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ABSTRACT

With increasing requirements for food free from microbiological health hazards plus extended shelf life of refrigerated and nonrefrigerated foods, many persons will need fundamental training in irradiation techniques and methods of handling irradiated food. Special training needs and criteria for training were defined by conducting interviews with 69 persons knowledgeable in the work performed by technicians associated with food and radiation. Major conclusions were: (1) Some post-high school vocational or college training is needed, (2) Core training should include radiation technology, health physics and safety, food processing, food chemistry, and mathematics with supplementary courses in biological sciences, packaging and electronics, (3) On-the-job training should be a definite entity in the training program, (4) Technicians must demonstrate logical thinking ability, neatness, accuracy, and responsibility, (5) A 2-year curriculum offered through a technical college or community college appears to be the most feasible, and (6) Continued inservice education is recommended. The document includes sections relating to (1) personnel safety, (2) facilities, (3) a conference on training food irradiation technicians, (4) a Federal Drug Administration report, and (5) an appendix of resource materials. Sixteen course outlines are included. (DM)

FINAL REPORT
Project No. 8-A-007
Contract No. OEG-1-8-08A007-0034-058

AN EXPERIMENTAL GUIDE FOR PERSONNEL TRAINING REQUIREMENTS OF TECHNICIANS IN FUTURE FOOD IRRADIATION TECHNOLOGY INDUSTRIES

Philip G. Stiles
Associate Professor
Poultry Science Department
University of Connecticut
Storrs, Connecticut 06268

September, 1969

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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SUMMARY

The use of ionizing radiation to preserve foods and eliminate public health hazard microorganisms is now technically feasible and will soon be a commercial process. Interest in radiation processing of food is worldwide. Every country with nuclear research capabilities has undertaken some food irradiation development. However, personnel training in food irradiation methods has been limited to pilot plant and demonstration operations. It is inevitable that with the increasing requirements for food free from microbiological health hazards plus extended shelf life of refrigerated and nonrefrigerated foods, many persons will need fundamental training in irradiation techniques and methods of handling irradiated food. The objectives of this study were to define the special training needs and criteria for training the technician level of persons responsible for food irradiation in future commercial food processing organizations.

To accomplish these objectives interviews were conducted with persons knowledgeable in work performed by technicians associated with food and radiation. These included government and academic persons who had worked with radiation plus commercial employers who supervise people at the technician level. A total of 69 persons were interviewed.

Conclusions drawn from respondent interview analyses were as follows:

1. Food irradiation technicians must have a minimum of a high school diploma and some post high school vocational training or college training.
2. Core training should consist of courses in radiation technology, health physics and safety, food processing, food chemistry, and mathematics. Supplementary courses in the biological sciences, packaging, and electronics would complement the core program.
3. On-the-job training with cooperative industries or governmental agencies should be a definite entity in the training program. This would develop skill and experience using up-to-date equipment and processing techniques.
4. Technicians specializing in food irradiation must possess a temperment that demonstrates logical thinking ability, neatness, accuracy in record keeping, and be able to maintain a high standard of responsibility while doing routine activities.

5. A two-year post-high school curriculum offered through a technical college or community college and supplemented with on-the-job training appears to be the most feasible training program for technicians seeking specialized skills in food irradiation.
6. Continued education in self study programs, refresher courses, and participation in technical and trade conferences would round out the technicians training requirements.

INTRODUCTION

For the past two decades a great amount of research has been accomplished in preserving food with various forms of irradiation. This process is rapidly approaching commercialization and will within the next decade become a major technique for processing foods to extend their shelf life and reduce or eliminate microbiological health hazards. Many foods subjected to ionizing irradiation have proven wholesome, nutritious, and free from induced radioactivity. Radiation treatments have included low dose pasteurization to eliminate certain health hazard organisms, high dose sterilization, insect disinfestation, potato sprout inhibition, and product change through ionization. The latter is particularly useful in molecule orientation of certain plastic packaging materials.

There are many forms of radiation ranging from radio and television waves to X-rays. However, only ultraviolet rays, X-rays, and alpha, beta, gamma and cosmic rays are capable of penetrating and ionizing food material. Ionization may be defined as the process in which one or more electrons are removed from an atom. Ionizing radiation penetrates a material with such energy that electrons are disrupted from their atoms thus making the atom unstable. Only electrons, X-rays, and gamma rays have sufficient penetrating ability to be of importance in food processing.

Radiation penetrating into food ionizes some atoms and alters certain large molecules in microorganisms to the point of their destruction. The food atoms do not become measureably radioactive and suffer no major harmful effects. There is some loss in vitamin potency as also frequently happens with other forms of food processing for preservation. Flavor changes also occur at higher radiation levels.

Historically the use of ionizing radiation to destroy bacteria dates back to 1898 when Pacionotti and Porcelli observed the effect of irradiation on microbes. In 1904 Prescott reported the effects of radium radiation on microorganisms and in 1930 a French patent was issued to O. Wust for preserving food with ionizing radiation. A series of irradiated food experiments were accomplished at Massachusetts

Institute of Technology in 1943 by Proctor, Van de Graaff and Fram. By 1950 the Atomic Energy Commission supported research on gamma emitting isotopes for food preservation.[1]

The first food to achieve clearance by the U. S. Food and Drug Administration for irradiation preservation was fresh bacon. This clearance was issued on February 8, 1963. Later that same year, wheat was cleared for disinfestation by ionizing radiation and on June 30, 1964, clearance was issued for inhibiting sprouting of potatoes by using gamma irradiation. Several flexible packaging films were also approved in 1964 for packaging food prior to its irradiation treatment. Several other foods have been petitioned for Food and Drug Administration clearance. In the Food Additives Amendment Act of 1958, Congress specified that a food is adulterated if it has been intentionally subjected to radiation, unless the use of radiation was in conformity with a specific regulation or exemption. The petitioner must obtain clearance prior to marketing the product. In 1967 the Food and Drug Administration declined approval for irradiated ham for human consumption and at the same time rescinded existing regulations that permitted radiation processing of bacon. Extensive animal feeding studies are required for approval of irradiated food for human consumption.

For sterilization of food high energy gamma rays are generally used at a dose of 2 to 4.5 megarads (million rads). A rad is that quantity of ionizing radiation which results in the absorption of 100 ergs of energy per gram of irradiated material. Enzyme stablized food exposed to this dose rate can undertake long term storage without refrigeration. A lesser dose rate of 200,000 to 500,000 rads is considered a pasteurization treatment and is useful in extending shelf life and in eliminating certain harmful bacteria. Doses of 20,000 to 50,000 rads are used to disinfest insects from grains and 4,000 to 15,000 rads are applied to potatoes and onions for sprout inhibition.

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[1]Source: Radiation Preservation of Food, TID-21431, Business and Defense Services Administration, U. S. Department of Commerce, Washington, D. C., 1965.

The food processing and distribution industries are on the threshold of several major technological and social advances that will change the entire character of these industries and the training needed by those who work in them. Foremost among these advances are the use of ionizing radiation to preserve foods and eliminate hazards to public health and secondly, the use of computers to control product flow and data in a highly efficient manner. Research developments in these fields are now available for general usage with the major holdbacks being a lack of training by the people needed to give it commercial application.

Dr. Samuel Nabrit[1] of the Atomic Energy Commission recently reported "The concept of radiation preservation of foods is one of the few really new approaches to overcoming food spoilage since the development of thermal canning 150 years ago. More scientific research has been devoted to this process than to any other food preservation process." He further reported that limited usage of industrial radiation is a contributing factor causing a lack of persons in private industry who understand the use and effects of radiation and the general feeling of uneasiness that one finds, both in the industry and in the general populace, concerning the use of radiation in the treatment of foods. Dr. Edward Josephson,[2] Director, U.S. Army Radiation Laboratory, Natick, Massachusetts, recently said "Within 10 years the Food and Drug Adminstration and the U.S. Department of Agriculture will make irradiation mandatory to insure the American public that food products are free of public health hazards."

Interest in radiation processing of food is worldwide. Every country with nuclear research capabilities has understaken some food irradiation development. Success has been attained in disinfestation of grain, prevention of sprouting in potatoes, pasteurization of fish and other seafoods, and complete

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[1]Nabrit, Samuel. Overview of the developing technology of food irradiation. A talk presented February 2 at an Atomic Energy Commission briefing on radiation and preservation of foods, Oak Ridge, Tennessee, 1967.

[2]Josephson, Edward S. The army program. A talk presented February 2 at an Atomic Energy Commision briefing on irradiation preservation of foods, Oak Ridge, Tennessee, 1967.

sterlization of many meats. Irradiation of these foods has prevented spoilage in some fruits, extended the shelf life of others, and facilitated fresh meat flavor for extended time periods without refrigeration.

Personnel training in food preservation irradiation methods has been limited to pilot plant and demonstration operations. It is inevitable that with the high volume of food preserved and consumed, both in this country and even more so in many foreign countries, many persons will need fundamental training in irradiation techniques and methods of handling irradiated food. While much research effort has been devoted to making use of atomic energy by-products for achieving better and more stable food products, a large void exists in defining how training will be accomplished for those charged with commercializing this feat of science.

Food processing industries employ approximately 1,657,700 persons which can be considered a major segment of our economy. The breakdown of the employment is shown in Table 1. The meat, seafood, bakery, and canned products units will be most subject to change over into irradiation processing methods. This involves over 800,000 persons or approximately half of the total figure. Of these, nearly 20,000 persons are in technician class positions that will require technical training in this processing method.

Within the State of Connecticut there are over 12 meat and poultry processors or further processors and over 100 other food processors that may use irradiation processing when the products they manufacture are approved for using this preservation treatment. These food companies employ several thousand people, many of whom will require training or a knowledge in processing and handling irradiated foods. In addition, there are several nonfood irradiation companies within Connecticut that could adapt their irradiation source to food products when Food and Drug Administration approval is attained.

Mr. Arthur H. Nelson[1] of the American Technical Education Association recently reported that the rapid technological change and increasing complexity of interrelated technologies present a major challenge to technical education. He outlines four reasons for moving ahead in experimental curriculum development for emerging programs. These are as follows:

1. The development of the new technology was retarded because of lack of thoroughly trained technicians to assist engineers and scientists.
2. Equipment manufacturers utilizing the new technology struggled with inadequately trained technical personnel in quality control, sales and service who lacked sufficient basics and whose in-plant training was based on an inadequate foundation.
3. Thousands of students, through lack of readily available technical education, missed out on excellent career opportunities for entering on the "ground floor" of the new technology and many were trained instead for work in a declining technology where employment opportunities were drying up.
4. This traditional technical education lag of ten or more years in new technologies is no longer acceptable. The economic and social costs are far too great. The inefficiency is far too apparent. Nowadays a new technology may be approaching maturity within a period of ten years and may be of great importance to the nation. An older technology within the same time period may be changed almost beyond recognition.

[1]"A coordinated research effort - developing technical education programs in emerging technologies." A paper presented by Arthur H. Nelson, President, Technical Education Research Center, 142 Mt. Auburn Street, Cambridge, Massachusetts, for the Annual Meeting of the American Technical Education Association in Denver, Colorado on December 5, 1966.

TABLE 1: Nonfarm Food Processing Employment

Commodity Group	Production Workers	Total Employment
Meat products	266,200	330,400
Dairy products	116,600	249,900
Canned, cured and frozen foods	201,600	244,100
Grain mill products	96,400	136,000
Bakery products	163,800	279,400
Sugar	42,900	48,900
Confectionary and related products	66,900	81,900
Beverages	116,600	230,600
Miscellaneous foods	93,600	142,800
Total food and kindred products	1,142,900	1,721,500

Source: Monthly Labor Review, U.S. Department of Labor, Washington, D. C. pp91, March, 1969.

