RADIATION STANDARDS, INCLUDING FALLOUT

WEDNESDAY, JUNE 6, 1962

U.S. CONGRESS,
SUBCOMMITTEE ON RESEARCH,
DEVELOPMENT AND RADIATION,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The subcommittee met, pursuant to recess, at 2 p.m., in room AE–1, the Capitol, Hon. Melvin Price (chairman of the subcommittee) presiding.

Present: Representatives Price, Holifield, and Hosmer.

Also present: James T. Ramey, executive director; George F. Murphy, Jr., Kenneth S. McAlpine, and Jack R. Newman, professional staff members, Joint Committee on Atomic Energy.

Representative PRICE. The committee will be in order. We will resume hearings today covering primarily radiation standards, after spending all day yesterday on worldwide fallout since 1959.

We have four scientists with us today, two of whom will make presentations on medical and industrial radiation exposure, and the final two will cover the basic facts about genetic and somatic biological effects of radiation and their implications for standards.

Our first witness will be Dr. Chamberlain, of the University of Pennsylvania, to be followed by Dr. Parker, of Hanford, Dr. Hasterlik, of the Argonne Cancer Hospital, and Dr. H. Bentley Glass, of Johns Hopkins University.

I perhaps should also note that there was some more fallout yesterday. Without any notice to the chairman of the Joint Committee or of the subcommittee holding these hearings, a report was apparently released yesterday to the press. Much of the good testimony which we received yesterday was superseded by the report in the press. The series of press leaks, and then the release of the report in the middle of our hearings is an old technique by the Public Health Service. We feel that it is a disservice to the program and discourteous to the committee and the Congress, especially in view of the fact that this report was discussed in the first 2 days of the hearings and a request was made to the staff of the Public Health Service for a copy of the report prior to its release. Consequently, I am requesting the Surgeon General to be present tomorrow to explain this matter.

Dr. Chamberlain, will you come around, please, and make your presentation.

You may proceed, Doctor.

STATEMENT OF RICHARD CHAMBERLAIN,[1] PROFESSOR OF RADIOLOGY, UNIVERSITY OF PENNSYLVANIA

Dr. CHAMBERLAIN. Thank you, sir.

I have given you a prepared statement. Would you like for me to extract what I think are the salient features from it rather than read it?

Representative PRICE. I think that would perhaps be better and the complete statement will be included in the record.

Dr. CHAMBERLAIN. Thank you, sir.

In looking at the situation, particularly as it may have changed in the past 2 years, or as we may appreciate it better with regard to exposures involved in medical practice, I think that it is of interest to continue to try to get assessments as to the amounts of both gonadal and somatic exposures. We do not at this time have any nationwide reliable statistical study on this feature, that I am aware of at least in the United States, that is based on modern statistical methods. However, some very important studies have come out of the Western European countries, notably the Adrian report out of England, which is of great interest and which was beautifully done. The interesting thing about all of these studies, and particularly the Adrian Committee report from the United Kingdom, is that the present estimates of these countries, as to the amount of radiation involved in medical and dental exposures, is considerably less than the earlier estimates. In the general appreciation of what is being done in the United States in regard to radiological work, I think it is reasonable to presume that quite likely the earliest estimates in the United States may also be somewhat high. But we simply do not have figures on this, that I am aware of. There are several things that are changing these figures all the time. I personally doubt if the exact figure is of very great importance. It is of interest because of the comparison with other

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Consultant in therapeutic radiology, Veterans' Administration Hospital, Philadelphia, Pa.
Visiting professor of radiology, University of Lund, Sweden, 1956.
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Member, Executive Committee, NCRP.
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Member, International Commission on Radiological Units.
Member, NAS–NRC Committee on Pathologic Effects of Atomic Radiation.
Member, National Advisory Council on Radiation of the U.S. Public Health Service, 1958 to 1960; Chairman, Subcommittee of National Advisory Council on Radiation to Review Training Grants for Training Radiological Health.
AEC and State Department consultant on nuclear affairs to Poland, 1958.
Technical adviser to Second International Conference on Peaceful Uses of Atomic Energy, 1958.
Former member, Committee on Isotope Distribution of AEC.
Former Chairman, AEC Subcommittee on Human Applications of Radioactive Isotopes.
Chairman, Civilian Advisory Committee on Radiation Hazards and Safety, city of Philadelphia.
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figures, but while we are reducing some unproductive radiation that was previously being given we are at the same time increasing the volume and increasing the new procedures which are done in radiological work for our population. Where it is going to finally wind up, I don't know.

Quite likely, for the best good of the Nation, we ought to give our population three or four times as much radiation exposure as we are now giving in order to accomplish the best medical care and the best medical good for them. I think there are trends in this direction of which I would like to speak a little more of later.

Representative PRICE. Let me understand you. You say we ought to give them more exposure?

Dr. CHAMBERLAIN. Quite likely we are not yet doing all of the medical procedures which can be done for the people, and there are new procedures being developed which, when they are properly incorporated into medical care, will raise the amount given for medicine.

Representative PRICE. Will you proceed, please?

Dr. CHAMBERLAIN. I thought it was of interest to try to get some assessment as to what has been done about trying to improve radiation practice in the United States, and particularly because I feel that the most important element is the educational one in trying to assess this.

During the past 5 years there has been an increasing amount of activity in medical journals and medical societies and in the various medical exhibits and other methods of educational technique which are used in medical education. We did a survey to try to get some estimate of this. About half of the radiologists of the country who are members of the American College of Radiology replied to this questionnaire. I thought it was interesting and important that this half had personally given something like 15,000 speeches, talks, exhibits, and papers on radiation protection and the proper use of radiation to other physicians and workers in the medical field. It seemed to me that this was a commendable indication. The medical schools were also investigated and only two of the schools do not have formal instruction, or plans for it, in the immediate future. Seventy-eight do have definite formal instruction in radiation protection now, with an average of something like 4½ hours spread across the various schools.

There has also been a great increase in the number of papers published on radiation use and its control in the medical press. We analyzed several journals including the radiology specialty journals, the State journals, and the Journal of the American Medical Association, finding an increase in all of these.

We also looked into the numbers of aids, slides, movies, and so on that were used. A very beautiful movie has been done by the U.S. Navy Medical Department. We find that these have reached a very wide and representative audience—something like a third of all the physicians in the United States have seen the American College of Radiology movie. The booklet that the American College of Radiology put out has gone to every practicing physician in the United States. Not only are these specialty groups working on trying to encourage good practice, but a group of other physicians, such as the Academy of Pediatrics, have done commendable work to this end. An official action by the Academy of Pediatrics discourages the use of conven-

tional fluoroscopy by their members, reserving it for problem cases, and then done by people especially trained in it. Similar efforts have been done by the Academy of Gynecology and Academy of Dermatology.

In looking at the impact of regulatory codes which the greatest number of States either already have put into effect or are planning to do, I think that we could say that most of these have been moderate measures and have been very well conceived. Most of them are based on the National Committee of Radiation Protection recommendations, and have had a generally favorable impact. There are difficulties in trying to elaborate these codes, particularly in medicine. Some of this is because what looks like a sensible recommendation for most instances may actually be a great hindrance in a specific small group. I have given one example of such, but in most instances the codes have been very good.

As an example of how effective regulatory codes have been, again on an opinion, but an informed—and I think a highly informed—opinion, Dr. Blatz, who has been most active in this field in the city of New York, estimates that his regulatory code activities have been instrumental in producing about a 25-percent reduction in radiation exposure in the past 3 years in New York City. Many other cities have had voluntary programs from their medical and dental groups working in conjunction with the official State or other local government.

Another major influence on the medical picture is what is going on in research and in the development of new techniques. I think that diagnostic radiology, far from being a fairly stable development in medicine now, is still in its relative infancy, or certainly not past adolescence. We are bringing to bear in dose reduction now, just beginning to bring to bear, some of the real fruits of television and electronic research systems, so that amplified fluoroscopes are now coming into wide use in large departments. As they become more stabilized in design, and with some further improvements, I am sure they will be used even more widely. These machines allow us to do procedures quite regularly at one-tenth of previous radiation dosage values, and in some instances up to an improvement of one-hundredth of the original dosage values.

Also new materials are being developed for intensifying screens and a variety of other minor improvements, but nevertheless important ones, in such things as the speed of X-ray films.

I don't know where this is going to lead us finally but quite likely we can do an appreciable amount of the work which we are doing now at still lower dosages in the future. But operating against this so far as dose reduction is concerned, is the increasing use of radiological procedures. I don't think we are yet saturated in the country for the present procedures. It is quite likely that we need to do a much greater volume. My own estimate would be at least three or four times the volume of present procedures.

Even more remarkable is what is going on in new procedures. The patient that used to come to a hospital and have one or two examinations performed, now has perhaps as many as 8 or 10 radiological procedures directed to the same part of the body in order to find out not the same as we used to find out but much more than we used to find out. This allows us to direct his treatment, his operations, and

his management during his therapy with greater precision. We don't see where the end of this is going to come. This is one of the reasons why I personally feel that the exact figure as to the amount of radiation exposure used in medicine is of secondary importance. We ought to use the amount that will do the most good for our people.

The amounts generally involved have a very small degree of hazard compared to the good that is derived for the individual person. But of course we ought to do it with the least wastage of radiation and the avoidance of radiation that is unproductive. I personally feel again that educational methods will have by far the greatest impact on this in the future and moderate regulatory measures will be of some assistance.

Thank you.

(Dr. Chamberlain's prepared statement follows:)

Medical Radiation Exposure

(By Richard H. Chamberlain, M.D.)

In evaluating radiation dosages from other sources, it is appropriate to discuss the exposure of the population to ionizing radiation used for the beneficial purposes of medicine and dentistry. During the past 2 years much thought and effort has been expended on appraisals of the amounts of radiation delivered to the gonads and other portions of the body from this source. Even more attention has been given to reasonable methods of reducing the radiation dosage without losing the vital benefits of radiological diagnosis and therapy. The pertinent features may be discussed under the following three points:

1. Epidemiological estimates of dosage values.
2. Control and improvement measures.
   (*a*) Educational.
   (*b*) Regulatory.
   (*c*) Research.
3. Perspective and prospects in medical exposures.

1. Epidemiological estimates of dosage values

Early attempts at estimates of average population exposures were largely confined to gonadal exposures and were largely based on fragmentary data from published papers of experiences in a few hospitals and local regions. They reflected the best that could be obtained from such sources, but left much uncertainty in the validity of the 150-millirad-per-year average figure which was derived for gonadal radiation dosage up to age 30 in the United States. In the past few years, very comprehensive analyses have been attempted in several other countries, notably Sweden, the United Kingdom, and Denmark. The Adrian Committee report from the United Kingdom is based on a large-scale study of measured doses and patient procedure distribution. It was well designed for proper statistical sampling. It indicates that in the United Kingdom the average gonadal exposure per year for medical purposes is between 15 and 25 millirads, with about 20 millirads as the probable figure. Figures from other Western European countries range from about 25 to 60 millirads. The Japanese estimate is about 40 millirads. No comparable study or estimate has been made in the United States, and to duplicate the United Kingdom study here would require a huge undertaking. From general comparisons of the development of radiological procedures in the United States and those countries that have reported, however, we would not expect great discrepancies. It seems reasonable to assume, therefore, that our own exposures are probably closer to 25 to 50 millirads per year than the preliminary estimate of 150 millirads.

It is not clearly known, as yet what may be significant in the assessment of somatic exposures. Investigations of dose and procedures may result in fairly homogeneous coverage of the body as averaged over large segments of the population. If this is true, the figures for somatic exposure are likely to be roughly comparable to those for gonadal exposure. Among the difficulties encountered in arriving at meaningful figures are the proper corrections for such factors as the individual prognosis relevant to the large proportion of use of major radiological procedures in patients with serious illnesses and limited life expectancy.

All of the potential somatic effects of radiation, at dosage levels involved in diagnostic radiology, require long latent time periods. In patients who will not survive for a sufficiently long time for the effects to become manifest there is no real hazard and their exposures are not significant.

All studies of radiation exposures have emphasized that, whatever the dosage figures may be, there is room for improvement by reduction of exposure required for the procedures that are being done and also in the choice of procedures. It is also evident that the means to accomplish significant improvement are at hand. This brings us to the second major consideration:

2. CONTROL AND IMPROVEMENT MEASURES

(a) Educational measures

Physicians and dentists are confronted with a great variety of factors which must influence each decision in regard to each patient. The judgment which balances possible radiation hazards against vital information or other benefit to be obtained must be an educated one which gives proper weight to each relevant factor. Many of the most important technical factors in dosage reduction also depend on highly skilled application of intelligence rather than inherent characteristics of radiation apparatus. In this light, by far the most important technique for medical radiaton control and reduction is educational.

The American College of Radiology has been very active in this field, both in its own program and in the encouragement of such programs by medical societies, other specialist groups, and professional journals.

During March and April of this year, polls were conducted by the American College of Radiology to determine the amount of emphasis now given to the problem of radiation safety, protection, and control, as compared with that of 5 years ago. Information was solicited from three groups of people:

(1) The 4,966 active members and fellows of the college who are diplomates of the American Board of Radiology.
(2) Fifty-four State and regional medical societies.
(3) Eighty-seven approved medical schools in the United States.

In every group, the educational effort expended in the area of radiation protection has shown a measurably high increase.

The 4,966 practicing radiologists were asked to estimate the number of talks, speeches, and programs on radiation safety and control they have taken part in in the last 5 years; the number of such programs they know to have been given in their area in the same period; the number of papers, editorials, or exhibits they have prepared on radiation protection during this time; and a percentage estimate of the extent of attainable improvement in medical radiation protection measures that have occurred in their area in the last 5 years. A total of 49.4 percent replied to the questionnaire. The final results of the survey are given in table A in the appendix to this paper. It is worthwhile noting that since 1957, some 14,898 talks, speeches, programs, papers, editorials, and exhibits have been presented by these responding radiologists. Of those responding, 46 percent estimated that there had been a 50 percent or better improvement in medical radiation protection measures. Only 3.4 percent indicated no improvement.

The second group surveyed was 54 State and regional medical societies. There were 25 responses. Each of these societies publishes an official journal, and the respondents indicated a total of 196,325 subscribers. These subscribers comprise 88.8 percent of the total number of physicians in the United States. Within the past 5 years, the medical societies responding to the questionnaire have published 218 articles on radiation safety, control, or protection, have sponsored 166 speeches and programs at their meetings, and have presented 119 exhibits and motion pictures dealing with education in radiation safety. The majority of these societies show a 50- to 75-percent increase in the educational emphasis on radiation safety in the last 5 years. Every society responding has a committee on disaster planning to deal with problems inherent in atomic disasters, military or otherwise. With one exception, they have all indicated they are reasonably to very active in National, State, or local disaster planning efforts. The full figures on this poll are given in table B in the appendix.

The 87 medical schools surveyed were asked to estimate the hours of instruction in radiation safety, protection, and control given to medical students and others. They were also questioned as to the type of visual aids employed in this instruction, and the percentage of increase or decrease in hours devoted to such instruction now, as compared with 5 years ago. Of the 78 respondents,

only 4 indicated they give no formal instruction in radiation protection, and 2 of these have plans underway for such a course. The average number of hours of education in radiation safety given to medical students is 4.4. Paramedical personnel (X-ray technicians, nurses, etc.) are required to take from 1 to 10 hours of study in this specific area. Many schools have a continuing program of informal instruction on new developments for their house staff. Nearly all of the schools use slides from their own collections or those available from the American College of Radiology. A majority also use movies from several sources such as: The ACR film "Radiation: Physician and Patient"; a U.S. Navy film, "Radiation Safety in Nuclear Medicine"; and films from the Department of Defense. Of the responding schools, 45 indicated an average increase in the hours devoted to instruction in radiation safety, protection, and control of over 50 percent, within the past 5 years. There were no schools showing a decrease. A tabulation of this survey is given in table C.

The American College of Radiology motion picture entitled "Radiation: Physician and Patient," has been used extensively in educating groups about safety, protection, and control of ionizing radiation. From October of 1959 to March of 1962, the Eastman Kodak Co. has sent out 431 prints of this picture. These prints were used in 453 showings before a total audience of 22,932. The Division of Radiological Health of the Public Health Service has shipped out prints of the film 325 times since September of 1959, and for the most part, each booking constituted multiple showings. They have estimated that "the film must have been shown at least 500 to 600 times, with an average audience of 50 per showing. This would give an average total audience of 27,500. In addition, the American Medical Association also books this film. They have indicated a total number of showings to date of 356. Based on the average audience of 50, estimated by the Public Health Service, this would result in a figure of 17,800. The cumulative professional audience total from all three booking sources is 68,232.

A check of the indexes of the Journal of the American Medical Association shows that during the period of January 1957 to March 1962 there were 218 articles published dealing with radiation control, protection, and safety. The previous 5-year issues, 1952–57, contained only 116 articles on the same subject. There was an 88-percent increase in the past 5 years over the earlier period.

The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine during the years 1952 through 1956 published 137 articles dealing with radiation protection and hazards. During the years 1957 through 1961, they published 160. This is an increase of 16.8 percent. A breakdown of the types and number of articles by years is shown in table D.

During the years 1952 through 1956, there were 236 articles on radiation protection, safety, and control published in Radiology, the journal of the Radiological Society of North America. These articles consisted of 188 abstracts of current literature and 48 articles and news notes. In the succeeding 5 years, 1957–61, a total of 308 were published. These are broken down into 211 abstracts and 97 articles and news notes. The last 5 years shows an increase of 30.5 percent over the 1952–56 period.

The American College of Radiology has published a pamphlet dealing with radiation safety and protection entitled "A Practical Manual on the Medical and Dental Use of X-Rays With Control of Radiation Hazards." Since its initial printing in 1959, 225,000 copies have been distributed in North America. In addition, 22,000 copies published in Spanish and 4,000 in Portuguese have been distributed, primarily to Latin American countries.

A large percentage of the medical schools queried have indicated that they make use of the American College of Radiology slide series on radiation protection. Since 1958 nearly 600 sets of these slides have been sold. In addition, the American College of Radiology provides a radiation protection kit containing much factual information regarding radiation protection, safety and control. From January of 1960 to date nearly 1,400 of these protection kits have been mailed out to radiologists.

Other medical groups have shown great interest in the promotion of radiation safety and protection. Examples are furnished by the actions of the Academy of Pediatrics in discouraging conventional fluorscopy of infants and children by their members, the published statements of policy by the American Thoracic Society and the Academy of Gynecology, and the preparation of a manual of radiation protection by the Academy of Dermatology.

The educational program for the training of radiation health specialists has received a great impetus from the support of the Radiological Health Division of the U.S. Public Health Service. This program, aimed primarily at producing

highly educated specialists, is being conducted in approximately 15 colleges and universities, leading to master's or doctor's degrees in the field. These men will greatly influence all types of radiation control, including medical aspects, and their highly skilled abilities should assist future educational as well as regulatory measures.

(*b*) *Regulatory measures*

The States, largely through their departments of health, have increasingly promoted regulatory codes relating to radiation and most of these have provisions affecting minimal standards for equipment, features which can be inspected, such as filtration and shielding. Most of these codes have been based on the recommendations of the National Committee on Radiation Protection and Measurements. In transferring from recommendations to codes with legal force, some difficulties arise in relation to medical uses. For example, in most usual diagnostic X-ray examinations there is no need to use beams with filtration of less than 2 millimeters of aluminum half value layer, and the NCRP recommendation is to this effect. In certain special examinations, however, such as X-ray diagnostic studies for cancer of the breast, a very serious medical problem, the technique requires much lower filtration. Codes such as have been adopted in some States have the effect of making these examinations illegal, though such was not the intent of the NCRP, nor did the State agencies purposely intend to so interfere with a potential lifesaving procedure. The need for caution, highly skilled interpretation, and reappraisal in the promulgation and enforcement of regulatory codes is, nevertheless, apparent.

Most of the impact of the moderate measures embodied in the better regulatory codes has been favorable, however. Much of the good has been indirectly achieved by the byproduct educational activities of inspectors in the course of their duties and the educational effects of registration requirements.

In many instances, local medical and dental societies have been highly cooperative and have augmented the official program with voluntary campaigns of their own. A notable example of this has occurred in Philadelphia. In New York City, Dr. Hanson Blatz, director of the Office of Radiation Control of the City of New York, estimates that his department has been instrumental, during the last 3 years, in reducing radiation exposures 25 percent. (Exhibit E in the appendix is a copy of a letter from Dr. Blatz.)

(*c*) *Research measures*

The 66 years since the discovery of X-rays have seen tremendous strides in using technical advances which produce more information from less radiation. The development of intensifying screens, very fast film emulsions and fluorescent screens, higher energy and more greatly filtered beams have all had great impact. Precision apparatus and precision processing put the radiation where it is desired and insure the best results from the amount of radiation that is used. But we have far from exhausted the potentialities of modern technology. Only in the past few years have applications of television and electronic systems reached practical stages in medical radiology. In the past 2 years image-amplified fluoroscopes have come into wide use in departments that can afford the large initial financial outlay and quick obsolescence associated with complex apparatus undergoing rapid improvement and modification. In the better forms, radiation dosage can be reduced to one-tenth or even to one-hundredth of former values while obtaining the same or greater diagnostic information than before. Television, cine recording, and magnetic tape storage enhance the potential of these developments in present apparatus and offer great future promise. New developments in intensifying screen materials seem highly promising in dose reductions of the order of one-fourth or more as applied to regular radiography. Constant improvements are also being made in the speed of X-ray films, the design of beam collimators and shields, and in the reliability and production control of film exposures and development. These researches and developments should be vigorously supported not only for their effect on dose reduction, but more importantly for the great benefits to be achived in improved medical diagnosis. Though the cost is tremendous, few medical developments have more promise.

