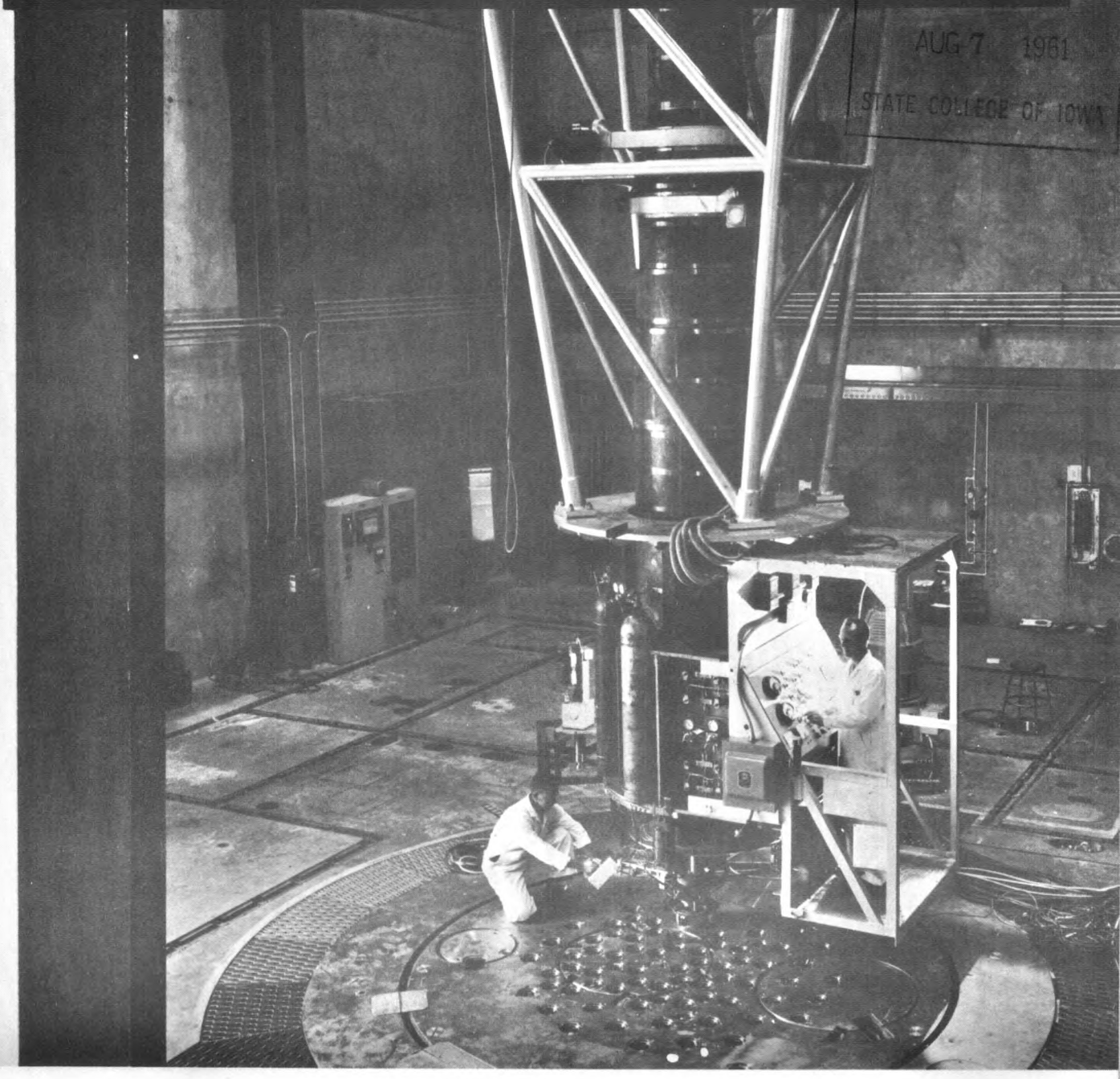
EMPLOYMENT IN THE ATOMIC ENERGY FIELD

A 1960 Occupational Survey



Bulletin No. 1297

UNITED STATES DEPARTMENT OF LABOR
Arthur J. Goldberg, Secretary

BUREAU OF LABOR STATISTICS
Ewan Clague, Commissioner

Prepared for the
UNITED STATES ATOMIC ENERGY COMMISSION

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PREFACE

This bulletin (No. 1297) presents the results of an employment and occupational survey of major U.S. Atomic Energy Commission prime contractors. The survey, which was conducted for the Atomic Energy Commission by the Bureau of Labor Statistics of the U.S. Department of Labor, relates primarily to employment by occupation in January 1960 and employment which was anticipated in January 1961.

The Atomic Energy Commission and the Bureau of Labor Statistics are grateful to the organizations and individuals whose cooperation made the study possible, especially to the establishments that supplied the statistical data on employment.

The study was carried out under the sponsorship of the Atomic Energy Commission's Office of Industrial Relations, Oscar S. Smith, Director. Valuable assistance was provided in all phases of the survey by John Chapman, Chief, Contractor Personnel Branch of that office, and by John Rudolph of his staff. All photographs were supplied by the Atomic Energy Commission.

The survey was conducted in the Bureau of Labor Statistics by the Division of Manpower and Employment Statistics. Mannie Kupinsky directed all work on the project. Arthur Neef prepared the bulletin with the assistance of Anna M. Latimer.

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EMPLOYMENT IN THE ATOMIC ENERGY FIELD

Introduction

This bulletin summarizes the findings of a survey of employment in the atomic energy field that was conducted by the U.S. Department of Labor's Bureau of Labor Statistics under the sponsorship of the Atomic Energy Commission (AEC). The survey was carried out in the spring and summer of 1960. Employment and occupational data, on an establishment basis and as of January 1960, were collected by mail questionnaire from establishments which were engaged in atomic energy activities under direct contract with the Commission.

The survey covered 159 establishments which held major prime contracts with the Atomic Energy Commission as of September 30, 1959.[1] This report is based on data representing complete returns from 158 respondents. Also included, but tabulated separately, is an occupational breakdown of Atomic Energy Commission personnel.

About two-thirds of all workers estimated to be employed in the atomic energy field were covered by this survey.[2] The survey covered all workers in some atomic energy activities—such as uranium milling and the production of feed materials and enriched uranium—but only a portion of the workers in other activities—such as the manufacture of nuclear reactors. The remaining one-third of employment in the atomic energy field that was not covered by this survey, included both workers engaged in those activities that were only partially represented in the survey and workers in atomic energy activities that were not represented in the survey—such as uranium mining and nuclear instrument manufacturing. All text and appendix tables in this bulletin refer only to employment in the 158 establishments surveyed, and not to the entire atomic energy field.

Employment covered by this survey was, for the most part, supported by funds supplied by the Atomic Energy Commission. The Commission also supports some employment in the atomic energy field that was not covered by this survey. The remaining uncovered employment was either privately supported or supported by funds from Government agencies other than the AEC, primarily the Department of Defense.

This survey replaced the AEC's Annual Report on Professional Personnel, which was a count of employment, by selected occupation, by Commission contractors. The present survey differs from that report both as to coverage and detail of data collected. The Bureau of Labor Statistics survey provides more detailed occupational information, includes all major prime contractors, and, for the most part, covers all employment in an establishment, whereas the AEC's Annual Report covered only cost-reimbursable operating and research and development contractors at AEC installations with 50 or more employees and included only employees paid out of AEC funds.

In succeeding surveys of employment in the atomic energy field, the collection of data from industrial establishments will be coordinated with the surveys of scientific and technical personnel in American industry that are conducted by the Bureau of Labor Satistics for the National Science Foundation. In addition, future surveys will not be limited to major AEC prime contractors and, therefore, will provide a broader coverage of the atomic energy field than is presented here.

Since research and production activities covered by this survey are highly complex, the report includes for those unfamiliar with this field a brief description of atomic energy in nontechnical language (appendix D) and a discussion of some of the applications of atomic energy (appendix E).

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[1] Coverage was generally limited to establishments under prime contract to the Atomic Energy Commission with accumulated obligations in excess of $1 million as of September 30, 1959. (Not covered in the survey were the many subcontractors who had contracts with prime contractors to build components or to supply services or materials.) Coverage was also limited to contractors who were working directly on atomic energy in some way or who were constructing facilities for such work; excluded were contractors who were supplying materials for office work, office equipment, coal, etc. Since respondents were asked to report on an establishment basis (with the exception of construction establishments and private research laboratories, which reported only those employees engaged in atomic energy work), the survey includes some employees paid from other than AEC funds. (See appendix B for a more detailed discussion of the coverage of the survey and for a description of how the survey was conducted.)

[2] The estimate of total employment (about 200,000) in the atomic energy field is an approximation which was developed from the employment reported in this survey and estimates of employment in the remainder of the field. The atomic energy field is not an "industry" as the term is customarily defined. See footnote 8, p. 4.

Summary of Findings

Nearly 126,000 workers were employed in January 1960 in the 158 establishments covered in this survey of Atomic Energy Commission prime contractors. As indicated previously, this accounted for about two-thirds of estimated employment in the entire atomic energy field. Employment rose by about 2 percent between January 1959 and January 1960 in the 158 surveyed establishments. Contractors expected that their employment would increase by another 3 percent to 130,000 by January 1961.

Many different activities are involved in the production and application of nuclear energy.[3] These include the mining and milling of uranium-bearing ores, the refining of the ore, and the manufacture of nuclear fuels, the manufacture of nuclear reactors and reactor components, the operation and maintenance of reactors, the manufacture of nuclear instruments, and a great deal of research and development work.

In the portion of the atomic energy field covered by this survey, the two largest fields of employment in January 1960 were the Atomic Energy Commission research facilities and the facilities producing defense materials, accounting for about 34 and 28 percent of the surveyed employment, respectively. (See table 1.) Nuclear reactor manufacture and production of feed materials and enriched uranium (reactor fuel) each accounted for more than 9 percent of total employment. Over 5 percent of the surveyed employees were engaged in the construction of nuclear facilities and another 4 percent were working in private research laboratories. Most of the remaining 10 percent were employed in the production of special materials, uranium milling, and fuel element fabrication segments.[4]

The occupational distribution of employment in the establishments surveyed reflects the concentration on research and development work in the atomic energy field. Engineers, scientists, technicians, and other technical personnel accounted for about one-third of the total surveyed employment in January 1960. These technical workers made up a higher proportion of employment in this field than in most other fields of work. Engineers and scientists combined accounted for about 20 per-

[3] The portion of the atomic energy field represented by the 158 establishments covered in this survey was divided into 10 major segments, or activities, each establishment being classified according to its primary activity: (1) Atomic Energy Commission research facilities; (2) defense production facilities; (3) reactor manufacture; (4) production of feed materials and enriched uranium; (5) construction of nuclear facilities; (6) private research laboratories; (7) production of special materials; (8) uranium milling; (9) fuel element fabrication; and (10) power reactor operation. A miscellaneous category was set up for seven establishments which could not be fitted into any of the above activities. (See appendix B for definitions of each segment.)

[4] The proportion of the surveyed employees working in any of the segments into which the atomic energy field has been divided is not representative of the proportion of total employment accounted for by that segment in the entire atomic energy field. For example, this survey covers all AEC research facilities. However, only a portion of establishments engaged in reactor manufacture are covered; those establishments not covered are not major AEC prime contractors.

TABLE 1. EMPLOYMENT IN THE ATOMIC ENERGY FIELD, BY SEGMENT, JANUARY 1959, JANUARY 1960, AND ANTICIPATED EMPLOYMENT IN JANUARY 1961

Segment	Number of establishments	Employment					
		January 1959		January 1960		January 1961 (anticipated)	
		Number	Percent	Number	Percent	Number	Percent
Total, all segments	158	123,530	100.0	125,921	100.0	130,007	100.0
Atomic Energy Commission research facilities	19	40,531	32.8	42,172	33.5	43,951	33.8
Defense production facilities	11	35,627	28.8	35,590	28.3	36,945	28.4
Reactor manufacture	16	12,049	9.8	11,760	9.3	12,149	9.3
Production of feed materials and enriched uranium	6	12,003	9.7	11,717	9.3	11,631	9.0
Construction of nuclear facilities	12	6,319	5.1	6,575	5.2	6,320	4.9
Private research laboratories	34	4,832	3.9	5,295	4.2	5,725	4.4
Production of special materials	10	3,222	2.6	3,584	2.9	3,855	3.0
Uranium milling	26	3,261	2.6	3,432	2.7	3,506	2.7
Fuel element fabrication	8	2,924	2.4	2,903	2.3	3,021	2.3
Power reactor operation	9	235	.2	366	.3	531	.4
Miscellaneous	7	2,527	2.1	2,527	2.0	2,373	1.8

TABLE 2. EMPLOYMENT IN THE ATOMIC ENERGY FIELD, BY OCCUPATIONAL GROUP, JANUARY 1960

Occupational group	Number	Percent
Total employment	125,921	100.0
Engineers	15,112	12.0
Scientists	9,488	7.5
Technicians	14,612	11.6
Other technical personnel	3,744	3.0
Managerial personnel	12,417	9.9
Clerical personnel	18,537	14.7
Skilled workers	23,881	19.0
Nuclear reactor operators	881	.7
All others	27,249	21.6

cent of the employment. Many highly trained craftsmen were also employed. Skilled workers accounted for 19 percent of the employment in the surveyed establishments (table 2).

On a primary work function basis,[5] approximately half of the workers surveyed were engaged in the fabrication and manufacture (production and operations) of products, such as reactors, fuel elements, and nuclear fuels. A particularly large proportion, about 30 percent, were engaged in research and development work. Seventy-two percent of the skilled workers were in production and operations. On the other hand, 84 percent of all scientists, 54 percent of the engineers, and 51 percent of the technicians were in research and development. (Table 3 provides a distribution of employment by function for selected occupational groups.)