METHODS FOR DETERMINING
FOOD IRRADIATION TECHNICIAN TRAINING NEEDS

What is a food irradiation technician? This question was invariably asked by each person canvassed in this study. Webster's dictionary[1] defines the technician as one who is versed or skilled in the technical details of a subject or art. A more recent edition[2] exemplifies a technical expert who is of service to the management side of industry but not of it. The food irradiation technician thus is a specialist in the operations of food preservation by the use of ionizing methods. He is technically trained to perform the irradiating services and has responsibility for the techniques and mechanisms for carrying out this function. His responsibility centers around the physical handling of the product at the point of irradiation. Normally his responsibility does not extend into program planning, policy making, or marketing the product. However, his technical advice may be sought when feasibility studies are undertaken or when problems arise with the product. The technicians interviewed all considered themselves as professionals. It is most likely that when the irradiated process becomes commercialized many technicians will classify themselves as professionals and a member of the management team in their society memberships and salary mode. They also may be uion members and considered a part of the labor force. Their training would be a major factor in determining status level.

Technicians are a well established functional part of most technical fields, such as electronics, chemicals, food industries, and others. Their training normally consists of on-the-job experience, post-high school vocational studies, college matriculation, or a combination of these. Food irradiation technicians exist today in the several government and institutional irradiation laboratories throughout the country and world. Their training programs were not specifically oriented toward the job, but generally consisted of two or more years of college, with science or engineering emphasis, on-the-job experience, and

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[1]Neilson, William A. (ed.) Webster's New International Dictionary, G. and C. Merriam Co., Springfield, Massachusetts, 1951.
[2]Gove, Philip G. (ed.) Webster's Third New International Dictionary, G. and C. Merriam Co., Springfield, Massachusetts, 1966.

special government training programs. The government programs consisted primarily of health safety courses and radioisotope usage courses. The Atomic Energy Commission provides formal training in these subject areas at levels ranging from vocational practice to post-doctorate research. Many colleges and research organizations also offer both short-term and long-term sudy and self improvement programs for persons working with irradiation. None of these are specific to food radiation technicians but most are basic to general irradiation and radioisotope handling. The special training needs of production, management, and technical personnel responsible for food irradiation in a commercial organization have not been defined or met by existing training programs. The major objectives of this study was to establish this definition and the criteria needed for training irradiation operational personnel as will be required for food processing and distribution organizations in the future. These objectives are presented as follows:

1. Define the special training needs of the technician class of personnel responsible for food irradiation in a commercial organization.
2. Establish the criteria needed for training food irradiation technicians as related to current food processing and distribution training requirements.
3. Ascertain the level and type of training needed to initiate commercial food irradiation programs.
4. Outline a pilot training program for training food irradiation plant technicians.

The procedure for accomplishing the objectives consisted of interviewing persons knowledgeable in the work performed by technicians associated with food. These included several government and academic persons who had worked with radiation, plus commercial employers who recognize their needs in finding people at the technician level. Interviews were conducted both by correspondence and by direct contact. A total of 69 persons completed the interview form. Many of the persons interviewed were administrators and nearly all considered themselves as professional men or women.

The questionnaire listed three basic issues with each issue subdivided into appropriate components. The issues were (1) what educational level is realistic for food irradiation technicians?, (2) what would you suggest as being the optimum training program for food irradiation technicians?, and (3) what are the relative values for the following courses (listed) for food irradiation technicians? Respondents were asked to check the appropriate blank for each subdivision component as to its large need, moderate need, no need space, and comments. Instrument analyses consisted of assigning relative values of 4 to those checked large need; 2 to those checked moderate need; and zero to those checked no need. Checks in between these categories were assigned proportionate values. Abstentions were not considered in the assigned value analyses.

FINDINGS AND ANALYSES

"In a tribal society an individual's references were what other members of the tribe knew of his family and how the individual had performed in different situations. In our present society we frequently depend upon a slip of paper stating completion of a formal course in a subject as a reference to indicate competence. Unfortunately, technology changes rapidly and what we learn as one method of doing something is obsolete within four or five years." This statement by Dr. Richard Henderson[1] illustrates the key issue in defining the technicians role in an industry that is new and subject to rapid change.

Each question on the interview instrument was tabulated individually with a weighted average based upon assigned values for relative need. The data as shown in Table 2 indicate food irradiation technicians must have a minimum of a high school diploma and some vocational or post-high school or college training. Although high school training was not subdivided in the survey instrument, respondents indicated that high school training should be along basic science programs. Most of the respondents were not particularly familiar with vocational and technical high school curricula. Thus, this fact may account for why they did not express specific food or radiation oriented training at the high school level. However, the need for a firm understanding of secondary mathematics, biology, chemistry, physics, and English was discussed and favored by nearly all respondents as a prerequisite to post secondary food irradiation training. None of the respondents explicitly favored vocational skill development in existing technology or home economics secondary courses. Perhaps a more favorable response at this level would have been expressed if the survey had included more persons who were in direct contact with secondary level education. College training had a higher rating (2.98) than post-high school vocational training (2.60). Most respondents indicated no need for graduate college training. Discussions with respondents indicated persons with a college degree or higher would seek higher positions and would not be satisfied as a technician. Reeves (1968)[2] expressed that technicians should be trained from among those people who by intellect or force of circumstance cannot continue beyond the second year of college. His studies of technicians in industry

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1 Henderson, Richard, Comments from "Training food irradiation technicians workshop," University of Connecticut, Storrs, Connecticut, May 9, 1969.

2 Reeves, William D. Modesto Junior College, Modesto, California. Personal correspondence, 1968.

indicated that technician level jobs very often do not require any training beyond the second year of college because of the repetitive mechanical nature of the procedures involved. Bachelor Degree level people in such positions work below their ability and tend to become dissatisfied. The two-year community college level of training appears to be sufficient for this program in the opinions of most respondents.

The type of program the respondents felt would provide optimum training for food irradiation technicians is summarized in Table 3. On-the-job training received the highest value (being 3.62) as 52 respondents felt it had a large need. Special courses added to the standard cirriculum also rated high and would provide excellent training when supplemented by on-the-job instruction. Short courses of 2 or 3 weeks and special schools received lower ratings. Comments emphasized the needs for experience in food processing plants which would be quite helpful. One respondent felt lectures by management would be an aid to technicians, particularly in the areas of radiation chemistry and physics. Another respondent emphasized that course demand would be hard to predict and that each facility would present sufficient differences as to make on-the-job training the most feasible means for technician development. Several government and institutional organizations offer special courses in various aspects of irradiation and particularly in the areas of safety and health physics. It was recommended that these be taken advantage of whenever possible.

The nonrandom selection of respondents to the survey instrument perhaps increased the opportunity for biased answers and analyses in that all respondents were college trained personnel and probably few if any were graduates of technical or vocational high schools. On the other hand, these respondents were selected for their knowledge of the requirements and criteria necessary for training food irradiation technicians. They were left free to express themselves on educational requirements at all levels. Their comments did center around college and post-high school training. They did, however, range from the high school level through Ph.D. graduate studies. By leaving the training level open for comment, the area of greatest need was expressed and a program developed for this area. Undoubtedly, by concentrating the program within a narrow segment of the educational spectrum, omissions probably occurred at both higher and lower training levels. The on-the-job guided experience was expressed as the vital training role for acquiring the commercial skills regardless of the employee's educational level.

The third area polled in the survey was the individual courses needed to train technicians in food irradiation. These were divided into four groups of fundamentals, food courses, irradiation skills, and social skills. The data are presented by groups in Table 4 and by rank in Table 5. Irradiation hazards, irradiation equipment, and safety had very high ratings, and should certainly be a major part of any irradiation technician training program. Food processing and food microbiology rated slightly lower but should be included in a food processing technic.an study program. These five courses would form the application core in a student's basic curriculum. A total program should include the 18 highest ranked courses as shown in Table 5. Courses ranked from 19 through 30 are not necessarily needed but would be useful in providing a broader background for a student. Their usefullness would become more evident as an employee progressed to more responsible positions in management and sales.

A model two-year curriculum is presented in Table 6. This curriculum provides for the courses having the highest respondent assigned values plus on-the-job training and a government course which is a requirement for many schools. Outlines for each of these courses are presented in another section of this publication. In addition to these courses, on-the-job experience should be a definite entity within the program. A coordinated work-study schedule associated with a radiation facility is recommended for the second year and also for the full summer break between the first and second years of study. The work-study program could be implemented by after school or evening employment or a special project effort where employment is not feasible. A minimum of 10 hours per week during the second year was recommended. A full 35 to 40 hours per week during the summer break would provide the initial experience and allow the later part time work-study effort to be more routine. Credit may or may not be provided for the work experience depending upon the school's general policy for work activity.

Several respondents designated temperment as one of the keys to the technician's fullfillment of his position. He should be neat and accurate with his work. Precise records must be kept for this process and this would be within the technician's responsibility. The records would become routine, but at no time should they become disorderly or erroneous. One respondent commented women frequently have more merit than men in record accuracy. It is probable in most instances women would be given equal consideration to men for the irradiation technicans' position.

TABLE 2: Respondent Opinions on the Educational Level Realistic for Food Irradiation Technicians.

Education Level	No. of Respondents Indicating Large Need (4)*	Moderate Need (2)*	No Need (0)*	No Indication	Average of Assigned Value
High school	42	2	3	20	3.66
Vocational Post-high school	19	18	6	25	2.60
Some college training	31	23	3	12	2.98
Graduate college training	6	15	23	24	1.23

*Assigned value.

TABLE 3: Respondent Opinion on the Optimum Training Program for Food Irradiation Technicians.

Education Level	No. of Respondents Indicating Large Need (4)*	Moderate Need (2)*	No Need (0)*	No Indication	Average of Assigned Value
Special courses added to a standard curriculum	36	22	1	10	3.19
On-the-job training	52	12	--	5	3.62
Special school	10	22	12	25	1.91
Short courses (2 or 3 weeks by Government agencies)	14	23	8	24	2.27

*Assigned value.

TABLE 4: Respondent Opinion on the Courses Needed for Training Food Irradiation Technicians.

Course	No. of Respondents Indicating Large Need (4)*		Moderate Need (2)*	No Need (0)*	No Indication	Average of Assigned Value
Fundamentals						
English & composition	15		45	3	6	2.38
Mathematics	30	2	33	—	3	2.95
Chemistry	36	2	31	—	—	3.07
Physics	36	1	28	1	2	3.08
Government	—		25	31	13	0.89
Economics	1		32	26	10	1.10
Food Courses						
Food processing	44	1	18	3	3	3.26
Equipment	36	1	21	4	7	3.04
Food microbiology	41		24	2	—	3.16
Quality control	35		24	6	4	2.89
Food identification	14	1	37	10	7	2.15
Food merchandising	2		27	28	10	1.19
Food packaging	22		35	5	7	2.55
Food chemistry	31		20	2	5	2.92
Unit operations	8	1	32	15	10	1.77
Irradiation Skills						
Irradiation equipment	59		6	1	3	3.76
Irradiation hazards	65		2	1	1	3.88
Health physics	36		25	5	2	2.99
Safety	58		7	2	2	3.67
Physical chemistry	9		44	13	3	1.88
Nuclear physics	9		36	18	5	1.71
Electronics	13	2	41	7	6	2.22
Irradiation math	23	1	34	7	2	2.51
Toxicology	21		31	10	6	2.35
Social Skills						
Public speaking	7		36	21	5	1.56
Sociology	—		20	42	7	0.65
Psychology	—	1	18	43	7	0.70
Physical education	2		17	41	9	0.70
Business management	3		28	31	4	1.10
Merchandising	3		21	36	8	0.90

*Assigned value.

TABLE 5: Courses Ranked in Order of Need.

Rank	Course	Assigned Value
1	Irradiation hazards	3.88
2	Irradiation equipment	3.76
3	Safety	3.67
4	Food processing	3.26
5	Food microbiology	3.16
6	Physics	3.08
7	Chemistry	3.07
8	Equipment	3.04
9	Health physics	2.99
10	Mathematics	2.95
11	Food chemistry	2.92
12	Quality control	2.89
13	Food packaging	2.55
14	Irradiation math	2.51
15	English and composition	2.38
16	Toxicology	2.35
17	Electronics	2.22
18	Food identification	2.15
19	Physical chemistry	1.88
20	Unit operations	1.77
21	Nuclear physics	1.71
22	Public speaking	1.56
23	Food merchandising	1.19
24	Business management	1.10
25	Economics	1.10
26	Merchandising	0.90
27	Government	0.89
28	Psychology	0.70
29	Physical education	0.70
30	Sociology	0.65

TABLE 6: Model Two-Year Curriculum for Food Irradiation Technicians.