3. PERSPECTIVE AND PROSPECTS OF MEDICAL EXPOSURES

It is of interest to assess the extent of radiation exposure from medical uses and to relate it to that from other sources and to potential hazards which accompany all human radiation exposures. It is far more important to see that we are

using radiation for medical purposes with a high degree of control of dosage, without unnecessary wastage, and with wise choice of indications for its use. Such considerations result in a progressive reduction of radiation dosage in achieving any given amount of good. The full utilization of present radiological methods for the maximum benefit of the population is not yet achieved and an increase in volume of many studies is a desirable goal which will and should accompany the further advance of medical care. Most remarkable, however, is the recent great expansion in new studies and procedures which have not been available before. The accuracy of diagnosis, the guidance to appropriate surgery or other therapy, and the management of complications have been extended to phenomenal limits with such new procedures. For example, in a suspected renal tumor, the usual studies of a few years ago might well have been limited to a single plain film and perhaps three or four exposures during the excretion of a urographic contrast medium. In our large medical centers today this is commonly amplified with more conventional contrast films and renal arteriographic serial studies, perhaps more films with retroperitoneal gas injection, frequently elaborated with multiple body section X-ray films, and may be extended to venous contrast examinations and visualization of the lymphatic system. The value judgments as to when each procedure is indicated and to the benefits derived are not precisely definable, particularly in advance. The general prospect is clear, however, in that more and more of these elaborate techniques are needed, they furnish vital information, and they will be an increasingly important part of future medical practice. It would appear almost paradoxical that we are striving to reduce radiation dosage while encouraging and welcoming large increases in it. The two objects should be sharply distinguished, however, for the first is to reduce unproductive radiation exposure, while the latter is to appreciate that medical benefits from indicated procedures, no matter how extensive, usually far outweigh the relatively small potential hazard from the radiation. The following summary points seem justified:

1. We do not know the exact extent of radiation exposure from medical use in the United States. It is probably smaller than indicated in earlier estimates, but is being constantly influenced toward reduction by improved techniques and control and toward increase by greater use of present methods and new developments in radiological diagnosis. The exact figure is probably not of great importance.
2. Medical groups have been commendably active in educational and voluntary control measures toward reducing unproductive medical radiation exposure.
3. State and other regulatory bodies have increased their activities in regulatory codes, and these have had a generally good effect when carefully administered.
4. New research developments are expanding the potential of human benefits from medical radiological procedures and many incorporate desirable dose reduction potentialities.
5. The best needs of our people are likely to be served by expanded medical use of radiation, without prejudged limits as to its extent, but with intelligent and informed control of the radiation used.

TABLE A.—*Survey of the members and fellows of the American College of Radiology on radiation protection, safety and control*

Number responding	Number of talks, speeches, and programs given personally	Number of other such programs known to have been given	Estimate of percentage improvement in medical radiation protection						Papers, exhibits, and editorials prepared personally
			None	10 percent	25 percent	50 percent	75 percent	Other	
2,545	13,211	27,156	87	339	554	817	331	27	1,687

TABLE B.—*Survey of 25 medical societies*

Total membership	Those publishing official journals	Total subscribers	Radiation safety articles, last 5 years	Speeches and programs, last 5 years	Exhibits, last 5 years	Motion pictures, last 5 years
112,874	25	196,325	218	166	40	79

Increase in educational efforts in radiation protection						Committee on disaster planning		Estimate of activity in National, State, or local disaster planning efforts			
None	10 percent	25 percent	50 percent	75 percent	100 percent	Yes	No	Do not know	Relatively inactive	Reasonably active	Very active
3	4	0	5	7	1	25	0	0	1	19	5

TABLE C.—*Survey of 78 medical schools*

Instruction given in radiation safety		Total number of hours given						Number of schools employing visual aids		
Yes	No	Medical students	Residents not radiologists	X-ray technicians	Nurses	Others [1]		Movies	Slides	Others
						A	B			
74	4	346	145	138	50	21	35	35	59	14

Percentage of increase, or decrease, in hours devoted to instruction as compared with 5 years ago							
Decrease	Same	Under 50 percent	50 percent	75 percent	100 percent	Over 100 percent	No answer
0	18	11	14	1	18	12	4

[1] Key: A—Instruction given, but hours not specified. B—Hours noted, but recipients not specified.

TABLE D.—*American Journal of Roentgenology, radium therapy, and nuclear medicine*

Year	Volume	I[1]			II[1]			III	Total
		A	B	C	A	B	C		
1952	67	1	7	2	3	0	0	2	15
	68	1	10	1	0	0	0	0	12
1953	69	0	9	0	4	0	0	0	13
	70	4	5	0	0	0	0	0	9
1954	71	2	6	1	0	3	0	3	15
	72	5	9	0	2	1	0	3	20
1955	73	7	3	0	1	1	1	2	15
	74	2	4	0	2	3	0	0	11
1956	75	5	4	0	1	3	0	0	13
	76	2	7	0	1	4	0	0	14
Subtotal									137
1957	77	3	2	2	2	4	0	1	14
	78	7	2	0	1	2	0	4	16
1958	79	5	2	1	2	3	0	0	13
	80	5	6	1	0	1	0	3	16
1959	81	1	5	2	2	4	0	3	17
	82	3	7	1	3	2	0	3	19
1960	83	6	9	1	2	1	0	1	20
	84	4	2	0	1	2	1	1	11
1961	85	4	7	0	3	7	1	2	24
	86	3	1	0	1	4	1	0	10
Subtotal									160
Total		70	107	12	31	45	4	28	297

[1] Key:
I—Protection, safety, and control.
II—Actual and potential radiation hazards.
III—Releases by committees concerned with radiation protection.
A—Original articles.
B—Abstracted articles of literature.
C—Editorials.

EXHIBIT E

THE CITY OF NEW YORK,
OFFICE OF RADIATION CONTROL,
New York, N.Y., April 3, 1962.

The AMERICAN COLLEGE OF RADIOLOGY,
Chicago, Ill.
(Attention: F. Brandt.)

GENTLEMEN: As an associate fellow of the American College of Radiology I have received a copy of the postcard inquiry for data to be used at the hearings to be conducted by the Joint Congressional Committee on Atomic Energy in May 1962.

First of all, I am not a radiologist nor a physician. I am a radiological physicist. For the past 3 years I have been devoting my entire time to the various subjects covered in the questionnaire. I have made many speeches and talks and have been on a number of radio programs concerned with radiation safety and control. The activity in the New York City area has been great in this field.

I believe that the program of the New York City Health Department with a personnel of about 35 and a budget close to $200,000 a year devoted exclusively to the control of radiation (of which about maybe 95 percent of the problem is in the medical and dental use of X-rays) has been quite effective over the past 3 years and I will estimate that we have been able to reduce radiation exposures in this area approximately 25 percent. We are now conducting a research project under the sponsorship of the Public Health Service in which we are accumulating statistical data on the degree of radiation exposure in medical radiography. In addition I have published about six papers in the past few years on the subject.

I am also an associate professor of industrial medicine at the New York University Medical Center where I give a course on the introduction to radiological health and participate in several other courses covering the subject.

I was not certain whether this information was of interest or value to you and also whether my activities would be considered an activity in the medical profession.

Sincerely yours,

HANSON BLATZ, *Director.*

Representative PRICE. Thank you, Dr. Chamberlain.

The committee is happy to have your fine paper. May I commend you on the effective summary which you gave. You touched on every point in your statement which I followed through as you went on.

Doctor, you state on page 1 of your formal statement that during the past 2 years much thought and effort has been expended on radiation appraisal. What has occurred in this field that has brought about such an intensive effort?

Dr. CHAMBERLAIN. In the last 2 years particularly you mean?

Representative PRICE. Yes.

Dr. CHAMBERLAIN. I think that it really dates from 5 years ago, sir, but one of the influences on this, I imagine, is the former hearings of this group itself. The interest in the medical profession has been rising for about 3 years, after the National Academy of Sciences report, to a crescendo which has been most active during the past 2 or 3 years. I think the international commissions and the National Commission on Radiation Protection also have been in great part responsible for this.

Representative PRICE. On what criteria are you able to make the assumption that you make on page 2 that the average patient dose in the United States would be about the same as in countries where it has been surveyed?

Dr. CHAMBERLAIN. There are two things involved in this: I personally have traveled extensively and have been a visiting professor at such places as the University of Lund in Sweden. I have had interchange with other Western civilized countries to see what they do and how they do it. I think in general our medical practice is quite comparable to Sweden and United Kingdom and not greatly different from the Netherlands and parts of Western Germany.

There are some differences that are important, but they probably are less important than the uncertainties of the earlier estimates that were made in those countries and in our own country as to this medical amount. As I say, I simply don't know what the figure is, but I think there is good reason to think that these studies which have been carefully done in the other countries, with a roughly comparable extent of radiological expertise, would make us think that we are probably within the same ballpark at least.

Representative PRICE. What was the impetus in these studies in the countries that you have mentioned?

Dr. CHAMBERLAIN. What made them do the studies originally?

Representative PRICE. Yes.

Dr. CHAMBERLAIN. I don't really know exactly except that this increase in interest in radiation exposure has been general, and, as I say, the International Commission on Radiological Protection has been particularly active in promulgating this and also the rules by which such studies ought to be done.

Representative PRICE. On page 3 you say it is also evident that the means to accomplish significant improvement are at hand. You are talking about radiation exposure, and so forth, there?

Dr. CHAMBERLAIN. Yes, sir.

Representative PRICE. What are the means that you are thinking about here?

Dr. CHAMBERLAIN. I think they are exactly the ones that the National Committee on Radiation Protection has been drumming into everyone. Generally, the increase in filtration, the more careful use of cones and such things that have to do with equipment, but even more importantly the educated judgment of the people who choose what procedures to do and how often to do them on which patients.

This to my mind is the place at which the great improvement in the intelligent use of radiation can be achieved.

Representative PRICE. Also on page 3 of your statement you say that many of the most important technical factors in dosage reduction also depend on highly skilled application of intelligence rather than inherent characteristics of radiation apparatus.

Dr. CHAMBERLAIN. Yes, sir.

Representative PRICE. Do all doctors and dentists have this skill?

Dr. CHAMBERLAIN. This goes through on to techniques and to everyone who is involved in this. I think that, as I seem to be repeating myself as to what I said a couple of years ago, there is a variation in this expertise, but I hope that this survey of our educational program indicates that it is improved. At least a great number of us who are practicing medicine think it is improved. The medical schools are doing something about it, too.

Representative PRICE. I am talking about the questionnaire on page 4. You say a total of 49.4 percent replied to this questionnaire.

Dr. CHAMBERLAIN. Yes.

Representative PRICE. What about the other 50 percent?

Dr. CHAMBERLAIN. Of course 50 percent is pretty good for a questionnaire reply in medicine.

Representative PRICE. This is a highly technical professional thing.

Dr. CHAMBERLAIN. Yes, sir.

Representative PRICE. I would say in a normal questionnaire this would be an exceptional response.

Dr. CHAMBERLAIN. I thought it was pretty good. At least 50 percent that replied gave 15,000 speeches, and I don't know whether the other 50 percent gave none or gave a few more. I thought it was pretty good.

Incidentally, our reply from the State medical societies was also just about a 50-percent reply. Perhaps doctors get so much mail that they are not as careful about looking at it as they should.

Representative PRICE. Do you think they get as much as we get?

You state on page 5 that the average number of hours in the medical school on radiation safety given to medical students is 4.4. Do you think this is adequate?

Dr. CHAMBERLAIN. Of course, if this were the only mention made of radiation protection and radiation control I would say it is not adequate.

I would like to see that raised some, too, but it is difficult to know just what you ought to do in medical curricula, picking out separate

hours on a subject. A lot of us believe that the best education is one that is integrated into a whole picture.

I would much rather see a biochemist in the first year of medical school make a passing reference to radiation safety in the course of doing an experiment. That might be more effective than the specialist spending 15 minutes talking about it as a subject. I think this is an indication at least that the medical schools have looked at this as something worth teaching and hopefully it is an indication that it is being taken seriously in medical curricula.

Representative PRICE. Does this include actual use of radiation machines?

Dr. CHAMBERLAIN. Usually the operation of machines is not taught to medical students during the period of their undergraduate school. Most of the time that is done at the interne or resident phase.

Representative PRICE. On page 8 you mention that the Academy of Pediatrics is discouraging conventional fluoroscopy of infants and children by their members. Does this mean actual discontinuance of use of fluoroscopes?

Dr. CHAMBERLAIN. Not completely because there are conditions which infants and children have for which they should be fluoroscoped. As a matter of fact, we fluoroscope them regularly in my own department for adequate indication. But the motion of the Academy of Pediatrics was to discourage their members from doing it for conventional purposes and doing it themselves unless they had special training in this. There are some pediatricians who are very highly trained in radiological procedures, too, as well as certified radiologists.

Chairman HOLIFIELD. Why do you have to use a fluoroscope examination in place of an X-ray?

Dr. CHAMBERLAIN. Usually it is for things in which the physiological motion of the inside part is part of the diagnostic situation. Such things as foreign bodies in the lungs, the fluoroscopy of the gastrointestinal tract and such. For these and with the amplified fluoroscopes that we are using now, we can feel relatively safe in doing most everything for which fluoroscopy is of vital importance. However, I still would rather use the old fluoroscope for a sufficiently serious condition rather than to say you should not do it at all.

Chairman HOLIFIELD. Is it possible to protect the gonads in the event of an extended fluoroscopic examination?

Dr. CHAMBERLAIN. It is, unless the part that you are doing is in this area. I make the proviso because for some very important urology studies done on children recently, for example, it is absolutely impossible to protect the gonads. But this is a situation in which the child's health is so vital and this study is so necessary to it——

Chairman HOLIFIELD. You have to take a relative risk?

Dr. CHAMBERLAIN. Yes; that is exactly the point.

Representative PRICE. Doctor, in this modern age most of us assume that almost every child today is in the care of a pediatrician. But what do the records show as to the number of children, percentagewise, that have the services of pediatricians?

Dr. CHAMBERLAIN. I don't know the figure, sir. I am sure that it is not the majority of the children in the country as a whole who are taken care of by pediatricians regularly. I really don't know the figure.

Representative PRICE. On the use of the fluoroscope, are there any records of radiation injuries to the patients? Forget the patient for a minute. But the attending doctor or technician. Is there some place you can go to the record of radiation injuries?

Dr. CHAMBERLAIN. I am not sure I understand, sir. From fluoroscopy particularly?

Representative PRICE. Yes; from the use of fluoroscope instruments.

Dr. CHAMBERLAIN. With modern machines we just don't see somatic injuries to doctors and technicians any more. As you know there were many of these people in the early days of radiology and scattered instances of people who simply didn't use any precautions at all from as recently as 20 or 25 years ago.

Representative PRICE. Some of the older physicians are suffering from it?

Dr. CHAMBERLAIN. That is right, from what they got that long ago; yes, sir. Nowadays we just simply don't get into this order of dosage even out in the hinterland. I think it is practically unknown for people to use fluoroscopes to the point of demonstrable damage. However, in modern departments we wear film badges and do all the control methods to insure that we don't get anywhere near demonstrable effects from radiation and stay below the radiation guide levels. Most of us stay down to a third or a quarter of the most stringent levels.

Chairman HOLIFIELD. Has there been any study of the degree of radiation from television sets in order that you might give us a relative figure of the amount that is involved there with children who hover around these television sets for hours on end and in relation to fallout radiation?

Dr. CHAMBERLAIN. I know of the one major paper on this by Dr. Braestrup and a coauthor whose name I can't think of for the moment. The amounts given in this were very, very low. The question was whether the radiation amount was as hazardous to the child as the intellectual hazard of watching it for so many hours. It was getting down to something like two one-hundredths of a rad per year, or something like that for prolonged watching. I am sorry I don't recall the exact figures. That one paper is the standard one, I think.

Chairman HOLIFIELD. Is there a strong protective scrutiny of the sets for that purpose?

Dr. CHAMBERLAIN. It is my understanding that it is. I am sure someone else could tell you more properly about this. This, incidentally, has to do with conventional receivers. There is some hazard in projection receivers for which they have to take considerably more precaution. But, of course, children would not be involved there.

Representative PRICE. Mr. Hosmer.

Representative HOSMER. Dr. Chamberlain, why should it be necessary in connection with a profession which dedicates itself to the health and well-being of mankind to have Government police that profession and its use of radiological equipment?

Dr. CHAMBERLAIN. I don't know if I can answer that question, sir. There are some precedents, of course, in it. In State licensure of physicians, physicians stand examination; presumably for the protection of the public and the insuring of some reasonable level of standards that physicians are licensed in the various States. I think my own feeling is that regulatory measures are less effective generally

than educational ones and that most doctors will respond to appeal to their consciences and their intellects to do a better and better job.

Representative HOSMER. Have the doctors of the city of New York had their consciences and intellects appealed to in this connection?

Dr. CHAMBERLAIN. I think you can look at what Mr. Blatz is doing in a way in which much of what he found, I imagine, was unknown to the physicians and was an unwitting situation that could be improved.

Representative HOSMER. Doesn't the physician have an obligation to know the safety of the equipment that he uses on his patients?

Dr. CHAMBERLAIN. He should be as skilled and as knowledgeable as possible.

Representative HOSMER. Yet Mr. Blatz in January 1962 in New York City inspected 393 X-ray machines in the offices of medical doctors in that city, and he found only 52 of these pieces of machinery in a satisfactory condition; 13 percent satisfactory, 87 percent unsatisfactory.

Dr. CHAMBERLAIN. This, of course, has to do also with what the rules of satisfactory and unsatisfactory are. We did a similar survey in Philadelphia.

Representative HOSMER. Were Mr. Blatz' rules unreasonable?

Dr. CHAMBERLAIN. No; they are reasonable. But they are of relative degree of importance. We did a similar study in Philadelphia and by critical standards about 75 percent of the apparatus did not meet what we liked it to.

Representative HOSMER. In that connection, Dr. Chamberlain, 2 years ago you testified that 66⅔ percent was out of whack.

Dr. CHAMBERLAIN. Exactly.

Representative HOSMER. Are you correcting your figure?

Dr. CHAMBERLAIN. That is my nearest recollection. But the greater majority of those machines could be brought up to satisfactory condition with very minor changes which simply were not known to the owners of the apparatus.

Representative HOSMER. That survey was a control survey and was made about 6½ years ago; is that right?

Dr. CHAMBERLAIN. That one in Philadelphia?

Representative HOSMER. Yes.

Dr. CHAMBERLAIN. No; not that long ago.

Representative HOSMER. In 1960 you testified it was made about 4½ years ago.

Dr. CHAMBERLAIN. Was that the dental one or the medical one, sir?

Representative HOSMER. That was the medical one.

Dr. CHAMBERLAIN. I will take your word. I did not look that up in advance.

Representative HOSMER. That was a control study, and it was supposed to be followed up. What happened in connection with the followup?

Dr. CHAMBERLAIN. It has been followed up. I do not have the figures. The dental one also.

Representative HOSMER. You say at the present time all of the equipment in the city of Philadelphia has been inspected?

Dr. CHAMBERLAIN. I think at least 95 percent of it has. I do not know, again, the exact figure.

Representative HOSMER. Is it a continuous program?

Dr. CHAMBERLAIN. Yes.

Representative HOSMER. Are they still finding about two-thirds or three-fourths of the equipment deficient?

Dr. CHAMBERLAIN. My impression is that they have regularly found the equipment to be improved every time that they have reinspected, but I do not have the figures.

Representative HOSMER. Do you have the figures on the latest inspection?

Dr. CHAMBERLAIN. No, I do not, sir.

Representative HOSMER. In this survey that you mentioned that was carried on by the American College of Radiology a number of questions were asked relative to the public relations operations of the radiologists, how many speeches they made and articles they had written and so forth. Were there any questions submitted to them with respect to the equipment and its maintenance, or lack thereof?

Dr. CHAMBERLAIN. The speeches and such were not public relations things. These were professional education of the medical profession. It had nothing to do with speaking before the lay public. No question was asked in this questionnaire concerning specific items of equipment. A question was asked which was more germane, however—although it was an opinion—as to what they thought of the achievable improvement that had been accomplished in their local area. I would be the first to emphasize that this is an opinion but I don't know any other way to arrive at this.

Representative HOSMER. Let me ask you this question:

In the University of Pennsylvania medical courses on radiological safety, or whatever it is you call them, what standards are suggested to budding M.D.'s with respect to the maintenance of any X-ray or other radiological equipment that they may acquire in their practice?

Dr. CHAMBERLAIN. You mean an outline of what is taught to them?

Representative HOSMER. I want to know what you teach them to do. Specifically with respect to keeping their equipment in good order.

Dr. CHAMBERLAIN. I don't think, as I say, that the equipment ought to be overemphasized in this. We teach our people, however, that they ought to have their equipment inspected by someone who is qualified in this. If they personally become qualified by training this is all right. If not, they ought to get someone who is. We teach them the features of fluoroscopes and radiographic equipment which are quite the same as the National Committee on Radiation Protection Standards and the college booklet and such all emphasize. But more importantly we try to teach them the philosophy of how to use radiation with care and with what we hope is wisdom. I think that the equipment side of this should not be overemphasized. It is only one part of the whole picture.

Representative HOSMER. I happen to believe that the status of the equipment has been underemphasized. It was so indicated in your previous testimony, and I am trying to find out if there is any improvement that has been made.

Specifically, you have stated thus far that you tell your students that they ought to have their equipment in good order and ought to have it inspected if they do not become technical experts in the equipment themselves?

Dr. CHAMBERLAIN. That is right.

Representative HOSMER. With what frequency do you suggest that they have the equipment inspected by some qualified individual?

Dr. CHAMBERLAIN. This is different for different types of equipment. If a man is using a fluoroscope, for instance, only occasionally and there is no change made in the tube or the other arrangements of the machinery I am sure once every 2 or 3 years is quite adequate. In another situation such as a machine in high use in my own department we will inspect it as often as once a week with a check calibration.

Representative HOSMER. The doctor himself, when he leaves the medical school, what does he feel his responsibility is with respect to checking his equipment?

Dr. CHAMBERLAIN. Most of them who are using the equipment occasionally, once every 2 or 3 years is quite sufficient, unless a change is made.

