, and raise them rather than to the employers who hire those parents or the courts."

The decision was unanimous; however, there was some disagreement among the justices on some aspects of the decision, including the possibility

of torts. The majority opinion held that "if under general tort principles, Title VII bans sex-specific fetal-protection policies, the employer fully informs the woman of the risk and the employer has not acted negligently, the basis for holding an employer liable seems remote at best. Moreover, the incremental cost of employing members of one sex cannot justify a discriminatory refusal to hire members of that gender."<sup>(16)</sup>

#### CONSIDERATIONS FOR ASSESSMENT AND CONTROL OF FETAL EXPOSURE

To comply with the ruling of the Supreme Court on the Johnson Control's case, it is important that women as a class not be restricted from jobs that are classed as a reproductive hazard. Although the Supreme Court did not rule on the advisability of restricting women who are pregnant from jobs where there is a reproductive hazard, they did state that "Title VII, as amended by the PDA, mandates that decisions about the welfare of future children be left to the parents who conceive, bear, support, and raise them rather than to the employers who hire those parents or the courts." This suggests that it is appropriate for the individual woman to make the decision as to whether she needs to be protected from a specific reproductive hazard. On the other hand, the Supreme Court also stated (when discussing the issue of tort litigation) that it is best for the employer to "fully inform the woman of the risk" and "not act negligently." For this reason, a program that is voluntary in nature, and where the employer takes major steps to ensure that the reproductive hazard is communicated to the employee, may be the best

option. The following items are important for consideration by facilities that in the absence of specific Federal guidance, are developing programs to protect the embryos/fetuses of female radiation workers.

#### Declaration of Pregnancy/Declaration of Pregnancy Termination

Based on the information given in the Johnson Controls case, it appears that the voluntary aspects of the declaration of pregnancy are important. Consideration should be given to implementing a standard method by which workers can declare their pregnancy, and indicate that they understand that by declaring their pregnancy they will be placing themselves under a more restrictive dose limit for the duration of the pregnancy. Further consideration may be given to allowing female workers who are not yet pregnant, but are planning a family, also to declare their "decision to become pregnant," and thus fall under the more restrictive dose limits for the embryo/fetus. This would provide protection to the embryo/fetus during the early stages of pregnancy, when the worker may not yet realize that she is pregnant.

Additional considerations should be given to the period of time over which the lower dose limits would remain in place. One solution would be to request that the worker declare that the pregnancy has been terminated, in much the same way that she declared that the pregnancy had begun. It is important to note, however, that because of previous Supreme Court rulings on privacy, and out of consideration for the

worker, it may be inappropriate to request that the worker explain how or why the pregnancy was terminated, or to require documentation of the termination (such as a note from a physician).

There are two negative aspects that could result from a voluntary program. First, a worker might not declare the pregnancy, while appearing obviously pregnant. Second, a worker may declare that she is pregnant or "intends to become pregnant" when neither statement is true. These problems are not easily solved, but either could occur as a result of an employer's attempt to be responsive to the Supreme Court's ruling as explained above, and the employer's concerns for protecting the fetus and avoiding later litigation. One potential step of good faith that could be taken is to provide the worker with the ability to obtain free and confidential pregnancy tests, and to provide a knowledgeable contact for confidential counseling.

### Training

Training is another aspect of a fetal protection program that is discussed by the Supreme Court. As mentioned previously, it is important that the employer "fully inform the woman of the risk." This implies training to ensure that the worker understands radiation risks at various stages of gestation, and also understands how those risks relate to nonoccupational and nonradiation hazards. It is also important that the worker understand the dose limits and the specific facility's policies regarding declaration of pregnancy and work

restrictions. Consideration should be given to training not just the female radiation workers at the facility, but all workers, especially those that interact with the female radiation worker, for example, her co-workers and supervisors. Consideration may also be given to testing the workers after they receive training in order to document that they understood the training information.