Employment in the atomic energy field is heavily concentrated within a few States, although there are people doing atomic energy work in every State. Nearly 50 percent of the employees covered by this survey were working in the four States of Ohio, Tennessee, New Mexico, and California. Table 4 provides a regional distribution of employment.

TABLE 3. PERCENTAGE DISTRIBUTION OF EMPLOYEES IN THE ATOMIC ENERGY FIELD IN SELECTED OCCUPATIONAL GROUPS, BY PRIMARY WORK FUNCTION, JANUARY 1960

Occupational group	All functions	Primary function			
		Research and development	Production and operations	Construction	Other
Engineers	100	54	29	14	3
Scientists	100	84	13	(1)	3
Technicians	100	51	40	4	5
Other technical personnel	100	47	30	17	6
Skilled workers	100	11	72	10	7

[1] Less than 1 percent.

In addition to supplying information for January 1960, all establishments were asked to estimate what their employment would be by January 1961. (See table 1.) An overall employment increase of about 4,100 (over a 3-percent gain) from January 1960 to January 1961 was indicated. More than three-fourths of this increase was expected to occur in the Atomic Energy Commission research facilities and defense production facilities.

Employment in each of the occupational groups was expected to increase with the exception of clerical and other office personnel, for which a 1-percent decline was indicated. (See table 9.) Engineers and scientists together accounted for the largest proportion of the anticipated total increase, followed by technicians and skilled workers. Within the scientific, engineering, and technical occupational groups, the occupations of physicist, electrical and electronics engineer, electronics technician, and mechanical engineer, respectively, were the ones expected to increase the most between January 1960 and January 1961.

A more detailed discussion of these survey data is found in the sections on distribution of employment by occupation and distribution of employment by segment.

TABLE 4. REGIONAL DISTRIBUTION OF EMPLOYEES IN THE ATOMIC ENERGY FIELD, JANUARY 1960

Region [1]	Number of establishments	Percent of total employment
All regions	158	100
Northeast	53	17
North Central	34	22
South	22	24
Mountain	33	18
Pacific	16	19

[1] The regions are defined as follows: *Northeast*—Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont; *North Central*—Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin; *South*—Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia; *Mountain*—Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming; and *Pacific*—California, Oregon, and Washington.

[5] All establishments were asked to classify their employees according to the work functions in which the employees were primarily engaged—research and development, production and operations, construction, or all other. (See the questionnaire in appendix C for definitions of the functions, and the section on Definitions in appendix B, Scope and Method of Survey, for a description of problems encountered and adjustments made in the distribution of employees by function.)

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Many peaceful uses of atomic energy as well as military uses have been developed in recent years, and, in fact, the two greatly overlap.[6] Today, in addition to submarines powered by nuclear energy and developmental work directed toward the eventual nuclear propulsion of surface ships, aircraft,[7] missiles, and space satellites, nuclear reactors are supplying electricity to electric utility lines and producing radioisotopes which have become extremely valuable as research tools in agriculture, medicine, and industry, and as inspection and control devices in industrial production (for example, radioisotope gages may be used to regulate the thickness of materials).

The atomic energy field covers manifold activities[8] which are directed toward inquiring into the nature of the energy contained within the atom and the development and use of this energy. Included in the atomic energy field are uranium mines and mills; refineries which process uranium and thorium bearing ores; plants which produce nuclear fuels; plants which manufacture reactors, reactor components, and nuclear instruments; concerns which design, engineer, and construct nuclear facilities; establishments which operate and maintain nuclear reactors; companies which specialize in the disposal of radioactive wastes; and research laboratories. Generally excluded from the atomic energy field are establishments which are concerned with the indirect applications of atomic energy, such as those which use electricity generated by nuclear reactors and those which utilize radioisotopes in industrial and medical applications. Employment at some establishments, such as uranium mills or facilities producing nuclear fuels, falls entirely within the atomic energy field. On the other hand, many establishments, such as laboratories performing atomic research, may be only partially engaged in atomic energy work: Only some of the employees in these establishments are included in the atomic energy field.

Many of the basic atomic energy activities are supported by the Federal Government. The Atomic Energy Commission directs the Federal Government's atomic energy program and regulates the use of nuclear and byproduct materials. The AEC, in directing the Federal program, has a statutory responsibility to encourage the widespread use of atomic energy in such a manner as to strengthen free competition in private enterprise. To this end, the Commission follows a policy of procuring all goods and services from private industry, wherever practical, and contracts with industrial firms and educational institutions to operate and manage AEC-owned facilities. (Commission-owned plant and equipment were valued at over $7 billion in 1960 and included research facilities, uranium-processing plants, nuclear reactors, and weapon-manufacturing plants.)

Much of the research and development work in this field is carried on at the AEC-owned research facilities. However, a considerable amount of independent research in atomic energy is done without financial assistance from the Commission. The Commission encourages private participation in the atomic energy field by making available, to the fullest extent possible, scientific data on atomic energy, Government-owned facilities for conducting experiments, and equipment for scientific projects. It also provides financial assistance to

[6] See appendix D for a brief description of atomic energy and appendix E for a discussion of the major applications of atomic energy.

[7] This survey included the two AEC research facilities engaged in developing nuclear-powered aircraft engines. It should be noted that, since the bulletin was prepared for publication, the AEC has directed its contractors to discontinue this work.

[8] The atomic energy field is not an "industry" as this term is customarily used for classification purposes. *The Standard Industrial Classification Manual* (Executive Office of the President, Bureau of the Budget, p. 431, 1957), which is used by the Federal Government and other organizations in the classification of establishments by type of activity in which engaged, defines an industry as "a grouping of establishments primarily engaged in the same or similar lines of economic activity." For manufacturing industries, "the line of activity is generally defined in terms of the product made, materials consumed, or process of manufacture used." The atomic energy field, as used in Bureau of Labor Statistics publications, includes all activities directed toward the development and use of atomic energy. Thus, it includes employment in establishments owned and/or operated by private industry engaged in mining, milling, refining, manufacturing, construction, and research and development; employment in federally owned laboratories operated by educational institutions; and employment in governmental agencies. Therefore, the atomic energy field, rather than being an industry in the accepted sense, includes establishments in many different industries.

private organizations in construction of research and power reactors and may make available the necessary fuel.

Private concerns in their own installations are engaged in every type of atomic energy activity except development and production of military weapons and certain nuclear fuel-processing operations. Many of these activities, such as ore mining and milling, the manufacture of heat transfer equipment, and the construction of facilities, differ little from nonatomic energy operations of the same sort. Other activities, such as manufacture of fuels needed to run reactors, are unique to the atomic energy field.

Distribution of Employment by Occupation [9]

In January 1960, the 158 establishments surveyed employed about 126,000 workers. Engineers and scientists together accounted for a large proportion, nearly 20 percent, of the total (see tables 2 and 10), reflecting the fact that atomic energy is a relatively new, complex, and growing field with a large proportion of its work force devoted to basic and applied research and to the development and design of new and improved products and methods of production.[10] In contrast to the large proportion that engineers and scientists combined represented of total employment in the atomic energy field, they made up only about 3.5 percent of total employment in manufacturing industries as a whole in January 1959, according to information from a recent Bureau of Labor Statistics survey. This 1959 survey showed that even in such research-oriented industries as aircraft and parts and chemicals and allied products, engineers and scientists accounted for only 11 and 9 percent of employment, respectively.[11] The highly technical nature of much of the work in the atomic energy field is further reflected by its employment of many technicians, accounting for nearly 12 percent of total employment (table 2). Other technical personnel, such as designers and technical writers, accounted for another 3 percent of employment.

Many highly skilled craftsmen are employed in the atomic energy field because of the custom manufacturing of most products, the precise tolerances that must be maintained, and the great amount of complex machinery and equipment which must be serviced. Skilled workers represented 19 percent of employment in January 1960. The remaining employment was divided among clerical personnel (15 percent of total employment), managerial and administrative personnel (10 percent), and all other occupations (22 percent), including nearly 900 nuclear reactor operators, an occupation unique to the atomic energy field.

Of the 126,000 employees covered in the survey, approximately 51 percent were engaged in production and operations, 30 percent in research and development, 6 percent in construction, and the remaining 13 percent in all other functions. The functional distribution of employment varied greatly among occupations. Eighty-four percent of the scientists, 54 percent of the engineers, and 51 percent of the technicians were doing R&D work. (See table 3.) With the exception of health physicists and the small number of geologists and geophysicists, over 75 percent of the employees in every scientific occupation were in R&D.

Total employment was expected to increase by about 4,100 (3 percent) between January 1960 and January 1961. The employment of additional engineers and scientists was expected to account for nearly half of this increase. (See table 9.)

Major findings of the survey as they relate to employment by occupational group and individual occupation are discussed on the following pages.

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[9] See appendix C for a sample of the questionnaire. Also, see appendix B for a description of some of the problems involved in classifying employees.

[10] Some limitations inherent in this survey indicate that comparisons of occupational distributions should be used with caution. For example, returns probably overstate the ratio of engineering, scientific, and technical personnel to total employment (and also the proportion of employees engaged in research and development work) for the atomic energy field as a whole, since the survey covers relatively more of the employees in those segments of the atomic energy field in which the amount of research and development work performed is particularly extensive. However, if information had been collected on the entire atomic energy field, it is believed that these ratios would still be exceptionally high in comparison with other industries. Another factor which should limit comparisons with other industries, is that this survey covers some employment at educational institutions.

[11] *Scientific and Technical Personnel in American Industry,* Report on a 1959 Survey, NSF 60–62, Prepared for the National Science Foundation by the U.S. Department of Labor, Bureau of Labor Statistics, (1960), table 2, p. 10.

Chemist using a remote control manipulator to handle radioactive liquid behind a protective wall of lead bricks and special lead glass.

Engineers

Engineers in the atomic energy field are engaged primarily in designing nuclear reactors and other equipment, in supervision of the production of fuels and materials, and in research and development work concerning the uses of atomic energy. While some of the engineers are highly trained in nuclear technology, and most have had some orientation in atomic energy, engineers in all major engineering disciplines are employed in substantial numbers.

About 15,100 engineers were employed by the surveyed establishments in January 1960, accounting for 12 percent of the total establishment personnel. The proportion of total employment accounted for by engineers in the various segments of the atomic energy field ranged from over 20 percent in establishments which design and construct nuclear facilities or design and manufacture nuclear reactors to about 3 percent in uranium mills and in establishments which produce special materials for use in reactors.

More than half of the engineers (54 percent) worked in R&D. Most of the remaining engineers worked either in production and operations (29 percent) or construction (14 percent) (table 3). The type of work being performed varied considerably among the different segments of the atomic energy field. Only 3 of the 10 segments in which the establishments were classified used more than half of their engineers in R&D work—the AEC research facilities (82 percent), private research laboratories (93 percent), and reactor manufacturers (53 percent)—but these 3 segments employed about two-thirds of all engineers; in a fourth segment, the construction firms, the majority of engineers designed or supervised the construction of nuclear facilities. In the other segments, most of the engineers worked in production and operations.

Mechanical engineers (4,391), who comprised the largest single group among the engineers employed by the surveyed establishments (table 5), worked in such activities as the development and design of reactor components, such as heat transfer equipment, pressure vessels, core tanks, and remote-handling equipment, and the testing of reactor mechanical components. About half of the mechanical engineers worked in R&D.

Electrical and electronics engineers (3,015), who constituted the second largest group of engineers, were employed in such work as the development and design of radiation detection instruments and nuclear instrumentation and control circuitry for reactors and in supervising the maintenance of electronic instruments and controls. Sixty percent of these engineers worked in R&D.

TABLE 5. EMPLOYMENT OF ENGINEERS IN THE ATOMIC ENERGY FIELD, BY OCCUPATION AND PRIMARY WORK FUNCTION, JANUARY 1960

Occupation	All functions	Primary function			
		Research and development	Production and operations	Construction	Other
Engineers, total	15,112	8,208	4,408	2,055	441
Mechanical	4,391	2,276	1,429	569	117
Electrical and electronics	3,015	1,812	703	429	71
Chemical	1,820	1,062	670	67	21
Reactor	1,724	1,362	267	69	26
Metallurgical	916	651	247	18	0
Civil	905	161	146	566	32
Aeronautical	93	75	15	2	1
Other engineers	2,248	809	931	335	173

A nuclear physicist lowers a bottle of "heavy" water to expose it to gamma rays from a radioactive source.

The surveyed establishments also employed large numbers of chemical engineers (1,820) for such work as the development of chemical processes for the purification of reactor materials, research in fuel element reprocessing, and for the supervision of the chemical processing of materials. Nearly 60 percent of the chemical engineers were in research and development.

The surveyed establishments reported the employment of 1,724 reactor engineers (specialists in nuclear reactor technology) who were engaged in such work as the development and evaluation of reactor concepts, including the determination of fuel element types, critical masses, and shielding requirements.[12] Nearly 80 percent of the reactor engineers worked in R&D.

[12] While "reactor engineer" was listed separately on the questionnaire, it is not universally recognized as a separate engineering discipline such as mechanical or chemical engineer. Therefore, personnel classified as reactor engineers in one establishment might be classified as mechanical or chemical engineers by another establishment, even though performing similar work. Reporting on this occupation may, therefore, have a large margin of error.

Metallurgical (916), civil (905), and a small number of aeronautical (93) engineers were also employed by the surveyed establishments. Metallurgical engineers study the properties of materials (including many newly developed materials) of interest to the successful design and operation of nuclear reactors and work on the development of suitable techniques for the fabrication of fuel elements and other products. About 70 percent of the metallurgical engineers were in R&D work. About two-thirds of the civil engineers were working in construction, particularly in the designing of plant facilities for nuclear reactors and supporting facilities and the supervision of their erection. Most (81 percent) of the aeronautical engineers were in R&D work aimed at developing nuclear propulsion systems for aircraft and other space vehicles. Also employed were a large number of engineers (2,248) who were not classified by the surveyed establishments according to any of the listed engineering disciplines.