Representative HOSMER. Isn't the man who uses the equipment least frequently the one who may use it most grossly?

Dr. CHAMBERLAIN. But he uses it on fewer people less often.

Representative HOSMER. In other words, the risk to the total population is less but to the individual is greater?

Dr. CHAMBERLAIN. None of these levels that we are using now are of any significant risk to the individual anyway. This is of importance in the whole movement to cleaning up radiation. It is largely one of good hygiene and also of trying to reduce large volume effects over population groups.

Representative HOSMER. How many hours' schooling does a medical student take?

Dr. CHAMBERLAIN. In the total in his 4 years?

Representative HOSMER. Yes.

Dr. CHAMBERLAIN. I haven't worked it out.

Representative HOSMER. I am trying to get some feeling. You say the average number of hours of radiation safety given to medical students is 4.4?

Dr. CHAMBERLAIN. Specifically to this purpose. This is not counting what may be indirectly brought into other parts of his courses.

Representative HOSMER. Is that a semester-hour figure?

Dr. CHAMBERLAIN. No; this is a total of the 4 years of medical training in most medical schools.

Representative HOSMER. How many hours of training do they get a year, then?

Dr. CHAMBERLAIN. They usually go for 9 months all day long, 5½ days a week. I can't work it out for you this fast.

Representative HOSMER. You mean over the 4 years that they go to medical school they spend a total of 4 hours and 24 minutes hearing about radiological safety. Is that what you intend to say?

Dr. CHAMBERLAIN. That is the best average figure we could work out from inquiring from the professors in the various medical schools. I think it is probably good compared to some other important subjects such as the toxicology of serious drugs and so forth. It is quite a commendable amount of time. Probably about in order, as Mr. Price said, would I increase it—I think I would increase it to perhaps 5 or 6, but I think anything more than that would probably be a loss of perspective in the total of medical education.

Representative HOSMER. These 1,400 kits that the College of Radiation have sent out, what were they, kits full of literature of some kind?

Dr. CHAMBERLAIN. They are reprints from the literature having to do with radiation control. There are a couple of my papers in them and similar things as written by Dr. Hodges and other people. They are the basis for making up lectures and talks on radiation protection for other practitioners.

Representative HOSMER. On what basis were the persons who received them selected?

Dr. CHAMBERLAIN. They asked for these kits. Announcements were made in radiology journals that they were available and they were sent out on request.

Representative HOSMER. In other words, this was a speech kit?

Dr. CHAMBERLAIN. An educational kit.

Representative HOSMER. Some 5,000 belong to the American College. Are they the ones who specialize in radiology?

Dr. CHAMBERLAIN. It is essentially the total medical specialists in radiology with a few certified radiological physicists who are associated members.

Representative HOSMER. I suppose those who specialize in this field take a great deal more time in instruction in that than the ordinary practitioner, is that right?

Dr. CHAMBERLAIN. Yes, sir. This is a 3-year minimum specialty course in radiology alone after medical school and internship.

Representative HOSMER. Yet the average practitioner will usually have an X-ray machine in his office, will he?

Dr. CHAMBERLAIN. I don't think the average do. We have had figures on that in the past. But I think it is considerably less than half of the general practitioners.

Representative PRICE. Are you getting away from that?

Dr. CHAMBERLAIN. Yes.

Representative PRICE. And you have the practitioner sending his patients to the radiologist?

Dr. CHAMBERLAIN. There is less and less of the general practitioner doing his radiological work for many reasons. Even by numbers it doesn't give you an accurate picture of this because of the relative volume of work being done. But it is mostly a matter of background, of elaborateness of apparatus, as well as economics.

Representative HOSMER. Let me say this, Doctor, I don't think the profession has really executed its responsibility until this percentage of OK inspections reaches just about a hundred.

Dr. CHAMBERLAIN. I would like to see it myself.

Representative HOSMER. From the present total of 13.

Dr. CHAMBERLAIN. I would certainly agree.

Representative HOSMER. Thank you, Mr. Chairman.

Mr. RAMEY. In your testimony in 1960 you mentioned that the American Medical Association was establishing a committee on atomic medicine and ionizing radiation and that this might represent a broader entrance of the AMA into this field of interest. Since that time have they shown any increased activity or interest?

Dr. CHAMBERLAIN. I cannot answer that, Mr. Ramey. I have not been a part of this activity of the American Medical Association.

Mr. RAMEY. One other question, Mr. Chairman: In some of our earlier discussions we have looked at the Federal Radiation Council guides and the maximum permissible doses established by the NCRP and ICRP. Both of those types of guides do not include medical exposure under their maximum figures. The National Academy of Sciences, I believe, however, did in a sort of additive way as I recall, set up one.

Do you think it would be desirable in setting guides that it would not be mandatory or regulatory that the amount of medical exposure to the population be taken into account?

Dr. CHAMBERLAIN. This is a most troublesome question. I can again only give you a personal opinion on this because there are people with different opinions. Some who feel there ought to be a bank account from which you can only draw so much. As I look at the hazards of life and of what we have to undergo—how much hazard we have to undergo—in order to do things we want to do, it seems to me that any such limit that you would put on medical use would only be put there to be broken for adequate cause. Consequently I can see no purpose of putting the limit on to begin with.

As I indicated a little while ago, if we can appreciably help the health of people for relatively minor risks by quadrupling or even increasing tenfold the radiation exposure, I think we will accept it and we probably should accept it. If we were not going to get very much out of it, I would feel less and less happy about an increase being made. I think that even those who are more concerned or who have expressed the most concern, such as the genuine interest of people in the National Academy of Science genetics group particularly in not wanting to exceed certain levels, they felt that this ought not to be exceeded without good solid reason. Perhaps they were not as aware of what is the potential trend in the future of benefits to be derived from an increased use of radiation.

As long as they set a warning not to exceed a level on the basis that we could improve what we were doing then, I would agree with them. If you set a level which we should not exceed in the future and then use it to stymie the development of worthwhile medical procedures, I am against it.

Mr. RAMEY. Actually according to your figures it has been going down on the average?

Dr. CHAMBERLAIN. I am not sure it went down. I am not sure but what the earlier estimates were based on very fragmentary background. But it probably has gone down some. At the same time it wouldn't surprise me to see it go up manifold in the next few years.

Mr. RAMEY. On the average?

Dr. CHAMBERLAIN. Productive radiation; yes, sir.

Mr. RAMEY. Or just for individuals?

Dr. CHAMBERLAIN. I think we have to get prepared for the total use of radiation to increase. I think a great part of this, however, will be on people who are sick. Hopefully, however, if we can keep them alive longer by doing these procedures then their radiation becomes significant again.

Representative PRICE. Thank you very much, Dr. Chamberlain. The committee appreciates having your statement.

Dr. CHAMBERLAIN. Thank you, Mr. Price.

Representative PRICE. The next witness will be Dr. Herbert Parker, manager of the Hanford Laboratories.

STATEMENT OF HERBERT M. PARKER,[1] MANAGER, HANFORD LABORATORIES, GENERAL ELECTRIC CO.

Mr. PARKER. Mr. Chairman and members of the committee, the material I am reporting was assembled by a number of my associates whose help I would like to acknowledge. Perhaps my submitted paper will be acceptable for the published record and I will try to condense it here.

In the hearings on radiation protection criteria and standards conducted by the Joint Committee, Dr. Failla, whose loss its being keenly felt by all of us in the field, made some observations entitled "Giving Credit Where Credit Is Due," in which he congratulated the Joint Committee on the excellence of the hearings on radiation protection. It is a privilege to contribute to the present hearings to bring these matters up to date. Dr. Failla's testimony also emphasized the importance of the recommendations of the NCRP and the ICRP, many others at that time noted that the basis for most of the standards used for the protection of both individuals and populations at that time were recommendaions of these two bodies. The situation is essentially unchanged today. Important activities in detailed formulation of standards and regulations continue in many other bodies, AEC, FRC, some of the States, Public Health Service, American Standards Association, and others, but the bases for these standards are still predominantly the recommendations of the NCRP.

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[1] Herbert M. Parker, manager, Hanford Laboratories, Hanford Atomic Products Operation, Richland, Wash. Place of birth: Accrington, England. Date of birth: April 13, 1910. Naturalized in the State of Washington, 1946. Marital status: Married. Education; Manchester University (England); B.S., physics, 1930; M.S., physics, 1931; fellow, Institute of Physics, 1937.

Assistant professor radiology, University of Washington, 1952 to date; honorary trustee, Northwest Scientific Association (past); technical adviser, U.S. Delegation, Peaceful Uses of Atomic Energy, Geneva, 1955; Janeway lecturer, 1955; qualified in radiological physics by the American Board of Radiology; qualified in health physics by the American Board of Health Physics.

Work history: 1932 to 1938, Holt Radium Institute, Manchester, England, physicist; 1938 to 1942, Tumor Institute, Swedish Hospital, Seattle, Wash., physicist; 1942 to 1943, Metallurgical Laboratory, University of Chicago, research associate; 1943 to 1944, Clinton Laboratories, Oak Ridge, Tenn., section head, health physics; 1944 to 1946, E. I. duPont Co., Richland, Wash., manager, health physics; 1946 to 1948, General Electric Co., Richland, Wash., assistant superintendent, medical department (in charge of radiation protection); 1948 to 1951, General Electric Co., Richland, Wash., superintendent, health instruments; 1951 to 1956, General Electric Co., Richland, Wash., director, radiological sciences; 1956 to present, General Electric Co., Richland, Wash., manager, Hanford Laboratories.

Professional societies: Fellow, American Nuclear Society; fellow, American Physical Society; associate fellow, American College of Radiology; fellow, Institute of Physics (Great Britain); fellow, AAAS; associate member, Radiological Society of North America; American Radium Society; Radiation Research Society; Atomic Industrial Forum; N.Y. Academy of Sciences; honorary member, faculty of radiologists, Great Britain; American Management Association; member, British Institute of Radiology; member, Society of Nuclear Medicine.

Committee memberships: Member, Committee on Units, Standards and Protection, American College of Radiology; International Commission on Radiological Protection, Chairman, Subcommittee on Isotopes and Waste Disposal (past); National Research Council, member, Subcommittee on Radiobiology (past); Subcommittee on Radiological Instruments (past); National Academy of Sciences, member, Committee on Waste Disposal (biological effects of radiation study) (past); chairman, Technical Advisory Panel 04 of the American Institute of Physics to the National Bureau of Standards; member, General Electric Reactor Safeguards Council (past); member, Executive Committee, NCRP; chairman, Subcommittee on Basic Radiation Protection Criteria; member, Subcommittee on Permissible Dose From External Sources (past); member, Subcommittee on Permissible Internal Dose (past); member, AEC Safety and Industrial Health Advisory Board (past); member, Committee on Radiation Protection Standards, Atomic Industrial Forum (past); member, Washington State Technical Advisory Board on Radiation Control.

As to new developments since 1960, they are possibly not too striking. In this period the philosophy and concepts and quite often the actual language of the recommendations of the NCRP and ICRP have been applied and incorporated into sections of Federal and State codes and into policies of the private industrial organizations. Noteworthy applications in this field have been made by the Federal Radiation Council and you have heard from other witnesses about the range concept which carries, as I see it, the promise of introducing much needed flexibility.

Another noteworthy development has been a statement by the NCRP on exposure limits that would apply to emergency situations. This is their Report No. 29. Although this is pitched more directly at the civil defense situation it applies quite reasonably to guide justifiable action in the event of serious emergencies of industrial origin.

Turning directly to the industrial situation, we can perhaps define three categories of industrial users of radiation. The largest single category is composed of AEC contractors who account for two-thirds of the estimated employment in the entire atomic energy field. These are involved in quite complex uses of radiation sources and need to apply their standards to a wide variety of conditions. In controlling this the AEC is assured by contract terms that the contractor proposes to maintain certain minimum radiation protection standards. These are controlled by the AEC manual chapters which are themselves based rather directly on the NCRP recommendations.

The second category of industrial users we would define as AEC licensees. This is the principal general industrial group, complying with regulations specifically formulated for the purpose and applied by the Commission.

I am told there are some 10,500 such licenses in force and compliance with standards is required through title 10 of the Code of Federal Regulations.

In this case there is a very wide spectrum of need. The standards utilized by licensees vary from minimum controls over small separate sources to situations about as complex as those characterized in the principal AEC contractors' work.

The third group would include the users of radiation sources not covered by the Atomic Energy Act. This is made up of a group of industrial firms engaged in such activities as nondestructive testing as well as those actually manufacturing radiation machines and instruments. Of course, in these kinds of work they use radiation sources such as X-ray machines, radium, and some radionuclides that escape from the AEC aegis. The principal guidance in this case is contained directly in the recommendations of the NCRP, with about half our States having State regulations which exercise some control over these situations. It is possible, of course, one should note, for one industrial firm simultaneously to fall under the jurisdiction of all three of these types of control.

In practical administrative application, almost without exception some modification or interpretation of standards and codes is necessary and must be provided before a standard becomes implemented as a working reality in the work atmosphere.

In the case of the modest user, the maximum hazard he is concerned with may be both small in itself and easily predictable. In those cases he may well elect to relate his performance directly to the langu-

age of the formal legal standards. More generally the quantity and variety of radiation sources or the very complexity of the facilities involved is such that the program has to be headed by a separate responsible radiological safety officer. Such a man will have at least some knowledge of the history and development of the basic recommendations and is in a position to guide the program by applying the underlying philosophy and intent of the standards as well as the actual terminology of the legal instruments.

The first chart (table I, p. 319) if Dr. Taylor will be good enough to show it shows some of the details which get involved in the work of the large contractors in making a tight internal system of control with the controls responsive to the legal standards but characteristically are more stringent because of the potential for significant exposure which arises in these cases and mainly because of the complexities of converting different types of exposure to a common base, which I believe is still actually the major problem for all of us.

Another important administrative aspect is the establishment in the larger industrial concerns of a work climate and an employee attitude favorable to good radiological control. We believe that written standards and procedures alone just do not give assurance that people have the understanding to enable them consistently to do the right thing.

Continuing education in the basic intent of protection standards seems to be important in this. The final success of such a radiation protection program is then, as we see it, usually more dependent on the voluntary acceptance of a way of life in dealing with radiation than upon literal conformance to some rule.

A word now about the present problem areas in the industrial application of standards. Let me say first that we see no current major problem in this area, except the one I mentioned before of the realistic adding up of all the contributions to exposure. With this limitation the possible problems are like this. First, the transfer of certain regulatory responsibilities from the AEC to the States has been going on in the period we are talking about. Despite the probable intent of all the parties to maintain reasonable uniformity within the State regulations there is opportunity for inconsistencies, gaps, and overlaps between these several codes. Some of these, although in truth they are relatively minor, have already appeared. The future or potential problem encountered by an industrial firm which may have atomic activities in several States each with different requirements and also having licensee and contractor relationships with the AEC is obvious.

Another problem is the actual format and language of the standard itself. We have our divergent viewpoints on the degree of specificity and the amount of methodology which should be contained in these standards, but broadly the industrial users join in making a very strong plea that it is important that the standards be written as performance standards and not as a specific detailing of the mechanics or interpretive methods for doing the jobs. Identifying the end point and not the method is the key issue here.

Relating to these problems of incorporating methodology into standards is the imparting of the same apparent sense of validity and weight of law in the various secondary standards that are so used as is warranted in the case of the primary or basic standards. The

question of internal depositions is partly under this heading because the internal depositions may come largely from breathing and drinking. Our recommendations tend to consist of lists of permissible concentrations or radiation protection guides, in air or water. These are in themselevs somewhat secondary standards, very useful ones, as guides to prudent operation. The application of these lists in a rigorous or statutory manner instead of going back to the basic dose requirements with respect to the individual can either be very burdensome on the one hand, or actually not restrictive enough on the other hand where various biological concentrating mechanisms intervene between the initial water supplies and the consumption of food after the processing of products through a food chain.

Another significant problem not related to standards but to the way we think about them is the natural tendency among the public and perhaps to some extent even in the courts to equate the exceeding of some specific limit with injury to the recipient. Serious problems will enter into the business if radiation protection guides are erroneously used as criteria for determination of either the existence or the extent of injury. In this country radiation protection standards are not based on concepts of establishing permissible doses at levels just below the point of injury.

As I understand the present efforts of the Public Health Service, that agency is particularly cognizant of this overall problem of oversimplification of limits and tends to what I call a retrospective assessment of each case on its own merits.

As seen by industry, this approach carried to the limit won't stand up. Industry and the public which rightly attempts to judge the actions of industry must have prospective targets, not retrospective ones. Unfortunately in industry, which is technology based here, we tend to equate prospective target with a very simple go, no-go gage or the discrimination of black and white.

One almost hears a modern Decatur exclaiming, "Our numbers, may they be always in the right, but our numbers, right or wrong." The two extreme positions are not yet reconciled. If we accept the principle of acceptable risk in radiation exposure, and there is no alternative today, instead of black and white, we have only infinite gradation of gray from perhaps a black relating to significant overexposure, grading down but never reaching white. It is beyond our wits to quantify such a scale. Yet the attempt has to be made at least to define bands of gray. The three ranges as used by the Federal Radiation Council, I think, are precisely such an attempt which I have translated into fashionable color terminology with range I being Arcadian gray, range II being Achillean gray, and range III being Augean gray.

Representative HOSMER. Do you have a color chart with you?

Mr. PARKER. I am not able to put precise numbers on these shades of gray but I classify Arcadian gray as pure and clean for the relevant purpose, and Augean gray containing a reference to the well-known stables of history, and the middle range, if I may clarify that, as I recall Achilles, he was pretty sound but he had a couple of weak spots one on each heel. That is the derivation of these ranges.

Public education, or in other words, doing a better job than I can do pictorially in interpreting the shades of gray we have in mind, is still vitally needed and does not come easily. We look to the Fed-

eral Radiation Council mainly to provide the Nation with authoritative judgments. Their recent Report No. 3, which we received since this was written, appears to me to be an excellent example of this as applied to the specific topic of fallout.

We see that the radiation protection standards over the past period, 20 years if you like to use that period, have served the Nation well and further aggressive research in support of establishing better principles and achieving more resourceful codification of these principles should help us to make this statement again 20 years from now.

Let us take a brief look at the numbers that we can invoke from the industrial experience. We are talking about what is looked on as an explosively expanding industry but it is neither explosive nor quite so expanding when we remember that there are said to be some 200,000 people in the present work force in atomic energy. This is small in comparison with major industries. Nevertheless, a reasonable body of experience is accumulating which points, I believe, on the whole to success in minimizing exposure through prudent design and strict enough control. We have to pick small portions of the total record to put numbers on them, and table 1 shows some of these for external exposure alone. I will not elaborate these because they are in the published record by the AEC.

Exposure records show on the whole that the vast majority of workers in the AEC complex only receive a radiation dose of less than 1 rem per year and furthermore only in a very few cases—and we count about 1 worker in 10,000—has the National Committee on Radiation Protection short-term control limit of 3 rems in 13 weeks been exceeded. This always seems to come from some kind of accident rather than from regular planning.

We attempted, since your committee announced these hearings, to make a survey to get more up-to-date information from all industry and were not able to obtain data that I would consider comprehensive. But from a fairly substantial body of representative major users covering about 30,000 people who were all actively engaged in this field, and this includes private work as well as that responsive to AEC contracts, the average annual radiation exposure for the last 2 years, that is, 1960 and 1961, seems to run at about three-tenths of a rem per person.

Thinking for a moment of the fairly standard formula for maximum accumulated dose, the one which is written as $5(N-18)$ rems with N being a number equal to the present age of the individual in years, replying to your survey and including ours, since we have recently acquired one, only two cases showed accumulated doses exceeding the formula values. If you go back to sources that we cannot always document but come from the professionals talking with each other in the field we know altogether of about 15 cases in the country in which this formula has been exceeded and we guess that if our sources were complete, this number might be doubled. So there may be about 30 situations in the whole of industry exceeding the maximum accumulated dose. I should reiterate that many of these do not represent real injury to the recipients and some, again by the numbers, will be self-correcting, since the respective values of N for these people is steadily increasing and most of them are now withdrawn from additional radiation work.

To the best of our knowledge these cases are principally due to single large accidental exposures rather than to a running steady accumulation over the years.

Coming now to the case of the experience of the small users here we could find little or no public data that would give us values needed by the committee. We examined the most recent data on licensing experience as reported by the AEC for about a 1½-year period ending last November. In that period there were some 10,000 licenses in force. There were 40 radiation incidents reported which you would classify mostly as being minor in nature. None of them, in fact, reported a very serious level of radiation exposure.

Going now to the internal deposition which is more difficult to put into numbers, the nationwide experience in this respect is just not available. We tried to get some more in our limited survey and the answers there were interesting in that they showed a nearly complete absence of significant deposition cases.

In order to have numbers that we can support better, however, let me quote the Hanford experience which was: 6,000 man-years of direct work with one of our most dangerous elements, namely, plutonium, shows us with only three employees with body burdens of plutonium approximating or exceeding the present standards. These quantities are such that none is expected to present any clinically observable symptoms and none have appeared.

At Hanford, with about 75,000 man-years of experience in working with other radionuclides, no other internal depositions have occurred except for a few minor transitory cases involving materials of short half-life.

The important aspect of the environmental radiation is what we contribute to our friends and neighbors around a plant such as we have at Hanford. Here we can conclude—again without giving wholly reliable numbers—that persons living in the vicinity of such installations receive but a small fraction of radiation from these additional sources of that acquired from natural background. In fact, the contribution there received is for the most part overshadowed by the contribution from worldwide fallout which I understand is already regarded as not being very high at this time. As to the average exposure from industrial operations which would relate to the genetically significant population around the atomic energy plants, if we tried to spread this over a few million people, we are not able to give precise numbers but we can give some evidence that it must certainly be only a small fraction of 1 millirem per person per year. You will recall the dose from natural background ordinarily falls in the range of 100 to 200 millirem. The gonad dose from fallout in our region, which is lower than that reported for the Nation at large, is about on the order of 5 millirem per year at the present time.