First Year

First Semester	Credits	Second Semester	Credits
Chemistry	3	Physics	3
Food microbiology	4	Food processing	3
Food identification	2	Quality control	3
English and composition	3	Mathematics	3
Elective	3	Electronics	3
Physical education	0	Physical education	0
	15		15

Summer Break

On-the-job training in a food irradiation facility

Second Year

First Semester	Credits	Second Semester	Credits
Food packaging	2	Toxicology	2
Irradiation mathematics	3	Irradiation equipment and dosimetry	3
Health physics	3	Food chemistry	3
Equipment and/or engineering	2	Irradiation hazards and safety	4
Government and legal actions	3	Work-study	3
Work-study	3		15
	16		

TABLE 7: Federal Government Food Irradiators.

Irradiator	Location	Use	Source
U.S. Army Natick Laboratory	Natick, Massachusetts	Pilot studies on all food, emphasis meat	1,600,000 curie ^{60}Co. and linear electron accelerator
Marine Products Development Irradiator	Gloucester, Massachusetts	Pilot studies on seafoods	250,000 curie ^{60}Co.
Hawaii Development Irradiator	Honolulu, Hawaii	Tropical fruit processing	250,000 curie ^{60}Co.
AEC Portable Irradiator	Industry locations	Industrial development	170,000 curie ^{137}Cs.
AEC Mobile Gamma Ir-	Davis, California	Fruit harvest demonstrations	100,000 curie ^{60}Co.
AEC Research irradiator (4)	At several universities	Contract irradiation	35,000 curie ^{60}Co.
AEC Shipboard irradiator (3)	Several ports	Seafood irradiation	30,000 curie ^{60}Co.
USDA Grain product irradiator	Savannah, Georgia	Grain disinfestation	25,000 curie ^{60}Co.

MODEL TRAINING PARAMETERS

Food irradiation technicians will be specialists and initially will be required only in limited numbers. Ideally, their training would be specific to their needs. However, a more realistic approach would be to include this program as a modification to existing food and/or engineering technical training programs. The model two-year program as shown in Table 6 has in its first two semesters only basic courses that would generally be offered by existing programs in food technology and engineering technology. The courses specific to irradiation are all offered in the second year and could even be concentrated into one semester if absolutely necessary. However, it is preferred to have the radiation mathematics, health physics, and basic equipment courses offered in one term to serve as fundamentals to be followed by more detailed courses in toxicology, irradiation equipment, and irradiation hazards. Although these courses would tend to be applied, they could be presented in considerable depth to students with sufficient background. Students who spent their first year concentrating in a food or engineering program could easily shift into the irradiation technician program without major loss of time or credit. The irradiation technician program should be a part of an existing food or engineering division rather than a separate entity. Modifications to include irradiation technology int . existing food and engineering curricula would not be difficult. The interdisciplinary status of this field would be synergistic to both food and engineering programs. This would be most evident in upgrading science courses, stimulating student interest, and in increasing the teacher's professional stature.

Teacher Requirements:

Teachers would definitely need experience and training in irradiation and the handling of radioisotopes. Teachers with a food, engineering, or biological science background could readily undertake the necessary training through special teacher-training programs offered by several governmental laboratories, universities, or other basic science groups. The Argonne National Laboratory near Chicago, Illinois, offers a nuclear safeguards training course which would aid one teaching in this subject area. Oak Ridge Associated Universities, Oak Ridge, Tennessee, offer five applicable courses which are as follows:

1. The use of radioisotopes in research.
2. The use of radioisotopes in medical diagnosis.
3. Special radioisotope applications.
4. Nuclear medical technology.
5. Activation analyses.

The Oak Ridge Associated Universities also offer other courses in health physics and summer institutes for physics teachers. Most large colleges and universities offer special training programs in irradiation or radioisotope techniques. One commercial company, Irradiation, Inc., 50 Van Buren Avenue, Westwood, New Jersey, offers a demonstration program to food processors at no cost. This company is the operating contractor for the Atomic Energy Commission's Portable Cesium Irradiation program and has an 18 ton, trailer mounted unit containing a cesium-137 source of approximately 150,000 curies. This demonstration unit was developed to aid processors in integrating irradiation technology into food production lines and is available on a scheduled basis.

Student Selection:

Ideally, students concentrating in the food irradiation program should have an interest both in food processing and in engineering or electronics. This interest can be stimulated by developing an awareness for employment opportunities. Tours through food plants and nulcear industries such as atomic power plants help encourage student interest. Guest speakers and movies also provide incitment.

The dynamic nature of this field necessitates a rather high degree of flexibility in student selection and training. Considerable interchange of students from other disciplines should foster motivation for further studies in irradiation technology. In some cases a complete interdisciplinary approach of a core program in irradiation technology may provide adequate training if it is supplemented by proper guidance in on-the-job training. Readings in the current trade and technical literature will be necessary for all employees as a part of their continual on-the-job training.

Many well established curricula in both two-year and four-year schools could consider an irradiation technology core for modifications of either a food or an engineering program. Such a core offering could include the following courses:

Irradiation Technology (equipment and techniques)
Health Physics and Safety
Food Processing
Food Chemistry
Mathematics and Physics

A core offering of this nature would provide foundation knowledge for a technician to enter industry as a food irradiation specialist with relatively little modification of traditional curricula. He would further his skills and knowledge with direct on-the-job experience and should be encouraged to participate in trade meetings and professional societies related to his employment. The potential for growth of both the individual and the organization for which he works will depend upon the successful application of the combined skills of those associated with the enterprise. The more these skills are cultivated, the greater the growth potential.

The intelligence level required of technicians for the commercial industry probably falls into the middle range classification. While a moderate intelligence rating is necessary, it must be complimented with characteristics of diligence, reliability, and respect. Accuracy in process control and trustworthy performance are paramount in assurance of product quality. The public health hazard possibility must be zero. The human responsibility for this attribute dictates that the technician must have high moral character and be receptive to rigid control in quality standards. Persons of low intelligence most probably could not handle this responsibility. Conversely, persons with rather high intelligence may become weary of the routine and hence not be of ideal character.

PERSONNEL SAFETY

All persons working in connection with a radiation source must adhere to high standards of health safety and accident prevention. Physical examinations of all employees are generally part of their preemployment qualifications. These examinations include blood and urine analyses and should be routinely performed at least once a year for persons working in radiation areas or with radioactive materials.

Standard procedures have been established for radiation monitoring and control. All persons should wear film badges in the radiation area. These are exchanged either once a month or at least every 13 weeks. Film badges are assayed for exposure level and become a part of the employee's permanent record requirement plus aid management and employees in ensuring their protection from radiation hazard. Pocket dosimeters should be carried by persons working in exposure areas. These provide immediate warning of exposure since they directly indicate exposure and are easily read. General surveillance monitors can be used to measure radiation in exposure areas, equipment, and possible contamination zones. Air, water, and products should be routinely monitored as a safety measure.

Maximum permissible dose rates are shown in Table 8. Accumulated records need to be kept for each individual. An accidental dose of up to 25 rems may be received only once in a lifetime. Higher rates may be necessary during an extreme emergency. Persons taking emergency exposure should be made aware of the possible consequences before exposure. Maximum permissible concentration for continuous occupational exposure of unidentified nuclides is 10^{-7} microcurries per cc in water and 4×10^{-13} microcurries per cc in air.[1]

[1]Radiation Safety and Control, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1968.

TABLE 8: Recommended Permissible Dose to the Body[1*]

Organ	Maximum Permissible Dose (Rems) Weekly	Quarterly	Annual
Total body	0.1	3	12
Skin	0.6	10	30
Hands, forearms, feet	1.5	25	75

[1]These values are in addition to doses from medical and background exposures.

*Source: Radiation Safety and Control Training Manual, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1968.

TABLE 9: Nonoccupational Exposures.

Nonoccupational group	Total body, lenses, of eyes, or gonads
Adults who work in the vicinity of the controlled area	1.5 rems/year
Persons living in the neighborhood	0.5 rems/year
Population at large	0.17 rems/year

The median lethal radiation dose of LD_{50} is specified as that which kills half of those exposed. This is estimated to be 400 to 500 rad for the whole body of man. Large doses cause the neurochemical effect of nausea and vomiting and loss of body fluids and salts. General destruction of lymphocytes, granulocytes, and the ability to make antibodies occurs. There is inflamed or bleeding intestines, bloody diarrhea and general anemia. Sublethal doses of the 200 to 400 rad range cause hemorrhage, depression of immunity, and anemia within a few weeks. Between one and two weeks the skin reddens and the hair falls out. Longer term effects are eye cataracts, sterility and possible genetic effects.

Policy on safety at Oak Ridge National Laboratory:[1]

1. "Carry out all operations with the lowest reasonable personnel exposure to radiation and contamination. In no case shall internal or external exposures exceed the recommendations of the Federal Research Council and the National Committee on Radiation Protection.
2. "Perform all work in such a manner that losses resulting from contamination are minimized. Such losses may include research, development, and production time; facility and/or equipment abandonment; and the cost of cleaning up contamination.
3. "Maintain environmental contamination at a level as low as consistent with sound operating practice. In no case shall the atmospheric and water contamination outside the controlled area exceed the maximum permissible concentration values for the neighborhood of an atomic energy installation."

[1]Source: Radiation Safety and Control Training Manual, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1968.

FACILITIES

In 1967, there were 138,000 people employed in nuclear activities. Of these, 35,000 were employed in privately owned facilities and 103,000 in Government owned facilities. Only a small portion of these are currently working with food products. The main employment in private establishments centers around reactors and instruments. However, over 4,000 people are currently employed in nuclear associated milling, feed production, and special materials. The radiation processing market was estimated to exceed $100 million in 1967 and is growing at a 25 percent annual rate.[1] There are over a thousand irradiation facilities currently in use for experimental work throughout the world and new facilities are being constructed at an increasing rate each year.[2]

Food irradiation facilities have been limited to pilot plant and demonstration units because of Government clearance regulations. In a study by Ketchum[3] the estimated cost for radiation sterilization of bacon is 4.8 cents per pound at the processing rate of 16 million pounds per year. This represented a total capital investment of $1,562,200 and a yearly operating expense of $538,400 with an addition return on equity capital of $234,000. Included within the operating expenses were labor and technician expenses of $64,000. Josephson et al.[4] reported that irradiation costs depend greatly on the volume cf product handled. Annual volumes of approximately 300,000 pounds of meat would have a sterilizing processing cost ranging from $.45 to $.65 per pound. Higher volumes approximating 30 million pounds annually would have reduced costs in the range of 2.3 cents per pound at 100 million pounds annual volume using a 10 Mev linac facility (electron linear accelerator). Cost calculations are based on the following formula:

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1 The Nuclear Industry. U.S. Atomic Energy Commission, Washington, D.C., 1968.

2 Status of the Food Irradiation Program, Hearings before the Subcommittee on Research Development and Radiation, Joint Committee on Atomic Energy, Congress of U.S., Washington, D.C., pp 88, 1968.

3 Ketchum, Harry W., "Food irradiation check list of cost considerations." Paper presented at the Conference on Radiation Preservation of Foods, Oak Ridge, Tennessee, 1967.

4 Josephson, Edward S., Ami Brynjolfsson, and Eugen Wierbicki. "Engineering and economics of food irradiation." Transactions of the New York Academy of Sciences, Series II, Volume 30:4:600-614, 1968.

$$X = \frac{794 \cdot W \cdot n}{D}$$

Where: X = pounds per hour irradiated with a dose of D megarad
W = kilowatt output of radiation
D = dose in megarad
n = efficiency factor - a ratio between useful irradiation energy absorbed in the product to the radiation energy emitted from the source
1 kwatt = 67,480 curies of Co-60
312,000 curies of Cs-137

These costs do not include associated refrigeration or liquid nitrogen costs.

Both high energy electron beam accelerators and gamma irradiators can be used to process foods. Food irradiation using electron energy is limited by the possibility of induced radioactivity as is usually of energies no greater than 10 Mev. The types of accelerators used are linear accelerators, Van de Graaff accelerators, cascade generators, and resonance transformers. The advantages of accelerators are that they can be started and stopped at any time, need no shielding when they are not operating, and require no transportation of radioactive material. Also, the dose rate from accelerators greatly exceeds that from isotopes sources; so objects can be irradiated for very short times under continuous process conditions. Electron accelerators do not have the penetrating power, however, that gamma sources have.