#### Work Restrictions following Declaration

There are various options for dealing with work restrictions. Based on data obtained from the DOE Annual Exposure reports (as presented earlier in this report), for most female radiation workers, work restrictions to control the dose to the embryo/fetus are not necessary, since the majority of monitored workers are already below the dose limit for an unborn child. However, it may be appropriate to review the worker's environment to determine whether a work restriction is necessary. Work restrictions can include limiting the duration of work in various areas or totally removing the worker from radiation areas. Options other than employing a work restriction include teaching exposure-reduction techniques or remodeling the work area to ensure that the radiation exposure received will be below the mandated limit.

During development of any work restrictions, it would also be appropriate to consider the possibility of a dose being received by the embryo/fetus as a result of the female worker's receiving an intake of radionuclides.

### Dose Calculation and Measurement

There are several methods that can be used to calculate the dose to the embryo/fetus. For external radiation, the ICRP recommends calculating the dose to the surface of the woman's abdomen. The proposed changes to 10 CFR 20 adopt this approach. The dose to the embryo/fetus from external radiation could be estimated by use of the worker's personnel dosimeter or by use of an additional dosimeter worn on the abdomen of the pregnant radiation worker.

An interim report discussing the contribution of maternal radionuclide burdens on prenatal radiation doses has recently been published.<sup>(16)</sup> This report uses methodologies developed by the Medical Internal Radiation Dosimetry (MIRD) Committee of the Society for Nuclear Medicine to calculate radiation absorbed doses to the embryo/fetus. Although it is better to prevent radionuclide intakes for declared pregnant workers, in areas where this is not possible, consideration may be given to adjusting the bioassay frequency to ensure that exposure rates are not exceeded.



### Record-Keeping

Record-keeping requirements need to be determined based on the policy or requirements of the regulatory agency, and based on the facility's specific needs. Suggestions for records to be kept include 1) the date the pregnancy was declared, 2) the estimated dose during the gestation period prior to the declaration of the pregnancy, 3) the monthly dose and total dose during the pregnancy, 4) dose due to intakes during gestation, 5) the date that notification was made of the termination of the pregnancy, and 6) any training-related records.

### CONCLUSIONS

As a result of the increased sensitivity of the embryo/fetus to radiation, Federal regulations limit the dose to an unborn child as a result of occupational exposure of a worker to 0.5 rem (0.005 sievert). Information obtained from DOE indicates that during 1989, the majority of DOE female radiation workers (approximately 99%) received annual radiation doses below this level. However, the number of women employed as radiation workers has increased dramatically during the past 10 years, thus prompting many facilities to institute fetal protection programs. The desire to protect the embryo/fetus from radiation must also be balanced against a recent Supreme Court ruling that indicates that employers may not bar women of childbearing age from certain jobs because of potential risk to their fetuses. This requires that employers consider appropriate methods for identifying pregnancies, for training workers, for developing and applying work restrictions, for

calculating and measuring doses, and for keeping records in an effort to protect the embryo/fetus without being discriminatory to the worker.

ACKNOWLEDGEMENT

Pacific Northwest Laboratory is operated for the U. S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

## REFERENCES

- 1) National Research Council (NRC): Health Effects of Exposure to Low-Levels of Ionizing Radiation. Committee on Biological Effects of Ionizing Radiations. (BEIR V). National Academy Press. Washington, D.C. (1990).
- 2) United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR): Genetic and Somatic Effects of Ionizing Radiation. United Nations. New York. (1986).
- 3) International Commission on Radiological Protection (ICRP): 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Pergamon Press, New York. (1990).
- 4) National Council on Radiation Protection and Measurements (NCRP): Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally-Exposed Women. NCRP Report No. 53, Washington, D.C. (1977).
- 5) National Council on Radiation Protection and Measurements (NCRP): Recommendations on Limits for Exposure to Ionizing Radiation. NCRP Report No. 91. Washington, D.C. (1987).
- 6) Environmental Protection Agency: Radiation Protection Guidance to Federal Agencies for Occupational Exposure. 52 FR 17, 2822. Dated Tuesday, January 27, 1987. (cited as 52 FR 2822). (1987).