Scientists

About 9,500 scientists were employed in the surveyed establishments in January 1960, accounting for almost 8 percent of total employment. Compared with most industries or other fields of work, this is a large proportion, reflecting the intensive basic and applied research being undertaken in the atomic energy field. The surveyed establishments employed scientists trained in physics, mathematics, chemistry, metallurgy, and biology, 84 percent of whom were working in research and development.

TABLE 6. EMPLOYMENT OF SCIENTISTS IN THE ATOMIC ENERGY FIELD, BY OCCUPATION AND PRIMARY WORK FUNCTION, JANUARY 1960

Occupation	All functions	Primary function			
		Research and development	Production and operations	Construction	Other
Scientists, total	9,488	7,984	1,195	48	261
Physicists	3,431	3,132	251	26	22
Chemists	3,057	2,399	609	7	42
Mathematicians	760	600	82	5	73
Metallurgists	608	533	69	4	2
Biological scientists	475	461	7	0	7
Health physicists	377	214	109	1	53
Medical scientists	166	126	25	0	15
Geologists and geophysicists	83	53	25	4	1
Agricultural scientists	32	32	0	0	0
Other natural scientists	499	434	18	1	46

Physicists (3,431) and chemists (3,057) together accounted for more than two-thirds of the total number of scientists. (See table 6.) Nearly all of the physicists were engaged in research and development work—91 percent—such as basic research on the structure of nuclei and the development and design of nuclear reactors, particle accelerators, automatic controls, and radiation measuring instruments.

About three-fourths of the 3,057 chemists employed by the surveyed establishments were engaged in research and development work, including the development of processing methods for uranium and irradiated reactor fuels, and research to determine the nature and mechanism of chemical reactions caused by radiation and by extremely high temperatures.

Nearly 80 percent of the 760 mathematicians employed by the surveyed establishments were working in R&D, in such work as the numerical analysis associated with reactor design problems. Most of the 608 metallurgists, 88 percent, were also engaged in R&D, in such work as research on metals and alloys directed toward developing suitable materials for reactor construction. Nearly all of the 475 biological scientists, 97 percent, were working in R&D.

The surveyed establishments employed 377 health physicists. Their occupation is unique to the atomic energy field and concerns the radiological safety of personnel at a facility and of people in the surrounding area. Health physicists were engaged in administering radiological safety programs, supervising the monitoring of personnel, and performing research related to the control and minimization of radiation hazards.

In addition to the above scientists, a few medical scientists (166), agricultural scientists (32), and geologists and geophysicists (83) were employed. About 500 other natural scientists (not classified by the surveyed establishments as to scientific discipline) were also reported.

Technicians

The development and use of atomic energy requires a large number of technicians to assist engineers and scientists in research and development work and in the designing and testing of equipment and materials. The term "technician" was defined in the questionnaire as a person engaged in work requiring knowledge of physical, engineering, mathematical, biological, or other natural sciences comparable with knowledge acquired through a technical institute, junior college, or other formal post-high-school training, or through equivalent on-the-job training or experience.

TABLE 7. EMPLOYMENT OF TECHNICIANS AND OTHER TECHNICAL PERSONNEL IN THE ATOMIC ENERGY FIELD, BY OCCUPATION AND PRIMARY WORK FUNCTION, JANUARY 1960

Occupation	All functions	Primary function			
		Research and development	Production and operations	Construction	Other
Technicians, total	14,612	7,495	5,830	602	685
Draftsmen	2,660	745	1,097	498	320
Engineering and physical science:					
Electronic	2,036	1,380	561	50	45
Instrument	627	337	275	10	5
Other	6,100	3,819	2,143	27	111
Health physics	720	233	442	0	45
Medical, agricultural, and biological	569	355	126	4	84
Other technicians	1,900	626	1,186	13	75
Other technical personnel, total	3,744	1,776	1,109	642	217
Designers	1,160	273	385	465	37
Technical writers	195	63	67	12	53
Other technical personnel	2,389	1,440	657	165	127

About 14,600 technicians were employed in the surveyed establishments, accounting for approximately 12 percent of total employment. There were about 59 technicians for every 100 engineers and scientists employed. However, the ratios of technicians to 100 engineers and scientists varied widely by area of work within the atomic energy field, from over 150 in the production of special materials to under 30 in the construction of nuclear facilities. (For comparative purposes, it might be well to note that, in all manufacturing industries, according to a Bureau of Labor Statistics survey of scientific and technical personnel, there were 67 technicians for every 100 engineers and scientists in January 1959, the ratios varying by industry from about 100 to less than 40.[13]

More than half (51 percent) of the technicians assisted engineers and scientists in research and development work. The ratio of technicians per 100 engineers and scientists in R&D work, 46,

[13] *Scientific and Technical Personnel in American Industry*, op. cit., table 4, p. 19.

was lower than the corresponding figure (59) for all types of work combined. Other technicians assisted engineers and scientists in such work as designing, testing, and quality control.

The largest individual occupation among the technicians was that of draftsman (2,660). (See table 7.) Draftsmen were engaged in such work as the preparation of detailed drawings from design layouts and the development of routine designs. The surveyed establishments employed 2,036 electronic technicians and 627 instrument technicians. The work of these technicians included assisting professional personnel in the preparation of specifications for the fabrication and installation of electronic and other instrument components and systems; designing minor circuits and components; and testing and modifying electronic equipment and mechanical instruments.

The survey covered 720 health physics technicians, who aided health physicists in the radiation protection of workers. Overall, there was an average employment of about two health physics technicians per health physicist, but this ratio varied considerably among individual establishments; it was generally higher in establishments primarily engaged in production work and lower in research laboratories.

A large group of technicians, 6,100, were classified as "other engineering and physical science technicians" (other than electronics or instrument technicians), such as chemical analysts, engineering aids, mathematics aids, and other physical science aids. The duties of these technicians included the testing of materials to determine their chemical and physical properties, the inspection of fabricated components using X-ray machines and nuclear counters, and the assembling, testing, and modifying of laboratory models and experimental equipment.

The surveyed establishments also employed 569 medical, agricultural, and biological technicians—primarily to assist in research work related to the effects of radiation on living organisms—and 1,900 "other technicians" (technicians who were not classified by the respondents according to any of the listed categories).[14]

[14] At least some of the "other technicians" probably should have been classified as "other engineering and physical science technicians." See appendix B, Scope and Method of Survey—Definitions.

Other Technical Personnel

In addition to scientists, engineers, and technicians, the surveyed establishments employed 3,744 other technical personnel. Of those workers who were classified by occupation, 1,160 were designers and 195 were technical writers. (See table 7.) The work of the designers included making conceptual designs under the supervision of engineers, making mathematical calculations to validate designs, determining the materials and processes to be used, and directing draftsmen in the preparation of detailed drawings.

Skilled Workers

The largest occupational group in the establishments surveyed was the skilled worker group. These journeymen craftsmen represented 19 percent of total employment.

In establishments producing feed materials and enriched uranium, establishments which construct nuclear facilities, and in uranium mills, they constituted over 25 percent of total employment. On the other hand, they accounted for only about 6 percent of employment in private research laboratories and about 11 percent in the AEC research facilities, establishments which design and manufacture reactors, and in establishments which fabricate fuel elements.

TABLE 8. EMPLOYMENT OF SKILLED WORKERS IN THE ATOMIC ENERGY FIELD, BY OCCUPATION AND PRIMARY WORK FUNCTION, JANUARY 1960

Occupation	All functions	Primary function			
		Research and development	Production and operations	Construction	Other
Skilled workers, total	23,881	2,771	17,218	2,302	1,590
Maintenance mechanics (including machinery repairmen and millwrights)	3,635	269	2,857	201	308
Chemical operators	3,227	132	3,095	0	0
Machinists, (all-round)	3,071	871	2,026	82	92
Electricians	2,256	149	1,478	365	264
Plumbers, pipefitters, and steamfitters	1,456	122	767	360	207
Welders	1,320	137	1,030	120	33
Instrument mechanics (including instrument repairmen)	1,269	200	1,066	0	3
Carpenters	717	55	278	240	144
Sheet-metal workers	646	95	465	39	47
Instrument makers (including experimental machinists and others who fabricate instruments	537	67	440	0	30
Tool and die makers	504	227	277	0	0
Boilermakers	114	3	29	71	11
Other skilled trades	5,129	444	3,410	824	451

A worker wearing protective clothing while monitoring a work area that has been contaminated with radioactive material.

The employment of large numbers of skilled workers is attributable to such factors as the need to fabricate special parts and equipment for use in experimental and pilot work, the custom manufacturing of many products, the close tolerances that must be maintained to insure the efficient operation of equipment, and the need for large maintenance forces to care for the considerable amount of complex equipment and machines used in atomic energy work.

Maintenance mechanics, including machinery repairmen and millwrights (3,635), accounted for about 15 percent of the skilled workers; chemical operators (3,227), who operate chemical-processing equipment, 14 percent; and all-round machinists (3,071), 13 percent. (See table 8.) Maintenance mechanics were employed in all segments of the atomic energy field to maintain and repair the large amount of machinery and other mechanical equipment used in much of the work. Over 80 percent of the chemical operators were employed in the production of defense materials and the production of feed materials and enriched uranium, primarily chemical processing operations. All-round machinists were employed in most segments of the field. In contrast to the chemical operators and maintenance mechanics, nearly all of whom were employed in production and maintenance work, over one-fourth of the all-round machinists were working in R&D.

In addition to the above occupations, a large number of electricians (2,256), many carpenters (717), and plumbers, pipefitters, and steamfitters (1,456) were employed. Construction firms employed many of these workers in the construction of facilities while establishments in other areas of work employed many of them in maintenance work. Many welders (1,320) and sheet-metal workers (646) were employed to fabricate parts and equipment, and many instrument mechanics, including instrument repairmen (1,269), were employed. A number of tool and die makers (504), about half of whom were in R&D work, and instrument makers (537), were also employed.

Other Occupations

Clerical and other office personnel made up the second largest occupational group. They accounted for about 15 percent of total employment, but their proportionate employment ranged from as low as 8 percent in uranium mills to as much as 17 percent in the AEC research facilities and in establishments which design and manufacture reactors (tables 11–20, inclusive). The employment of managerial, administrative, and other professional (other than scientific and technical) personnel varied from a low of 6 percent of total employment in construction firms and 7 percent in private research laboratories to 13 percent in plants producing feed materials and enriched uranium. The managerial occupational group represented about 10 percent of employment for all segments combined.

The surveyed establishments employed nearly 900 nuclear reactor operators who were classified separately in the survey, since this occupation is unique to the atomic energy field. The reactor operator's job in a nuclear power station is basically the same as that of a boiler operator's job

in a conventional power station, the operation of the steam-generating portion of the power plant. It is unique in that he operates the controls of a nuclear reactor rather than the controls of a conventional boiler.

The remaining employment (about 22 percent of total employment) in the surveyed establishments consisted mostly of semiskilled and unskilled workers in production and maintenance work and of service workers. Many of the service workers were engaged in plant protection or security work.

Anticipated Changes in Occupational Employment

According to the estimates made by the reporting establishments, total employment was expected to increase by only a little more than 3 percent between January 1960 and January 1961. Employment was expected to increase in each of the occupational groups, with the exception of a 1-percent decline in clerical and other office personnel. Table 9 shows the expected percentage change in employment by occupational group and by selected individual occupation, and the distribution of employment as of January 1960 and as anticipated by January 1961. Engineering, scientific, and technical personnel were expected to account for 72 percent of the anticipated employment increase, whereas they represented only 34 percent of total employment in January 1960. Even so, the percentage distribution of employment by occupational group would change little over the year.

Within the engineering, scientific, and technical occupational groups, the anticipated increase of 320 physicists was the largest increase reported for any occupation. (See appendix table A–2.) Physicists constituted only 3 percent of total employment in January 1960, but the expected employment of 320 additional physicists would account for nearly 8 percent of the projected employment increase over the year. Other occupations in which employment was expected to increase by more than 200 were those of electrical and electronics engineer (247), mechanical engineer (218), reactor engineer (201), chemist (209), and electronics technician (220).

The occupation expected to increase the most on a percentage basis was that of mathematician (15 percent). Metallurgists and reactor engineers were expected to increase by nearly 12 percent; metallurgical engineers, biological scientists, and electronics technicians, by about 11 percent; and physicists, by more than 9 percent.

TABLE 9. CHANGES IN OCCUPATIONAL EMPLOYMENT ANTICIPATED BY SURVEY RESPONDENTS, JANUARY 1960–JANUARY 1961

Occupation	Number employed		Anticipated percentage change, January 1960–January 1961
	January 1960	January 1961 (anticipated)	
Total employment	125,921	130,007	3.2
Engineers, total	15,112	16,154	6.9
Mechanical	4,391	4,609	5.0
Electrical and electronics	3,015	3,262	8.2
Chemical	1,820	1,976	8.6
Reactor	1,724	1,925	11.7
Metallurgical	916	1,019	11.2
Civil	905	901	−.4
Other engineers	2,341	2,462	5.2
Scientists, total	9,488	10,333	8.9
Physicists	3,431	3,751	9.3
Chemists	3,057	3,266	6.8
Mathematicians	760	876	15.3
Metallurgists	608	680	11.8
Biological scientists	475	527	10.9
Health physicists	377	404	7.2
Other natural scientists	780	829	6.3
Technicians, total	14,612	15,393	5.3
Draftsmen	2,660	2,690	1.1
Engineering and physical science:			
Electronics	2,036	2,256	10.8
Instrument	627	683	8.9
Other	6,100	6,352	4.1
Health physics	720	771	7.1
Medical, agricultural, and biological	569	607	6.7
Other technicians	1,900	2,034	7.1
Other technical personnel, total	3,744	4,017	7.3
Designers	1,160	1,168	0.7
Other technical personnel	2,584	2,849	10.3
Managerial personnel	12,417	12,599	1.5
Clerical personnel	18,537	18,413	−.7
Skilled workers	23,881	24,383	2.1
Nuclear reactor operators	881	958	8.7
All others	27,249	27,757	1.9

Distribution of Employment by Segment

The development, production, and application of nuclear energy involves many different activities. Since employment patterns vary markedly between establishments engaged in different activities (for example, as between a uranium mill and a research laboratory), the surveyed establishments were classified into 10 segments of the atomic energy field on the basis of the primary activity in which they were engaged.[15] The AEC research facilities and defense production facilities were the two largest segments, accounting for about 34 percent and 28 percent, respectively, of total surveyed employment in January 1960. Only a total of 18 percent of employment was reported by establishments in the six smallest segments combined. (See table 1.)