Gamma irradiators utilize the gamma ray energy expelled from certain long lived radioactive materials, particularly cobalt -60 and cesium 137. These are usually in a hollow cyclinder or two place systems. Radioactive sources arranged at the periphery of a cylinder create a definite volume in which the gamma field is essentially homogenous. The radioisotope source must be adequately shielded when not used. A frequent shielding method is to store the material in a water pool 4.5 meters deep. The source may then be raised to come into close contact with the product to be irradiated, or the product may be lowered in a sealed container through the water until it reaches the source proximity. Conveyor mechanisms transport the product to and from the source. An illustration of a source and associated conveyor system is presented in Figure 1. Water shielding around the source are simple and allow movement flexibility. In emergencies the source can be dumped into the water pool for safety precautions. The disadvantages are that it cannot be used in mobile equipment and the pool must be reliably waterproofed. A mobile gamma irradiator mounted on a truck has been developed by the Atomic Energy Commission for experimentally irradiating fruits and berries. Objects to be irradiated are transported by conveyor belt into the source chamber, allowed to be exposed for the proper time, then are returned by moving belt to the preparation area. The chamber is protected by lead shielding. Atomic Energy of Canada Ltd., produces Gammacell and Gammabeam type experimental irradiators for small amounts of food products.

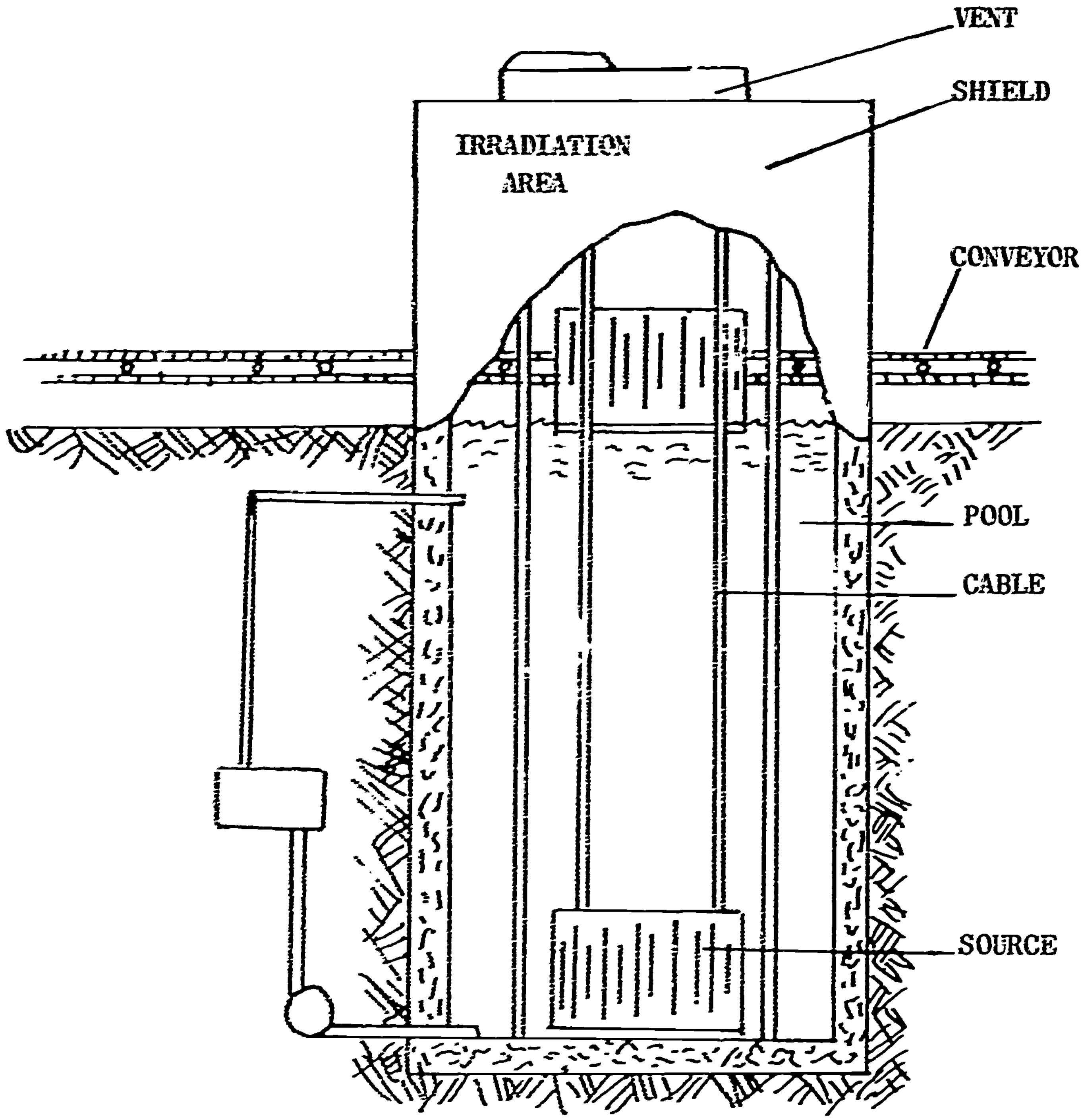

Figure 1: Typical Irradiation Demonstration Unit.

EVALUATION CONFERENCE ON TRAINING FOOD IRRADIATION TECHNICIANS

A conference consisting of government, academic and industry personnel familiar with radiation techniques and food processing was held May 9, 1969 at the University of Connecticut. Speakers were provided advance discussion copies of the model food irradiation training program and were asked to present their views on how to train technicians for responsible positions in commercial food irradiation plants. Dr. Eugen Wierbicki of the U. S. Army Natick Laboratories, illustrated why the U. S. Army is interested in irradiated meats and demonstrated how fresh meat can be preserved without refrigeration for up to two years. The U. S. Army Natick Laboratory is sponsoring basic research in meat irradiation. They feel persons entering this field must demonstrate thoroughness, skill, and good intelligence. The army research emphasizes sensory characteristics, microbiological control, nuclear effects, packaging, and wholesomeness of food products. Technicians are heavily involved in work with dosimetry, dose distribution, and induced activity. An understanding of packaging is also very important to technicians. Technicians are asked to participate in taste test panels and to sit in on monthly open discussion meetings with professional staff.

Mr. John Kaylor of the Fish Irradiation Laboratory, U. S. Bureau of Fisheries, Gloucester, Massachusetts, remarked that the fish irradiation laboratory on-the-job training program emphasized radiological health safety plus basic experience in working with radiation instruments. High school students showing aptitude and interest would qualify for further radiation technical training and could receive on-the-job experience at one of the several food pilot plant irradiation centers in the United States. He also added technicians should learn both administrative and radiation protection procedures. Fish Irradiation Laboratory technicians must take formal training in radiological health consisting of a two-week course provided by the Public Health Service. This course includes radiation exposure, atomic structure, radioactive decay, instrumentation, dose rates, radiation protection, and information sources. On-che-job training is of large value for technicians since it qualifies them for the particular needs of the plant at which they are employed.

Mr. Dale Robinson, Chairman of the Nuclear Technology Program, Hartford Technical College estimated a demand for over 100 nuclear technicians are needed each year in Connecticut and that their training enables them to enter many of the expanding atomic energy industrial facilities.

Mr. Francis Rizzo, a physicist from Brookhaven National Laboratory, explained that technicians are the backbone of an irradiation installation. Technicians must be able to think in a logical manner and to work with professional health physicist, food technologists, and engineers. He further indicated that a large safety training program is not needed as this should be under the responsibility of a trained health physicist. He differed from Mr. Kaylor's viewpoint in saying adequate health physics training cannot be accomplished in a two week training period. Scare techniques should not be used in teaching radiation safety. If technicians are afraid of radiation usage, then the general public will also show a fear reaction. The radiation industry has one of the best safety records of all industries. He commented that dosimetry and electronics training are somewhat separate from food technology training and perhaps should be taken separately or be the responsibility of different people.

Dr. Richard Henderson of Olin Mathieson Corporation suggested technicians be well trained in basic science which would allow them to grow into meaningful positions. Company sponsored training plus self organized study continually improve an individual's knowledge and worthiness to a company. Industrial accidents are a major concern to every commercial organization and are frequently due to emotional and psychological upsets. A continuing physical education program throughout one's adult life helps prevent emotional disturbance. Hospitals located in the proximity of radiation facilities must be alert to the possible radiation accidents and the special treatment required for recovery. It would not be feasible to give all persons involved in radiation a complete health physics program. It is better to educa e the technicians in the basic sciences and then build the curriculum around these fundamentals. The individual can then upgrade his education through self study and on-the-job educational release time. Dr. Henderson also commented on the curriculum in follow up correspondence: "It is the rapid rate of technological change and obsolescence that leads me to recommend heavy emphasis on basic concepts and on how to learn..... The model curriculum provides basic courses in chemistry and physics but no basic course in biological science. The overall objective of food irradiation is to bring about changes in biological systems by means of physical agents and yet maintain the usefulness of the changed biological systems for another biological system, namely man. Some basic biological concepts can be woven into a course in food microbiology, but I believe it would be better to teach the biological concepts first."

A reaction panel consisting of Mr. John Hamann, U. S. Department of Agriculture, Agriculture Research Service; Mr. Robert Mayer, Windsor Nuclear Corporation; Mr. Carmelo Greco, Connecticut State Department of Education; and Dr. Howard Martin, University of Connecticut, summarized the training skills required of technicians who will enter this new field of study. Plant foremen, quality control men plus radiation management personnel will have to meet basic training requirements. Cooperative arrangements between industry and educational institutions will be essential so that students can learn the operations of up-to-date equipment and at the same time industry employees can up-date their science background by participating in classroom activity. Technicians should be given a year of basic science training and a year of radiation skill development. Anticipated problems in developing a training program were how to attract students into this specialty plus how to obtain starting salaries that exceed $7,000 annually.

Mr. Robert Mayer summarized his remarks as follows: "In general, I feel that the program is an excellent arrangement of course work to prepare the technician for his responsibilities. I do believe, as some of the other speakers stated, that the individual courses should be delineated further to reflect their actual protions of theory and practical laboratory. As was mentioned at the conference, a technician is a person who does things. To leave out the laboratory portion of his training is to overlook the primary purpose of the curriculum - to train people who can do things, and in this case highly specialized things. The laboratory program is fine for physics majors in their senior year, but I question whether it is too ambitious an undertaking for a typical technician. Would it not be a good idea to obtain a laboratory course from those speakers at the conference who have and still are training technicians? From my own experience, I find the practical portion of a technician's training is the most valuable in the long run."

Mr. Lew Turner of the Connecticut State Department of Agriculture presented other general comments centering around technician training programs. "High school chemistry and physics teachers do not know the current needs for this type of training;" and "How do we get teachers in public schools to make teaching more meaningful and relevant?" Mr. Rizzo followed with "We can get too bogged down in the math and theory and loose the operational experience and logic." He also inquired as to why the training program should be limited to food since many other fields may have similar training needs. The model program is valid for several other fields. Dr. Howard Martin noted that professionals frequently try to limit the upgrading of technicians to subprofessional levels. He indicated people should not be blocked from growth positions.

It was noted that food irradiation jobs are not as plentiful as in the engineering fields thus class size would be small. The program might require costly equipment for just a few students. On the other hand high equipment costs and possible rapid obsolescence can be held to a minimum through cooperative training with industry where usage of the most recent equipment can be readily achieved.

FOOD IRRADIATION: AN FDA REPORT[1]

by Alan T. Spiher, Jr.

"The potential of ionizing radiation as a food processing technique has been of major interest to both Government and industry for more than two decades, but experimental work with irradiated foods has shown that there are still significant questions concerning the safety of the proposed uses.