- 7) U. S. Department of Energy: Radiation Protection for Occupational Workers. DOE ORDER 5480.11, December 12, 1988. U.S. Department of Energy, Washington D.C. (1988).
- 8) U.S. Code of Federal Regulations (10 CFR Part 20): Standards for Protection Against Radiation. Title 10, Part 20. (1991).
- 9) Kelly, J.J: Experiences in Limiting Radiation Exposure to the Embryo/Fetus in Nuclear Power Plants. In: Proceedings of the 24th Mid-Year Topical Meeting of the Health Physics Society, Raleigh, N.C. D. B. Jorgensen; L. W. Seagondollar, and J. W. Watson, Jr.; Eds. (January 21-24, 1991).
- 10) Title VII of the Civil Rights Act of 1964. 42 U.S.C. 2000e (1982).
- 11) Zuniga v. Kleberg. 692 F.2d 986 (United States Court of Appeals, Fifth Circuit, December 6, 1982).
- 12) Hayes v. Shelby Memorial Hospital. 726 F.2d 1543 (United States Court of Appeals, Eleventh Circuit. March 16, 1984).
- 13) Wright v. Olin. 697 F.2d 697 (United States Court of Appeals, Fourth Circuit, December 23, 1982).
- 14) Grant v. General Motors Corporation. 908 F.2d 1303 (United States Court of Appeals, Sixth Circuit. July 20, 1990).
- 15) Automobile Workers v. Johnson Control. 59 U.S.L.W. 4209 (Supreme Court, March 20, 1991).

- 16) Sikov, M. R.; R. J. Traub and H. K. Mezmarich: Contribution of Maternal Radionuclide Burdens to Prenatal Radiation Doses. NUREG/CR-5631. U.S. Nuclear Regulatory Commission. Washington, D.C. (1990).

Table I. Dose Distribution of Male, Female and All Radiation Workers at DOE Facilities (1989).

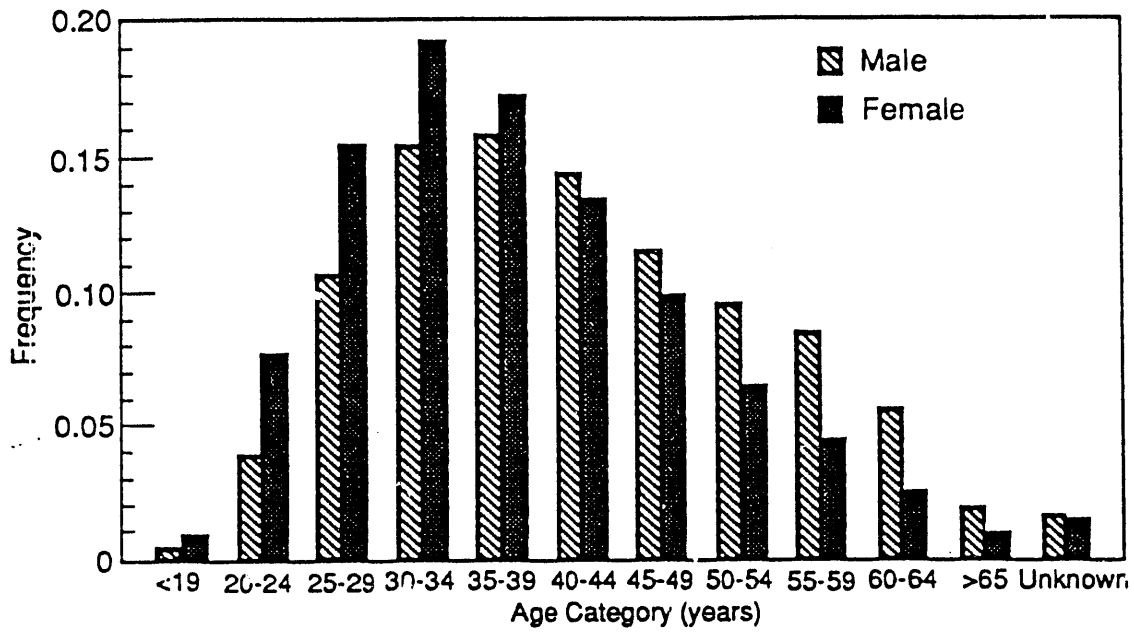
<u>Dose (rem)</u>	<u>Male Workers</u>		<u>Female Workers</u>		<u>All workers</u>	
	<u>Number</u>	<u>%</u>	<u>Number</u>	<u>%</u>	<u>Number</u>	<u>%</u>
<Meas.	50095	60.12	12030	(70.33)	63123	(60.97)
Meas.-0.10	26921	32.31	4269	(24.96)	33185	(32.06)
0.1-0.25	3479	4.18	446	(2.61)	4006	(3.87)
0.25-0.5	1579	1.89	192	(1.12)	1785	(1.72)
0.5-0.75	525	0.63	70	(0.41)	600	(0.58)
0.75-1.0	309	0.37	43	(0.25)	352	(0.34)
1.0-1.5	327	0.39	42	(0.25)	370	(0.36)
1.5-2.0	72	0.09	11	(0.06)	83	(0.08)
2.0-2.5	17	0.02	1	(0.01)	18	(0.02)
2.5-3.0	3	0.004	0	(0)	3	(0.003)