The distribution of employment by occupational group varied considerably among the different areas in the atomic energy field, reflecting the kinds of activity conducted within each segment. (See table 10.) Engineers, scientists, and technical personnel, as a percentage of total employment, ranged from about 66 percent in private research laboratories and 50 percent in AEC research facilities to 13 percent in uranium mills and 11 percent in plants producing special materials. Skilled workers, as a percentage of total employment in the different segments, varied from about 36 percent in plants producing feed materials and enriched uranium to about 6 percent in private research laboratories.

The employment growth anticipated by the reporting establishments varied considerably by type of activity. For all segments combined, employment was expected to increase by about 3 percent between January 1960 and January 1961. By far the largest employment increase (45 percent) was expected in the nine establishments classified as operating power reactors because only one of the establishments so classified was actually operating a reactor in January 1960, whereas two more estabilshments were expected to be in operation by the end of 1960 and another was expected to begin operations in 1961. Within the other nine segments, the sharpest increases in employment were expected by private research laboratories (8.1 percent) and establishments producing special materials (7.6 percent). Establishments in these two segments also had large employment increases between 1959 and 1960 (nearly 10 percent and 11 percent, respectively). The AEC research facilities and fuel element fabricators were the only other segments expecting employment to increase by 4 percent or more. The only segments (other than miscellaneous) in which employment was expected to decline were the establishments producing feed materials and enriched uranium and the establishments constructing nuclear facilities.[16] Employment in the establishments producing feed materials and enriched uranium also declined between 1959 and 1960.

[15] See footnote 5, p. 3, and appendix B.

[16] The decline in employment in construction firms was expected because two establishments indicated that they would not be in the atomic energy field in January 1961. The remaining establishments in this segment, combined, expected a slight increase in employment.

TABLE 10. PERCENTAGE DISTRIBUTION OF EMPLOYEES IN THE ATOMIC ENERGY FIELD, BY SEGMENT AND OCCUPATIONAL GROUP, JANUARY 1960

Segment	All employees	Engineers	Scientists	Technicians	Other technical personnel	Managerial personnel	Clerical personnel	Skilled workers	Nuclear reactor operators	All others
Total, all segments	100.0	12.0	7.5	11.6	3.0	9.9	14.7	19.0	0.7	21.6
Atomic Energy Commission research facilities	100.0	15.2	13.2	17.1	4.4	9.1	17.4	11.6	0.3	11.7
Defense production facilities	100.0	7.3	2.8	6.8	2.7	10.8	13.0	23.8	1.7	31.1
Reactor manufacture	100.0	21.1	6.1	13.4	2.0	9.3	16.9	11.1	.7	19.4
Production of feed materials and enriched uranium	100.0	6.0	4.3	7.0	.3	12.7	13.1	36.1	0	20.5
Construction of nuclear facilities	100.0	23.7	.3	6.6	7.8	6.1	13.7	28.9	0	12.9
Private research laboratories	100.0	13.6	26.3	24.2	2.2	7.0	11.6	5.5	.3	9.3
Production of special materials	100.0	2.7	1.7	6.9	.1	12.0	11.3	22.0	0	43.3
Uranium milling	100.0	3.3	2.6	5.7	1.0	9.2	7.9	26.8	0	43.5
Fuel element fabrication	100.0	8.6	3.7	11.0	.1	8.5	13.3	11.6	0	43.2
Power reactor operation	100.0	27.9	4.1	11.7	.3	8.2	10.9	1.4	7.4	28.1
Miscellaneous	100.0	3.4	.5	3.6	.6	13.0	16.3	29.9	0	32.7

The effects of radiation on the growth of plants being measured in a field that has been subjected to radiation.

Major findings as they relate to employment in the 10 segments by which the atomic energy field has been divided are discussed below.

Atomic Energy Commission Research Facilities

The Atomic Energy Commission supports a large nuclear research and development program. A major portion of this research and development work is conducted in Government-owned [17] research facilities operated by educational institutions and industrial concerns. The AEC research facilities employed over 42,000 people in January 1960, representing about one-third of all employees in establishments included in this survey.

The AEC research facilities are the major centers for basic and applied nuclear research in the physical, engineering, and life sciences. The research facilities are the AEC's major centers for work in the development and use of particle accelerators for nuclear physics research and for the development, design, and testing of nuclear reactors. They also develop and often fabricate fuel elements, instruments, and other vital reactor components. In addition, the research facilities do research and development work on the recovery of uranium from ores, the separation of fissionable uranium from natural uranium, the processing of irradiated fuel elements, and the production and uses of isotopes, and they are the major producers of both radioactive and stable isotopes. In several research facilities scientists specialize in research aimed at learning more about the life processes of animals and plants; one research facility operates a large farm in connection with these studies. Other research facilities specialize in the development and fabrication of nuclear weapons and other classified materials. Besides their research and development activities, several of the research facilities conduct nuclear training programs in reactor and radioisotope technology and in radiation health protection.

A great many engineers and scientists were employed by the surveyed research facilities to perform the numerous and diverse research and development activities for which they were responsible. The 19 establishments classified as AEC research facilities employed about 6,400 engineers and over 5,550 scientists, together accounting for 28 percent of the total research facility employment (table 11). Engineers and scientists of many different specialties were employed. The research facilities employed 2,030 physicists and 1,580 electrical and electronics engineers (table A–1) in such work as the development of nuclear

[17] While nearly all of the research facilities in this segment are owned by the AEC, some are partially or wholly owned by the U.S. Department of Defense.

TABLE 11. EMPLOYMENT IN ATOMIC ENERGY COMMISSION RESEARCH FACILITIES, BY OCCUPATIONAL GROUP AND PERCENT IN R&D FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in research and development
Total, all employees	42,172	100.0	
Engineers	6,396	15.2	82
Scientists	5,565	13.2	95
Technicians	7,203	17.1	67
Other technical personnel	1,836	4.4	71
Managerial personnel	3,857	9.1	
Clerical personnel	7,355	17.4	
Skilled workers	4,872	11.6	44
Nuclear reactor operators	146	.3	
All others	4,942	11.7	

reactors and particle accelerators. Many of the 1,672 chemists and 637 chemical engineers employed in these establishments were doing research on nuclear fuel problems. The development of new and improved metals for nuclear applications requires metallurgists and metallurgical engineers. In all, 309 metallurgists and 272 metallurgical engineers were employed. The research facilities also employed 2,017 mechanical engineers, 667 reactor engineers, and 411 mathematicians, many of them in the development and design of nuclear reactors. Many biological scientists (338) were employed for research work on the effects of radiation on plants and animals and for other research with radioisotopes. Health physicists (204) were employed in work dealing with the problems of radiation safety.

About 7,200 technicians and nearly 4,900 skilled workers were employed by the AEC research facilities to aid scientists and engineers in their work. The majority of the technicians were engineering or physical science technicians (4,854), including electronics technicians (1,270) and instrument technicians (482). More than 1,000 draftsmen were also employed. The largest occupations found among the skilled workers were those of the all-round machinist (1,076), maintenance mechanic (475), electrician (435), plumber, pipefitter, and steamfitter (296), tool and die maker (252), welder (235), and instrument maker (228).

The laboratories also employed many people in managerial and administrative positions (3,857) and in clerical and related office jobs (7,355). Together these two occupational groups accounted for 27 percent of total AEC research facility employment. About 1,000 workers were engaged in plant protection and security operations.

Defense Production Facilities

In January 1960, more than 35,000 persons (table 12) were employed in the establishments primarily devoted to the production of atomic weapons and related materials. Included in this segment were the two major plutonium production facilities and a number of plants producing classified materials.

The types of work and, therefore, the occupational patterns vary among the different defense production facilities. Workers in the plutonium production facilities perform a great deal of research and development work, such as the development of reactors and fuel elements and the development of methods for processing irradiated materials, along with the operation of reactors and other production work. On the other hand, in most of the remaining establishments, workers are almost exclusively engaged in production work, such as the metallurgical and chemical processing of materials and the manufacture and assembly of weapons components.

TABLE 12. EMPLOYMENT IN DEFENSE PRODUCTION FACILITIES, BY OCCUPATIONAL GROUP AND BY PRIMARY WORK FUNCTION FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in—	
			Research and development	Production and operations
Total, all employees	35,590	100.0		
Engineers	2,608	7.3	25	64
Scientists	1,006	2.8	41	49
Technicians	2,399	6.8	21	73
Other technical personnel	945	2.7	35	50
Managerial personnel	3,850	10.8		
Clerical personnel	4,640	13.0		
Skilled workers	8,473	23.8	2	93
Nuclear reactor operators	616	1.7		
All others	11,053	31.1		

Ten percent of the employees in this segment were engineers or scientists. Included among these were 702 mechanical, 591 chemical, 408 electrical and electronics, and 237 metallurgical engineers; 440 chemists, and 264 physicists. About 100 health physicists were employed to supervise the radiation protection of personnel. More than 1,100 engineering and physical science technicians, 400 draftsmen, and about 200 designers were employed to assist engineers and scientists.

The defense production facilities employed nearly 8,500 craftsmen. Included among these skilled workers were 1,304 maintenance mechanics, 963 chemical operators, 937 all-round machinists, 809 electricians, 642 instrument mechanics, and 522 plumbers, pipefitters, and steamfitters.

More than 600 nuclear reactor operators were employed in this segment of the atomic energy field, all of whom were employed at the two plutonium production facilities. The establishments in this segment also employed many people in managerial and administrative positions and in clerical and other office jobs. These two occupational

groups together accounted for almost one out of every four employees. More than 1,400 workers were employed in jobs involving plant protection and security.

Reactor Manufacture

The primary activity of 16 establishments covered in this survey was the design and manufacture of nuclear reactors and reactor components. These establishments employed nearly 12,000 workers. In addition to designing the reactor power plant, reactor manufacturers generally fabricate and test some of the intricate components, such as fuel elements, reactor cores, control rods, reactor vessels, and heat exchangers, but many of the reactor's components are manufactured by other firms following the reactor designer's specifications.

TABLE 13. EMPLOYMENT IN REACTOR MANUFACTURE, BY OCCUPATIONAL GROUP AND BY PRIMARY WORK FUNCTION FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in—	
			Research and development	Production and operations
Total, all employees	11,760	100.0		
Engineers	2,480	21.1	53	38
Scientists	717	6.1	77	22
Technicians	1,582	13.4	49	49
Other technical personnel	242	2.0	22	49
Managerial personnel	1,094	9.3		
Clerical personnel	1,985	16.9		
Skilled workers	1,301	11.1	13	83
Nuclear reactor operators	79	.7		
All others	2,280	19.4		

Engineers were the largest occupational group of employees in this segment, constituting 21 percent of total employment (table 13). Since the ultimate product of the establishments in this segment was the design and construction of nuclear reactors, they employed a great many engineers who were specialists in reactor technology. Of the nearly 2,500 engineers employed by the 16 establishments, 816 were classified as reactor engineers. A great many mechanical engineers (718) were likewise employed to work in such activities as the development and design of pressure vessels and heat transfer equipment and to supervise their fabrication. In addition, these establishments employed 299 physicists, 190 chemists, 170 electrical and electronics engineers, 169 metallurgical engineers, and 151 chemical engineers.

Cans of evaporated milk and a sack of potatoes being lowered into a water-filled canal containing spent fuel elements to test the effects of radiation on food.

Many technicians and skilled workers moreover were employed in this segment. Nearly 1,600 technicians were employed to assist scientists and engineers. Of these, 730 were engineering and physical science technicians and 539 were draftsmen. About 1,300 craftsmen were employed, including 353 all-round machinists, 348 welders, and 179 sheet-metal workers.

Production of Feed Materials and Enriched Uranium

The AEC has a multibillion dollar investment in facilities for the production and enrichment of feed materials for use as fuel in reactor cores and for national defense purposes. Two AEC-owned and privately operated facilities and one privately owned facility were engaged in the chemical refining and reduction of uranium ores and concentrates. Private contractors also operated the three AEC-owned facilities which produced enriched uranium. These six establishments employed nearly 12,000 workers in January 1960.

TABLE 14. EMPLOYMENT IN THE PRODUCTION OF FEED MATERIALS AND ENRICHED URANIUM, BY OCCUPATIONAL GROUP AND BY PRIMARY WORK FUNCTION, FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in—	
			Research and development	Production and operations
Total, all employees	11,717	100.0		
Engineers	699	6.0	26	69
Scientists	505	4.3	51	40
Technicians	815	7.0	14	79
Other technical personnel	34	.3	9	88
Managerial personnel	1,490	12.7		
Clerical personnel	1,532	13.1		
Skilled workers	4,236	36.1	1	98
All others	2,406	20.5		

At the three feed materials facilities, milled uranium is processed in a series of refining operations to remove impurities, following which it is converted to metal or intermediate chemical products of acceptable purity for reactor fuel preparation. Conventional chemical and metallurgical processes are employed, but they must meet more exacting standards than in other industries. In the other three plants, the output of the feed materials plants is further processed by the gaseous diffusion method to obtain enriched uranium. Enriched uranium is used as the fuel for most reactors.