A slightly less favorable aspect refers to situations which may arise in the immediate vicinity of any large atomic energy plant such as ours which lead to doses several times those which currently exist from fallout. This will arise mainly with individuals with uncommon food habits or other idiosyncracies. It is very hard indeed to make reliable calculations of what these exposures may be, but using the best data available to us we have concluded for some time that in the vicinity of the Hanford project, as an example of the larger scale

operations, these doses may come to about 30 percent of the appropriate limits.

Representative HOSMER. What kind of an uncommon food habit would create this situation? Like a liking for plutonium?

Mr. PARKER. No; we have not yet gotten so sold on the virtues of plutonium, although we regard it highly, as to consider it a food. We for example, Mr. Hosmer, unwittingly or unavoidably at the present time insert radioactive products into the Columbia River. This will go through various life forms including a rather noted deposition in shellfish. An uncommon food habit example might be a man who lived exclusively on shellfish rather than the normal diet.

The British situation has a community which eats a seaweed and this seaweed would have to be the one that accumulates a rather spectacular amount of radioactive debris that the British insert into the sea. This is representative——

Representative HOSMER. In other words, you cannot be a faddist in the State of Washington. That is what can be concluded.

Mr. PARKER. I think one could broaden that and say "Don't be a food faddist in any State."

Mr. RAMEY. Was there someone around Calder Hall who ate lobsters entirely as an advertisement and they had to raise their standard on his intake so they wouldn't hurt?

Mr. PARKER. I am not familiar with that specific instance.

In our case in this area where we do have uncertainty because of these individual habits things are looking up with the expanded availability of the whole body counter which is giving us a method of measuring what radioactive materials actually exist in the body. We hope, if we are asked to report to you at some subsequent time, that the data here will be very much improved.

One can get some indirect reference to the situation in industry by looking at accidents, Accidents can range all the way from minor spills of radioactive contaminants to the serious nuclear excursions, the criticality incidents up to and including loss of life. These latter are the ones that are spectacular. They are well characterized and well reported. The next chart (table II, p. 319) reveals the rate at which criticality type accidents are accruing in the United States. Within the limit of statistics of numbers like 1 and 2, one has to say that 1 and 2 are equal and the summation of this experience is that major accidents in the business is continuing at a steady rate. That situation is not conspicuously favorable nor is it conspicuously unfavorable since presumably some accidents will always occur.

I hoped to report on the feasibility and cost to industry of maintaining appropriate levels of protection, since these are important ultimately to a thriving industry. I find nothing new to report here.

I would say a good quality of protection is being achieved, though not too cheaply, and this will continue as long as the applicable base limits continue to be more or less stable. Neither do I see evidence that calls for a radical change in these limits. In some cases, in fact, as in plutonium deposition, there may even be a tendency to regard the present safety margin as more than adequate.

Finally, Mr. Chairman and gentlemen, there is a tendency to relate the careful control and work climate in this specific application of

standards to safety performance as a whole. For reference, the final table (table III, p. 320) I have which I will not read gives the data for AEC contractors compared with similar experience by all industries. It is suggested that continued performance of this type should lead to a better appreciation by the general public that the Atomic Energy installations are indeed among the safest of our industrial plants.

Thank you, gentlemen.

(Mr. Parker's prepared statement follows:)

Radiation Protection Standards: The Industrial Situation

(By H. M. Parker, manager, Hanford Laboratories, General Electric Co.[1])

INTRODUCTION

My name is Herbert M. Parker, and I am employed by the General Electric Co. as manager, Hanford Laboratories, Richland, Wash. The material that I am reporting was assembled by a number of my associates, including particularly A. R. Keene, L. A. Carter, J. W. Vanderbeek, and R. F. Foster, whose help I acknowledge.

I should also identify my position as chairman of the NCRP subcommittee on basic radiation protection criteria.

PRINCIPAL RADIATION PROTECTION STANDARDS APPLICABLE TO INDUSTRY

In the hearings on "Radiation Protection Criteria and Standards" conducted by the Joint Committee on Atomic Energy in 1960, one of the most knowledgeable and respected men in the the radiation protection field presented his usual thought-provoking testimony to the committee on the development and status of the bases for radiation protection standards. He also included some observations which he titled "Giving Credit Where Credit Is Due." In this last section of his testimony he offered his congratulations to the Joint Committee on the excellence of the public hearings which were conducted by the committee. He stated that these hearings have "served the purpose of clarifying the problems in the public mind and the printed reports provide an up-to-date summary of the scientific status of this field." (1)[2] It is a privilege to contribute to the hearings which the Joint Committee is conducting at this time, to bring these matters up to date.

The 1962 hearings will be missing the mature and valuable contributions of Dr. Gioacchino Failla whose well-balanced observations were an important contribution in the 1960 hearings. His loss both as a friend and as an unselfish principal contributor to the foundations of radiation protection in this country has been felt and will continue to be felt for many years by all of us.

In his testimony, Dr. Failla also gave credit to the National Committee on Radiation Protection and Measurements (NCRP) for the "introduction of many new concepts on radiation protection which are now standard practice throughout the world." (1) His testimony emphasized the importance of the recommendations of the International Commission on Radiological Protection (ICRP) in the matter of permissible limits for large populations. Many others noted that the bases for most of the standards used for the protection of individuals and populations against radiation at that time were the recommendations of the ICRP and the NCRP.

This situation is essentially unchanged today. Important activities in formulation of radiation protection standards and regulations continue in the Atomic Energy Commission, the Federal Radiation Council, some of the States, the U.S. Public Health Service, the American Standards Association, and other such agencies or bodies. The bases for such standards development and application continue to be predominantly the recommendations of the independent NCRP.

[1] Work done under prime contract AT(45-1)-1350 to the U.S. Atomic Energy Commission.

[2] References at end of statement.

NEW DEVELOPMENTS SINCE 1960

The philosophy, concepts, and often the actual language of the recommendations of the NCRP and ICRP have been applied, adopted, and incorporated into sections of Federal and State codes and into policies of private industrial firms. Noteworthy applications and modifications of the recommendations of the NCRP and the ICRP during the past 2-year period have been made by the Federal Radiation Council (FRC).

The FRC, since its inception has offered guidance to Federal agencies in its Staff Report No. 1 issued in May 1960,(2) and Staff Report No. 2 issued in September 1961(3). In Report No. 2 the FRC adopted a range concept in stipulating the control of radiation dose to certain critical organs of the body, which carries the promise of introducing much needed flexibility. In Report No. 2 guidance to the Federal agencies is provided in the form of allowable daily intake rates for strontium 89, strontium 90, iodine 131, and radium 226. Briefly stated, range I is the lowest of the three ranges and it spans the intake rate which is equivalent to essentially no radiation dose up to a dose equivalent to one-tenth of the so-called radiation protection guide or permissible dose. Range II extends from one-tenth of the radiation protection guide to the full radiation protection guide level; operation in this range requires a quantitative surveillance program and routine control of the releases of radionuclides to the public domain. Range III is the uppermost range and spans an order of magnitude above the radiation protection guide; operation in range III requires an evaluation program and application of additional control measures as necessary to reduce the exposure.

While the guidance offered by the FRC is for application by Federal agencies. the extension of this guidance to the industrial firm is commonplace because of the thousands of firms having a licensee or contractor relationship with the Atomic Energy Commission. A primary standard or limit for controlling radiation hazards is an expression in terms of limitation of dose to individuals or to populations at large. Federal Radiation Council Report No. 2 offers definitive guidance on a method of controlling radiation by limitation of daily rates of intakes of certain radionuclides by members of the public. This portion of Report No. 2 has the nature of a secondary standard. The incorporation of such secondary standards into a collection of Federal guides may have advantages for those engaged in activities limited to work with modest amounts of one or two radionuclides. For those activities where large quantities of radioactive materials are processed, the release, under controlled conditions, of extremly small fractions of the quantity of materials being handled requires sophisticated environmental evaluation programs. For these types of activities, rigorous application of a secondary standard may have important disadvantages. I will come back to this point later.

Since the 1960 hearings another noteworthy development has been the statement of the NCRP on exposure limits applicable to the emergency situation. These recommendations are contained in NCRP Report No. 29, "Exposure to Radiation in an Emergency" (4). They provide definitive dose and risk criteria for justifiable action in the event of serious emergencies of an individual origin as well as possible nuclear warfare. This recent guidance by the NCRP is a valuable addition to the other NCRP recommendations.

INDUSTRIAL USERS OF RADIATION PROTECTION STANDARDS

While there have been few changes in the basic radiation protection standards since the hearings in 1960, there have been many activities bearing on the generation of standards and their use and application in this formative period through which this country is now going in the area of radiation standards regulation. This is becoming particularly evident as the transfer of responsibilities for certain source, byproduct, and special nuclear materials from the Atomic Energy Commission to the States is occurring under the revision of the Atomic Energy Act.

There are perhaps three definable categories of industrial users of ionizing radiation. The largest single category is composed of AEC contractors who account for about two-thirds of the estimated employment of the entire atomic energy field (5). These contractors are frequently involved with extensive and complex uses of radiation sources and therefore often have need to apply radiation protection standards extensively to a wide variety of conditions. In its re-

lationship with its contractors, the AEC is assured by contractual arrangement that the contractor proposes to maintain certain minimum radiation protection standards. The recommendations of the NCRP have been the bases for these standards as incorporated in AEC Manual chapters (6). It is my understanding that future revisions of these manual chapters will reflect more directly the specific guidance offered to Federal agencies by the Federal Radiation Council.

The second category of industrial users is composed of AEC licensees which constitute the principal industrial group complying with regulations specifically formulated and applied by the AEC. As of December 31, 1961, there were about 10,500 licenses in force (7). In issuing individual licenses the Commission requires compliance with the standards presented in title 10 of the Code of Federal Regulations (8). The standards utilized by licensees can vary from minimum controls over small individual radiation sources to extensive controls which cover as full a range of application as for the more complex atomic energy facilities.

The third group includes the users of radiation sources not covered by the Atomic Energy Act. This group of industrial firms is engaged in activities such as nondestructive testing. In the course of their work they may use radiation sources such as X-ray machines, radium, and radionuclides produced by Van de Graaff generators. The principal guidance to these firms is contained in the recommendations of the NCRP. In many States such firms may also be under regulations promulgated by State authorities such as the State department of health. It is possible, of course, for an industrial firm simultaneously to fall under the jurisdiction of all of the above types of application of standards.

ADMINISTRATIVE ASPECTS OF STANDARDS APPLICATION

The adoption of standards by regulatory agencies of the Federal or State Governments does not, in itself, insure that significant radiation exposures will not be received by workers or persons living in the vicinity of industries which handle sources of radiation. The industry or user must conduct his operations in such a manner that the standards will be easily met under normal operating circumstances with a margin to make it highly improbable that they will be exceeded under foreseeable adverse conditions. The amount of precaution which is necessary is obviously related to the size and nature of the user's business. At one extreme is the technologist who uses minute quantities of a particular radionuclide for tracer-type work and whose total supply of radioactive material is so small that it constitutes an insignificant radiation hazard, no matter how casually he may handle the material. Compliance with standards is, in this case, assured at the time the radioactive material is dispensed to the technologist.

At the opposite extreme is the large atomic energy facility which handles many tons of irradiated nuclear fuel and which must install elaborate safeguards to assure that equipment or human failure does not result in serious overexposures to perhaps hundreds of people.

Whatever the nature of the operation, the governing stature, or the contractual obligation may be, it is the common situation that there are important administrative aspects in implementing the applicable standards. Few users of ionizing radiation will find that the applicable regulatory or guiding instrument will be applied directly in his individual case. Almost without exception some modification, interpretation, selection, or emphasis will be necessary and must be provided before the standard can be implemented effectively and intelligently.

In the case of the modest user the maximum hazard may be both small and easily predictable. In such cases the user may elect to relate his performance directly to the language of the legal standards without establishing additional working limits of his own.

In the more typical situation the quantity and variety of radiation sources or the complexity of the facility is such that the radiation protection program is usually headed by a responsible radiological safety officer. This officer is responsible for assuring that the operating protection policies and practices of the installation are sound, and, with proper implementation assure that radiation exposures will remain within statutory and contractual requirements. The fully qualified radiological safety officer has expert knowledge of the history and development of the basic recommendations issued by such bodies as the NCRP and, therefore, is in a position to guide the radiological program by application of underlying philosophy and intent as well as by the terminology of the legal instruments.

The complex modes of exposure encountered in such installations often preclude a simple direct comparison to basic standards on a day-to-day basis at the operating level. It is often necessary, therefore, to set up in-plant stand-

ards and operational controls. Such local voluntary controls are responsive to the legal standards but characteristically are more stringent because of the potential for significant exposure and because of the complexities of converting different types of exposure to a common base. A few examples of the kinds of in-plant standards are—

(*a*) Limitations on the radiation exposure which may be received by a worker in any one administratively convenient or necessary unit of time shorter than the formal or codified time base. For example, to assure limitation of radiation dose to individuals to say 3 rems in 13 weeks, it is usually necessary to establish additional internal controls which limit dose to some fraction of 3 rems per week or per month.

(*b*) Requirements for the wearing of dosimeters, protective clothing, respiratory equipment, etc.

(*c*) Guides for the controlled release of radioactive effluents.

(*d*) Calibration requirements of radiation measuring instruments.

(*e*) Formal procedures for action in case of emergencies.

Only through the use of such inplant administrative standards is it practical to implement the generally accepted philosophy of minimizing exposure to radiation wherever possible. Control of this type would be difficult, if not impossible, to achieve under a direct and rigid application of many basic or codified standards.

In the situation where there are no statutory or contractual requirements and the user of ionizing radiation is being guided principally by the recommendations of the NCRP, he will usually have an internal set of standards which may deviate in part but require compliance with the general intent of the recommendations of the NCRP. In such cases the principal motivating force is in the quality and the value of the guidance which is offered by the standards. The high degree of voluntary acceptance of the recommendations of the NCRP and the ICRP over the last 30 years is an outstanding example of what can be achieved by the user having high confidence in standards which are offered for voluntary acceptance and application.

Another important administrative element is the establishment of a work climate and employee attitudes favorable to good radiological control. Written standards and procedures alone just do not give assurance that people will have the understanding to enable them consistently to do the right thing. Continuing education in the basic intent of protection standards is important.

The success of a radiation protection program is, therefore, usually dependent as much or more on the voluntary acceptance of a way of life as upon literal conformance to a rule.

PROBLEM AREAS IN INDUSTRIAL APPLICATION OF RADIATION PROTECTION STANDARDS

While the development and application of radiation protection standards for control of industrial exposure are not without problems, there are perhaps no current major problems in this area. Within this framework, however, I would like to mention several areas which contain the seed of future problems.

The transfer of certain regulatory responsibilities from the Atomic Energy Commission to the States of our Nation has only recently begun. In the States where this transfer has been effected or is close at hand, State regulations generally seek to assure the level of control provided in title 10 of the Code of Federal Regulations for application to licensees. In spite of the intent of all parties to maintain reasonable uniformity within the State regulations, there is considerable opportunity for inconsistencies, gaps, and overlaps between States and between State codes and Federal codes. Some of these, although relatively minor, have appeared. The potential problems which could be encountered by an industrial firm having atomic energy activities in several States, each with differing requirements, and also having licensee relationships and contractor relationships with the Atomic Energy Commission, are obvious. Some problems of reciprocity and jurisdiction have yet to be worked out to minimize the administrative problems of industrial firms.

Another problem in the development of radiation protection standards is the format and language of the standard itself. There are divergent viewpoints on the degree of specificity and methodology which should be contained in radiation protection standards. It is important that standards be written as performance standards, or functional specifications, not as a specific detailing of mechanistic or interpretive methods to be used. The radiation conditions encountered by various users in industry differ so markedly that a standard

which emphasizes method must necessarily fit poorly at one extreme or the other. Standards which define basic criteria, while permitting needed latitude in the methods employed, apply equally well to all users. Identifying end point, not method, is the key issue. The present efforts of the NCRP are concentrating on this point.

Related to the problems resulting from incorporating methodology into standards is the imparting of the same validity and weight of law into such secondary standards as is warranted in the case of primary or basic standards. As an example, in controlling the internal deposition of radioactive materials in humans the principal standard is the limitation of the amount of a radioactive material in an organ of interest. Since two principal modes of entry into the body are breathing and drinking, recommendations of the NCRP include a listing of permissible concentrations of radionuclides in air and water (9). Inclusion of such secondary standards as a guide to prudent operation is often helpful. Application of such secondary standards in a rigorous or statutory manner in lieu of assessment against primary dose standards can be unduly burdensome or expensive on the one hand, or not restrictive enough on the other hand, where biological concentrating mechanisms in the human food chain can intervene.

There is a natural tendency among the public and perhaps even in the courts to equate an exceeding of a specific permissible limit with injury to the recipient. Serious problems will result if radiation protection guides are erroneously used as criteria for determination of existence or extent of injury. Radiation protection standards in this country are not based on concepts of establishing permissible doses at levels just below the point of injury. Knowledgeable medical interpretations and decisions in the courts should provide adequate resolution of this potential problem.

As I understand the present efforts of the USPHS that agency is particularly cognizant of the problem of oversanctification of numerical limits and tends toward retrospective assessment of each case on its own merits. As seen by industry this approach, carried to the limit, would be untenable. Industry, and the public which attempts to judge its actions informally and fairly must have prospective targets. Unfortunately, a technology-based industry tends to equate prospective target with a go, no-go gage or the discrimination of black from white. One almost hears the modern Decatur exclaiming, "Our numbers, may they be always in the right, but our numbers, right or wrong." The two extreme positions are not yet reconciled.

With the principle of acceptable risk in radiation exposure, instead of black and white there is a definable black for significant overexposure, and below that, infinite gradations of gray down to but never quite reaching white. It is beyond the wit of man to quantify such a scale—there is, for example, no gray that is 10 times lighter or darker or grayer than another gray. Yet the attempt has to be made at least to define bands of gray. The three ranges as used by the Federal Radiation Council are precisely such an attempt which I would translate into color terminology as—

Range I: Arcadian gray.
Range II: Achillean gray.
Range III: Augean gray.

Public education on the acceptability of a given radiation risk or, pictorially, the interpretation of a particular gray is vitally needed. It cannot be achieved simply. Neither is it helped when prominent scientists, erroneously accepted by the public as expert in this particular field, express palpably different views on the prudence or radiation safety of actions or plans in the atomic energy field. Such differences come from socioeconomic rather than scientific interpretations. Here the Federal Radiation Council, more readily than the NCRP, could provide the Nation with authoritative or at least broadly considered value judgments.

In spite of these problems, on balance, radiation protection standards over the past 20 years do seem to have served this country well. Aggressive research in support of refined establishment of basic protection principles and standards and resourceful codification of these principles should permit this statement to be repeated 20 years hence. A very brief look at the industrial exposure experience is convincing that an effective set of controls has been in force throughout the rapid expansion of the atomic energy business in this country in the last 20 years.

INDUSTRIAL EXPOSURE EXPERIENCE

Although the employment of workers by industry engaged in the handling of large sources of radiation has expanded rapidly during the past 20 years, the present work force of some 200,000 (7) is still very small in comparison with that of the major industries. Nevertheless, a substantial experience record has been accumulated which attests to the exemplary success of the operators in minimizing radiation exposure through prudent engineering design and strict control. Quantitative assessment of the performance of the larger atomic energy sites is practical in four broad areas, viz:

(1) The magnitude of the exposure from external sources received by employees during the normal course of their work assignments.

(2) The small burden of radioactive materials which may be deposited in the bodies of the workers.

(3) The magnitude of the exposure received by persons who live in the vicinity of the plant.

(4) The frequency and severity of accidents which result from loss of control.

The first three classes of exposure can be compared with pertinent limits, and the accident experience can be followed as a trend.

Compilations of exposure records for recent years (table I) indicate that the vast majority of workers employed by AEC contractors receive a radiation dose of less than 1 rem per year. Only in very few cases (about 1 worker in 10,000) has the NCRP short-term control limit of 3 rems in 13 weeks been exceeded and invariably this has resulted from some sort of an accident rather than imprudent work assignments.

We were unable to make a comprehensive survey of the radiation experience of the whole of industry. While our information from industrial users is incomplete, in replies from representative major users covering about 30,000 people, the average annual radiation exposure in 1960 and 1961 was about 0.3 rem per person.

There is a widely used formula for the control of accumulated dose for an individual over the years, which is written (10)

$$MPD=5\ (N-18)\ \text{rems}$$

where MPD = maximum permissible accumulated dose, and

N is a number equal to the present age of the individual in years; (the formula begins to apply after age 18, the employment of minors below this age being avoided).

Among the group replying to our survey, including ourselves, only two cases showing accumulated doses exceeding the formula values appeared. Including all the radiation accident cases known to us, the total is less than 15; if our resources had been complete, the total would probably remain below 30. It is important to reiterate that many of these do not represent real injury to the recipients and some will be self-correcting as the respective values of N increase. To the best of our knowledge these cases are principally due to single large accidental exposures. We were not able to uncover any specific case in which an employee was in excess of this limit due to radiation received chronically in the course of his work.

There is very little public data available on the radiation control experience of the small users. Examination of the most recent data on licensee experience reported by the Atomic Energy Commission for about a 1½-year period ending November 30, 1961, gives some indication of the degree of control experienced by the small user. In this 17-month period during which about 10,000 licenses were in force, the great majority of the 40 radiation incidents reported were minor in nature. None of the incidents reported resulted in a serious level of radiation exposure.