Table II. Dose Frequency Distribution for Female Radiation Workers of Childbearing Age at DOE Facilities (1989).

<u>Dose Range</u>	<u>Frequency</u>	<u>Workers</u>
<Meas.	68.2%	8664
Meas.-0.10	26.53%	3370
0.1-0.25	2.98%	378
0.25-0.5	1.23%	156
0.5-0.75	.46%	59
0.75-1.0	.28%	36
1.0-1.5	.28%	35
1.5-2.0	.04%	5
2.0-2.5	.01%	1
2.5-3.0	0.00%	0

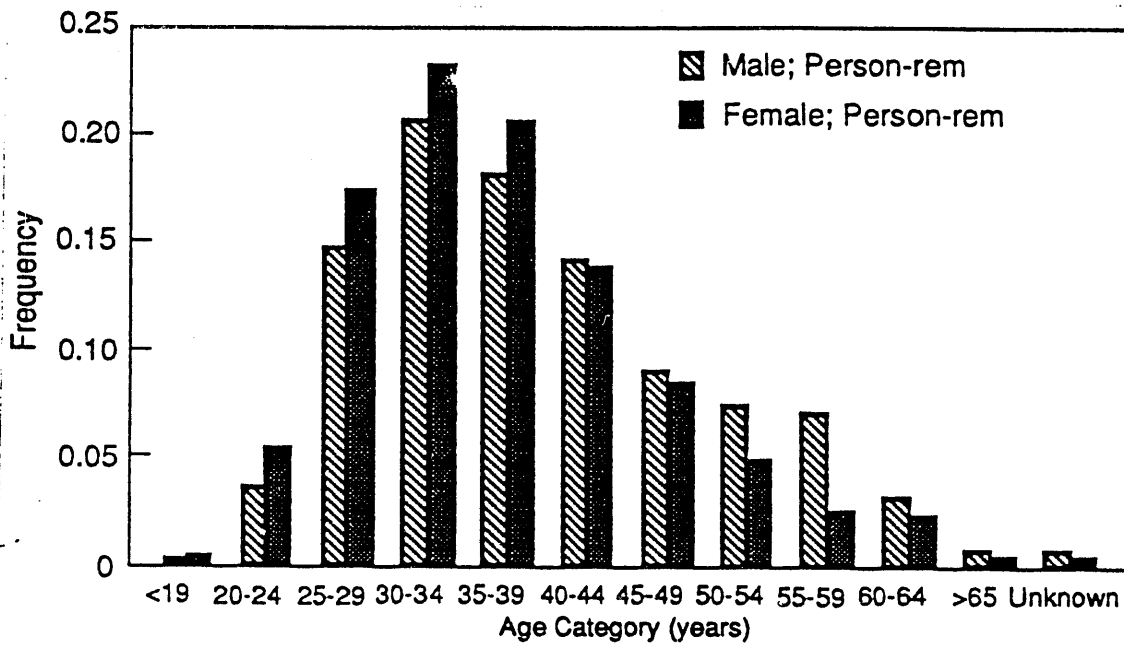
#### FIGURE CAPTIONS

- Figure 1. Frequency Distribution of Male and Female Workers at DOE Facilities by Age for the Year 1989.
- Figure 2. Frequency Distribution of Person-rem for DOE Facilities by Age for Male and Female Workers for the Year 1989.



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Figure 1



S9111020.2

Figure 2



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