Engineers and scientists together constituted 10 percent of total employment in this segment (table 14). Since the production operations at these facilities are largely chemical processes, half of the 1,200 scientists and engineers were either chemists (336) or chemical engineers (271). In addition, 187 mechanical and 129 electrical and electronics engineers were employed. Another 7 percent of the employees were technicians. About two-thirds of the more than 800 technicians were engineering and physical science technicians, primarily working in chemical analytical laboratories associated with the production processes.

About 1,700 of the more than 4,200 skilled workers in these six establishments were chemical operators. Most of the remaining skilled workers were employed to maintain the large amount of complex equipment. Included among these were 1,035 maintenance mechanics, 361 electricians, 333 instrument mechanics, 187 welders, and 179 all-round machinists.

Construction of Nuclear Facilities

Several companies specialize in the designing and construction of nuclear facilities. Many other architect-engineer firms and construction firms also design and construct such facilities or segments of facilities. This survey covered only a few of the many firms engaged in such work. The employment data below were obtained from seven firms which were doing design and engineering work only and five firms which were also doing the actual construction. The employment data include only those employees engaged in atomic energy work.

These 12 architect-engineer and construction firms employed nearly 6,600 workers in January 1960. About 24 percent of the employees were engineers and another 29 percent were skilled workers (table 15). Over 1,550 engineers were employed, including 456 mechanical engineers, 409 civil engineers, and 334 electrical and electronics engineers. Assisting the engineers were 396 designers and 374 draftsmen. The establishments which were undertaking the actual construction of facilities employed workers in all construction crafts, including plumbers, pipefitters, and steamfitters (329), electricians (290), carpenters (179), and welders (116).

Private Research Laboratories

In addition to the research at the AEC–owned laboratories, a great deal of atomic energy research is performed at private laboratories under AEC contract. This survey covered only those private laboratories which held AEC prime contracts with accumulated obligations of more than a million dollars, although a great deal of addi-

TABLE 15. EMPLOYMENT IN THE CONSTRUCTION OF NUCLEAR FACILITIES, BY OCCUPATIONAL GROUP, JANUARY 1960

Occupational group	Number	Percent
Total, all employees	6,575	100.0
Engineers	1,558	23.7
Scientists	18	.3
Technicians	435	6.6
Other technical personnel	513	7.8
Managerial personnel	404	6.1
Clerical personnel	899	13.7
Skilled workers	1,898	28.9
All others	850	12.9

TABLE 16. EMPLOYMENT IN PRIVATE RESEARCH LABORATORIES, BY OCCUPATIONAL GROUP AND PERCENT IN R&D, FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in research and development
Total, all employees	5,295	100.0	
Engineers	722	13.6	93
Scientists	1,392	26.3	97
Technicians	1,283	24.2	85
Other technical personnel	115	2.2	79
Managerial personnel	372	7.0	
Clerical personnel	612	11.6	
Skilled workers	293	5.5	76
Nuclear reactor operators	13	.3	
All others	493	9.3	

tional research was sponsored by the Commission. Most of the laboratories covered were operated by educational institutions, but a few were operated by other nonprofit institutions and by industrial concerns. Thirty-four establishments were classified as private research laboratories. They employed about 5,300 persons, only 4 percent of the employees covered in this survey. Establishments in this segment reported only the personnel engaged in atomic energy work rather than total establishment employment.[18]

Two-thirds of these employees at the private research laboratories were in engineering, scientific, or technical occupations (table 16), the scientists, as would be expected, comprising the largest occupational group. More than half of the nearly 1,400 scientists were physicists (760), reflecting the great amount of nuclear physics research at these laboratories. In addition, 285 chemists, 100 mathematicians, and 97 biological scientists were employed. Among the more than 700 engineers employed were 323 electrical and electronics engineers, 115 mechanical engineers, and 101 metallurgical engineers. Almost as many technicians were employed as scientists, including 375 electronics and 585 other engineering and physical science technicians.

Production of Special Materials

Many of the materials used in nuclear reactors must meet stringent specifications and must have certain special nuclear properties. Covered in this survey and classified under this segment were establishments with major AEC prime contracts to produce some of these materials—beryllium, zirconium and hafnium, and magnesium and calcium. Special production processes had to be developed for some of the special materials in order to meet the rigid requirements. For example, it is necessary that zirconium for use in reactors be free of hafnium. Since all zirconium ores contain a small percentage of hafnium and the two metals have similar properties, new chemical separation processes had to be developed.

In January 1960, nearly 3,600 employees were working at the 10 surveyed plants producing special materials for use in reactors. About two-thirds of these employees were plant workers in production, maintenance, and service jobs. Chemical operators (225), all-round machinists (152), and maintenance mechanics (105) were the most numerous among the skilled workers. Scientists and engineers together (table 17), primarily chemists and chemical engineers, accounted for less than 5 percent of the employees in this segment.

TABLE 17. EMPLOYMENT IN THE PRODUCTION OF SPECIAL MATERIALS, BY OCCUPATIONAL GROUP AND BY PRIMARY WORK FUNCTION, FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in—	
			Research and development	Production and operations
Total, all employees	3,584	100.0		
Engineers	97	2.7	33	62
Scientists	60	1.7	47	53
Technicians	246	6.9	27	70
Other technical personnel	5	.1	20	80
Managerial personnel	429	12.0		
Clerical personnel	406	11.3		
Skilled workers	790	22.0	0	100
All others	1,551	43.3		

Uranium Milling

In uranium mills, metallurgical and chemical processes are used to extract uranium from the mined ore. The basic steps included are ore preparation (primarily crushing and grinding), leaching, and product recovery. These operations are similar to those used in the milling of other metal-

[18] Some reported only those employees paid from AEC contract funds. Also, some reported full-time equivalent employment rather than total employment.

TABLE 18. EMPLOYMENT IN URANIUM MILLING, BY OCCUPATIONAL GROUP, JANUARY 1960

Occupational group	Number	Percent
Total, all employees	3,432	100.0
Engineers	112	3.3
Scientists	90	2.6
Technicians	197	5.7
Other technical personnel	34	1.0
Managerial personnel	315	9.2
Clerical personnel	271	7.9
Skilled workers	921	26.8
All others	1,492	43.5

lic ores. This survey covered all uranium mills in operation at the time of the survey. All of the mills were privately owned and operated, but under contract to the AEC.

The uranium mills employed 3,432 workers in January 1960 (table 18), less than 3 percent of the total number of employees covered by this survey. Only a total of about 200 scientists and engineers were employed, nearly half of whom were chemists and metallurgical engineers. Of the 921 skilled workers employed in the milling operations, more than a third were maintenance mechanics (330) and nearly 20 percent were chemical operators (179).

Fuel Element Fabrication

The heart of a nuclear reactor is its fuel elements. Fuel elements for research and power reactors are prepared in a variety of forms and employ different kinds of fuel and cladding materials. The principal steps in the fabrication of solid fuel elements are forming, cladding, and machining, followed by extensive inspection and testing. Establishments which are primarily concerned with the design, development, and fabrication of fuel elements are included in this segment. The eight establishments in this segment employed about 2,900 workers in January 1960.[19]

TABLE 19. EMPLOYMENT IN FUEL ELEMENT FABRICATION, BY OCCUPATIONAL GROUP AND BY PRIMARY WORK FUNCTION, FOR SELECTED OCCUPATIONAL GROUPS, JANUARY 1960

Occupational group	Number	Percent	Percent in—	
			Research and development	Production and operations
Total, all employees	2,903	100.0		
Engineers	251	8.6	13	86
Scientists	108	3.7	81	18
Technicians	319	11.0	38	59
Other technical personnel	4	.1	0	50
Managerial personnel	246	8.5		
Clerical personnel	386	13.3		
Skilled workers	336	11.6	12	87
All others	1,253	43.2		

Engineering, scientific, and technical personnel accounted for about 23 percent of employment in the plants fabricating fuel elements (table 19). Among these personnel were 101 mechanical engineers, 71 metallurgists, and about 200 engineering and physical science technicians. Of the 336 skilled workers, 161 were all-round machinists and another 78 were welders.

Power Reactor Operation

Nine establishments were classified as being primarily engaged in the operation and maintenance of a power reactor for the production of commercial electricity. At the time of this survey, only one of the reactors was in operation, and it could not be considered typical of such operations, since a great deal of research and testing was being conducted in connection with operating the reactor.

TABLE 20. EMPLOYMENT IN POWER REACTOR OPERATION, BY OCCUPATIONAL GROUP, JANUARY 1960

Occupational group	Number	Percent
Total, all employees	366	100.0
Engineers	102	27.9
Scientists	15	4.1
Technicians	43	11.7
Other technical personnel	1	.3
Managerial personnel	30	8.2
Clerical personnel	40	10.9
Skilled workers	5	1.4
Nuclear reactor operators	27	7.4
All others	103	28.1

The eight other establishments classified in this segment were in planning stages preliminary to operation in January 1960, but two expected to be operating reactors for the commercial production of electricity in 1960, another in 1961, and the remaining five establishments in 1962 or 1963.

An electric utility system consists of power generating, transmission, and distribution facilities. The major change brought about by atomic energy is the replacement of the coal, gas, or oil-burning steam generator with a nuclear reactor. The num-

[19] Three establishments reported only those employees engaged in atomic energy work rather than total establishment employment.

ber of operating personnel required for a nuclear power station is expected to be greater than for a conventional power station, partly because relatively little experience has been acquired in the operation of a nuclear station in comparison with the conventional station, and partly because of the extra precautions that must be taken to insure health and safety protection. The one operating power reactor covered in this survey had an operating staff of about three times that required by a coal-fired station of similar size, but many of the additional employees were engaged in research, testing, or training activities not required for the operation of the reactor, and these employees would not be required under normal operating procedures.

The nine establishments employed a large number of engineers relative to total employment. Twenty-eight percent of all employees were engineers (table 20), most of whom were mechanical and electrical and electronics engineers. Reactor engineers, chemists and chemical engineers, and health physicists were employed in smaller numbers. Technicians, such as health physics technicians and chemical analysts, accounted for about 12 percent of employment. Twenty-seven nuclear reactor operators were employed, some of whom were in training.

Distribution of Employment in the Atomic Energy Commission

In addition to the AEC prime contractors covered by the survey, information on employment in the Atomic Energy Commission itself was obtained (table 21). The data for the AEC, however, were not combined with that for the contractors, but are presented here separately.

As of October 31, 1959, the AEC had a total employment of 6,659—less than the peak employment of over 7,000 in 1958.[20] Since the AEC is primarily an administrative and regulatory agency, nearly 70 percent of the Commission's employees were in managerial and administrative or in clerical and other office positions. Approximately 1,000 scientists and engineers were employed by the Commission, including personnel in nearly every major scientific and engineering discipline. These included 114 reactor engineers, 91 civil engineers, 80 chemists, 54 electrical and electronics engineers, and 53 health physicists. Another large body of workers (463) were engaged in protective and security activities.

[20] The AEC report applies to October 1959 rather than January 1960 (used by all other respondents), since the data for that report were collected in conjunction with the Civil Service Commission's yearly survey of Federal Government employment.

TABLE 21. EMPLOYMENT IN THE ATOMIC ENERGY COMMISSION, BY OCCUPATIONAL GROUP AND SELECTED OCCUPATION, OCTOBER 31, 1959

Occupational group and selected occupation	Number	Percent
Total, all employees	6,659	100.0
Engineers, total	712	10.7
Reactor	114	1.7
Civil	91	1.4
Electrical and electronics	54	.8
Chemical	39	.6
Mechanical	34	.5
Other engineers	380	5.7
Scientists, total	284	4.3
Chemists	80	1.2
Health physicists	53	.8
Physicists	42	.6
Metallurgists	26	.4
Geologists and geophysicists	22	.3
Biological scientists	17	.3
Mathematicians	14	.2
Other natural scientists	30	.5
Technicians	188	2.8
Other technical personnel	124	1.9
Managerial personnel	2,036	30.6
Clerical personnel	2,581	38.7
Skilled workers	21	.3
All others, total	713	10.7
Plant protection and security	463	6.9
Other	250	3.8