"The Food and Drug Administration is responsible for protecting the public from harmful and adulterated foods, drugs, and cosmetics through the Federal Food, Drug, and Cosmetic Act. FDA's jurisdiction over irradiated food and sources of radiation intended for use in producing, packing, and transporting food derives specifically from the Food Additives Amendment to the Act. Congress provided thereby in 1958 that a food is adulterated if it has been intentionally subjected to radiation unless the use of the radiation was in conformity with a specific regulation or exemption. The food additives section sets forth the requirements for a petitioner to obtain such a regulation prior to marketing the products (FDA Paper, May 1967).

"Among other things, a proponent of food irradiation must provide adequate and sound scientific evidence that the proposed use is safe and will accomplish the intended technical effect.

"Recently, FDA advised a petitioner that the Agency cannot take favorable action on his petition for irradiated ham. Based on data supplied in the ham petition, FDA also has proposed to rescind existing regulations that permit radiation processing of canned bacon.

"A careful analysis by FDA of all data presented (including 31 looseleaf notebooks of animal feeding test results) showed (1) significant adverse effects produced in animals fed irradiated food, and (2) major deficiencies in the way some of the experiments were designed and conducted.

"What were these adverse effects?

1. Rats were fed diets containing approximately 35 percent bacon and approximately 35 percent fruit compote, both in the same ration. Nine different combinations were made up by one or both of the test

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[1] Reproduced from <u>FDA Papers</u>, October, pp15-16, 1968.

foods being irradiated at anyone of three levels: 0 megarads (controls), 2.79 megarads, or 5.58 megarads. Rats fed test diets containing bacon irradiated with a 5.58 megarad dose combined with the fruit compote portion irradiated at 0, 2.79 and 5.58 megarads exhibited a 13.68 percent decrease in surviving weaned young for each mating when compared with the animals on the control diet containing unirradiated bacon and unirradiated fruit compote.

Because irradiated compote might enhance or diminish the effect of irradiated bacon in the diet, the rats that consumed only irradiated bacon and unirradiated compote were compared with those consuming diets containing only unirradiated bacon and unirradiated compote. The animals on the diet containing bacon irradiated with a 2.79 megarad dose showed a decrease of 20.7 percent in surviving weaned young when compared with the animals on the unirradiated diet. The animals on the 5.58 megarad-treated bacon showed a decrease of 28.7 percent in surviving weanlings. Such reductions are highly unlikely to be due to chance.

2. Five experiments with rats fed irradiated pork produced mixed results. One, completely reported, showed no adverse findings. This involved feeding pork at 35 percent of the diet with the port irradiated at 0 (controls), 2.79 megarads, and 5.58 megarads. One experiment with cooked pork was so incompletely reported that evaluation was impossible.

   One experiment with rats fed with group pork constituting 60 percent of the diet, irradiated at 2.79 megarads, showed a reduction in live weanlings and a reduction in the weight of the weanlings at 33 days when compared with the control animals on the unirradiated diet.

   One experiment involved feeding diets with 35 percent frozen pork and irradiated with a dose of 2.79 megarads or 5.58 megarads. The numbers of weaned progeny per litter and mean weight of progeny were reduced by comparison with control animals.

   One experiment involved feeding an organ mixture containing 9 percent pork kidney at 60 percent of the total diet and irradiated at 2.79 megarads. There were discrepancies in the reported data and arithmetic errors. At 28 days after birth, the weight of the test group was 11.65 percent less than that of the control group and at 33 days after birth, the reduction was 9.35 percent.

3. Dogs fed a diet containing 35 percent pork irradiated at 5.58 megarads exhibited a highly significant 32.3 percent decrease in surviving progeny from the number of surviving progeny of the animals on the control diet containing 35 percent unirradiated pork.
4. One strain of mice fed diets containing 10-20 percent bacon lipid irradiated at 5.58 megarads weighed an average of 1.2 percent less after 1 month, and 6.0 percent less at the end of 18 months than did animals fed corresponding diets containing unirradiated lipid. A second strain of mice on the diet showed 3.4 percent less after 1 month and 17.6 percent less at the end of 18 months.
5. Dogs on diets containing 35 percent bacon irradiated with a 5.58 megarads dose weighed 5.8 percent less on the average at the start of an experiment than did the dogs on unirradiated control diets. After 105 weeks on the irradiated diet, the dogs weighed 11.3 percent less on the average than the animals on control diets.
6. Rats fed a diet containing 35 percent bacon irradiated at 5.58 megarads with 35 percent unirradiated fruit compote exhibited a greater cumulative mortality than the animals on the control diet with both bacon and compote unirradiated beginning between the 40th and 59th week of the test. All of the animals on the irradiated diet had died by the 104th week on the test diet compared with only 83 percent of the animals on the unirradiated combination.
7. Data on rats fed both irradiation levels of bacon and fruit compote suggested that malignant tumors may be associated with irradiation of bacon or of fruit or of both. Malignant tumors were reported in eight of the 254 animals on the irradiated test rations but none was found among the 77 animals on the unirradiated control diet.
8. Three of 104 rats fed diets containing pork irradiated at 2.78 or 5.56 megarads developed carcinomas of the pituitary gland. None was reported in 52 control animals. This was a particularly disturbing finding since this is an extremely rare type of malignant tumor.

"What were the deficiencies in experimental design and execution?

"FDA's evaluation of the submitted data showed major deficiencies in the design and execution of the petitioner's irradiated food studies. His test foods were irradiated under conditions quite different from those now expected to be used commercially.

"The petitioner used spent fuel rods or irradiation instead of the cobalt-60 or cesium-138 sources requested in the petition to FDA. FDA has received no data to show whether or not the chemical changes produced in food by the mixed radiation from fuel rods are comparable to those produced by the gamma radiation of pure cobalt or pure cesium. Nor did the petitioner present data to show that the test foods received the doses claimed.

"The varous investigators for the petitioner used comparatively small numbers of experimental animals in chronic feeding studies, particularly in those with dogs. When small numbers of animals are used in toxicity experiments, virtually any difference in response between test and control animals may be insignificant in a statistical sense, but may be of considerable concern when viewed in terms of potential health problems.

"Further work also is needed to explain the aberrations in performance and condition of animals on irradiated diets which some of the investigators attributed to "marginal nutritional inadequacies." Such a conclusion appears untenable because the animals were administered amounts of nutrients well in excess of their total requirements and no analyses were performed on the diets as administered to the animals.

"The petitioner's investigators appear not to have pursued the indication in some studies (including those employing enzyme systems) that an antinutrient factor may be produced by irradiation. There are also indications that this factor may affect unirradiated nutrients administered to the animal separately from the irradiated portions of the diet.

"Although a number of scientists have made suggestions that the risk of tumor formation may be enhanced by the irradiation of food, the petition on ham did not include an adequate pathological examination of tissues for tumors. The bacon study involved 222 rats for which no tissue was examined for tumors or other lesions. Nor was information presented on gross postmortem observations of these animals.

"Similary, the petitioner apparently conducted an inadequte pathological examination on the eyes of experimental animals despite the reported increased risk of cataract formation in rats fed irradiated bacon. Data on eye changes submitted so far have been of questionable reliability.

"Adding up the foregoing comments on the experimental studies, it is clearly apparent that the FDA cannot conclude that the irradiation of ham (and bacon) has been shown to be a safe process. On the other hand, the FDA scientists are not in a position to conclude that all conditions of processing by irradiation would produce an unsafe food. Certainly the door is still open to further consideration on the basis of additional studies designed to answer the several questions which have been raised so far."

End of article.

Author's Note:

This article is included to illustrate that food irradiation is a controversial issue regarding its long term safety and is under careful scrutiny by the Food and Drug Administration. Commercial licensing was originally approved for bacon then later rescinded pending more research and development to prove beyond any doubt the safety of this new process. This is a necessary step to ensure public faith and a favorable reaction when the food is made available to consumers. Continuing research by the U. S. Army Natick Laboratories and several academic institutions indicates that commercial feasibility and Food and Drug clearance will take place in the near future thus creating a demand for food irradiation technicians in commercial plants throughout the United States and in many foreign countries. Food clearance by the Food and Drug Administration normally is for a specific commodity when associated with an additive or new process. Likewise with food irradiation, clearance will be for specific commodities each with separate safety documentation. As clearance is achieved and the commercial applications brought "on stream," the demand for technicians will also increase. Initially, however, they will be needed only in limited numbers.

APPENDIX

Nuclear Industry Periodicals Having Food Irradiation Interests

Food Irradiation. European Nuclear Energy Agency, Saclay, France.

International Journal of Applied Radiation and Isotopes. Pergamon Press, 4401 21st. Street, Long Island City, New York 11101.

Nuclear Industry. Atomic Industrial Forum, Inc., 850 Third Avenue, New York, New York 10022.

Nuclear News. American Nuclear Society, Hinsdale, Illinois 60521.

Nuclear Safety. Division of Technical Information, U. S. Atomic Energy Commission, Nuclear Safety Information Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 37830.

Nuclear Science and Engineering. American Nuclear Society, Hinsdale, Illinois 60521.

Radiation Biology. Taylow and Francis Ltd., Red Lion Court, Fleet Street, London EC4.

Technical Societies Having Food Irradiation Interests

American Chemical Society, 1155 16th Street, N.W., Washington, D. C. 20036.

American Dietetic Association, 620 North Michigan Avenue, Chicago, Illinois 60602.

American Nuclear Society, Hinsdale, Illinois 60521

American Meat Science Association, 36 South Wabash Avenue, Chicago, Illinois 60610.

American Public Health Association, 1790 Broadway, New York, New York 10019.

Atomic Industrial Forum, Inc., 850 Third Avenue, New York, New York 10022.

Institute of Food Technologists, 221 N. LaSalle Street, Chicago, Illinois 60601.

Society of Nuclear Medicine, 430 North Michigan Avenue, Chicago, Illinois 60602.

Government Agencies Having Food Irradiation Interests

Bureau of Commercial Fisheries, U. S. Department of Interior, Gloucester, Massachusetts 01930.

Business and Defense Administration, U. S. Department of Commerce, Washington, D. C. 20230.

Consumer Marketing Service and Agriculture Research Service, U. S. Department of Agriculture, Washington, D. C. 20250.

Food and Drug Administration, Department of Health, Education, and Welfare, Washington, D. C. 20204.

Irradiated Food Products Division, Food Laboratory, U. S. Army Natick Laboratories, Natick, Massachusetts 01760.

U. S. Atomic Energy Commission, Division of Technical Information, Washington, D. C. 20545.

Food Industry Periodicals Having Food Irradiation Interests

Food Technology

Institute of Food Technologists, 221 N. LaSalle Street, Chicago, Illinois 60601.

Packaging Engineering

Angus J. Ray Publishing Company, 2 North Riverside Plaza, Chicago, Illinois 60606.

Food Processing

Putnam Publishing Company, 111 E. Delaware Place, Chicago, Illinois 60611.

Quick Frozen Foods

E. W. Williams Publications Inc., 1176 Broadway, New York, New York 10019.

Food Engineering

Chilton Company, Chestnut and 56th Streets, Philadelphia, Pennsylvania 19130.

Modern Packaging

McGraw Hill, Inc., 330 West 42 Street, New York, New York 10036.

Movies

The following 16mm movie films are available through the Audiovisual Branch, Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545. This is only a partial listing. Regional film libraries and a complete film catalog are available at the above address.

Alpha, Beta, and Gamma
Atom and Agriculture, The
Atom and Biological Science, The
Atom and Industry, The
Atom in Physical Science, The
Atomic Energy as a Force for Good
Atomic Physics
Atomic Research: Areas and Development
Atoms for the Americas
Down on the Farm
Engineering for Radioisotopes
High Energy Radiations for Mankind
Industrial Atom, The
Invisible Bullets
Isotopes
Jobs in Atomic Energy
Living with Radiation
Man and Radiation
Man and the Atom
Physical Principles of Radiological Safety
Practical Procedures of Measurement
Practice of Radiological Safety
Primer on Monitoring
Properties of Radiation
Protecting the Atomic Worker
Radiation and Matter
Radiation and the Population
Radiation Detection by Ionization
Radiation Detection by Scintillation

Radiation in Biology: An Introduction
Radiation in Perspective
Radiation Protection in Nuclear Medicine
Radiation Safety in Nuclear Energy Explorations
Radiation: Silent Servant of Mankind
Radioisotope Applications in Industry
Radioisotope Applications in Medicine
Radioisotopes: Safe Servants of Industry
Radiological Safety
Transportation of Radioactive Materials, Part II, Accidents
Transportation of Radioactive Materials, Part III, Principles of Regulation
Understanding the Atom Series
Working with Radiation

Books

Aglintsev, K. K., V. M. Kodyukov, A. F. Lyzkov, and Yu, V. Sivintsev. *Applied Dosimetry* (translation of the Russian Work). Chemical Rubber Company, Cleveland, Ohio. No date.