Nationwide experience on internal deposition of radionuclides in industrial workers is not readily available in published reports but in our limited survey, there was a nearly complete absence of significant deposition cases. In our own experience at Hanford in 6,000 man-years of direct work with one of the most dangerous elements, plutonium, only three employees have acquired body burdens of plutonium which approximate or exceed the present applicable standards. The quantities involved are not expected to produce clinically observable symptoms and none have appeared.[3] Additionally, in about 75,000 man-years

[3] There is growing evidence that the present standard for plutonium, which is based on analogy with radium depositions, may have a very considerable safety margin.

of experience in working with other radionuclides at Hanford no internal depositions of radionuclides in excess of applicable permissible limits have occurred except for a few minor transitory cases involving materials with a short biological half-life.

The contribution made by industry to the radiation exposure received by the average persons living in the vicinity of the installations continues to be but a small fraction of that received from natural background and, for the most part, is overshadowed by the contribution from worldwide fallout. Although the average exposure from industry to the reproductive organs of a genetically significant population consisting of a few million people cannot be stated precisely, it must certainly be only some small fraction of 1 millirem per person per year. The dose from natural background ordinarily falls in the range of 100 to 200 millirems per year, and the gonad dose from fallout is probably on the order of 5 millirems per year at this time.

Situations may arise in the immediate vicinity of large atomic energy plants which lead to doses several times those which currently exist from fallout. Persons with uncommon food habits or other idiosyncrasies fall into this classification. Because of the relatively few individuals involved, somatic rather than genetic considerations of the significance of the exposures are appropriate. Estimates for such persons living in the vicinity of the Hanford project suggest that their doses may approximate 30 percent of the applicable limits.

The greatly expanding availability of whole body counters in the last few years has provided the technical means for measuring the radioactive body burdens in many cases with comparative ease. The present areas of uncertainty can be substantially reduced in the next few years.

Accidents associated with radiation sources range in severity from the minor spills of radioactive contaminants to serious nuclear excursions (criticality incidents) sometimes involving the loss of life. Because they are readily characterized and extensively reported, the frequency of occurrence of criticality type accidents can be watched as an indication of performance. Table II shows the experience in this country to date. Desirably there should be no accidents of this type. Realistically, some must be anticipated in an expanding technology which is heavily dependent upon new research and development. Within this framework the trend to date should not be viewed as unfavorable.

The feasibility and cost of maintaining appropriate levels of radiation protection are important factors in the ultimate development of a thriving atomic energy industry. In these phases we find nothing new to report. A good quality of protection is achievable, although not too cheaply, as long as the applicable basic limits continue to be more or less stable. There is no evidence which seems to call for a major change. Stiffening of some limits could cause considerable difficulty to the industry. It is more likely that some specific limits, for example, for plutonium deposition, may be demonstrated to have much more than ample safety margins. In any case, the organizations which provided data for our survey pointed to the need for sound basic standards unencumbered as far as possible by detailed administrative and procedural regulation. This is the avenue deemed most likely to provide the stimulus for innovation and improvement in radiation protection.

The careful control and work climate in atomic energy plants which is responsible for good radiological performance is also reflected in outstanding safety performance in other areas as well. This is evident from table III which compares the number of lost-time injuries from all types of accidents experienced by AEC contractors with similar experience by all industries. Continued performance of this type should lead to a better appreciation by the general public that atomic energy installations are among the safest of all industrial plants.

SUMMARY AND CONCLUSIONS

In brief summary, there has been no outstanding development or basic change with respect to radiation protection since 1960. The key questions identified in 1960 remain the key questions in 1962. (11) It is natural, then, that there has been no outstanding development or major change in the industrial situation with respect to radiation protection in this interval. Such minor changes as are reported are generally in the favorable direction. Exceptions are a growing concern over possible conflicts of interpretation where more than one group has real or implied authority to set standards, and most importantly an almost universally adverse reaction to such code and regulation as pinpoints specific methods and administrative procedures.

The recommendations of the National Committee on Radiation Protection and Measurements and the International Commission on Radiological Protection continue to be the bases of radiation protection standards and regulations in this country. Radiation protection standards have been, and appear to be, keeping pace with the growing needs of the atomic energy industry.

Expansion of NCRP considerations to cover emergency situations on the one hand, and more amplification of the broad aspects of group and population exposures on the other are favorable trends. The introduction of the range concept by the Federal Radiation Council is regarded by many as a start in getting away from the rigidity of specific control numbers.

The industrial exposure situation continues to be characterized by good compliance with current radiation protection standards for long-term radiation control. The serious accident experience does not show any unfavorable trends, and while there is room for improvement, the accident experience of the atomic energy industry compares very favorably with other elements of industrial safety.

Some minor difficulties principally associated with implementation of standards or codification of the basic principles of good practice into regulations have appeared and very likely will continue to appear. Some problems of jurisdiction and reciprocity will be difficult to avoid in the course of the transfer of regulatory responsibilities from the Atomic Energy Commission to individual States.

Not peculiar to industry's role, but nevertheless having substantial effect on the industrial climate, is an apparent lack of public understanding in depth of nuclear energy and its associated hazards. It appears that considerable effort will have to be expended before the potential hazards associated with sources of ionizing radiation can be viewed in perspective by the layman. Comprehensive hearings such as these and others conducted in the past by the Joint Committee are major factors in increasing public understanding of this complex subject of radiation protection in the atomic energy field.

APPENDIX

SOME FACETS OF INDUSTRIAL EXPOSURES EXPERIENCE

TABLE I.—*Exposures of contractor personnel to penetrating radiation, summarized for 1959 and 1960*

Range of annual total exposure in rems	1959 (13)		1960 (7)	
	Number of workers	Percent of total number of workers	Number of workers	Percent of total number of workers
0 to 1	71,630	94.73	77,522	94.31
1 to 5	3,912	5.17	4,629	5.63
5 to 10	66	.09	41	.05
10 to 15	2	<.01	2	<.01
Above 15	1	<.01	3	<.01
Total	75,611		82,197	

TABLE II.—*U.S. criticality accident experience (12)*

Year	Number of criticality accidents	Number of fatalities	Year	Number of criticality accidents	Number of fatalities
1945	3	1	1955	1	
1946	1	1	1956	1	
1947			1957	1	
1948			1958	2	1
1949	1		1959	1	
1950			1960	1	
1951	2		1961	2	3
1952	2		1962 through April	1	
1953					
1954	3		Total	22	6

TABLE III.—*Industrial injury frequency rates in number of lost-time injuries per million man-hours* (7), *1960*

Group:	
All industries	6.04
All AEC contractors	1.71
AEC operating contractors (excludes construction)	1.18

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Representative PRICE. Thank you, Dr. Parker.

Dr. Parker, on page 2 you state that the basis for most of the standards used today are the recommendations of the ICRP and the NCRP and that this situation is essentially unchanged today. What then is the role of such an agency as the FRC?

Mr. PARKER. This, sir, in no way downgrades the role of that very important body. I am separating rather, and perhaps even artificially, basic standards, the broad outlook on what has to be done in the technical area. You will recall previous discussions in which it is agreed that one never completely separates the technical area from other areas of judgment.

In the technical area the standards are still essentially those put together by these two bodies. We conceive a Federal Radiation Council role as continuing to apply value judgments which are indeed no less important than the basic technical judgments and making these available to the Nation.

As I mentioned in the script, sir, I received a very recent Report No. 3, and it is a very valuable contribution in this area in making value judgments relative to fallout.

Representative PRICE. You state on page 3 that the FRC Report No. 2 carries the promise of introducing much needed flexibility. In what way does it offer flexibility?

Mr. PARKER. I think it is conceived generally in the field that through this concept of the three ranges, one gets away from some earlier objections to what was wrongly interpreted but was interpreted as a rigorous edge-of-night limit; namely, the permissible limits of the NCRP for a specific situation, such and such a number would be a limit and beyond that is bad and below it is good, has been to some extent in the past a misinterpretation of the intent. By having these three ranges, there is introduced the thought that it is perfectly reasonable to go along with a situation in which the possible exposures being received may be creeping up, provided that the looking at it, namely, the measuring devices and controls which are stipulated along with the requirements for these range applications, are in proportion to the degree of exposure that may be being received.

Representative PRICE. You further state that the FRC Report No. 2 may have advantages for those working with modest amounts of one or two radionuclides. What are some of these advantages?

Mr. PARKER. This gets back to a point that I hoped to make clear in the script, sir. My report as a whole I would like to characterize as perhaps not fairly representing the problems and situations of the very small users, since we ourselves come in contact with this rather superficially. His situation is such that he cannot have his own specialist who can study and offer professional local judgments on interpretation of cases, or say an interpretation of what the three ranges of the FRC would mean. He has to have a textbook which gives him a number. I intended this reference in that sense.

Representative PRICE. On the bottom of page 4, when you are talking about NCRP Report No. 29 and the reference to emergency exposure, was this an outgrowth of the Windscale incident?

Mr. PARKER. No, sir. Dr. Taylor is in the room and is perhaps better qualified than I to particularize this. But I believe this work was primarily started in the interest of civil defense preparation in this Nation and was finally put together in the present form. I am stipulating here that it turns out, allowing a little leeway for interpretation, to be very useful in the industrial situation, and we have already had occasion ourselves so to use it. It was not specifically prepared for that case, as I see it.

Mr. RAMEY. Did you use that in the case of one of the emergencies at Hanford?

Mr. PARKER. In our recent critical incident it was extremely valuable, sir.

Representative PRICE. You refer to transfer of responsibility from the AEC to the State for certain radioactive materials. Do you foresee about 50 different State regulations in connection with this?

Mr. PARKER. I foresee more than one. Whether it will ever get to 50—I suppose one could make 50 different variations if you tried hard. I would see perhaps a dozen variations.

Representative PRICE. What is your own feeling on the matter? What do you think should be done in this area?

Mr. PARKER. I think one has to go in this direction and do what we can to get a common understanding later. This is partly dependent on the degree to which specific items are included in the final code or the extent to which you are willing to go back to basic principles. The basic principles are certainly intended to be the same in all cases, as I see these points.

The minor items to which I refer are indeed minor. One State, Kansas, I believe, has a regulation that characterizes dose in one calendar quarter, and another State would have a limitation on any consecutive 13 weeks. This is just an internal administrative nuisance rather than any reevaluation of the hazard to man.

Representative PRICE. Do you know when the AEC plans to bring their manuals up to date with respect to plans for revisions which must be made to reflect FRC guides for Federal agencies?

Mr. PARKER. I have no date on that, sir. I just mention in the script, as you say, that we understand from the Commission that it will more directly reflect in the next revisions, and perhaps Commission representatives could be more responsive to the timing.

Representative PRICE. On page 6 you mention a third group of radiation source users. What seems to be their safety record compared to the others you indicate?

Mr. PARKER. This is the group who were not covered by the Atomic Energy Act, sir. It is very difficult again. We have no comprehensive data which allows one to testify, and one goes by impression and conversation in meetings with this group. It is characteristic that those of us with the larger enterprises who have full-time staffs in this work tend to think that our controls are more successful than others. It would be rather peculiar if that were not the case. I do believe it is in that direction. The extent to which the situation could be considered bad in this third group, I do not know, and know of no real evidence which points to a poor situation.

Representative PRICE. In the charts that you displayed and particularly in table No. 2, you listed the U.S. criticality accident experience since 1945 up until April of 1962. You give the number of criticality accidents as 22 and the number of fatalities as 6. Is this a complete and accurate picture of the accident history of the AEC?

Mr. PARKER. To the best of my knowledge, sir, this table is intended to contain the total experience on criticality incidents. There can be other accidents.

Representative PRICE. Does this include the SL–1 accident?

Mr. PARKER. Yes; that would be included.

Representative PRICE. Including that, there is a total of only six fatilities in all the years of operation of the AEC.

Mr. PARKER. I looked at a chart this morning which would add one to this. I would like, perhaps, the liberty of submitting a second look at this particular number later, so that I do not actually misquote it. It is conceivable that it may be wrong by one.

Representative PRICE. If it is, will you correct this table?

Mr. PARKER. I will do that, sir.

Representative PRICE. The figure 22, is that absolutely actual for criticality accidents in the Atomic Energy program?

Mr. PARKER. These are supposedly my associate's counting of the published number of criticality accidents.

Representative PRICE. What is the nature of these accidents? The 22?

Mr. PARKER. They were wide and varied. The early ones occurring were manipulation of weapons parts. Others came from accidents with plutonium- or uranium-bearing solutions in various vessels spread around many of the principal sites of the Commission. The so-called Y–12 incident is in here. Many of the incidents at Los Alamos are included in here.

Representative PRICE. Will you be absolutely certain before we complete the record to have the accurate figures in here?

Mr. PARKER. I will see that the figures are reviewed and accurate figures given.

(The information requested follows:)

GENERAL ELECTRIC CO.,
ATOMIC PRODUCTS DIVISION,
Washington, D.C., June 7, 1962.

Hon. MELVIN PRICE,
Chairman of the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy, U.S. House of Representatives, Washington, D.C.

DEAR MR. PRICE: During the hearings on radiation protection before your committee on Wednesday, June 6, I was asked to give assurance of the completeness of a table II—U.S. Criticality Accident Experience, which appears in the appendix to my submitted material entitled "Radiation Protection Standards: The Industrial Situation."

The subject data were taken principally from reference 12 of my report which is "A Summary of Industrial Accidents in U.S. AEC Facilities," Division of Operational Safety, TID–5360 supplement 3, revised December 1961.

On page 7 of that document appears a listing of 21 criticality accidents divided into 4 categories, viz:

Metal systems in air	5
Solution systems	8
Inhomogeneous water moderated systems	5
Miscellaneous systems	3
Total	21

In transcribing these into the chronological table used in table II, an unaccountable error was indeed made. Instead of one incident each in the years of 1956 and 1960, the record should show two in 1956 and none in 1960.

I appreciate the opportunity to correct the record.

The total of 22 incidents given is believed to be correct. It adds the incident occurring at Hanford in 1962 to the previous list. This belongs in the "solutions systems" category.

As indicated in the hearing, the three fatalities in 1961 do refer to the SL–1 incident. Reference 12 does not in itself identify the number of fatalities. A separate check indicates that the total of six given in table II is correct to the best of our knowledge. I would appreciate being informed of any data which contraindicate this.

Very truly yours,

H. M. PARKER,
Manager, Hanford Laboratories.

Representative PRICE. What does this cover? It does not cover the whole area of the atomic energy program?

Mr. PARKER. This only covers a situation in which an accident occurred because a critical mass was brought together inadvertently.

Representative PRICE. It would not cover normal industrial accidents in atomic energy?

Mr. PARKER. No, sir. Only those in which a critical mass is accidentally brought together.

Mr. RAMEY. You would have other accidents that involved radiation spills, radiation burns, all these other things?

Mr. PARKER. They are accidents. The only reason for presenting the criticality experience was that this is the case which is supposed to be conclusively reported so that one could use it to measure trend. I intended to use this only to show the trend of accident experience. AEC reports include these days considerable reference to so-called radiation incidents which define and elaborate a broader class. We found no way of picking these up from all sources. They come only from the licensee sources.

Representative PRICE. On page 12 you refer to the retrospective method of operation by the Public Health Service and on the other hand the prospective target needs of industry. Will you elaborate on your statement concerning needs for reconciling these differences?

Mr. PARKER. Yes, sir. Please recall that this is a personal interpretation or conceivably a misinterpretation of what I think the Public Health Service is trying to achieve in this field. I think their posture is that they would like to have things go along and then step in from time to time and say, "We examine this case now and our analysis is thus and so." This may be good or it may be that you should not have gone this far. It is to that possibility that industry is properly very sensitive. Let us assume that industry is trying to make a proper showing in radiation control, then you have to do this at the beginning of any time period and not leave oneself subject to being told after the event that this was not very wise, that you should have done it some other way.

It is this telling us in advance what we should be shooting for that I am defining as the prospective target which we need and which the public needs in order to examine our performance against these targets.

Representative PRICE. You also touched on certain inconsistencies, although relatively minor, I think you said, that have appeared in the transfer from the AEC to the States of certain regulatory responsibility. What are some of these?

Mr. PARKER. I mentioned one already. If I may refer to notes, I would have a few more. This difference on the time base between Kansas, Illinois, and New York. These States have three different time bases for measuring their external exposure. The permissible concentrations of materials put into unrestricted waters differs in minor detail between the States of New York, New Jersey, and California. The amount of material exempt from registration differs over quite a remarkable range between the States of Kansas, Minnesota, and New Jersey.

The definition of radiation area is different in the New York Code from the recommendations of title 10 Code of Federal Regulations, section 20. Surprisingly, the alleged definition of the roentgen has three different appearances as between the codes of Florida, Illinois, and Kansas.

That covers the present differences, and perhaps with the exception of this rather wide range in exemption from registration, these are administrative nuisances at the present time.

Representative PRICE. The committee staff intends to make a study of the problems involved in terminology. We have been interested in this area for some time.

You mentioned the problem of reciprocity and jurisdiction that have yet to be worked out. How would this situation affect a company such as General Electric, or others, with divisions in many States?

Mr. PARKER. I think this affects part of such companies with which I have the least acquaintance. For example, one is manufacturing radiation emitting devices, and these are to be used against different codes. One has a problem of some magnitude conceivably with the writing of certain codes which could be insuperable. This is what one has in mind in part in this industrial problem. I don't profess to be directly concerned or acquainted with this aspect.

Representative PRICE. Are there any further questions?

If not, thank you very much. You made a fine statement and contributed a great deal to the committee's knowledge on the subject.

There is a quorum call in the House. I think we will take a recess for about 10 minutes.

(The subcommittee took a short recess.)

Representative PRICE. The committee will be in order.

The next witness will be Dr. Robert Hasterlik, of the Argonne Cancer Hospital, University of Chicago.

STATEMENT OF ROBERT J. HASTERLIK, M.D.,[1] PROFESSOR OF MEDICINE, UNIVERSITY OF CHICAGO, AND ASSOCIATE DIRECTOR, ARGONNE CANCER RESEARCH HOSPITAL, CHICAGO, ILL.

Dr. HASTERLIK. Mr. Chairman, members of the subcommittee, it is a pleasure and a privilege to appear again before this subcommittee. I have been asked to discuss with you today the somatic effects of radiation and to draw attention to developments in the field that have taken place since Dr. Austin Brues appeared before you in a similar capacity 3 years ago.

I shall attempt to limit my discussion to pertinent data derived from studies of man. Over the past many years you have, I am certain, become aware of the difficulties of applying data to man derived from studies done on the small experimental animal.

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Honorary societies: Phi Beta Kappa, 1934; Alpha Omega Alpha, 1938; and Scientific Research Society of America (RESA), 1950.
Military service: 1942–46, lieutenant (junior grade) to lieutenant commander, Marine Corps, U.S. Naval Reserve; active duty with the U.S. Navy; served at sea with the amphibious forces in the Pacific, and chief of medical services at the U.S. Marine Barracks, Klamath Falls, Oreg.
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The 1957 hearings introduced the argument concerning proportionality or linearity in dose-effect relationships and of the existence of a threshold for radiation effects. Dr. Brues' testimony in 1959 carried forward the argument and presented data from studies done on man, notably those of Dr. Alice Stewart, of Oxford University, those done on small experimental animals, especially those of Dr. R. H. Mole, of England, and of Dr. Arthur Upton, of the Oak Ridge National Laboratory. This subcommittee has been belabored over the years with evidence and arguments for and against the presence of a threshold and proportionality. The paper submitted in the 1959 hearings by Dr. Brues, "Critique of the Linear Theory of Carcinogenesis," summarizes succinctly the viewpoint of many.

Have data been developed during the past 3 years from human sources which may shed more light on the area of somatic effects, especially proportionality and threshold? I wish I could say today that I am able to present data which would ease the lot of this subcommittee and of all committees and persons concerned with the long-range effects of ionizing radiation delivered at low-dose rate over long periods of time.

During the past 3 years no data have accumulated, which could strengthen convictions concerning the presence or absence of proportionality and threshold. We must again state as was stated in the 1959 summary of the hearings—

> and here again, it was pointed out, no experiments aimed at observing these biological effects have ever been conducted at radiation levels very close to natural background. As before, all conclusions based on experimental or clinical data use data obtained at higher radiation levels.

Let us now review some of the recent developments in the field. The work of Dr. Alice Stewart in England, and discussed in 1959, suggested that children who received whole body radiation in the range of 1 to 10 roentgens before birth, while the mother was receiving X-rays to the abdomen for pelvic measurements, and so forth, had about twice the incidence of cancer or leukemia than did children whose mothers were presumed to have received no abdominal irradiation during pregnancy. Specifically, Stewart's group found a higher frequency (13.7 percent) of diagnostic X-ray abdominal exposures in mothers of children dying from cancer than in mothers of control children (7.2 percent).

Four similar retrospective studies have been carried out in this country. One of these is in line with the observations of Stewart and others. Three other studies do not bear out these observations. Of prime importance in retrospective studies is the choice of the control group. This has varied for the most part, in all of these studies done retrospectively, nor do they differentiate clearly between the apparent increased incidence of leukemia and (*a*) the effects of ionizing radiation and (*b*) the effect of the medical conditions which prompted the original abdominal X-ray examination of the mother, or of other diseases of the mother occurring during the pregnancy.

An extensive and important prospective study of the incidence of leukemia in children irradiated in utero during the course of abdominal or pelvic X-ray examination of the mother was published by Court Brown, Doll & Hill, in 1960.

Information was obtained from eight British hospitals about 39,166 liveborn children whose mothers were known to have been subjected to abdominal or pelvic irradiation during their pregnancy in the years 1945–56. The children who died of leukemia in this group were discovered by comparing their names with the list of names of all children dying of leukemia in Britain between 1945 and 1958.

In the irradiated group, nine were discovered to have died of leukemia before the end of 1958. The expected number, derived from age specific mortality tables, was estimated to be 10.5. In this study there would not appear to be a disproportionate occurrence of leukemia among children irradiated before birth. The published data on the leukemogenic effect of irradiation in utero would therefore seem to be conflicting and the earlier reported increased incidence of leukemia in children thus irradiated not established. However, it must be stated that the data of Court Brown and others do not disprove Stewart's thesis.