Appendix A. Tables

TABLE A–1. EMPLOYMENT IN THE ATOMIC ENERGY FIELD, BY OCCUPATION AND SEGMENT, JANUARY 1960

Occupation	All activities	Segment										
		AEC research facilities	Defense production facilities	Reactor manufacture	Production of feed materials and enriched uranium	Construction of nuclear facilities	Private research laboratories	Production of special materials	Uranium milling	Fuel element fabrication	Power reactor operation	Miscellaneous
Total, all employees	125,921	42,172	35,590	11,760	11,717	6,575	5,295	3,584	3,432	2,903	366	2,527
Scientists, total	9,488	5,565	1,006	717	505	18	1,392	60	90	108	15	12
Agricultural scientists	32	27	3	0	0	0	2	0	0	0	0	0
Biological scientists	475	338	24	0	16	0	97	0	0	0	0	0
Chemists	3,057	1,672	440	190	336	4	285	39	50	25	8	8
Geologists and geophysicists	83	16	5	2	0	0	40	0	20	0	0	0
Health physicists	377	204	99	33	24	0	6	1	0	4	6	0
Mathematicians	760	411	89	112	42	5	100	1	0	0	0	0
Medical scientists	166	93	25	0	10	0	37	1	0	0	0	0
Metallurgists	608	309	47	78	17	3	46	17	20	71	0	0
Physicists	3,431	2,030	264	299	60	6	760	1	0	6	1	4
Other natural scientists	499	465	10	3	0	0	19	0	0	2	0	0
Engineers, total	15,112	6,396	2,608	2,480	699	1,558	722	97	112	251	102	87
Aeronautical	93	69	0	18	0	2	4	0	0	0	0	0
Chemical	1,820	637	591	151	271	25	76	36	15	8	8	2
Civil (architectural, construction, structural, sanitary, etc.)	905	229	76	106	31	409	23	0	5	12	4	10
Electrical and electronics	3,015	1,580	408	170	129	334	323	3	2	10	27	29
Mechanical	4,391	2,017	702	718	187	456	115	22	10	101	42	21
Metallurgical	916	272	237	169	32	13	101	16	40	35	0	1
Reactor	1,724	667	136	816	0	42	45	0	0	0	18	0
Other engineers	2,248	925	458	332	49	277	35	20	40	85	3	24
Technicians, total	14,612	7,203	2,399	1,582	815	435	1,283	246	197	319	43	90
Draftsmen	2,660	1,063	403	539	94	374	107	28	8	30	1	13
Engineering and physical science:												
Electronics	2,036	1,270	249	43	14	21	375	2	1	17	2	42
Instrument	627	482	37	38	9	10	36	0	6	6	0	3
Other	6,100	3,102	837	649	511	20	549	171	70	173	11	7
Health physics	720	289	311	61	19	0	5	6	0	18	11	0
Medical, agricultural, and biological	569	323	55	15	46	4	110	6	8	1	1	0
Other technicians	1,900	674	507	237	122	6	101	33	104	74	17	25
Other technical personnel, total	3,744	1,836	945	242	34	513	115	5	34	4	1	15
Designers	1,160	457	199	84	3	396	7	4	0	1	0	9
Technical writers	195	104	19	29	3	17	19	1	0	0	0	3
Other technical personnel	2,389	1,275	727	129	28	100	89	0	34	3	1	3
Managerial, administrative, and other professional personnel (other than scientific and technical), total	12,417	3,857	3,850	1,094	1,490	404	372	429	315	246	30	330
Clerical and other office personnel, total	18,537	7,355	4,640	1,985	1,532	899	612	406	271	386	40	411
Skilled workers (journeymen only), total	23,881	4,872	8,473	1,301	4,236	1,898	293	790	921	336	5	756
Boilermakers	114	14	29	0	0	71	0	0	0	0	0	0
Carpenters	717	171	161	20	61	179	7	9	42	4	0	63
Chemical operators	3,227	151	963	0	1,697	0	0	225	179	0	0	12
Electricians	2,256	435	809	66	361	290	29	56	70	27	0	113
Instrument makers (including experimental machinists and others who fabricate instruments)	537	228	190	65	11	0	43	0	0	0	0	0
Instrument mechanics (including instrument repairmen)	1,269	159	642	78	333	0	6	19	12	8	3	9
Machinists (all-round)	3,071	1,076	937	353	179	67	112	152	21	161	0	13
Maintenance mechanics (including machinery repairmen and millwrights)	3,635	475	1,304	87	1,035	126	42	105	330	23	2	106
Plumbers, pipefitters, and steamfitters	1,456	296	522	29	97	329	16	44	13	10	0	100
Sheet-metal workers	646	183	146	179	55	28	4	2	0	3	0	46
Tool and die makers	504	252	204	16	12	0	4	12	0	3	0	1
Welders	1,320	235	263	348	187	116	5	35	46	78	0	7
Other skilled trades	5,129	1,197	2,303	60	208	692	25	131	208	19	0	286
Nuclear reactor operators	881	146	616	79	0	0	13	0	0	0	27	0
All others	27,249	4,942	11,053	2,280	2,406	850	493	1,551	1,492	1,253	103	826
Plant protection and security	3,100	1,004	1,430	147	323	6	44	51	15	58	12	10

TABLE A–2. EMPLOYMENT ANTICIPATED FOR JANUARY 1961 IN THE ATOMIC ENERGY FIELD, BY OCCUPATION AND SEGMENT

Occupation	All activities	Segment										
		AEC research facilities	Defense production facilities	Reactor manufacture	Production of feed materials and enriched uranium	Construction of nuclear facilities	Private research laboratories	Production of special materials	Uranium milling	Fuel element fabrication	Power reactor operation	Miscellaneous
Total, all employees	130,007	43,951	36,945	12,149	11,631	6,320	5,725	3,855	3,506	3,021	531	2,373
Scientists, total	10,333	6,048	1,063	852	520	21	1,506	77	95	122	16	13
Agricultural scientists	30	25	3	0	0	0	2	0	0	0	0	0
Biological scientists	527	385	24	0	16	0	102	0	0	0	0	0
Chemists	3,266	1,782	465	219	343	4	311	47	52	27	8	8
Geologists and geophysicists	83	13	5	2	0	0	41	0	22	0	0	0
Health physicists	404	222	99	42	23	0	6	1	0	4	7	0
Mathematicians	876	474	96	138	47	6	113	1	0	1	0	0
Medical scientists	178	104	25	0	9	0	39	1	0	0	0	0
Metallurgists	680	341	53	90	18	3	50	26	20	79	0	0
Physicists	3,751	2,202	282	358	64	8	821	0	1	9	1	5
Other natural scientists	538	500	11	3	0	0	21	1	0	2	0	0
Engineers, total	16,154	6,785	2,829	2,776	721	1,516	810	119	118	266	118	96
Aeronautical	101	71	0	23	0	2	5	0	0	0	0	0
Chemical	1,976	689	637	181	281	26	84	39	16	12	9	2
Civil (architectural, construction, structural, sanitary, etc.)	901	220	75	119	31	404	24	0	5	12	1	10
Electrical and electronics	3,262	1,685	457	198	129	339	374	4	2	12	28	34
Mechanical	4,609	2,131	767	742	197	432	128	31	14	102	40	25
Metallurgical	1,019	312	247	198	35	14	109	19	40	42	2	1
Reactor	1,925	726	138	943	0	42	50	0	0	0	26	0
Other engineers	2,361	951	508	372	48	257	36	26	41	86	12	24
Technicians, total	15,393	7,617	2,501	1,657	801	415	1,403	280	199	343	88	89
Draftsmen	2,690	1,085	424	518	92	360	123	32	8	33	1	14
Engineering and physical science:												
Electronics	2,256	1,386	290	47	13	18	438	2	1	20	3	38
Instrument	683	509	41	45	9	11	42	0	6	8	9	3
Other	6,352	3,249	794	712	505	20	576	194	79	187	29	7
Health physics	771	314	319	68	19	0	7	7	0	20	17	0
Medical, agricultural, and biological	607	362	55	17	45	3	117	5	1	1	1	0
Other technicians	2,034	712	578	250	118	3	100	40	104	74	28	27
Other technical personnel, total	4,017	2,089	973	294	34	451	117	5	33	4	0	17
Designers	1,168	485	209	98	3	349	7	5	0	1	0	11
Technical writers	200	104	19	34	3	18	19	0	0	0	0	3
Other technical personnel	2,649	1,500	745	162	28	84	91	0	33	3	0	3
Managerial, administrative, and other professional personnel (other than scientific and technical), total	12,599	3,799	3,983	1,197	1,483	370	389	455	314	247	34	328
Clerical and other office personnel, total	18,413	7,182	4,759	1,986	1,495	817	664	428	273	396	37	376
Skilled workers (journeymen only), total	24,383	5,076	8,819	1,254	4,209	1,911	312	829	917	348	14	694
Nuclear reactor operators	958	151	616	100	0	0	13	0	0	0	78	0
All others	27,757	5,204	11,402	2,033	2,368	819	511	1,662	1,557	1,295	146	760

Appendix B. Scope and Method of Survey

This survey of employment in the atomic energy field was conducted by the U.S. Department of Labor's Bureau of Labor Statistics under contract with the U.S. Atomic Energy Commission. The survey was designed to provide information on the employment of scientists, engineers, technicians, skilled workers, and others in work related to the development and production of atomic energy. Text and appendix tables refer only to employment in the 158 establishments surveyed, and not to the entire atomic energy field.

Survey Coverage

The list of establishments to be included in the survey was prepared by the Atomic Energy Commission and the Bureau of Labor Statistics. In general, an establishment was covered if it had a prime contract with the AEC with accumulated obligations in excess of $1 million as of September 30, 1959. Contractors from the following categories were included if they fell within the limits specified: Operating and research and development contractors at AEC-owned installations; architect-engineer firms; commercial establishments furnishing specialized materials, supplies, or equipment to the AEC; and research organizations (commercial and academic and other nonprofit).

Respondents were asked to report separately for each establishment engaged in atomic energy activities under contract with the AEC. Construction establishments and research laboratories not owned by the Federal Government were asked to report only those employees engaged in atomic energy work, since this might involve only a small proportion of total establishment employment. All other establishments were asked to report on their total employment, on the assumption that atomic energy work would constitute the primary activity of the establishment. No distinction was made between part-time and full-time employees; both were to be included in the response.[21]

This survey is not a count of all employees working under funds provided by the AEC, nor are all reported employees being paid out of such funds. As stated above, the survey did not cover all AEC contractors. Furthermore, the reporting basis for an establishment was either all employees or all employees engaged in atomic energy activities, which would include both employees paid from AEC funds and those paid from all other sources.

Conduct of the Survey

The questionnaire used in the survey was developed in cooperation with the U.S. Atomic Energy Commission. Comments on preliminary drafts of the questionnaire and other aspects of the survey were obtained from officials of industrial establishments, educational institutions, and AEC research facilities, as well as from personnel of the U.S. Department of Labor and the AEC. While the questionnaire was not ideally suited to all covered establishments, the small number of establishments included in the survey precluded the use of more than one form.

The questionnaires were mailed in early February 1960 to all establishments. A followup letter was sent in March and an additional followup was made either by telephone or through the AEC's regional offices. An almost complete response was obtained in the survey.

The data are subject to reporting, editing, and tabulating errors. Such errors have been largely eliminated through checking procedures and through correspondence with establishments whose reports appeared to involve inconsistencies or misinterpretation of terms or definitions.

Definitions

Major items on the questionnaire were defined in order to get consistent returns. The definitions (see appendix C) conformed as closely as possible to the definitions used by the National Science Foundation in its surveys of scientific and technical personnel. The definitions were also tested

[21] A few establishments classified as private research laboratories reported full-time equivalent employment rather than total employment.

through visits to establishments which would be receiving the questionnaire. The purpose was to develop definitions which would accurately and clearly describe the terms used and would conform as much as possible with definitions used in other surveys and with customary accounting practices. However, wide differences exist in methods of recordkeeping and in the classification of employees and these differences contributed to some variations in the interpretation and application of definitions.

An analysis of the returns disclosed that for some items on the questionnaire all establishments were not reporting on the same basis. One source of difficulty was in the classification of technicians according to the categories listed—with many establishments classifying a large number of technicians in the "other technicians" category. A spot check on some of these returns showed that in many instances a large proportion, or all, of the technicians so classified should have been reported as "other engineering and physical science" technicians.

Some establishments apparently also had difficulty in determining the intended distinction between workers to be classified functionally in "production and operations" or "research and development" and those belonging in the "all other functions" category. It is felt that some establishments incorrectly classified employees (e.g., workers engaged in testing associated with production or in the maintenance of the production process) in the "all other functions" category. In a few cases, where a large number of employees were so classified, the returns were corrected after correspondence with the respondent. No attempt was made to check returns which contained a relatively small proportion of the establishment's employees in the "all other functions" category although such a check probably would, in some cases, have led to the reclassification of some employees.

Classification of Establishments by Segment

On the questionnaire, the atomic energy field was divided into 14 segments.[22] Respondents were asked to select the one segment which best described the primary activity of the reporting establishment. Adjustments were made where information indicated that an establishment was incorrectly classified and in those few instances where more than one segment was selected. None of the surveyed establishments was found to be in four of the segments. Therefore, all establishments were classified in the 10 remaining segments or in a miscellaneous category adopted for those establishments which could not be properly classified in any of the listed segments.

Each establishment was classified in the segment which best described the primary activity of the establishment. Therefore, it should be kept in mind in interpreting statistics in this report relating to a particular segment, that the definitions used [23] were not necessarily completely accurate descriptions of each establishment within the segment. It should also be kept in mind that with the small number of establishments in many segments, some of the occupational information presented is largely a reflection of a few large establishments. Following is a list of the segments with pertinent information on the reporting establishments:

1. Atomic Energy Commission research facilities: Includes all AEC-owned plus other Federal Government-owned laboratories or research facilities operated by educational institutions and industrial concerns.

2. Defense production facilities: Includes all major facilities doing atomic energy work primarily devoted to the defense effort, including the two major plutonium production centers.

3. Reactor manufacture: Includes 16 establishments primarily concerned with the development, design, testing, and manufacture of reactors and reactor components. One establishment's report includes only those employees working under AEC contract funds.

4. Production of feed materials and enriched uranium: Includes plants producing feed materials for reactor and gaseous diffusion plant operations and the gaseous diffusion plants.

5. Construction of nuclear facilities: Includes seven establishments doing design and engineering only and five establishments which also do the actual construction. Establishments in this segment were asked to report only on employees engaged in atomic energy work.

6. Private research laboratories: Out of the 34 establishments included in this segment, 24 were connected with educational institutions and the remainder were either independent laboratories or connected with industrial concerns. Establishments in this segment were asked to report only personnel engaged in atomic

[22] See questionnaire in appendix C.

[23] See questionnaire in appendix C for definitions.

energy work. Some reported only employees paid from AEC contract funds. Also, some reported full-time equivalent employment rather than total employment.

7. Production of special materials: Includes four plants producing beryllium, four plants producing zirconium and hafnium, one plant producing magnesium and calcium, and personnel within a plant producing zirconium tube.