Agricultural and Public Health Aspects of Radioactive Containination in Normal and Emergency Situations. Food and Agriculture Organization of the United Nations, Rome, 1969.

Atomic Energy Facts. U. S. Atomic Energy Commission, Washington, D. C. 1957.

Bolt, Robert O., and James G. Carroll. *Radiation Effects on Organic Material.* Academic Press, New York, 1963.

Danforth, John P., and Robert P. Stapp. *Radioisotopes in Industry Training Program.* General Motors Institute, Flint, Michigan, 1959.

Desrosier, Norman W., and Henry M. Rosenstock, *Radiation Technology in Food, Agriculture and Biology.* Avi Publishing Company, Westport, Connecticut, 1960.

Fowler, Eric B. (Ed.) *Radiation Fallout, Soils, Plants, Foods, Man.* University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Elsevier Publishing Company, Amsterdam, London, New York, 1965.

Hoopes, Roy. *A Report on Fallout in Your Food.* Signet Book, published by the New American Library, 1962.

Hutton, Gerald L. *Legal Consideration on Ionizing Radiation.* Charles C. Thomas, Publisher, Springfield, Illinois, 1966.

Industrial Uses of Large Radiation Sources. International Atomic Energy Agency, Vienna, 1963.

Joslyn, Maynard A., and J. L. Heid. *Food Processing Operations,* Volume I. Avi Publishing Company, Westport, Connecticut, 1963.

Kuhn, James W. *Scientific and Managerial Manpower in Nuclear Industry.* Columbia University Press, 1966.

Lavrukhina, Malysheva and Povlotskaya. Chemical Analyses of Radioactive Materials. Chemical Rubber Company, Cleveland Ohio, 1967.

Meyer, Leo. Atomic Energy in Industry (A Guide for Tradesmen and Technicians). American Technical Society, Chicago, Illinois, 1963.

Radiation: A Tool for Industry. Arthur D. Little Incorporated, Cambridge, Massachusetts, 1959.

Radiation Preservation of Foods. Proveedings of an International Conference, Boston, Massachusetts, September 27-30, 1964. Publication 1273, National Academy of Sciences, National Research Council, Washington, D. C., 1965.

Russell, Robert Scott (Ed.) Radioactivity and Human Diet. Pergamon Press, Oxford, London, Edinborgh, New York, Toronto, Paris, and Frankfurt, 1966.

Safe Design and Use of Industrial Beta-Ray Sources. Handbook 66, U. S. Department of Commerce, National Bureau of Standards, Washington, D. C., 1958.

Safety Standard for Non-Medical X-Ray and Sealed Gamma-Ray Sources - Part I. General Handbook 93, U. S. Department of Commerce, National Bureau of Standards, Washington, D. C., 1964.

Slade, F. H. Food Processing Plant. Chemical Rubber Company, Cleveland, Ohio, 1967.

Booklets

The following is a series of basic radiation and nuclear energy educational booklets issued by the United States Atomic Energy Commission, Division of Technical Information, P. O. Box 62, Oak Ridge, Tennessee 37830.

Nuclear Reactors
Our Atomic World
Food Preservation by Irradiation
The Creative Scientist, His Training and His Role
Nuclear Power and Merchant Shipping
Atoms in Agriculture
Accelerators
Atoms at the Science Fair
Power from Radioisotopes
Power Reactors in Small Packages
Whole Body Counters
Atomic Fuel
Controlled Nuclear Fusion
Neutron Activation Analysis
Direct Conversion of Energy
Nuclear Terms, a Brief Glossary
Nuclear Propulsion for Space
Research Reactors
Rare Earths, the Fraternal Fifteen
Microstructure of Matter
Plutonium
Synthetic Transuranium Elements
Nondestructive Testing
Careers in Atomic Energy
Atomic Power Safety
Fallout from Nuclear Tests
The USAEC, What It Is and What It Does
Radioisotopes in Industry
Radioactive Wastes
Plowshare
Atoms, Nature, and Man
Radioisotopes and Life Processes
Computers
Snap-Nuclear Space Reactors
Gentic Effects of Radiation

Nuclear Energy for Desalting
Radioisotopes in Medicine
Nuclear Clocks
Nuclear Power Plants
Your Body and Radiation
Animals in Atomic Research
Index to the Understanding the Atom Series
The First Reactor
The Chemistry of the Noble Gases
Cryogenics - the Uncommon Cold
Lasers
Reading Resources in Atomic Energy

Bulletins

The AECL Radioisotope Handbook. Atomic Energy of CANADA Limited, Commercial Products Division, Ottawa, Canada, Technical bulletin RP3, 1960.

Aglintsev, K. K., V. M. Kodyukdv, A. F. Lyzkov, Yu, V. Sivintsev. Applied Dosimetry. The Chemical Rubber Company, Cleveland, Ohio, 1968.

Agriculture 2,000. United States Department of Agriculture, Washington, D. C., 1967.

Applicability of Radiation Pasteurization in the Southern Region. U. S. Atomic Energy Commission, Division of Isotopes Development, Southern Interstate Nuclear Board, 1964.

Appreticeship Standards of the Oak Ridge National Laboratory. The Laboratory General Apprenticeship Committee.

Hearings Before the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy. Congress of the United States.

1. Review of AEC and Army Food Irradiation Programs, 1962.
2. Review of the Army Food Irradiation Program, 1963.
3. Radiation Processing of Food, 1965.
4. Review of the Food Irradiation Program, 1966.
5. Status of the Food Irradiation Program, 1968.

The Future of Food Preservation. Proceedings of the Symposium, April 2-3. Sponsored by Midwest Research Institute, Kansas City, Missouri, 1957.

Josephson, Edwards S., and J. Harry Frankfort. Radiation Preservation of Foods. American Chemical Society, Washington, D. C., 1967.

Marine Products Development Irradiator Facility. Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Massachusetts Associated Nucleonics, Inc., 975 Stewart Avenue, Garden City, New York, 1964.

Medical Radioisotope Course Laboratory Manual. Oak Ridge National Laboratory, Oak Ridge, Tennesse, 1967.

Metlitskill, L. V., V. F. N. Rogachev, and V. G. Krushchev. Radiation Processing of Food Products. Isotopes Information Center, Oak Ridge National Laboratory, U. S. Army Natick Laboratory, Natick, Massachusetts, 1967.

Problems in the Evaluation of Corcenogenic Hazard from Use of Food Additives. National Academy of Sciences, National Research Council Publication, 749. Food Production Committee Food Nutrition Board, 1959.

Proceedings of the North Central Experiment Stations Workshop on Radionuclides in Foods and Agricultural Products. Cincinnati, Ohio, 1963. Special report series No. 1. Ohio Agricultural Experiment Station, Wooster, Ohio, 1963.

Radiation Preservation of Foodstuffs. Second Scandinavian Meeting on Food Preservation by Ionizing Radiation. Stockhom, September 9-11 . Iva Meddelande, V. R. 138, 1963.

Radiation-Processed Foods as a Component of the Armed Forces Feeding Systems. U. S. Department of Commerce, Office of Technical Services. (No date.)

Radiation Safety and Control Training Manual. Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1967.

Radioactive Materials in Food and Agriculture. Report of an FAO Expert Committee, Rome, 30 November-11 December, 1959. Food and Agriculture Organization of the United Nations, Rome, 1960.

Slavin, Joseph W., Joseph H. Carver, Thomas J. Connors, and Louis J. Ronsivalli. Shipboard Irradiator Studies. Technological Laboratory Bureau of Commercial Fisheries, Gloucester, Massachusetts, 1966.

Status of Irradiated Food Petitions to U. S. Food and Drug Administration. U. S. Department of Agriculture. U. S. Department of Commerce, Business, and Defense Service Administration, 1966.

Stiles, Philip G., W. Howard Martin, and Richard Lalley. Curriculum in Food Handling and Distribution. A Guide for Experimentation in High School and Post High School Vocational Training. University of Connecticut, Storrs, Connecticut, 1967.

Technical Basis for Legislation on Irradiated Food, The. Report of a Joint FAO/IAEA/WHO Expert Committee, Rome 21-28. Published by FAO/WHO World Health Organization, Geneva, 1966. World Health Organization Technical Report Series No. 316, FAO Atomic Energy Series, No. 6, 1964.

Wierbicki, Eugen, Morris Simon, and Edward Josephson. Preservation of Meats by Sterilizing Doses of Ionizing Radiation. U. S. Army Natick Laboratories, Natick, Massachusetts, 1964.

Irradiation Equipment, Design, and Fabrication Companies

The American Novawood Corporation
2432 Lakeside Drive
Lynchburg, Virginia 24501

Applied Radiation Corporation(ARCO)
2404 N. Main Street
Walnut Creek, California 94596

Gamma Process Company
160 Broadway
New York, New York 10038

Isotopes, Incorporated
A Teledyne Company
50 Van Buren Place
Westwood, New Jersey 07675

National Lead Company
Nuclear Division-
Wilmington Plant
Wilmington, Delaware 19801

Nuclear Technology Corporation
116 Main Street
White Plains, New York 10601

Radiation Facilities, Incorporated
63 Dell Glen Avenue
Lodi, New Jersey 07544

Stearns-Roger Corporation
660 Bannock Street
P. O. Box 5888
Denver, Colorado 80217

American Nuclear Corporation
P. O. Box 526
Oak Ridge, Tennessee 37831

Atomchem Corporation
20869 Mound Road
Warren, Michigan 48090

General Electric Company
Irradiation Processing Operation
Nuclear Energy Division
P. O. Box 846
Pleasanton, California 94566

Lockheed-Georgia Company
Nuclear Products Division
Dawsonville, Georgia 30534

Nuclear Materials and Equipment
Corporation (NUMEC)
609 Warren Avenue
Apollo, Pennsylvania 15613

Neutron Products, Incorporated
Box 95
Dickerson, Maryland 20753

Radiation Machinery Corporation
1280 Route 46
Parsippany, New Jersey 07054

Film Badge Services

Eberline Instrument Corporation
P. O. Box 2108
Sante Fe, New Mexico 87501

Card-Ray Film Badge Service
P. O. Box 117
Burlington, Massachusetts 01803

R. S. Landauer Company
Science Road
Glenwood, Illinois 60425

Nuclear-Chicago Corporation
333 East Howard Avenue
Des Plaines, Illinois 60018

Nucleonic Corporation of America
196 Degraw Street
Brooklyn, New York 11231

Radiation Detection Company
385 Longue Avenue
Mountain View, California 94042

Tracerlab Company
1601 Trapelo Road
Waltham, Massachusetts 02154

U. S. Air Force Radiological Health Laboratory
Wright Patterson Air Force Base
Ohio, 45433

U. S. Atomic Energy Commission
Idaho Operations Office
P. O. Box 2108
Idaho Falls, Idaho 83401

COURSE OUTLINES

Irradiation Health Physics

Unit	Topic
1	Irradiation and the individual a. Lethal doses b. Effect of irradiation on tissues and organs c. Irradiation syndromes d. Genetic effects e. Internal exposure f. External exposure g. Mechanisms of biological damage h. Chemical toxicity i. Variables affecting irradiation damage j. Accidents k. Medical examination l. Reports and evaluation
2.	Environmental contamination and containment a. Maximum permissible concentration b. Natural background c. Man-made irradiation impartation (medical, television, fallout) d. Process safeguards e. Waste materials f. Ventilation and gaseous waste g. Explosives h. Decontamination i. Cell containment j. Building containment k. Operational safety procedures
3.	Instruments for radiation detection a. Ionization chamber b. Proportional counter c. G-M tube d. Scintillation counter