What human data are available which might shed light on the relationship of chronic irradiation of the skeleton by bone-seeking radioelements to the induction of tumors? The committee, I hope, will pardon me if I quote from work carried out at the Argonne Cancer Research Hospital and the Argonne National Laboratory by Drs. Asher Finkel, Charles Miller, and myself.

These studies represent the first fruits of a renewed effort to study as many radium-containing individuals as possible, chosen because of occupational or medical history alone and not primarily because of the presence of symptoms. During the past 4 years, 264 persons formerly employed in the radium watch dial industry, or as radium chemists, or who received radium as a form of medical therapy, have been sought out, found, and measured for radium content. Of these, 233 represent cases previously unreported in the literature, the remainder are earlier cases recently restudied. Approximately 400 women who worked as radium dial painters at some time in the past live in the environs of Chicago.

This study, however, has concerned itself almost exclusively with those women whose occupational history antedated 1925. Among the reasons involved in the decision to study the pre-1925 group first were the observation by us that radium burdens were higher in the early group, the longer period during which their skeletons have been irradiated (greater than 36 years), and the older age of the group, which made necessary their early study before attrition from the diseases of aging reduced the number available for study.

Of the 264 persons whose body radium content has been accurately determined, it has been possible to complete detailed radiographic studies of the entire skeleton of 236. Parenthetically, may I add that two other research groups in the United States are at present carrying on similar studies of former radium dial painters; one at the Massachusetts Institute of Technology, and the other at the New Jersey State Department of Health.

The objectives of our group include the correlation of body content of radium to certain destructive changes in the bone, to tumors of bone and other structures surrounded by bone, and to the incidence of leukemia.

Of the 264 persons measured, the following is a listing of the numbers in each radium content group.

	Persons
<0.001 microcurie	23
0.001 to 0.01 microcurie	36
0.01 to 0.1 microcurie	102
0.1 to 1 microcurie	62
>1 microcurie	41

A total of 164 persons were measured whose radium contents were grouped in order of magnitude below and above the present occupational permissible level of 0.1 microcurie (μc). Of these, 151 were studied radiographically. In the range 0.01 to 0.1 microcurie, 80 out of 90 failed to show bone lesions, 8 had minimal, and 1 lesions of moderate severity. None had advanced lesions or malignancies. Of 62 persons measured in the range of 0.1 to 1 microcurie, 61 were radiographed. Of these, only 25 had no bone lesions; 13 had minimal; 9 mild; 9 moderate; and 5 advanced lesions. In this radium content range, three persons had malignant neoplasms.

Above 1 microcurie, 40 of 41 persons measured were radiographed. Of the 40 persons, 28 had advanced bone lesions. Of these, 14 had malignant neoplasms. Only 12 of the 40 persons had lesions of moderate or lesser severity.

An analysis of malignant neoplasms has been done both in the present group of persons reported and also in those other radium-bearing patients whom members of our group have had the opportunity to study to some lesser degree. A total of 24 persons developed malignant neoplasms out of approximately 300. In our group the lowest terminal body content at which a malignancy was seen was 0.45 microcurie; the highest, 6.8 microcurie.

No myeloid leukemias have been seen in the patients currently under study. A review of death certificates of former dial painters in the Chicago area turned up two listed as "splenic leukemia" in the early 1930's. By good fortune we were able to find and study the original blood smears made in 1931 on one of these two patients and are able to confirm the diagnosis of acute myeloid leukemia. The other "splenic leukemia" remains unconfirmed.

May I say parenthetically that in the past when people have talked about the radium dial painters, it has been stated that no leukemias were seen. I think we must now say that we can confirm the presence of one case of myeloid leukemia.

Representative PRICE. Were there any cancer cases found in the radium dial painters?

Dr. HASTERLIK. Yes, sir.

Representative PRICE. You cover that in your statement?

Dr. HASTERLIK. Yes, sir; there is a total of 17 malignancies.

Representative PRICE. But it is covered in your statement?

Dr. HASTERLIK. Yes, sir.

What dose-effect relationships can we tentatively draw from these studies? And they are tentative and very rough estimates. In the body content range between 1 and 10 microcuries we have a total of 41 persons with about 1,300 man-years irradiation experience. The probability per man-year of exposure—14 malignancies in this group—is thus about 1.06 times 10^{-2}. If we plot our only other point—that of the 2,200 man-years irradiation experience in the 0.1 to 1.0 microcurie

range—with our three malignancies—we have a probability of about 1.34 times 10^{-3}. Now let us make the usual worst assumption; namely, that the relationship at all dose levels is linear and that there is no threshold and let us extrapolate points at the lower body contents; namely, at 0.01 to 0.1 microcurie and at 0.001 to 0.01 microcurie. It can be seen that we would need at least 140 cases with 36 years' irradiation in order to just see one tumor above the natural incidence. We have 102 persons in this group. We would need at least 1,500 cases to see one tumor at 0.001–0.01 microcurie. We have only 36 cases in this group. From the number of persons available for study in the United States by the three groups it may be possible to add one more point at the 0.01 to 0.1 microcurie range.

There are probably not enough persons available in the world who carry a body burden of radium at the 0.001 to 0.01 microcurie range to make possible a determination of this point on our dose-malignant effects chart. However, these studies may lend confidence in the permissible body burden for radium at the occupational level.

They may at some time in the future make it possible to add another point on the chart at one order of magnitude below the occupational level of 0.1 microcurie. These studies represent the largest body of data on the long-term effects of bone-seeking radioelements in man. The number of persons available for study who carry a significant body burden of radium—that is, between 0.001 and 0.1 microcurie—is so small in relation to the number necessary to see one tumor above the natural incidence—making the most pessimistic assumptions concerning radiation tumorigenesis—that it would seem impossible to derive from these studies meaningful estimates of the risk of tumor induction in the human from the other bone-seeking radioelements, notably Sr^{90}, at levels of Sr^{90} present today in our skeletons and anticipated from future weapons tests.

What other human data exist which might aid in our understanding of radiation-induced neoplasia? Several studies have been carried out and others are now underway on the relationship of irradiation of the mediastinal structures in childhood and the subsequent development of leukemia and other tumors.

Some investigators have found an increased incidence of leukemia in children given radiation to the thymic area whereas others have not. Of prime importance, but infinite difficulty, is the selection of a satisfactory control group. The studies of Simpson and Hempelmann and others would indicate an increased incidence of both leukemia and other malignancies in 2,393 such treated children.

Most of the other excess malignancies were of the thyroid gland and occurred in children given 200 roentgens or more. Unfortunately, this study cannot as yet differentiate between the association of leukemia and either thymic enlargement or exposure to X-rays. Other studies fail to demonstrate an increased incidence of leukemia in these irradiated children, although several studies showed an increased incidence of thyroid neoplasia.

These data, while suggestive of heightened radiosensitivity of the thyroid for tumor induction in early life, are at present inadequate for the purposes of either establishing the presence or absence of a threshold or linearity of response. Moreover, the comparison of fallout radioiodine irradiation of the thyroid of children with the response noted in these clinical studies cannot be made. In the case of radio-

iodine deposition the thyroid alone is being irradiated—with a minute contribution of total-body irradiation from the radioiodine gamma rays—whereas in the case of thyroid cancer induction following mediastinal irradiation, significant irradiation of many other structures, probably including other endocrine glands, especially the hypophysics occurs at the same time.

During the past 3 years no significant body of data has been developed which throws light on the question of shortening of lifespan following total-body irradiation at low dose rates.

Studies will continue and be extended both in this country and abroad on the long-term effects of ionizing radiation on man. This is proper and important in spite of the fact that we already know as much or more about the toxicity of ionizing radiations than we do about almost any other toxic material in our present complex environment.

In conclusion, I would like to state my belief that the human studies underway and contemplated will not answer the important questions of linearity and threshold at doses and dose rates near, or a factor of a few higher than, background radiation levels. They may yield some answers concerning specific organ and age sensitivities to ionizing radiation.

Large-scale small experimental animal studies will continue to play their role in extending the range of our information concerning linearity and dose-rate dependency in these particular species. In the last analysis, our most important information will come from fundamental studies on the nature of the carcinogenic process.

Representative PRICE. Thank you very much, Dr. Hasterlik.

On page 4 you state that the data of Court Brown and others do not disprove the Stewart thesis. Why do you say that?

Dr. HASTERLIK. If you will note on page 3, Court Brown and others did the study of those 39,166 children whose mothers were irradiated between 1945 and 1956. The studies on the incidence of leukemia run between 1945 and 1958. A very considerable portion of the children studied had a very short life experience before the study terminated. I don't remember exactly the numbers, but it seems that something of the order of two-thirds of the children studied were less than 10 years of age at the termination of the study.

We do know that some of the cases of leukemia may develop at times later than 1958. So I believe that it is too early to say that the data are all in on this study. Besides, the number of cases here, the 9 cases, is very small compared with the expected 10.5. The numbers are small, and the probability of it not being a significant figure exists. I think it is an important study. These prospective studies are very important. I think it tends to help overcome a little of the uneasiness we all felt from the results of the Stewart studies, but I also must say it does not disprove Dr. Stewart's thesis completely.

Representative PRICE. You state that a total of 24 persons develop malignancies out of 300. In your group the lowest terminal body content at which a malignancy was seen was 0.45 microcurie. The highest was 6.8 microcuries. Are not these above the permissible level?

Dr. HASTERLIK. These are certainly above the occupational permissible level for radium. The present occupational permissible level

is a tenth of a microcurie. This is the working or occupational permissible level.

Representative PRICE. What do you estimate the original levels or average levels to have been?

Dr. HASTERLIK. Some early estimates would seem to indicate that they were probably a factor of 50 to 100 times as high as these later numbers. I think a reasonable number—and some animal data that will be presented in the immediate future by Finkel and Miller would make it seem that perhaps they are only a factor of 20 higher. But this would bring them up considerably higher than the present occupational permissible level.

To answer your question specifically, the levels might have been as high as 90 to 100 microcuries at the time these persons were working, or they might have been as low as 10 microcuries at the time the people were working.

Representative PRICE. How much of a bone exposure do you estimate was received by these persons?

Dr. HASTERLIK. It is not possible to answer that question, sir. If you want to estimate an average dose from all the forms of radiation, the beta, alpha, and gamma, I could give you a range from a few hundred to several hundred thousand rads in the same individual, depending on radiation dose to individual cells or a smoothed-out general distribution. I don't think a number is meaningful in this case. It is, however, a large radiation dose.

Representative PRICE. On page 8 you state it may be possible to add to the three groups referred to, one more point at the 0.01 to 0.1 microcurie range. Do the other groups have bone cancer cases at 0.01 to 0.1 micorcurie range?

Dr. HASTERLIK. No, sir.

Representative PRICE. They do not?

Dr. HASTERLIK. No, sir.

Representative PRICE. You state that most of the other excess malignancies were of the thyroid gland and occurred in children given 200 roentgens or more. Have all of the thyroid cases died?

Dr. HASTERLIK. None have died, sir.

Representative PRICE. Dr. Dunham stated in his testimony that they had responded fairly well to treatment and they evidently have.

Dr. HASTERLIK. Yes. Some of them have been treated with radioiodine.

Representative PRICE. On page 10 you state that no significant data in the last 3 years throw light on the question of shortening of lifespan following total body irradiation at low dose level rates. What do you recommend we do along research lines which might accelerate our progress for this or other important questions to be resolved?

Dr. HASTERLIK. I think studies, as I intimated, will have to go forward on this question in the small experimental animal because of the small numbers of individuals irradiated. The largest population group that one could possibly study exists in the State of Kerala in India where there are perhaps 100,000 people who have from 10 to 30 times the lifetime radiation exposure dose we have. The numbers there are also possibly too small to derive meaningful estimates of shortening of lifespan. In addition, the problems of infectious dis-

eases there are so great that they make difficult or impossible the sorting out of any specific effects of irradiation on life shortening.

I see very little probability of deriving data from human studies. I think in this area we will have to depend on large-scale small animal studies.

Representative PRICE. Mr. Ramey?

Mr. RAMEY. Are you getting anywhere with your research on dogs using strontium 90?

Dr. HASTERLIK. I am not involved in that at all, sir.

Mr. RAMEY. That is being conducted at Argonne?

Dr. HASTERLIK. At the Argonne National Laboratory. I am not involved in that.

Mr. RAMEY. I understand that.

Dr. HASTERLIK. I think that is getting underway at the present time.

Mr. RAMEY. How about their studies on water that is highly radioactive, relatively speaking?

Dr. HASTERLIK. Yes. As you know, there are areas in the State of Illinois where the drinking water is a factor of 10 to 50 times as high as Lake Michigan water. I think about 75,000 people drink this water. I do not think one can say much about any possible effects on these people because a complete study has not been done.

A first look has been made on the incidence of malignancies in that portion of the State. This is difficult because, again, of the usual problem we run into—the validity of the death certificates. Dr. Auerbach at the Argonne National Laboratory made a study on this point alone. I don't think we can answer this question.

Representative PRICE. What element is in the water?

Dr. HASTERLIK. Radium 226. This is naturally occurring radium 226. Lockport, Joliet, and some of the communities lying south of that extending toward Springfield draw their water from wells that go 2,000 feet deep. Surface waters have radium contents equivalent to Lake Michigan water. The deep well water radium content is considerably higher. This comes from a stratum in Canada.

Mr. RAMEY. I don't know whether this is in this bailiwick, either. I think in some of our earlier hearings mention was made of studies of AEC and contractor employees on their history as to the relative incidence of tumors and other things as a statistical study. Possibly Dr. Dunham reported on that a few years ago. Has anything happened in that study?

Dr. HASTERLIK. I know nothing about this.

Representative PRICE. Dr. Dunham is still with us. Maybe he would want to comment on it.

Dr. DUNHAM. That particular study showed no increased incidence at all. On the other hand, it is a highly selected population. Dr. Dunning may have some further data. I think there were some studies done at Oak Ridge.

Mr. RAMEY. It actually showed a lower incidence, but it was a younger population.

Dr. DUNHAM. That is right. It was a highly selected population, so I don't think it would be fair to draw any conclusions.

Representative PRICE. Thank you very much, Dr. Hasterlik. You have given us a fine paper, and I am sure it will be valuable to the record of this hearing.

Dr. HASTERLIK. Thank you very much.

Representative PRICE. The next and concluding witness for this afternoon will be Dr. H. Bentley Glass, of Johns Hopkins University.

STATEMENT OF H. BENTLEY GLASS,[1] DEPARTMENT OF BIOLOGY, JOHNS HOPKINS UNIVERSITY

Dr. GLASS. Mr. Chairman, members of the committee, I feel it is a privilege to appear here again before this committee, whose previous hearings have contributed so greatly to knowledge of the problems, including the genetic problems, of radiation.

I believe I am expected to summarize whatever developments have occurred since the hearings of 1959 in our understanding of the genetic effects of radiation and fallout. In certain respects this task has been greatly simplified for me by the 1960 report of the National Academy of Sciences Committee on the Genetic Effects of Atomic Radiation, of which I am a member. This report was itself designed to update the earlier report of that committee, dating from 1956. The 1960 report clearly indicates that the NAS Committee saw no reason to modify its basic conclusions or to alter its chief recommendations. The geneticists still hold that any amount of ionizing radiation, however small, increases the risk of harmful mutations arising in the reproductive cells. It still recommends that all exposures to ionizing radiations be avoided whenever possible, except for necessary exposures for medical or dental diagnostic or therapeutic reasons. It further holds to the recommendation that average dose received by the reproductive organs of any person during the first 30 years of life "should not exceed 10 roentgens of manmade radiation, and should be kept as far below this as is practicable." This recommendation is in essential agreement with that of the International Commission on Radiological Protection.

Since the earlier hearings before this committee there has been less dosage from ionizing radiations than was formerly estimated, but

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Degrees and honors: Baylor University, A.B., 1926; M.A., 1929; LL.D., 1958. University of Texas, Ph. D., 1932. Washington College, Sc. D., 1957. National Academy of Sciences; American Academy of Arts and Sciences.

Teaching career: Timpson High School, Timpson, Tex., 1926–28; Stephens College, Columbia, Mo., 1934–38; Goucher College, Baltimore, Md., 1938–47; Johns Hopkins University, since 1947; professor of biology, since 1952.

Subsidiary activities: Editor, Quarterly Review of Biology; advisory editor for biology, Houghton Mifflin Co.; editor, Survey of Biological Progress, vols. 3 and 4; coeditor, McCollum-Pratt Symposia, nine volumes; member, Board of School Commissioners, Baltimore City, 1954–58; member, Advisory Committee on Biology and Medicine, Atomic Energy Commission, 1955–56; member, National Academy of Sciences Committee on the Genetic Effects of Atomic Radiation, 1955– ; member, Governor's Advisory Committee on Nuclear Energy, Maryland, 1959– ; member, Committee on Science and Technology, Democratic Advisory Council, 1959–60; member, Continuing Committee, Pugwash Movement, 1958– ; national lecturer, Sigma Xi Society, 1958–59.

Offices: American Association for the Advancement of Science, board of directors, 1959–62; vice president and chairman of section F (zoology), 1956; editorial board, 1948–58. American Association of University Professors, president, 1958–60. American Society of Naturalists, secretary, 1950–52. Biological Abstracts, director, survey of biological abstracting, 1952–54; trustee, 1954–60; president, 1958–60. American Institute of Biological Sciences, president, 1954–56; chairman, biological sciences curriculum study, 1959– . American Civil Liberties Union, Maryland branch, president. Genetics Society of America, vice president, 1960. Conference of Biological Editors, chairman, 1957–59. Phi Beta Kappa, senator, 1961–67.

Publications: "Genes and the Man," 1963; "Forerunners of Darwin," 1959 (coeditor and contributor); "Science and Liberal Education," 1960; over 175 scientific, professional, and general articles.

that has been offset by other evidence of greater exposure or additional types of genetic damage which were previously not reckoned with. One could refer, for example, to the data from the two sizable populations living today which were subjected to intensive radiation; namely, the survivors of Hiroshima and Nagasaki. Whatever information is extractable from the two Japanese populations has been carefully collected and analyzed, in particular, possible changes in the sex ratio of infants born to irradiated parents.

From the nature of sex determination in the human species, it is to be expected that an irradiated male parent will on the average produce fewer daughters than sons, while an irradiated female parent will on the average produce fewer sons than daughters. Precisely these deviations in the sex ratio have indeed been found, indicating that radiation-induced mutations have slightly but significantly altered the prenatal viability of the young. However, the determination of the doses to which the individual parents were exposed is still very problematical; and there are many other conditions which may influence the sex ratio. It may be that studies of the mortality of the children born to irradiated persons would throw more light on the production of mutations that lower the viability or fertility of the affected children; but such studies must be prolonged for many years to come before death or sterility might become evident, and there is also an almost insuperable difficulty in finding a truly comparable control group to provide a baseline, to tell us what should be expected in the absence of irradiation of the population.

Surveys have been started of the populations living on the radioactive sands and soils of Kerala Province in India and in interior Brazil. Beyond preliminary radiation measurements and preparation of plans for the medical and genetic analysis of these populations, little progress has been made, however. A major difficulty will be that of finding comparable populations living on unradioactive soils to serve as controls and provide a baseline for evaluation of effects.

To the geneticist, however, there is nothing very discouraging about the prospect of having to turn to experimentally controlled organisms in order to get answers to questions such as we are posing. During the past 6 years a truly stupendous breakthrough has occurred in our knowledge of the chemical nature of the hereditary material. It has been shown not to be protein but to consist, in all organisms, of nucleic acid. In most living things, except for a few viruses, it is even the same kind of nucleic acid, known as deoxyribose nucleic acid, or DNA.

The chemical structure of this material is now well known, its chemical behavior outside the living system has been studied extensively, and it is known to behave qualitatively, if not quantitatively, alike in the face of radiation or chemical mutagenic agents, no matter whether it comes from microbe, man, or mouse. It is no longer relevant to say, as so many have said in the past when faced with unpleasant facts about the production of harmful mutations by radiation, "Well, a man is not a mouse, or a fruit fly, or a microbe." The genes produce different effects in the course of the life of different kinds of organisms, but the chemical nature of the genes is the same, their responses to radiation are of the same kind, and they evoke their effects in the same way, by controlling the synthesis of the proteins made in the cells. Thus, when ionizing radiation strikes

the DNA molecules of a cell, it can be demonstrated to have a comparable action in all cases. It fractures and disrupts the chromosomes which contain the DNA; it blasts the genes, usually with destructive effects; and it causes chromosomes to stick together and fail to enter the daughter cells properly, at the time when the parent cell is dividing.

We may expect to find differences, mainly quantitative ones, in the responses to radiation of different species. For that matter, it is now quite clear that the DNA and the chromosomes of the fruit fly's spermatozoa are not at the same level of susceptibility as those in the oocytes of the female fruit fly during her maturity. It is also true that the DNA and the chromosomes in the immature germ cells are far less susceptible to radiation than those in the mature germ cells. So it is not surprising to find that the reproductive cells of a mouse are more susceptible than those of a fruit fly, as indeed they are. What we need is more information of this sort from a variety of animal species; but the longer the animals live, and the fewer offspring each female can produce, the more laborious and expensive the experiments must be. The Atomic Energy Commission, Division of Biology and Medicine, is now supporting an experimental genetic study of mutation in irradiated pigs, but as may well be imagined, progress is slow and the expense is high.

We may be able to get at direct evidence of production of mutations in humans by radiation and of the quantitative level at which mutations are produced in relation to dosage. By growing human cells in artificial culture media and exposing them to ionizing radiation, a number of workers—Puck and Bender in this country, and Dubinin and his group in Russia—have demonstrated that the chromosomes are fractured and rejoined in various ways, and the number of chromosome breaks is linearly proportional to the dose. This has been demonstrated over a range from 10 roentgens up to several hundred roentgens. Moreover, the number of breaks produced by a given dose in human cells may be compared with the number produced by the same dose in comparable tissue cells of a monkey, mouse, or hamster. Bender has recently reported the results of irradiating with X-rays white blood cells freshly drawn from the human body, and then culturing them long enough to determine the frequency of chromosome breaks in these cells. A linear proportionality between frequency of breaks and radiation dose is demonstrated.