8. Uranium milling: Includes all 25 uranium mills in operation at the time of the survey plus an ore concentrate station.

9. Fuel element fabrication: Includes eight establishments primarily concerned with the design, development, and fabrication of fuel elements. Three establishments included only those employees engaged in atomic energy work.

10. Power reactor operation: Includes the operation and maintenance of power reactors used for the production of commercial electricity. Of the nine establishments classified in this segment, only one was in operation in January 1960. The remaining eight establishments were all in planning stages preliminary to operation. Two additional establishments were expected to be in operation in 1960, another in 1961, and the rest in 1962 or 1963.

Adjustments for Nonresponse

Reports were received from 156 of the 159 establishments to which schedules were sent. Reports were constructed for two of the three establishments which did not return questionnaires, on the basis of information from the files of BLS and the AEC and information obtained by telephone from an official of one of the establishments. It was not possible to construct a reasonable report for the one remaining nonrespondent.

A number of respondents omitted data on some items. The missing data were estimated on the basis of information available on these establishments, by obtaining information by telephone or through the AEC's Regional Offices, and by making estimations based on relationships shown by the respondent and by other establishments in the same segment.

B.L.S. No. 2657

Budget Bureau No. 44–5934
Approval expires April 30, 1960

Survey of
EMPLOYMENT IN THE ATOMIC ENERGY FIELD
Conducted for the
ATOMIC ENERGY COMMISSION

By the
U.S. DEPARTMENT OF LABOR
Bureau of Labor Statistics

Your reply will be held in
STRICT CONFIDENCE

The purpose of this survey is to collect employment data from establishments which are engaged in activities in the atomic energy field under contract with the Atomic Energy Commission. These data are needed by the Commission to develop programs and policies related to manpower requirements. All information supplied on this form will be seen only by sworn employees of the Bureau of Labor Statistics and the Atomic Energy Commission. Only statistical summaries that will preserve confidentiality of individual reports will be released. Your reply will be held in **STRICT CONFIDENCE.**

GENERAL INSTRUCTIONS

(Terms in HEAVY CAPITALS are defined on page 4)

Questionnaires are being sent to all **ESTABLISHMENTS** which are engaged in activities in the **ATOMIC ENERGY FIELD** under contract with the Atomic Energy Commission.

Please supply all the data requested. If some of the detailed figures cannot be provided without undue expenditure of time and effort, reasonable estimates should be made. Write "none" where appropriate rather than leave a blank space. All figures should apply, if possible, to the pay period ending nearest the 15th of January.

The usefulness of these data is in large part related to their timeliness. Accordingly, every effort will be made to tabulate and publish the results of the survey as rapidly as possible. The cooperation of respondents in completing and returning the forms as soon as possible will greatly facilitate this process.

If extra copies of the questionnaire would be helpful, they may be obtained on request. Mail completed questionnaire to:

COMMISSIONER OF LABOR STATISTICS
U.S. DEPARTMENT OF LABOR
WASHINGTON 25, D.C.

1. For the purpose of this survey, the atomic energy field is divided into fourteen major segments described on page 4. Please read the list of segments carefully, select the **one** segment which describes the primary activity of the reporting establishment (definition on page 4) and place the number of that segment in the box below.

THIS ESTABLISHMENT IS IN SEGMENT NO. ☐

2. Report total number of persons employed (see definition of EMPLOYMENT on page 4) in reporting establishment in:

A. January 1959_____ B. January 1960_____

Change address if incorrect

Name and title of official submitting return:

Name and location of establishment:

If you would like a copy of the release on the survey findings, please check: ☐

TERMS PRINTED IN HEAVY CAPITALS ARE DEFINED. PLEASE READ DEFINITIONS CAREFULLY

3. Classify in the table below **all** employees in reporting establishment (in January 1960) by the occupations and functions in which they are primarily engaged (rather than by their education or training). For example, an employee trained as a physicist but working as an electronic engineer should be reported as an electronic engineer. The job titles in your organization may not be the same as the occupations listed. If the difference is only in the title and not in job content, the employee should be reported in the appropriate occupation rather than in an "other" category.

An employee should be counted only **once**—in the occupation and in the function in which he spends the greatest proportion of his time. Personnel in borderline occupations such as biochemist should be classified in the listed occupation with which their work is most closely identified.

Total of column 1 should be the same as January 1960 figure in item 2 on page 1.

Occupations	Number employed in January 1960					TOTAL NUMBER EXPECTED TO BE EMPLOYED IN JANUARY 1961 (comparable to column 1)
	Total	Primary function				
		RESEARCH AND DEVELOPMENT	PRODUCTION AND OPERATIONS	CONSTRUCTION	ALL OTHER FUNCTIONS	
	(1)	(2)	(3)	(4)	(5)	(6)
000 Total, all employees						
100 **SCIENTISTS,** total						
110 **AGRICULTURAL SCIENTISTS**						
120 **BIOLOGICAL SCIENTISTS**						
130 Chemists						
140 Geologists and geophysicists						
150 Health physicists						
160 **MATHEMATICIANS**						
170 **MEDICAL SCIENTISTS**						
180 Metallurgists						
190 Physicists						
101 Other natural scientists						
200 **ENGINEERS,** total						
210 Aeronautical						
220 Chemical						
230 Civil (architectural, construction, structural, sanitary, etc.)						
240 Electrical and electronic						
250 Mechanical						
260 Metallurgical						
270 **REACTOR**						
280 Other engineers						
300 **TECHNICIANS,** total						
310 Draftsmen						
320 Electronic						
330 Instrument						
340 Other engineering and physical science						
350 Health physics						
360 Medical, agricultural, and biological						
370 Other technicians						
380 **OTHER TECHNICAL PERSONNEL,** total						
381 Designers						
382 Technical writers						
383 Other technical personnel						

Occupations	Number employed in January 1960					TOTAL NUMBER EXPECTED TO BE EMPLOYED IN JANUARY 1961 (comparable to column 1)
	Total	Primary function				
		RESEARCH AND DEVELOPMENT	PRODUCTION AND OPERATIONS	CONSTRUCTION	ALL OTHER FUNCTIONS	
	(1)	(2)	(3)	(4)	(5)	(6)
400 **MANAGERIAL, ADMINISTRATIVE, AND OTHER PROFESSIONAL PERSONNEL** (other than scientific and technical), total						
500 **CLERICAL AND OTHER OFFICE PERSONNEL,** total		X	X	X	X	
600 **SKILLED TRADES** (include journeymen only), total						
610 Boilermakers						X
620 Carpenters						X
630 Chemical operators						X
640 Electricians						X
651 Instrument makers (include experimental machinists and others who fabricate instruments)						X
652 Instrument mechanics (include instrument repairmen)						X
661 Machinists (all-round)						X
662 Maintenance mechanics (include machinery repairmen and millwrights)						X
670 Plumbers, pipefitters, and steamfitters						X
692 Sheet-metal workers						X
663 Tool and die makers						X
693 Welders						X
699 Other skilled trades						X
691 **NUCLEAR REACTOR OPERATORS**						
700 **ALL OTHER PRODUCTION, MAINTENANCE, AND CONSTRUCTION WORKERS,** total						
800 **SERVICE WORKERS,** total		X	X	X		
810 Plant protection and security		X	X	X		X
820 Other service workers		X	X	X		X

DEFINITIONS

(In order of first use of term)

ESTABLISHMENT.—An establishment generally is a single physical location where business is conducted or where services or industrial operations are performed; e.g., a factory, mill, power reactor, or laboratory. An establishment is not necessarily identical with the business concern, enterprise, or firm as these may consist of more than one establishment; and it should be distinguished from departments or divisions within the establishment. If two units at the same location operate in separate fields not usually associated, have significant employment in each field, and have records that permit separate reports, a form should be completed for each of them.

ATOMIC ENERGY FIELD.—The field is divided into the following segments:

(1) Uranium milling.—Reduction of uranium ores to concentrates for further processing as feed materials.

(2) Production of feed materials.—Refining and converting uranium and thorium, also uranium enrichment. Includes the recovery of scrap from the above processes.

(3) Production of special materials for use in reactors (e.g., reactor grade graphic, beryllium, zirconium, hafnium, heavy water, etc.).

(4) Fuel element fabrication and recovery activities.—Includes all establishments which have as *end product activity* the manufacture of fuel elements for reactors; the recovery and chemical processing of irradiated uranium and plutonium fuels to separate fission products from spent fuel elements; and the scrap recovery and processing of unirradiated uranium metal, alloys, and compounds from fuel element fabrication plants.

(5) Reactor and reactor component design and manufacturing.—The design and/or manufacture of nuclear reactors. Includes the assembly of reactors at the place of manufacture. Also includes establishments which are exclusively engaged in making reactor components for the atomic energy field and are not classified in other segments.

(6) Construction of nuclear facilities.—Design, engineering, and construction of nuclear reactor housing (including the assembly of reactors at sites), atomic energy laboratories, reactor manufacturing plants, reactor fuel processing plants, and other facilities for atomic energy applications. Includes establishments engaged in design or engineering of facilities, even though not part of construction firms. (See definition of employment below.)

(7) Power reactor operation and maintenance.—Operation and maintenance of power reactors used for the production of commercial electricity. Excludes research and test reactors that should be included under the activity or establishment with which they are associated.

(8) Radioactive waste disposal.—The packaging and disposal of radioactive waste materials, including both by-product and source material wastes.

(9) Nuclear instrument manufacturing.—Establishments engaged in manufacturing instruments primarily for the atomic energy field, such as accessory instrumentation for reactor controls, radiation detection instruments, and hot laboratory equipment.

(10) Processing and packaging radioisotopes.—Establishments primarily engaged in these activities.

(11) Particle accelerator manufacturing.—Includes the manufacture of particle accelerators and of components specifically designed for and unique to accelerators.

(12) Private research laboratories and centers engaged in atomic energy work.—Includes laboratories and university departments or units engaged in atomic energy work under contract with the Atomic Energy Commission. (See definition of employment below.)

(13) Commission laboratory and research facilities.—Commission owned and privately operated facilities such as Argonne National Laboratory, Knolls Atomic Power Laboratory, etc.

(14) Atomic energy defense production facilities.—Facilities which are primarily devoted to weapons production (*excludes* design and manufacture of aircraft reactors which is classified in segment 5).

EMPLOYMENT.—Enter the total number of persons in your establishment who worked during or received pay for any part of the pay period ending nearest January 15. *Include* both full-time and part-time employees. *Include* those on temporary assignment abroad. *Exclude* consultants and other individuals who are employed by organizations working for your establishment under contract. Construction establishments and private research laboratories should report only those employees engaged in atomic energy work.

RESEARCH AND DEVELOPMENT.—*Includes* basic and applied research in the natural sciences (including medicine) and engineering, and design and development of prototypes and processes. *Excludes* quality control, routine product testing, market research, sales promotion, sales service, research in the social sciences, legal work, or other technical or nontechnical services. If the primary objective is research projects which represent original investigation for advancement of scientific knowledge or to make further improvements on a product or process, then the work is research and development. If, on the other hand, the product or process is substantially "set" and the primary objective is to develop markets, do preproduction planning, or get the production process going smoothly, then the work is no longer research and development. *Include* the administration and supervision of research and development and directly related manual work.

PRODUCTION AND OPERATIONS.—Includes the producing, fabricating, and manufacturing of products and materials; modifying equipment and processes to meet specific problems; operating a facility (including a reactor); and design, analysis, and testing associated with production and operation which are not part of research and development. Include the administration and supervision of these functions.

CONSTRUCTION.—Includes the design and engineering of facilities, construction of facilities, the on-the-site assembly of reactors, and the administration and supervision of these functions.

ALL OTHER FUNCTIONS.—Include all employees engaged in functions not listed above. For example: technical sales, technical writing, technical purchasing, operations research, and other technical services and their administration and supervision.

TOTAL NUMBER EXPECTED.—Based on available budget figures, project the number expected to be employed in January 1961 in your establishment.

SCIENTISTS.—All persons engaged in scientific work at a level which requires a knowledge of physical, engineering, mathematical, biological, agricultural, medical, psychological, and other natural sciences equivalent at least to that acquired through completion of a 4-year college course with a major in these fields. *Include* scientists in research, planning, inspection, administration, technical service, technical writing, technical drawing and exhibit design, data collecting, and all other positions when they require a scientific background. *Exclude* social scientists, archeologists, anthropologists, and architects. *Include* astronomers.

AGRICULTURAL SCIENTISTS.—Scientists working in agronomy, animal husbandry, forestry, horticulture, range management, soil culture, and veterinary science.

BIOLOGICAL SCIENTISTS.—All scientists, other than agricultural and medical scientists, who work in sciences which deal with life processes, including pathologists, microbiologists, pharmacologists, bacteriologists, toxicologists, botanists, zoologists, entomologists, etc.

MATHEMATICIANS.—Scientists primarily engaged in development or utilization of advanced mathematical techniques. *Include* statisticians and programmers for computers only if they specialize in mathematical techniques. *Exclude* accountants.

MEDICAL SCIENTISTS.—Physicians, dentists, public health specialists, pharmacists, and members of other scientific professions concerned with the understanding of human diseases and improvement of human health, who are engaged in atomic energy work. *Exclude* those only engaged in providing care to patients, dispensing drugs or services, diagnosis, etc. *Exclude* those only engaged in application of radiation to patients. Also *exclude* persons employed as pathologists, microbiologists, pharmacologists, etc., from the figures on medical scientists but *include* them in the figures on biological scientists.

ENGINEERS.—All persons engaged in engineering work at a level which requires a knowledge of engineering, mathematical, physical, or other natural sciences equivalent at least to that acquired through completion of a 4-year college course with a major in these fields. *Include* all types of engineers (civil, chemical, electronic, metallurgical, reactor, etc.) engaged in research, administration, planning, technical service, technical writing, etc., when their work requires an engineering background. *Exclude* architects but *include* architectural engineers.