Electronics

Unit	Topic
1.	Training standards for the electrical industry
2.	Electron, theory, and Ohm's Law
3.	Series circuits
4.	Parallel circuits
5.	Electrical energy and power
6.	Conductors and wire sizes
7.	Wiring methods and materials
8.	Voltage loss on conductors
9.	Magnets and electromagnetism
10.	Inductance and inductance reactance
11.	Capacitance and capacitance reactance
12.	Basic principles
13.	Basic principles of transformers
14.	Tuned circuits and resonance
15.	Election tubes
16.	Instruments and measurements
17.	Power supply
18.	Transistors

Food Toxicology

Unit	Topic
1.	Food standards a. Physical standards b. Legal standards c. Microbiological standards
2.	Microbiological toxicology a. Non sporeforming bacteria b. Sporeforming bacteria c. Yeasts, molds, and mycotoxins d. Antibiotics
3.	Environmental toxicology a. Ammonia b. Carbon dioxide c. Ripening agents d. Package control
4.	Natural toxicants
5.	Chemical degradation of foods
6.	Chemical additives and residues
7.	Pesticides and their residues
8.	Chemical poisons
9.	Trace analysis of toxicants

Radiation Hazards and Safety

Unit   Topic

1. Safety policy and responsibility

2. Definition of radiation terminology

3. Permissible exposures

4. Effects of radiation on man
   a. Radiation types
   b. Chemical effects
   c. Penetration

5. Instrumentation and monitoring
   a. Radioactivity calculations
   b. Natural background count
   c. Dosimetry

6. Toxicity

7. Operational Safety criteria and evaluation

8. Personnel record reports and accumulation
   a. Film badges
   b. Pocket dosimeters
   c. Other special monitors

9. Radiation containment and protection
   a. Air and water
   b. Equipment
   c. Waste products

10. Health physics
    a. Laboratory area monitoring
    b. Neighborhood and distant monitoring

Unit	Topic
11.	Emergency procedures
	a. Control center
	b. Emergency zones
	c. Emergency supervisor and squads
	d. Communications center
	e. Emergency service
12.	Transfer of radioactive materials
	a. Hazard evaluation
	b. Responsibility
	c. Handling
	d. Storage
13.	Sources of irradiation
	a. Isotopes
	b. Reactors
	c. X-Rays
	d. Electron accelerator
	e. Natural sources

Basic Chemistry

Unit	Topic
1.	The elements
2.	Atoms and their components
3.	Valence
4.	Energy patterns in atoms
5.	Understanding the periodic chart
6.	Molecules
7.	Ions and radicals
8.	Hydrogen ion concentration (pH)
9.	Normality and molarity
10.	Examination
11.	Properties of gases
12.	Halogens
13.	Metals
14.	Carbon
15.	Aldehydes, ketones, and single sugars
16.	Carbohydrates structure
17.	Carbohydrate metabolism
18.	Lipids
19.	Amino acids
20.	Proteins
21.	Examination
22.	Fermentations
23.	Baking powders
24.	Food energy
25.	Sweeteners
26.	Preservatives
27.	Flavoring agents
28.	Antioxidants
29.	Regulations on food chemicals
	Final examination

Food Chemistry

Unit	Topic
1.	Development of food chemistry

2.	Fats and other lipids
	a. Occurrence in foods and composition
	b. Edible fats and oils
	  1. Fatty acids
	  2. Identification of natural fats and oils
	    a. Physical properties
	    b. Chemical properties
	c. The technology of edible fats and oils

3.	Food carbohydrates a. Monosaccharides b. Disaccharides c. Polysaccharides d. Identification e. Changes of carbohydates in cooking f. Browning reactions
4.	Proteins in foods a. Proteins in man's diet b. Chemical and physical properties c. Determination of protein in foods d. Heat treatment e. Some notable protein systems in foods
5.	Enzymes in foods a. Significance of enzymes in foods b. Occurrence and classification c. Mechanism of enzyme action in foods d. Enzyme inhibition

6.	Chemistry of food flavor
	a. The sensation of flavor
	b. Chemical compounds in food which are responsible for flavor
	  1. Mechanism of the formation of these chemical compounds
	  2. Relationship of chemical structure and flavor
	  3. Relationship of chemical structure and odor

Unit	Topic
	4. Development of off-flavors and their chemistry
	5. Defining desirable flavor
	c. Methods for isolation of flavor components
	d. Control of flavor and aroma in processed food
	e. Synthetic flavor substances
	f. Recent developments in flavor research
7.	Chemistry of food texture
	a. Definition of texture
	b. Structure and chemical composition of food products as related to texture
	c. Physical and chemical determinations related to food texture
8.	Chemistry of food color
	a. Definition of color
	b. The natural coloring matters
	1. Heme pigments in meat and fish
	2. Chlorphyll in green vegetables
	3. The cartenoids
	c. Non-enzymatic browning
	d. Color measurement
	1. Color difference measurement
	2. Instrumentation
9.	Food chemicals and their function in foods
	a. Types of food chemicals and their significance
	b. Methodology of government approval
	c. New chemical methods for their determination

Basic Food Chemistry

Laboratory Outline

Unit	Topic
1.	Understanding laboratory equipment and procedures
2.	Moisture determination
3.	Micro-analytical test for purity of foodstuffs (filth test)
4.	Measuring acidity and alkalinity
5.	Analyses of total ash
6.	Melting points
7.	Specific gravity determination
8.	Analyses of sugar
9.	Lipid analyses
10.	Kjeldahl nitrogen determination
11.	Iodine values
12.	Phosphate determination
13.	Determination of calcium
14.	Analyses of baking powder for available CO_2
15.	Rancidity
16.	Baking reactions

Food Identification

Unit	Topic

1. Flavor
   a. Flavor physiology and definitions
   b. Flavor thresholds, (sugar, salt, acid, and bitterness)
   c. Sensory evaluation
      1. Difference tests - list
      2. Preference tests - list
      3. Sample preparation and uniformity
      4. Panel selection and training
      5. Testing conditions (lights, schedule, containers, and procedures)
      6. Statistical analysis

2. Texture and composition
   a. Classification of texture
      1. Liquids and gels
      2. Fibers and cell aggregates
      3. Unctuous and friable foods
      4. Foams and sponges
      5. Structured foods
   b. Effects of processing on texture
   c. Texture degradation and physical change
      1. Effects and causes of physical change
      2. Nonenzymatic chemical change
      3. Enzymatic reactions and changes

3. Color of foods
   a. Vision and color preception
   b. Color space
   c. Color collections
   d. Color tolerance and natural coloring matters
   e. Instrumentation and evaluation

4. Legal standards
   a. U.S.D.A. Standards of identity
      1. Red meats and poultry
      2. Milk, eggs, and related products
      3. Fruits and vegetables
      4. Grain

Unit	Topic
	b. Standards for non USDA supervised products
	1. Manufactured foods
	2. Fish and crustacea
	3. Bakery items
	c. Food and Drug Administration regulations
	d. State regulations

Physics

Unit	Topic
1.	Definitions and consistent units of a. Mass b. Weight c. Force d. Gravitation e. Atomic particles f. Molecular energies
2.	Statics a. Force summation b. Moment summation c. One direction statics d. Multiple direction statics e. Vector algebra
3.	Dynamics a. Motion b. Velocity c. Acceleration and gravitation d. Orbital motion
4.	Law of inertia
5.	Linear momentum a. Center of mass b. Atomic collisions
6.	Energy
7.	Newtonian mechanics
8.	Conservation of mass, momentum and energy
9.	Eleasticity and harmonic motion
10.	Theory of gasses

Unit	Topic
11.	Theory of light
12.	Theory of sound
13.	Thermodynamics
14.	Physical properties of a pure substance
15.	Mixtures and solutions

Engineering and Equipment

Unit	Topic
1.	Units for mass, length, time, force, and temperature
2.	Slide rule usage
3.	Statics
4.	Kinetic theory
5.	Thermal properties of solids, liquids and gasses
6.	Work and heat
7.	Laws of thermodynamics and applications
8.	Entropy and enthalpy
9.	Power and refrigeration cycles
10.	Phase and chemical equilibrium
11.	Electrical circuit analysis
12.	Exponential excitation and excitation functions
13.	Frequency response
14.	A-C and D-C circuits
15.	Magnetic circuits and transformers
16.	Electromechanical energy conversion
17.	Electrical machines
18.	Linear accelerators
19.	Conveyor systems
20.	Safety lock and control devices
21.	Plant layout and design

Food Packaging

Unit	Topic	Laboratory
1.	Introduction	Package identification
2.	Paper containers	Paper testing
3.	Paperboard packages	Formed containers
4.	Plastic containers	Film identification
5.	Package testing	Strength tests
6.	Glass containers	Glass testing
7.	Metal containers	
8.	Aerosols	Can testing
	Quality control	
9.	Packaging fruits and vegetables	Moisture control
10.	Packaging meat and eggs	
11.	Packaging beverages	
12.	Institutional and military packaging	Package design
13.	Merchandising	
14.	Package development	Labels
15.	Legal consideration	Packaged food evaluation

Quality Control of Food Products

Unit	Topic
1.	Basic principles of organoleptic examination of food products a. Physiology of taste and smell b. Four senses used c. Primary tastes d. Practical use in industry etc.
2.	Flavor defects
3.	Texture, body and appearance
4.	Quality scores a. Flavor defects - relative scores b. Body and texture defects - relative scores c. Appearance defects - relative scores
5.	Fresh foods a. Types - sweet, salt c. Federal grades and grading d. Famous brand names and imports
6.	Frozen foods:(definitions, size, shape, age, colors, brands, defects of flavor, dehydration, packaging)
7.	Processed foods a. Definition and federal standards b. Manufacture of processed foods c. Package types sold and use
8.	Foreign foods a. Definition and standards b. Package types sold c. Use
9.	Dehydrated foods a. Definitions and standards b. Various types 1. Flavor additives 2. Package types and sizes c. Defects of flavor d. Defects of body and texture

Unit	Topic
10.	Ice creams a. Definitions, standards b. Types - delux, standard and low fat c. Defects of flavor d. Defects of body and texture e. Ice cream scoring
11.	Convenience specialities a. Cake rolls and cakes b. Tarts, pies, etc. c. Sandwiches and bars
12.	Beverages: (flavors, flavor defects, body and texture defects, scoring, solids content)
13.	Cultured foods a. Buttermilk b. Yoghurt

Laboratories should consist of observing and discussion the various products and product defects. Numerous samples should also be graded and scored to teach the student the over-all grade of the product and thus the comparative price value.