In my own laboratory, J. G. Brewen has used the corneal epithelium of the hamster for similar experiments, irradiating the tissue in its natural location in the eye, and again finds a range of doses from 25 to 150 roentgens yields linear proportionality of chromosome breaks to dose.

Since the 1960 report of the National Academy of Sciences Committee on the Genetic Effects of Atomic Radiation, a quite new aspect of the problem has come into prominence. In 1959 it was discovered in France and Great Britain that most of mongoloid idiocy are attributable to the presence in the cells of an extra chromosome, a very small one, No. 21 among the 23 pairs of human chromosomes. Shortly afterward, two forms of sexual maldevelopment accompanied by sterility were discovered to arise, the one from the presence of an extra sex chromosome, the other from the lack of a sex chromosome normally

present. Ever since 1915, abnormalities of this same kind had been known in fruit flies and had been found to be increased in frequency by radiation. They have also been described more recently in connection with certain abnormal types in mice.

These errors of chromosome number, which might be called a sort of mutation, arise in two general ways. The commonest is probably what is called nondisjunction; that is, the failure of two matched chromosomes to separate from each other and go singly into the reproductive cells. The result would be formation of one reproductive cell with an extra chromosome and another with one chromosome too few. The other way in which such errors arise is through the loss of the chromosome from the fertilized egg.

Recent studies at the Oak Ridge National Laboratory by Liane Russell and C. L. Saylors show that when a sperm of the mouse is irradiated, it is usually this second sort of error that occurs, 100 roentgens yielding 5.2 percent of cases of loss of the sex chromosome from the newly fertilized egg, but only about 0.2 percent when the sperms are irradiated before fertilizing the egg. Losses of other chromosomes than the sex chromosomes are fatal in early development in the mouse and presumably in humans losses of most chromosomes except the sex chromosomes and the smaller chromosomes of other sorts are likewise fatal. Many are now known to cause multiple congenital defects resulting in neonatal death.

In any event, in addition to the previous estimates of mutations arising from a given dose of radiation, we must now add something for this novel and previously unsuspected type of human damage. At the present time one cannot say how many mongoloid idiots and sexual aberrant types have been produced by radiation. It may indeed be a small proportion of the total. Yet until we know more about the relation of these conditions to radiation dosage, we must be exceedingly cautious, for there is no reason to doubt that radiation will cause such defects, particularly if administered to the female or her just-fertilized egg cell.

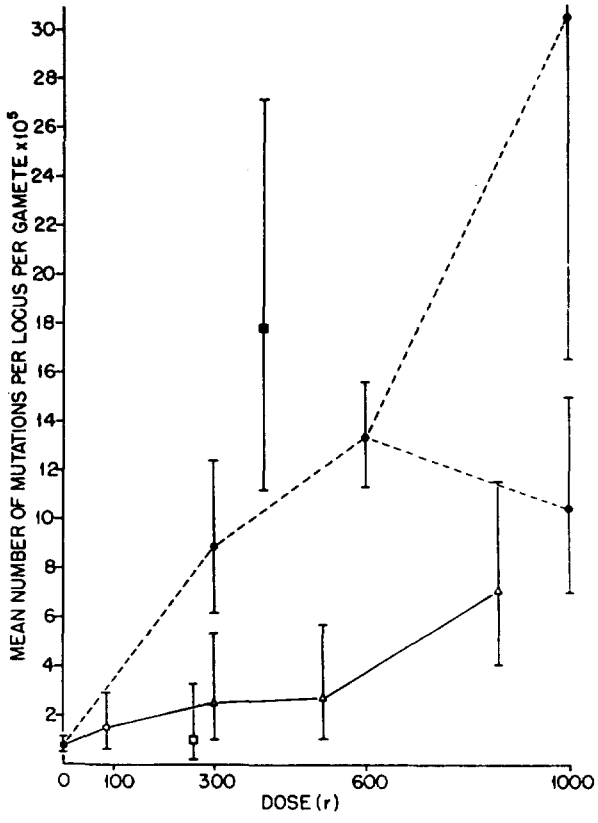
Until quite recent years all radiation exposures in genetic investigations were for some reason restricted to males. Gradually evidence began to accumulate from fruit fly experiments to show that just as there are differences in sensitivity between immature and mature reproductive cells in a single sex, so, too, there are differences in sensitivity to radiation between the male and female reproductive cells.

W. L. Russell at Oak Ridge has now obtained information bearing on the production of mutations in the oocytes of female mice. Although the data are still insufficient or scanty, it appears at present that at a high dose rate—80 to 90 roentgens per minute—the female germ cells are more sensitive than spermatozoa, whereas at a low dose rate—90 roentgens per week—they yield even fewer mutations than the male germ cells do. Moreover, there is some indication that the mutations in the female germ cells differ qualitatively from those in the male germ cells. Clearly, if an adequate idea of the sensitivity of a population to radiation is to be obtained, we will need to have sufficient data on both sexes and for the entire lifespan.

The most unexpected and most discussed development during these recent years in the study of mutations produced by radiation has been the demonstration by W. L. Russell and his Oak Ridge colleagues

that in mice there is definitely a difference in the frequency of mutations induced at high dose rates and at low dose rates. The difference as might already be gathered from the foregoing remarks, is greater in the case of the female germ cells, the oocytes, than it is in the case of the male germ cells, the spermatogonia. In the latter, for which much more extensive data have been accumulated, there are about four times as many mutations induced at a high dose rate as at a low dose rate.

The data of Russell and his group are shown in the accompanying figure. The range of dose is from zero to 1,000 roentgens. The curve obtained for the high dose rate runs up to a rate of 30 mutations per



Mutation rates of specific loci in the mouse, with 90 per cent confidence intervals. Solid points represent results with acute x-rays (80 to 90 r/min). Open points represent chronic gamma-ray results (triangles and square, 90 r/wk; circle, 10 r/wk.) Square points are mutation rates in females, all other points being mutation rates in males. The point for zero dose represents the sum of all male controls.

Source: Data from W. L. Russell, Liane Brauch Russell, and Elizabeth M. Kelly, 1959. Reproduced by permission of the authors from "Immediate and Low Level Effects of Ionizing Radiations," a special supplement to the International Journal of Radiation Biology.

locus per 100,000 gametes—the curve at low dose rate runs up to 6 mutations per locus per 100,000 gametes. They have not tested it to quite as high a dose. In the female sex they have only really tested, or at least published, on two doses, one of 400 roentgens at the high dose rate, and one of 250 roentgens at the low dose rate, so that the difference between the effect of a high dose rate and the low dose rate in the female germ cells is apparently greater than it is in the male reproductive cells. The data on the male germ cells are much more extensive. For both sexes taken together the yield at the high dose rate is about six times as great as at the low dose rate.

The most recent experiments, of which I have received a report just over the past weekend from Dr. Russell, have refined the definition of "high dose rate" and "low dose rate" and reveal a situation of increasing complexity. Initially 90 roentgens per minute and 0.009 roentgen per minute were used for the high and low dose rates, respectively. The quality of the radiation used was also different, 250-kilovolt X-rays for the high dose experiments and cobalt 60 gamma radiation for the low dose rate. But in experiments in which a high dose rate and low dose rate were both administered from the same source, any significant difference owing to the quality of the rays was ruled out.

The new tests have been conducted at intermediate dose rates of 9 roentgens per minute and about 0.8 roentgen per minute. These prove to be in the right critical range. For the male germ cells, the mutation rate at 9 roentgens per minute is intermediate between the results at high and low dose rates. At 0.8 roentgen per minute the mutation frequency is already that characteristic for a low dose rate.

In the case of the female germ cells, the situation appears to be somewhat different. The 0.8 roentgen per minute rate still yields an intermediate frequency of mutations. Obviously, the situation is quite complicated and a good deal more study will need to be done to clarify it completely.

I would like to emphasize that in terms of human exposure 0.8 roentgen per minute is not exactly what one would consider a very low dose rate, since at that rate it would require only 12 to 13 minutes to equal the level which was set by the NAS Genetics Committee as an upper limit for the average gonadal dose.

Work to confirm these results of Russell and his group has not gone very far at the present time. Some work has been done with Drosophila, but the results are conflicting. There is, I am told, a study at Harwell in England on mice which has given preliminary results that confirm the effect for the mice. There is also one at Harwell conducted for the fruit flies which confirms the dose rate effect.

In the mouse it is impossible without vast expense and labor to test the mutation rate for doses much lower than 86 roentgens. We still must resort to the fruit fly for study of very low doses. In my own laboratory we have recently completed a 3-year study of the mutation frequency produced by a dose of only 5 roentgens to the mature male and female germs cells, which is, I believe, the lowest dose studied for its mutagenic effect in any animal up to this time. Dominant mutations of a particular minute bristle type were studied, and a total of 1,360,948 individual flies descended from parents which had received a 5-roentgen dose of X-rays were scored. We called this a megafly

experiment. There were 50 separate replications of the experiment, each of exactly balanced irradiated and unirradiated control cultures and each replicated experiment coded so that the scorers were unaware which series had been irradiated.

The number of mutations found in the irradiated series exceeds that in the controls by slightly more than was originally predicted on the basis of the mutation frequency at doses of a thousand roentgens and above. The difference is statistically significant, so that one may conclude that even doses of 5 roentgens produce mutations at a frequency falling right on the linearly proportional dosage curve. There is no sign of a threshold or of a diminishing effectiveness at low doses.

Sterility, or loss of fertility through killing of germ cells or the production of dominant lethal effects that kill the offspring, may also represent genetic effects. In the Drosophila experiments with 5 roentgen doses, it was found the irradiated parents produced significantly fewer offspring than the unirradiated control parents of the same strain, bred in the same number and under the same conditions. The reduction amounted to slightly more than 1 percent. Even low doses may, therefore, produce a proportional reduction of fertility.

In mice the situation is quite different and seems to be more complicated. In male mice, following doses of 100 roentgens or more, temporary sterility results. But after passage of sufficient time, the fertility is recovered. In female mice the reverse is true. After acute radiation, a female mouse may produce one or a few litters, but even a dose of 50 roentgens leads generally to permanent sterility. If the radiation is administered at a low dose rate, it takes only a moderate increase to 80 roentgens to produce the same effect.

If human females responded to radiation in this way, the sterilizing effect of radiation would be the most fearful aspect of exposure to fallout and residual radiation among survivors of a nuclear attack on a population.

Studies at the Oak Ridge National Laboratory by the Russells and their coworkers, especially E. F. Oakberg, clarify certain aspects of this situation. Female guinea pigs and hamsters, as well as monkeys, are much more resistant than female mice to the sterilizing effect of radiation. It seems that in the female mice the oocytes in the ovary go into a prolonged arrest in development at a more sensitive stage in their maturation process than is the case in the guinea pig. This difference probably holds true for the other species mentioned and also for the dog and human female, for which evidence exists that sterility in the female is produced only by much higher doses.

Nevertheless, a word of caution seems due. It has been estimated that in the event of a nuclear attack on the United States of 3,000 megatons or more, most survivors will receive an accumulated dose from fallout of upward of 200 roentgens, most of it in the postshelter period and at relatively low dose rates. Under these conditions the major effect upon the surviving population might result from the sterilizing effect upon the females.

We need much more information about this matter than now exists, in particular to determine whether the dose level that produces complete or partial sterility at low dose rates is significantly lower than the dose level that produces radiation sickness and death.

Since the time of the last hearings on fallout before this committee, much attention has been centered on the hazards posed by the production of carbon 14 as a product of nuclear detonations. No exact appraisal of this hazard can be given at the present time, but it is clear that estimates of genetic damage must be revised upward because of the ready incorporation of carbon 14 into living tissues and into the hereditary materials themselves, and because of the long half-life of carbon 14.

The recently issued new edition of "The Effects of Nuclear Weapons" places the dosage of emitted beta radiation from carbon 14 as equal to that from cesium 137, although delivered at a very much lower dose rate; and the genetic damage from transmutation of carbon 14 into nitrogen 14 as equal to that from the emitted beta radiation. I see no reason to differ with these estimates.

There are other recent findings which increase our estimates of genetic damage done by atomic radiations. At the Oak Ridge National Laboratory, D. L. Lindsley has shown that in the fruitfly many lethal mutations remain undetected in the usual method of screening for sex-linked recessive lethals. Estimates of the total number of lethal mutations produced by a given dose thus need to be increased by 20 percent. Findings such as this one and the role of carbon 14 in the production of genetic damage tend to offset the reduction in the estimates of overall genetic damage which derive from the knowledge that low dose rates, with which we must be mainly concerned, are much less potent in producing mutations than the high dose rates commonly used in the past in experimental investigations.

In conclusion, I think it might be worth while to say a word about the genetic damage done by fallout from weapons tests or possible nuclear attacks upon the United States. I do not feel it advisable now to engage in the sort of "numbers game" that has been played in the past. It seems important to me to emphasize the vast range of uncertainty embodied in such estimates, an uncertainty extending over two orders of magnitude, or a hundredfold difference. Insofar as the effects being compared are produced by radiation at a low dose rate and are linearly proportional to dose, it is sufficient to keep in mind that the average accumulated fallout dose from weapons tests through 1959 to persons in the United States is estimated to be 0.15 roentgen, lifetime dose. (The new edition of "The Effects of Nuclear Weapons" states the dose as 0.1 rem.)

From this figure, taking the higher one, resulting from some 92 megatons of fission explosion, one can extrapolate to the fallout exposure for a similarly housed and unprotected population in the event of 1,500, 3,000, 10,000 megatons, or larger attacks or wars. Depending upon the assumptions as to the relative proportions of fission and fusion, one can calculate fallout doses to target nations rather inexactly and to nontarget nations more exactly.

It is worth emphasizing that the calculated dose from stratospheric fallout to a nontarget nation located in the Northern Hemisphere in the zone of heaviest deposition, between latitudes 30° and 60°, amounts to about 10 to 12 roentgens in the case of a 20,000-megaton war of which 50 to 60 percent might be fission. In other words, a nuclear war of such magnitude as to suffice to devastate the United States, the U.S.S.R., and all of Western Europe, would produce fallout that would only equal or slightly exceed in terms of its genetic

effect upon nontarget nations of the Northern Hemisphere what has been recommended as an upper limit for tolerable exposure of a population to manmade radiation.

This 10 roentgens of whole body radiation at a low dose rate would, if administered to an entire population, produce a change in the number of genetically defective individuals born alive. At the present time this is estimated to be probably 4 percent of all births. (That estimate is somewhat higher than what is used in the recent Federal Radiation Council paper, because they considered only very severe defects, and this estimate is for all grades of evident defect. My figure is based on the United Nations Scientific Committee report on "The Effects of Genetic Radiation.") A 10-roentgen dose to a population might increase the freqency of genetically defective persons born in that population from 4 to 5 percent, or perhaps less. This would not occur until many generations have passed, and if the exposure were limited to a single generation, the level would gradually drop back again to the original level of 4 percent. Even if the doubling dose, that is, the dose of radiation which would double the total number of mutations occurring spontaneously in the population, turned out to be as low as 10 roentgens instead of the value of 40 to 60 which was assumed in making that calculation, one would still not expect the level of genetically defective births in a population exposed to 10 roentgens to rise above 8 percent of all births.

This is a frightful conclusion, and yet it is nevertheless in a certain sense somewhat reassuring if applied to the genetic effects of a major nuclear war.

Finally, I would like to emphasize a point made in the 1960 report of the NAS Genetics Committee respecting the extent of damage in human populations due to unfavorable mutant genes. The damage is not simply a question of the frequency of these genes. It also depends on the relative amounts of harm they do to individuals and to society. As the report states: "How, for example, does one measure quantitatively the relative importance of a stillbirth, a feeble-minded child, and a death during adolescence?" Or, one might add, of a death very soon after conception, when the mother is often unaware that an abortion has occurred? In this connection I can only recommend for study the thought-provoking appraisal of the question by Prof. Sewall Wright, which was printed as an addendum to the 1960 report of the NAS Committee. All members of the Committee were not in agreement with Wright in his considerations, but all of them, I think, are fully agreed that much study of this sort is needed before we can reach a just appraisal of genetic damage to a population.

Representative PRICE. Thank you very much, Dr. Glass, for a very effective paper. Incidentally, the entire statement will be included in the record.

(The statement follows:)

STATEMENT OF H. BENTLEY GLASS, PROFESSOR, DEPARTMENT OF BIOLOGY, JOHNS HOPKINS UNIVERSITY, BALTIMORE, MD.

I believe I am expected to summarize whatever developments have occurred since the hearings of 1959 in our understanding of the genetic effects of radiation and fallout. In certain respects this task has been greatly simplified for me by the 1960 Report of the National Academy of Sciences Committee on the Genetic Effects of Atomic Radiation, of which I am a member. This report was itself designed to update the earlier report of that Committee, dating from 1956.

The 1960 report clearly indicates that the National Academy of Sciences Committee saw no reason to modify its basic conclusions or to alter its chief recommendations. The geneticists still hold that any amount of ionizing radiation, however small, increases the risk of harmful mutations arising in the reproductive cells. It still recommends that all exposures to ionizing radiations be avoided whenever possible, except for necessary exposures for medical or dental diagnostic or therapeutic reasons.. It further holds to the recommendation that the average dose received by the reproductive organs of any person during the first 30 years of life "should not exceed 10 roentgens of manmade radiation, and should be kept as far below this as is practicable." This recommendation is in essential agreement with that of the International Commission of Radiological Protection.

From the nature of sex determination in the human species, it is to be expected that an irradiated male parent will on the average produce fewer daughters than sons, while an irradiated female parent will on the average produce fewer sons than daughters. Precisely these deviations in the sex ratio have indeed been found, indicating that radiation-induced mutations have slightly but significantly altered the prenatal viability of the young. However, the determination of the doses to which the individual parents were exposed is still very problematical; and there are many other conditions which may influence the sex ratio. It may be that studies of the mortality of the children born to irradiated persons would throw more light on the production of mutations that lower the viability or fertility of the affected children; but such studies must be prolonged for many years to come before death or sterility might become evident, and there is also an almost insuperable difficulty in finding a truly comparable control group to provide a baseline, to tell us what should be expected in the absence of irradiation of the population.

Surveys have been started of the populations living on the radioactive sands and soils of Kerala Province in India and in interior Brazil. Beyond preliminary radiation measurements and preparation of plans for the medical and genetic analysis of these populations, little progress has been made, however, A major difficulty will be that of finding comparable populations living on unradioactive soils to serve as controls and provide a baseline for evaluation of effects.

To the geneticist, however, there is nothing very discouraging about the prospect of having to turn to experimentally controlled organisms in order to get answers to questions such as we are posing. During the past 6 years a truly stupendous breakthrough has occurred in our knowledge of the chemical nature of the hereditary material. It has been shown not to be protein but to consist, in all organisms, of nucleic acid. In most living things, except for a few viruses, it is even the same kind of nucleic acid, known as deoxyribose nucleic acid, or DNA. The chemical structure of this material is now well known, its chemical behavior outside the living system has been studied extensively, and it is known to behave qualitatively, if not quantitatively, alike in the face of radiation or chemical mutagenic agents, no matter whether it comes from microbe, man, or mouse. It is no longer relevant to say, as so many have said in the past when faced with unpleasant facts about the production of harmful mutations by radiation, "Well, a man is not a mouse, or a fruit fly, or a microbe." The genes produce different effects in the course of the life of different kinds of organisms, but the chemical nature of the genes is the same, their responses to radiation are of the same kind, and they evoke their effects in the same way, by controlling the synthesis of the proteins made in the cells. Thus, when ionizing radiation strikes the DNA molecules of a cell, it can be demonstrated to have a comparable action in all cases. It fractures and disrupts the chromosomes which contain the DNA; it blasts the genes, usually with destructive effects; and it causes chromosomes to stick together and fail to enter the daughter cells properly, at the time when the parent cell is dividing.

We may expect to find differences, mainly quantitative ones, in the responses to radiation of different species. For that matter, it is now quite clear that the DNA and the chromosomes of the fruit fly's spermatozoa are not at the same level of susceptibility as those in the oocytes of the female fruit fly during her maturity. It is also true that the DNA and the chromosomes in the immature germ cells are far less susceptible to radiation than those in the mature germ cells. So it is not surprising to find that the reproductive cells of a mouse are more susceptible than those of a fruit fly, as indeed they are. What we need is more information of this sort from a variety of animal species; but the longer the animals live, and the fewer offspring each female can produce, the more laborious and expensive the experiments must be. The Atomic Energy Commis-

sion, Division of Biology and Medicine, is now supporting an experimental genetic study of mutation in irradiated pigs, but as may well be imagined, progress is slow and the expense is high.

We need direct evidence of the production of mutations in humans, and of the quantitative level at which mutations are produced in relation to dosage. Indirectly, we may be able to get at this. By growing human cells in artificial culture media and exposing them to ionizing radiation, a number of workers (Puck, Bender, Dubinin, et al.) have demonstrated that the chromosomes are fractured and rejoined in various ways, and that the number of chromosome breaks is linearly proportional to the dose. This has been demonstrated over a range from 10 roentgens up to several hundred rotentgens. Moreover, the number of breaks produced by a given dose in human cells may be compared with the number produced by the same dose in comparable tissue cells of a monkey, mouse, or hamster. Bender has recently reported the results of irradiating with X-rays white blood cells freshly drawn from the human body, and then culturing them long enough to determine the frequency of chromosome breaks in these cells. A linear proportionality between frequency of breaks and radiation dose is demonstrated. In my own laboratory we have used the corneal epithelium as the chosen tissue for such experiments, since in this case it is easy to irradiate the cornea in the living animal and also to irradiate the corneal cells growing in a cell culture, and then to determine whether there is any difference in response as the result of growing the cells outside the body.