REACTOR ENGINEERS.—Personnel who establish the nuclear criteria in a system, figure the shielding requirements, predict reactor behavior, do the preliminary design of reactor cores, and make optimization studies.

TECHNICIANS.—All persons engaged in work requiring knowledge of physical, engineering, mathematical, biological, or other natural sciences comparable to knowledge acquired through a technical institute, junior college, or other formal post-high-school training, or through equivalent on-the-job training or experience. Some typical job titles are: engineering assistants, physical science aids, and electronic technicians. All employees in positions requiring the indicated level of knowledge and training should be *included* regardless of job title and department in which employed. *Exclude* craftsmen such as instrument makers, tool and die makers, machinists, electricians, etc.

OTHER TECHNICAL PERSONNEL.—*Include* all other *technical* personnel, such as designers, technical writers, and architects, not already classified as scientists, engineers, or technicians.

MANAGERIAL, ADMINISTRATIVE, AND OTHER PROFESSIONAL PERSONNEL.—(Other than scientific and technical): Executives, heads of departments, supervisors, and foremen who are primarily engaged in planning and directing the work of others and those who regularly exercise discretion and independent judgment in work directly related to management policies or general business operations such as administrative assistants, purchasing agents, personnel directors, wage rate analysts, etc. Also persons engaged in work at a level which requires a knowledge of a professional discipline (other than science and engineering) equivalent to that acquired through completion of a 4-year college course such as lawyers, accountants, social scientists, etc. *Exclude* employees such as senior scientists, leadmen, or working foremen who may be "in charge" of other employees but who spend most of their time in non-supervisory

work. (The employees to be counted in this category are those exempt under the Federal Wage and Hour Law as employed in an "executive, administrative, or professional capacity.")

SKILLED TRADES.—Include workers in a recognized craft or trade who generally acquire their skills through apprenticeship or equivalent training or experience. Include all craftsmen (including working foremen and leadmen) in production, operation, construction, maintenance, and laboratory work. Include *only* journeymen. Apprentices and trainees should be included in the **"ALL OTHER PRODUCTION . . . WORKERS GROUP."**

NUCLEAR REACTOR OPERATORS.—All persons whose *primary* duty is the operation of the controls of a nuclear reactor. Nuclear reactor operators possess an operating license obtained from the AEC (unless operating an AEC or military service reactor).

ALL OTHER PRODUCTION, MAINTENANCE, AND CONSTRUCTION WORKERS.—Include all production, maintenance, and construction workers other than those included in the skilled trades and service worker categories. Laborers, helpers, operators, apprentices, etc., should be included in this group.

SERVICE WORKERS.—All non-supervisory manual workers engaged in supporting activities not directly related to the primary activities of the establishment. Include employees engaged in protective, security, custodial, and other supporting services, e.g., guards, elevator operators, cafeteria workers, janitors, firemen, charwomen, laundry workers, drivers, etc.

REMARKS

Please note below any comments you wish to make concerning the definitions, limitations of the data you were able to supply, or other points.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

Dear Sir:

The Atomic Energy Commission has conducted a yearly survey to collect employment and occupational data from establishments which are engaged in atomic energy activities under contract with the Commission. The Commission has now asked the U.S. Department of Labor's Bureau of Labor Statistics to conduct this survey.

It is hoped in the future to coordinate the collection of these data for the Commission with broader surveys of scientific and technical manpower covering all segments of the economy which the Bureau of Labor Statistics may undertake for the National Science Foundation.

Your cooperation in providing the information requested in the enclosed questionnaire is of great importance to the success of this undertaking. We need a reply from each establishment receiving a questionnaire. It is also important that all departments and divisions within the establishment be covered. The data you furnish will be used for statistical purposes only and will not be published in a manner that would disclose information on individual establishments. Since the usefulness of the data is in large part related to their timeliness, please return the completed questionnaire as soon as practicable.

We shall be very grateful for your cooperation in supplying the requested information. The Atomic Energy Commission will also welcome any suggestions you may wish to make regarding the survey.

Sincerely yours,

A. R. Luedecke

A. R. Luedecke
General Manager

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

Dear Sir:

We wrote you last month regarding an employment survey which is being conducted by the Bureau of Labor Statistics for the Atomic Energy Commission. Since you have not yet replied to the Bureau, we are writing again to request your cooperation.

The purpose of the survey is to collect employment and occupational data from establishments which are engaged in atomic energy activities under contract with the Atomic Energy Commission. In the future, we hope to coordinate the collection of these data for the Commission with broader surveys of scientific and technical manpower covering all segments of the economy which the Bureau of Labor Statistics may undertake for the National Science Foundation.

Information for your establishment is of importance to the success of this survey. All information supplied will be in strict confidence and published information will not permit identification of data for individual establishments. We enclose additional copies of the form in case the previous ones failed to reach you.

Your prompt cooperation will be greatly appreciated.

Sincerely yours,

A. R. Luedecke
General Manager

Enclosures

Appendix D. A Brief Description of Atomic Energy

Atomic energy, or more accurately nuclear energy,[24] may be produced through two processes called fission and fusion. In fission, the nucleus of a heavy atom, such as uranium or plutonium, is spilt, thereby releasing energy in the form of heat and radiation. In fusion, energy is produced through the fusion (or combining) of the nuclei of two light atoms, such as hydrogen. The energy created by these two processes is tremendous. The detonation of atomic and hydrogen bombs is an application of a deliberately uncontrolled and explosive release of this energy through the use of the fission and fusion processes. Nonweapon applications require that release of this energy be carefully controlled and regulated so that it proceeds at a manageable rate. Scientists have developed practical methods of controlling the fission reaction, but have not yet mastered control of the fusion (or thermonuclear) reaction.

Both atomic fusion and fission take place in nature. Fusion is generally believed to be the source of the energy of the sun. Atomic fission occurs close to the earth through the interaction of cosmic rays. This is part of what is known as natural background radiation. Prior to the Atomic Age, X-rays were the most commonly known form of radiation. Radiation that arises during fission is called nuclear radiation because it comes from the nucleus of the atom. Nuclear radiation can penetrate matter and can be dangerous to man. It is also invisible and, therefore, identifiable only by sensitive recording instruments.

Controlled fission is produced in a nuclear reactor, or "pile" as it is often called, which can be thought of as an atomic furnace, although there is no fire and no combustion in the usual sense. The reactor, like other kinds of furnaces, needs fuel to operate. The principal source material for reactor fuel is uranium. Natural uranium contains a small quantity (0.7 of 1 percent) of the fissionable isotope uranium U–235. (An isotope is one of two or more species of the same element, such as uranium, having almost identical chemical properties but differing in atomic weight.) The remaining atoms are mostly uranium U–238.

When the U–235 atoms split, they release "atomic bullets" called neutrons which can be made to split other U–235 atoms. These in turn release additional neutrons which can similarly split more atoms. This is how the fission process is started and maintained. Due to the presence of the fissionable U–235 atoms, natural uranium may be used as a fuel in the reactor. However, a more powerful and efficient type of reactor fuel can be made by separating the fissionable U–235 atoms from the nonfissionable U–238 atoms and concentrating the former in metal or solution. This is the fuel referred to as "enriched uranium." While U–235 is the only naturally occurring fissionable material, two additional manmade fissionable materials (plutonium and uranium U–233) can be used as reactor fuel.

In the nuclear reactor, a specific mass of fissionable fuel is placed in a particular arrangement with certain other elements in a heavy metal vessel. The mass of fuel is sufficient to sustain what is called a "chain reaction"—the continuous fissioning (or splitting) of the nuclei of atoms—resulting in the release of energy in the form of heat and radiation. This reaction is carefully controlled, usually by inserting rods (which absorb neutrons without fissioning) into the fuel chamber, or "core" of the reactor. In this way, the speed of the fission reaction and of the energy produced can be regulated or stopped completely.

Thus, harnessed atomic energy is produced in a nuclear reactor in the form of heat and radiation. However, if reactors are to be used for power,

[24] The term nuclear energy is more appropriate, since it is the nucleus of an atom which splits during fission and which emits the radioactive rays. Therefore, it is the nucleus which provides the energy. Similarly, in fusion, the nuclei of two atoms combine, resulting in the release of energy.

this heat must be captured and put to work. In a nuclear power station, the reactor replaces only the coal furnace, the heat produced being converted to electricity through the use of conventional generating equipment.

During the fission process, neutrons and other forms of nuclear radiation are released. Nuclear radiation is dangerous to personnel and ruinous to equipment. Therefore, special metals which are resistant to intensive heat and the corrosive action of radiation had to be produced for use in reactors and extreme precautions are taken to protect personnel. To protect personnel, the nuclear reactor is housed in a special container and surrounded by shielding materials, such as concrete and lead, so that nuclear radiation is absorbed.

A valuable byproduct of reactor operation is the production or radioisotopes. The major method of producing radioisotopes is to expose stable atoms to neutrons emanating from the reactor core. Radioisotopes can also be produced by the bombardment of target materials placed in a particle accelerator (often referred to as an "atom smasher"), a machine which accelerates electrically charged particles to speeds of thousands of miles per second.

Appendix E. Applications of Atomic Energy

Controlled nuclear fission is a tremendous source of energy which provides both heat and radiation as useful products. The major nonweapon use appears to be the production of commercial electricity, using nuclear reactors as the heat source. In 1960, two large reactors and several smaller reactors were producing electricity which was being fed into electric utility lines for public consumption, while many more reactors were in the design or construction stage. They are, however, experiments and prototypes and as such are not expected to be economically competitive with conventional power stations. Although not economically competitive today, nuclear power stations are expected to supply a larger and larger share of the increasing power requirements of the Nation as advancing nuclear technology reduces costs. The Atomic Energy Commission's short-range goal is to make it possible by 1968 for utility companies to build large-size nuclear plants to produce electricity at costs competitive with conventional plants in areas where fossil fuel (e.g., coal or oil) costs are high. The longer range objective is to make nuclear plants competitive with conventional plants regardless of location or plant size. A vast multimillion dollar experimental and demonstration program is in progress to achieve these ends.

Atomic energy has many other uses. Heat from reactors can be converted into propulsive power. Reactors already power submarines and very shortly will be used to propel combat surface ships. Nuclear submarines have been highly successful because of their unique advantages of subsurface operation without the need to come to the surface and of nearly unlimited range without refueling. The advantages of nuclear ships make them militarily useful since cost is a secondary consideration. In the future, atomic energy may be used to propel commercial ships, but the one nuclear-powered commercial ship scheduled for operation in 1961 will not be economically competitive.

Nuclear energy has potential uses for providing propulsion for manned aircraft, missiles, space vehicles, and some types of overland vehicles; as a source of heat and electric power at remote land installations, for unmanned weather installations, and for space satellites; and as a source of heat for warming buildings and for chemical and metallurgical processing. Intensive research toward developing nuclear propulsion systems for aircraft,[25] missiles, and space satellites is in progress. Research is also underway to develop an extremely compact reactor capable of propelling an overland train and other vehicles for military use. A program to develop lightweight, portable nuclear power plants to provide space heat and electricity at remote installations has progressed rapidly. Such a reactor was installed on the Greenland ice-cap in 1960, another was scheduled to be installed early in 1961 in Alaska, and a third is to be installed in the Antarctic in 1962. Economical use of the heat generated by reactors for warming buildings or as a source of process heat is being investigated.

Reactors can be built primarily as a radiation source. As such, they are used for many kinds of research and also for training and experimental work in nuclear research centers and university and other laboratories. In addition, they are used as high intensity radiation sources to study chemical reactions, and may be used to initiate chemical reactions and to sterilize food.

Radioisotopes, once considered only as byproducts of nuclear reactors, have extensive applications in medicine, industry, agriculture, and research generally. They have become valuable products because of their unique property of emitting penetrating radiation which can alter materials and which can be detected even in minute quantities by sensitive recording instruments. Radioisotopes are used in four general ways. One way is in the irradiation of materials to change their properties. For example, high intensity radiation sources are used to destroy bacteria, to arrest the growth of cancer tissues, to sterilize insect pests, and to develop better strains of plants.

[25] Program discontinued. (See footnote 7, p. 4.)

Radiation is also used for measurement. For example, the thickness of metal or the liquid level in a closed container can be determined by measuring the amount of radiation penetrating the substance. Industry uses this method in product quality control. Radioisotope gages are now used on about 90 percent of U.S. cigarettes to control automatically the firmness and fullness of packaging, and are used to control the liquid level in many canned food products and to control the thickness of almost everything manufactured in sheet form, such as paper, plastics, and metals.

A third major use of radioisotopes is in industrial radiography—a nondestructive testing method used for the inspection of metal castings and welds for possible flaws. The use of radioactive sources in radiography units makes it possible to perform inspections which are uneconomic or impossible with X-ray machines.

The fourth major use of radioisotopes is as tracers. Radioisotopes can be placed in the blood stream of men and animals, for example, and traced by instruments recording the emitted rays. In medicine, this may permit the physician to diagnose a patient's illness, such as cancer of the thyroid. In agriculture, these tracers are used to study the fertilizer uptake by plants, leading to improved methods of fertilization. In industry, they are used to study the wear on engine parts in automobiles and the efficiency of detergents used in washing machines. Currently, tracing is probably the most important use of radioisotopes.

A potential use for radioisotopes which is being investigated is the small-scale production of electricity. Due to the long life of some radioisotopes, they may eventually be used to provide power for scientific instruments in satellites and for beacons in remote areas.

Nuclear explosives used for peaceful purposes also have great potential. For example, preliminary studies indicate that the tremendous amount of energy released in a nuclear explosion could be used as an inexpensive means of excavating harbors and canals and in the development of our natural resources by aiding in the recovery of minerals and oils.

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