In preliminary results obtained with the Chinese hamster, a strictly linear proportionality between frequency of chromosome breakage and X-ray dose has been demonstrated when the cornea was irradiated in its normal situation, for a range of doses from 25 roentgens up to 150 roentgens. There are thus excellent prospects that in a few years we may have definite quantitative knowledge about the relation of chromosome breakage to dose for a variety of human tissues. So far, no one has succeeded in culturing human reproductive cells, or even pieces of the ovaries or testes, for a sufficient period. Yet it may be hoped that studies on the relationship of chromosome breakage to dose of radiation can eventually be carried out successfully for the reproductive tissues, too.

Cells in which chromosomes are broken by radiation nearly always die. Consequently, such damage in a proliferating tissue (one in which the cells are dividing and in which the dying cell can be replaced by new sound ones) is not serious at low doses of radiation. The genetic damage that is serious is what is transmissible to cells that can continue to live and function and, if reproductive cells, participate in the production of offspring that will carry the mutated gene. Submicroscopic lesions in the chromosomes, our so-called point mutations, may also eventually be studied in cells growing in culture. What is necessary is to find a mutation that will produce some kind of chemical or structural alteration which can be observed in the individual cell, or to find some way of killing off the unmutated cells in the culture so as to leave only the mutated ones. Studies such as these are being pursued in a number of laboratories, including my own, and maybe success is around the corner for someone in this elusive pursuit.

Even since the 1960 report of the NAS Committee on the Genetic Effects of Atomic Radiation a quite new aspect of the problem has come into prominence. In 1959 it was discovered, in France and Great Britain, that most cases of mongoloid idiocy are attributable to the presence in the cells of an extra chromosome, a very small one (No. 21 according to size) among the 23 pairs of human chromosomes. Shortly afterward two forms of sexual maldevelopment, accompanied by sterility, were discovered to arise, the one from the presence of an extra sex chromosome, the other from the lack of a sex chromosome normally present. Ever since 1915 abnormalities of this same kind had been known in fruit flies and had been found to be increased in frequency by radiation. They had also been described more recently in connection with certain abnormal types in mice. These errors of chromosome number, which might be called a sort of mutation, arise in two general ways. The commonest is probably what is called nondisjunction, that is, the failure of two matched chromosomes to separate from each other and go singly into the reproductive cells. The result would be formation of one reproductive cell with an extra chromosome and another with one chromosome too few. The other way in which such errors arise is through the loss of a chromosome from the fertilized egg. Recent studies at the Oak Ridge National Laboratory by Liane B. Russell and C. L. Saylors show that when a male mouse is irradiated, it is usually this second sort of error that occurs, 100 roentgens yielding 5.2 percent of cases of loss of the sex chromosome from the

newly fertilized egg, but only about 0.2 percent when the sperms are irradiated before fertilizing the egg. Losses of other chromosomes than the sex chromosomes are fatal in early development in the mouse, and presumably in humans losses of most chromosomes except the sex chromosomes and the smaller chromosomes of other sorts are likewise fatal (dominant lethals). Many are now known to cause multiple congenital defects resulting in neonatal death. In any event, to the previous estimates of detrimental mutations produced by ionizing radiations we must now add something for this novel and unsuspected type of human damage. At the present time one cannot say how many mongoloid idiots and sexual aberrant types have been produced by radiation. It may indeed be a small proportion of the total. Yet until we know more about the relation of these conditions to radiation dosage, we must be exceedingly cautious, for there is no reason to doubt that radiation will cause such defects, particularly if administered to the female or her just-fertilized egg cell.

Until quite recent years nearly all radiation exposures in genetic investigations were for some reason restricted to males. Gradually evidence began to accumulate from fruit fly experiments to show that just as there are differences in sensitivity between immature and mature reproductive cells in a single sex, so too there are differences in sensitivity to radiation between the male and female reproductive cells. W. L. Russell has now obtained information bearing on the production of mutations in the oocytes of female mice. Although the data are still insufficient, it appears at present that at a high dose rate (80 to 90 roentgens per minute) the female germ cells are more sensitive than spermatozoa, where as at a low dose rate (90 roentgens per week) they yield even fewer mutations than the male germ cells do. Moreover, there is some indication that the mutations in the female germ cells differ qualitatively from those in the male germ cells. The frequencies at different gene loci, among the seven tested loci, are different in the male and female data. Clearly, if an adequate idea of the sensitivity of a population to radiation is to be achieved, we will need to have sufficient data on both sexes and for the entire lifespan. We are far from reaching any such goal at present, even for that most intensely studied species, the fruit fly *Drosophila Melanogaster*.

The most unexpected and most discussed development during these last years in the study of mutations induced by radiation has been the demonstration by W. L. Russell and his Oak Ridge colleagues that in mice there is definitely a difference in the frequency of mutations induced at high dose rates and at low dose rates. The difference, as might already be gathered from the foregoing account, is greater in the case of the female germ cells, the oocytes, than in the case of the male germ cells, the spermatogonia. In the latter, for which which mutations induced at a high dose rate as at a low dose rate. For both sexes taken together, the yield at high dose rate is about six times as great as at a low dose rate. The most recent experiments have refined the definition of "high dose rate" and "low dose rate" and reveal a situation of increasing complexity. Initially, 90 roentgens per minute and 0.009 roentgen per minute were used for the respective high and low rates. The total dose administered was of course adjusted to be the same. The quality of the radiation was different, since in the high dose rate experiments 250-kilovolt X-rays were used while in the low dose rate experiments cobalt 60 gamma radiation was used; but in experiments in which a high dose rate and a low dose rate were both administered from the same source, any significant difference owing to the quality of the rays was ruled out. Now tests have been conducted at intermediate dose rates of 9 roentgens per minute and about 0.8 roentgen per minute. These prove to be in the critical range for the dose rate effect. For the male germ cells, the mutation rate at 9 roentgens per minute is intermediate between the results at high and low dose rates. At 0.8 roentgen per minute the mutation frequency is already that characteristic for a low dose rate. In the case of the female germ cells, however, the 0.8 roentgens per minute rate still yields an intermediate frequency of mutations. It should perhaps be emphasized that in terms of human exposure 0.8 roentgen per minute is not what one would consider a very low dose rate, since at that rate it would require only 12 to 13 minutes to equal the level recommended by the NAS Genetics Committee as an upper limit for the average gonadal dose.

Russell's data indicate that for low to moderate dose rates there is some sort of recovery process such that potential mutations are restored to normal. This is very encouraging, from the point of view of the exposure of human populations of radiation, since most exposures are likely to be at moderate to low dose rates if the exposed person survives at all. It must be very strongly emphasized,

however, that there is no ground, on the basis of Russell's data, for concluding either that the relation of mutation frequency to dose is not one of linear proportionality or for concluding that there is any threshold at very low doses. In both of these important matters, the data show precisely the contrary. For the low dose rates, the frequency of mutations still increases linearly with the dose. There is no indication of a threshold. A total dose of only 86 roentgens at a low dose rate produced exactly the expected frequency of mutations.

Efforts to confirm this important finding of a difference in the effects of high and low dose rates applied to the immature germ cells of the mouse have been made. Work with *Drosophila*, carried out by Muller, Oster, and Zimmering, leaves the issue uncertain because of difficulties in dosimetry, although the first reports indicated a confirmation of the effect. It is reported that a similar experiment conducted at Harwell has confirmed the dose rate effect for *Drosophila*.

In the mouse it is impossible without vast expense and labor to test the mutation rates for doses much lower than 86 roentgens. For this kind of experiment we must resort to using a species that can be raised more cheaply and in far greater numbers, such, for example, as the fruit fly. In my own laboratory we have recently completely a 3-year study of the mutation frequency produced by a dose of only 5 roentgens to the mature male and female germ cells. This represents, I believe, the lowest dose studied for mutagenic effect in any animal up to this time. During the early days of the Manhattan project a team of expert geneticists spent several years in pushing the dosage curve for mutation down, first to 50 roentgens and finally to 25 roentgens. To those levels the dosage curve was shown to be strictly linear. The present study carries the dose relationship down to a level comparable to that of the normal human 30-year dose from background radiation. In order to carry out this study, dominant mutations of a particular minute bristle type occurring at some 60 genetic loci in the chromosomes were resorted to, instead of the usual recessive lethal mutation technique, which requires breeding a culture for every tested germ cell. In our recent study, 1,360,948 individual flies descended from parents each of which had received a 5 roentgen dose of X-rays were scored. There were 50 separate replications of the experiment, each of exactly balanced irradiated and unirradiated control cultures and each coded so that the scorers were unaware which series had been irradiated. The number of mutations found in the irradiated series exceeds that in the controls by slightly more than was originally predicted, on the basis of the mutation frequency at doses of 1,000 roentgens and above. The difference is statistically significant, so that one is entitled to conclude that even doses of 5 roentgens produce mutations at a frequency falling right on the linearly proportional dosage curve. There is no sign of a threshold or of diminishing effectiveness.

Sterility, or loss of fertility through killing of germ cells or the production of dominant lethal effects that kill the offspring, usually at a very early stage of development, may also represent genetic effects, although they are often not passed down beyond the immediate progeny of the treated individuals. In the *Drosophila* experiments with 5-roentgen doses, just described, it was found that the immediate parents produced significantly fewer offspring than the unirradiated control parents of the same genetic strain, bred in the same numbers and under the same conditions. The reduction amounted to slightly more than 1 percent. Even low doses may therefore produce a proportional reduction of fertility. In mice, however, the situation is quite different, at least in the female sex. In male mice, following doses of 100 roentgen or more, temporary sterility results; but after passage of sufficient time for the more sensitive spermatozoa, spermatids, and cells in the maturation divisions to be replaced by cells that were in the more resistant spermatogonial (immature) stages when they were irradiated, fertility is recovered. In female mice, the reverse is true. After acute radiation, a female mouse may produce one or a few litters, but even a dose of 50 roentgen leads generally to permanent sterility. If the radiation is administered at a low dose rate, it takes only a moderate increase (to 80 roentgen) to produce the same effect. If human females responded to radiation in this way, the sterilizing effect of radiation would be the most fearful aspect of exposure to fallout and residual radiation among the survivors of a nuclear attack on a population. Studies at the Oak Ridge National Laboratory by the Russells and their coworkers, especially E. F. Oakberg, now clarify certain aspects of this situation. Female guinea pigs and hamsters, as well as monkeys, are much more resistant than female mice to the sterilizing effect of radiation. It seems that in the female mice the oocytes in the ovary

go into a prolonged arrest in development at a later and more sensitive stage in their maturation process than is the case in the guinea pig. This difference probably holds true for the other species mentioned, and also for the dog and human female, for which evidence exists that sterility in the female is produced only by much higher doses (several hundred roentgens). Nevertheless, a word of caution seems due. It has been estimated that in the event of a nuclear attack on the United States of 3,000 megatons or more most survivors will receive an accumulated dose of upward of 200 roentgens, most of it in the postshelter period and at relatively low dose rates. Under these conditions, the major effect upon the surviving population might result from the sterilizing effect upon the females. We need much more information about this matter than now exists, in particular to determine whether the dose level that produces complete or partial sterility, at low dose rates, is significantly lower than the dose level that produces radiation sickness and death.

Killing of the sensitive female germ cells might not be attributable to the effects of the radiation on the chromosomes and DNA of the cells. Killing of many types of somatic cells, however, has been shown by T. T. Puck, M. A. Bender, and others to be mainly because of damage done to the chromosomes and genes; in other words, damage to the heredity material which is present in every cell and not solely in the reproductive cells. The target of the radiation is the same in the case of different kinds of cells, but the transmissibility of the damage depends on something else. To be transmissible, a defect must first of all be produced in the hereditary material of a reproductive cell; and, second, it must not be so severe as to cause the death or total incapacity of the reproductive cell to function. Total reproductive damage includes the nontransmissible (sterility) effects as well as the transmissible, hereditary effects.

Since the time of the last hearings on fallout before this committee, much attention has been centered on the hazards posed by the production of carbon 14 as a product of nuclear detonations. No exact appraisal of this hazard can be given at the present time, but it is clear that estimates of genetic damage must be revised upward because of the ready incorporation of carbon 14 into living tissues, and into the hereditary materials themselves, and because of the long half-life of carbon 14. The recently issued new edition of "The Effects of Nuclear Weapons" places the dosage of emitted beta radiation from carbon 14 as equal to that from cesium 137, although delivered at a very much lower dose rate; and the genetic damage from transmutation of carbon 14 into nitrogen 14 as equal to that from the emitted beta radiation. I see no reason to differ with these estimates.

There are other recent findings which also increase our estimates of genetic damage done by atomic radiations. At the Oak Ridge National Laboratory, D. L. Lindsley has shown that many lethal mutations remain undetected in the usual method of screening for sex-linked excessive lethals. Estimates of the total number of lethal mutations produced by a given dose thus need to be increased by 20 percent. Findings such as this one and the role of carbon 14 in the production of genetic damage largely offset the reduction in the estimates of overall genetic damage which derive from the knowledge that low does rates, with which we must be mainly concerned, are so much less potent in producing mutations than are the high dose rates commonly used in experimental investigations.

In conclusion, how can we evaluate the genetic damage done by fallout from weapon tests or possible nuclear attacks on the United States. It seems to me more than ever sensible not to play the "numbers game" in which so many, including myself, have indulged at times. In any case, I could not challenge the numbers previously presented to this committee in its hearings of 1959. The important matter, it seems to me, is to recognize the vast range of uncertainty embodied in the figures, and extending over two orders of magnitude (a hundredfold difference between the lower and higher limits of uncertainty around the most probable figure). Insofar as the effects being compared are produced by radiation at a low dose rate and are linearly proportional to dose, it is sufficient to keep in mind that the average accumulated fallout dose from weapon tests through 1959 to persons in the United States is estimated to be 0.15 roentgen (lifetime dose). (The new edition of "The Effects of Nuclear Weapons" states the dose as 0.1 rem.) From this figure, resulting from some 92 megatons of fission explosion, one can extrapolate to the fallout exposure, for a similarly housed and unprotected population, in the event of 1,500 megatons, 3,000 megatons, 10,000 megatons, or larger attacks or wars (two-way affairs). Depending upon the assumption as to the relative proportions of fission and fusion in the

total detonations, one can calculate fallout doses to target nations (rather inexactly) and to nontarget nations (more exactly). It is worth emphasizing that the calculated dose from stratospheric fallout to a nontarget nation located in the Northern Hemisphere in the zone of heaviest deposition, between latitudes 30° and 60°, amounts to about 10 to 12 roentgens in the case of a 20,000-megaton war of which 50 to 60 percent is fission. In other words, a nuclear war of such magnitude that it would suffice to devastate the United States, the U.S.S.R., and all of Western Europe, and to kill a majority of the populations of those countries, would produce fallout that would only equal or slightly exceed, in terms of its genetic effect upon nontarget nations of the Northern Hemisphere, what the Genetics Committee of the National Academy of Sciences has recommended as an upper limit for tolerable exposure of the population to manmade radiation.

What would 10 roentgens of whole body radiation at a low dose rate bring about genetically, if administered to an entire population? Estimates based on the so-called doubling dose, a dose of radiation that would double the frequency of spontaneous mutation occurring from all causes. This concept must be interpreted with great caution. Since different sorts of genetic effects occur spontaneously at different rates, they must each have a different doubling dose. If a particular kind of mutation has a very low spontaneous occurrence, its doubling dose will be very small; if the spontaneous rate is high, the doubling dose will be high. For example, in my *Drosophila* experiment, described above, the doubling dose for the dominant minute-bristle mutations is 60 roentgens. For chromosome breaks in the white blood cells irradiated by Bender in freshly drawn blood the doubling dose is less than 1 roentgen. The only significance of the doubling dose arises if it is in some way integrated over all types of transmissible hereditary defects, that is, all detrimental mutations, and if it is in some quantitative way related to the genetic burden of detrimental genes carried by the population and responsible for the current and future emergence of genetic defects in individuals. For transmissible gene mutations in most species that have been studied, the doubling dose falls in the range of 30 to 80 roentgens, with 40 to 60 roentgens more common. One cannot assert positively that such a value applies to human beings, but there is no reason to suppose that it does not. One would therefore conclude that a 10-roentgen dose to an entire population might produce one-fourth to one-sixth of the number of harmful mutations occurring spontaneously per generation. The number of genetically defective individuals born alive probably amounts to 4 percent of all births (an estimate somewhat higher than that used in the NAS Committee report of 1956 and based on the tabulation of specific hereditary traits and their estimated incidences given in the "Report of the United Nations Scientific Committee on the Effects of Atomic Radiation in 1958," annex H). By a recognized genetic principle, a doubling of the mutation rate will in time lead to a doubling of the amount of evident genetic defect in the population. That is, a 10-roentgen dose to a population might increase the frequency of genetically defective persons born in that population from 4 to 5 percent or somewhat less. This would not occur until many generations have passed, and if the exposure were limited to a single generation the level would gradually drop back again to the original level.

Even if the doubling dose for transmissible defects produced by mutations turned out to be as low as 10 roentgens, one would not expect the level of genetically defective births to rise above 8 percent. This frightful, yet nevertheless somewhat reassuring conclusion about the genetic effects of a major nuclear war on nontarget nations, even in the Northern Hemisphere, deserves in my estimation to be more widely circulated and appreciated.

Finally, I would like to emphasize a point made in the 1960 report of the NAS Genetics Committee respecting the extent of damage in human populations due to unfavorable mutant genes. The damage is not simply a question of the frequency of these genes. It also depends on the relative amounts of harm they do to individuals and to society. As the report states it: "How, for example, does one measure quantitatively the relative importance of a stillbirth, a feebleminded child, and a death during adolescence?" Or, one might add, of a death very soon after conception, when the mother is often unaware that an abortion has occurred? In this connection I can do little more than recommend for study the thought-provoking appraisal of the question by Prof. Sewall Wright, printed as an addendum to the report. All members of the committee were not in agreement with Wright in his considerations, but all, I think, are fully agreed that much study of this sort is needed before we can reach a just appraisal of genetic damage to a population.

Representative PRICE. On page 1 you mention the newer findings have in fact reinforced your convictions concerning the complexity of radiation effects along with additional evidence of genetic effects of low doses of radiation, and demand a spirit of caution and reserve. Are you referring to the latest findings indicated in the recent FRC report?

Dr. GLASS. At the time I wrote this testimony, I had not received a copy of the FRC report. I have since then had a chance to examine it. As far as the presentation of the problem of genetic damage is concerned, it appears to be based on the same data which I have discussed, and I see no reason to differ with the conclusions drawn.

Representative PRICE. Does usual caution and reserve imply that a reversal of the present genetic findings may possibly show up from some presently known effect?

Dr. GLASS. The experience of the past 3 years, since the last hearings, shows that new findings do turn up which change the appraisal of genetic damage, and these findings of Russell about the effects of a low dose rate are a case in point. If that had been the only new finding that turned up, we would now come to the conclusion that radiation was less damaging in producing mutations than we had formerly supposed, because most of the radiation from fallout would be at a low dose rate.

But there have been other findings that offset that: The attention devoted to carbon 14 which was not included in the earlier estimates of damage; and the indication of the other effects to which I referred—sterility effects, the chromosome losses producing such conditions as mongoloid idiocy and sexual aberrations. So, on the one hand, we lower the estimate we previously made. On the other hand, we increase it. These two pretty well offset one another as far as I can judge, and our original appraisal is still good.

But we do think that we don't know all we should about the subject and therefore ought to be cautious about drawing conclusions.

Representative PRICE. On page 8 you mention that in the case of female germ cells, the 0.8-roentgen rate sometimes yields an intermediate frequency of mutation. We understand that the 1954 fallout on the Marshallese people and the Japanese fisherman had this type of exposure from fallout. Has this level of exposure occurred to any others due to fallout?

Dr. GLASS. Not to my knowledge. I think the Marshallese would be about the only group that had received a fairly high dose rate, or what we call here an intermediate rate as far as the female is concerned, from fallout from weapons tests.

Representative PRICE. Have the Marshallese shown any genetic effects to date?

Dr. GLASS. The number of children born to the irradiated individuals is so small that it is not really to be anticipated that mutations would be discovered. To my knowledge, none have been discovered. I would say that the evidence we can get from the Marshallese is not likely to throw much light on the situation.

Representative PRICE. On page 11 of your complete statement you said that 200 roentgens would produce a sterilizing effect upon the female. Did any of the Hiroshima or Nagasaki survivors who were exposed in this range have fertility effects?

Dr. GLASS. My statement is that if they received upward of 200 roentgens, there might be a sterilizing effect upon the female or some of the females, because I believe there is inadequate knowledge of just what the sterilizing dose for the human female is. In the case of the Hiroshima females who were irradiated and who later reproduced, I do not know whether the dosage measurements are sufficiently accurate to throw light on this question or not. It would be worth looking into.

Representative PRICE. Mr. Hosmer.

Representative HOSMER. No questions. I was unable to listen to all of the testimony.

Representative PRICE. Does the staff have any questions?

If not, thank you very much, Dr. Glass, for a very fine presentation. In fact, all of the papers this afternoon were excellent and valuable to the committee.

(A letter received subsequent to the hearings follows:)

THE UNIVERSITY OF WISCONSIN,
DEPARTMENT OF MEDICAL GENETICS,
Madison, Wis., June 27, 1962.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
U.S. Senate Post Office, Washington, D.C.

DEAR MR. RAMEY: I have just read through Dr. Bentley Glass's testimony given at the recent hearings of your committee. I believe that he has covered the recent advances in genetic effects of radiation since the last hearings extremely well and that there is nothing essential that I could add. For this reason I have not prepared a statement for the record. I hope this is satisfactory.

Let me take this opportunity to express to the members of the Joint Committee and its staff my genuine appreciation for the great public service that they have accomplished through these hearings. I am very honored to have participated in the 1957 and 1959 hearings and to be invited to this.

With best personal regards.

Sincerely,

JAMES F. CROW.

Representative PRICE. The committee will recess until 10 a.m. tomorrow.

(Whereupon, at 5:12 p.m., the subcommittee recessed, to reconvene at 10 a.m., Thursday, June 7, 1962.)