Food Microbiology

Unit	Topic
1.	Introduction a. Definition and scope of bacterial activities b. Desirable and undesirable bacteria c. Importance of bacteriology d. General facts about bacteria - pathogens - saprophytes
2.	Morphology and classification of bacteria a. Size shape, habitat, method reproduction b. Nomeuclature, general cytology c. Yeasts, molds, viruses, phages d. Explanation of general terms used in bacteriology
3.	Nutrition and growth of microorganisms a. Necessity of certain classes of nutrients b. How bacteria obtain their food c. Role of enzymes - endo - exoenzymes d. Nomenclature of enzymes
4.	Culture mediums a. Composition of media b. Changes produced by bacteria c. Normal fermentation processes d. Acid, gas formation e. Proteolysis f. Certain defects related to bacterial activities - malty, ropy, sweet curd, etc.
5.	Sources of bacterial contamination a. Methods of control b. Destruction of microorganisms by heat c. Various methods of heat application - steam, hot water, hot air, etc. d. Pasteurization of food
6.	Classification of bacteria according to temperature requirements a. Effects of temperatures on bacteria

Unit	Topic
7.	Methods of determining sanitary quality of food and food products a. Platform quality tests - sediment tests b. Laboratory tests c. Application and limitations Reduction test d. Phosphatase test
8.	Diseases transmitted through food
9.	Bacteriology of frozen desserts
10.	Butter and cheese cultures
11.	Antibiotics

<u>Food Microbiology</u>

Laboratory

Unit	Topic
1.	The microscope: (uses, etc.)
2.	Morphology and straining of bacteria: (methylene blue, gram stain)
3.	Preparation of media: (litmus milk, standard agar and nutrient broth)
4.	Lactic fermentation of litmus milk
5.	Direct microscopic clump count: (calculation of microscopic factor, preparation and staining of films, method of counting and calculation of DMCC)
6.	Standard plate count: (method of making plates, dilutions selection and counting of plates, method of calculation of S.P.C.)
7.	Tests for coliform group
8.	Solid and liquid media a. Lactose fermentation b. Method of estimating numbers of coliform organisms present
9.	Phosphatase test: (uses and limitations, controls, interpretation)
10.	Laboratory pasteurization: (uses and interpretation)
11.	Antibiotics in food: (methods of testing)
12.	Growth of bacteria under various forms of irradiation

Food Processing

Unit	Topic
1.	Unit operations and processes a. Raw materials: (conveying, weighing, storage)
2.	Processing: (grading, disintegration, separation, mixing and blending, coating and forming, degassing, heat treatment, heat removal, dehydration and drying)
3.	Colloidal properties of doods: (classes of colloids, methods of preparation, properties, gels and sols, imbition, emulsions, foams, other edible emulsions)
4.	Food machines a. Principles of sanitary equipment design b. Simple equipment: (knives, vats and tanks, tables, trucks and troughs, beaters, shovels, pails, dippers) c. Power equipment: (mixing and blending, cutting and grinding, pumping and grinding, heating and cooling, dehydration)
5.	Food preservation by use of microorganisms a. Food as a source of energy for microorganisms b. Microbial food preferences c. Sugar fermentation d. Other fermentations
6.	Factors influencing the type of decomposition
7.	The preservation section of salt
8.	Chemical preservatives a. Definitions b. Classification c. Bacteriostatic fungistantic and germicidal agents

Unit	Topic
9.	Chemicals a. Antioxidants b. Neutralizers c. Stabilizers d. Firming agents e. Coatings and wrappings f. Expanded use of chemicals g. Gas storage h. Gas maturation
10.	Food preservation by temperature control a. Cool storage of foods b. Freezing preservation of foods
11.	Heat penetration and food process calculation methods a. Heat penetration curves b. Heat penetration equipment c. Heat penetration tests d. Probability of survival of microorganisms
12.	The canning process a. Preliminary considerations
13.	Basic operations in canning
14.	Spoilage in canned food a. Standards for canned food b. Canned food in relation to health c. Life of canned food d. Home canning e. Fallacies about canned food
15.	The dehydration of foods a. Dehydration principles b. Drying procedures c. Treatment prior to drying d. Detailed procedures e. Reconstitution and cooking f. Nutritive values of dehydrated foods g. Storage h. Biochemical deterieration

Unit	Topic
16.	Freeze drying of food products
	a. Methods and equipment
	b. Fundamentals of the drying process
	c. Application of freeze drying foods
17.	Food preservation by radiation
	a. Beta radiation
	b. Gamma radiation
	c. Effect of radiation on food
	d. Problems in radiation
18.	Washing detergency sanitation and plant housekeeping
	a. Washing and detergency
	b. Sanitation and plant housekeeping
	c. Insect control
19.	Food supervision by government agencies
	a. Federal agencies
	b. State agencies
	c. Muncipal agencies

Mathematics*

Unit	Topic
1-4	Fundamentals of arithmetic and inventory
5.	Review of arithmetic
6-7	Standard math test G.E.D.
8.	Literal numbers, exponents, algebraic terms
9.	Addition, subtraction, literal negative numbers
10.	Multiplication, algebraic terms
11.	Division, algebraic terms. Test
12.	Equations and formulas
13.	Equations and formulas test
14-15	The slide-rule and the powers of 10
16.	Electrical units and conversions
17.	Ohm's Law - Series circuits (math involved)
18.	Mid-term exam
19.	Ohm's Law - Series circuit test (Ohm's Law)
20.	Resistance-wire sizes (math involved)
21.	Resistance-wire sizes test
22.	Factoring-the monomial
23.	Factoring-the binomial and trinomial
24.	Factoring-the differences of squares
25.	Factoring-test
26-29	Fractions
30.	Fractions-test
31-32	Fractional equations
33.	Fractional equations-test
34.	Ohm's Law and parallel circuits (math involved)
35.	Ohm's Law and parallel circuits test
36.	Review and test
37-41	Simultaneous linear equations - graphs, graphical solution of equations, variables, analytical solutions, fractions summary and test
42-44	Mathematics involved in generator, motor, and battery circuits.
45-47	Exponents and radicals, definitions - addition subtraction, multiplication, and division Complex and imagenaries

*Source: Oak Ridge National Laboratory Electrician Apprentice Training Program.

Unit	Topic
48-50	Quadratic equations. Solutions of formula. Some electrical applications
51-53	Math involved in Kirchhoff's Laws. Problems in series circuits, 3-wire distribution systems, and net works, star and delta circuits
54.	Mid-term test
55-60	Logarithms. Definitions, log of a product, quotient, root summary. Common system, characteristics, mantessa tables and practical uses
61-63	Logarithms. Applications: decibels, transmission lines inductance, capacitance, general applications
64-65	Angles, definitions, generation positive and negative, radian measure applied geometry
66-68	Trigonometric functions: definitions of terms, interchangeables, solutions by construction, functions of the angle, line representation and variations
69-71	Tables of functions, exercises in the use of the table interpolation, relative accuracy, functions of angles in different quadrents, negative angles and reduction of functions to acute angles
72.	Review and test

The Van de Graaff Nuclear Physics Teaching Laboratory*

Basic Set of Experiments

EXPERIMENT 1: - Accelerator System Observation.

Purpose: A 400 keV Van de Graaff and ancillary equipment is demonstrated to give the student an understanding of the design and construction of a modern accelerator system.

Method: The component parts of the 400 keV Van de Graaff accelerator and ancillary equipment are studied. A short description and demonstration of the following equipment is presented:

a) the vacuum system, including types of pumps, ratings of pumps, vacuum gauges and vacuum interlock conditions
b) the accelerator, including the belt, spray supply, RF ion source, ion optics control, accelerating tube and pressure tank
c) beam-bending magnet with its power supply
d) beam-energy stablization system with its slits, amplifier and corona points
e) target chamber including the Faraday cup, current integrator, rotatable detector arm, and target support

Equipment: A 400 keV Van de Graaff accelerator and ancillary equipment and radiation monitors.

EXPERIMENT 2: - Accelerator System Operation.

Purpose: A 400 keV Van de Graaff accelerator and ancillary equipment is used to produce an anlyzed beam of protons.

*Source: Reproduced by permission of High Voltage Engineering Corporation, Burlington, Massachusetts.

Method: The accelerator is operated with a proton beam to obtain characteristics, size and intensity as a function of focus voltage, probe voltage, gas pressure, and beam energy. The magnet current settings as a function of generating voltmeter energy are determined at a number of beam energies for an on-target beam.

Equipment: A 400 keV Van de Graaff and ancillary equipment, scattering chamber, current integrator, and radiation monitors.

EXPERIMENT 3: - Detector Electronics.

Purpose: The detection system AEC-modular electronics will be studied to obtain familiarity and a facility of use. At the same time, instruction can be given on the basic pulse circuits.

Method: The pulser is used to drive preamplifiers, amplifiers, discriminators, scaler and coincidence circuit to allow a determination of pulse size and shape for each input and output.

Equipment: The full complement of AEC-modular electronics.

EXPERIMENT 4: - Accelerator System Calibration.

Purpose: The accelerator and analysis magnet is calibrated for future use so that the ion energy is precisely known.

Method: The yield of gamma rays from the reaction $F19 (p, \alpha \gamma)0^{16}$ as a function of proton bombarding energy is measured. Resonances in the reaction cross section at 224 keV and 340 keV are recognized and used to calibrate the magnet and generating voltmeter.

Equipment: A 400 keV Van de Graaff accelerator and ancillary equipment, scattering chamber, current integrator, fluorine target, NaI(T1) detector, preamplifier, amplifier, discriminator, scaler, timer, multichannel analyzer, and radiation monitors.

EXPERIMENT 5: - Ionization Chamber Detector.

Purpose: A determination of the half-life of a radioactive element is measured with a geiger counter. Health Physics procedures are shown with a radiation monitor.

Method: A deuteron beam from the 400 keV Van De Graaff bombards a deuterated target to produce a copious supply of neutrons from the $D(d,n)He^3$ reaction. The neutrons are moderated in a water tank and then captured by an (n,γ) reaction with In^{115}. The half-life of the In^{116} thus formed is measured with a geiger counter. The radiation monitor is used to exemplify the need for Health Physics procedures near an accelerator.

Equipment: A 400 keV Van de Graaff accelerator with deuteron beam, deuterated target, water moderator, geiger counter and supply, scaler, timer, radiation monitors, Cs^{137} source, indium target.

EXPERIMENT 6: - Scintillation Crystal Detectors.

Purpose: A familiarity with NaI(Tl) detectors provides the student with a knowledge of scintillation crystals. At the same time he learns about the fundamental interactions of photons with matter.

Method: Radioactive substances, Cs^{137}, Na^{22}, and Co^{60} emitting gamma rays are used to allow an energy calibration and a determination of detector resolution vs. gamma energy for a NaI(Tl) system. The gamma rays from the reaction $F^{19}\ (p,\alpha\gamma)O^{16}$ at a proton energy of 340 keV are measured to observe the compton and pair-production gamma-ray interactions with matter.

Equipment: NaI(Tl) detector, preamplifier, amplifier, multichannel analyzer, 400 keV Van de Graaff accelerator and ancillary equipment, scattering chamber, radiation monitors, Cs^{137}, Na^{22}, Co^{60} sources, and fluorine target.

EXPERIMENT 7: - Surface Barrier Semiconductor Detectors.

Purpose: The student uses a surface-barrier semiconductor detector so that he is familiar with it for future applications.

Method: The alpha particle spectrum from Po^{210} is measured with a surface-barrier semiconductor detector. The elastically scattered 400 keV protons from gold are also observed.

Equipment: Surface-barrier detector, scattering chamber, preamplifier, amplifier, multichannel analyzer, 400 keV Van de Graaff and ancillary equipment, gold-leaf target and Po^{210} source.

EXPERIMENT 8: - Rutherford Scattering in the Au(p,p)Au Reaction.

Purpose: The scattering of protons from a gold foil is observed and differential cross-section at various angles is measured.

Methods: 400 keV protons from the Van de Graaff are scattered from a gold-leaf target. The scattered particles are detected with a semiconductor detector and recorded through suitable electronics in a multichannel analyzer. The Rutherford scattering formula is compared to the experimental results by plotting the number of partilces observed as a function of $1/\sin^4(\theta/2)$. The actual counting rate is compared to that calculated from a knowledge of the particle flux, area-density of the gold foil and proton energy.

Equipment: 400 keV Van de Graaff accelerator and deflection system, surface barrier semiconductor detector, gold-leaf target, scattering chamber, preamplifier, amplifier, discriminator, scaler and multichannel pulse height analyzer.

DEFINITIONS

Alpha particle (Ray)	Nuclear radiation consisting of two protons and two neutrons, essentially the nucleus of a helium atom. They have a positive electrical charge and have little penetrating power.
Beta particle (Ray)	Nuclear radiation essentially the same as an electron and moderate in penetration.
Curie (c)	A quantity of radioactive nuclide in which the number of disintegrations per second is 3.7×10^{10}.
Decay (radioactive)	The gradual change of one radioactive element into a different element by a spontaneous emission of alpha, beta or gamma rays.
Dose rate	Dose per unit time.
Electron volt	The energy acquired by an electron in falling through a potential of one volt.
Exposure dose of radiation	The measure of the radiation based upon its ability to produce ionization.
Gamma ray	A highly penetrating type of nuclear radiation similar to X radiation, except that it comes from within the atom's nucleus.
Half life	The time required for half the atom in a radioactive substance to disintegrate.
Irradiation	Exposure to some form of radiation.
Nuclear energy	Energy produced by nuclear reation or by radioactive decay.

RBE	Relative biological effectiveness - a number expressing how much greater an absorbed dose of X or gamma radiation is needed to produce the same effect in human tissue as the radiation in question.
RBE dose	The product of the absorbed dose in rads and the RBE with respect to a particular radiation effect.
Rem	Roentgen equivalent man. The unit of RBE dose.
Roentgen (r)	An exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air produces in air, ions carrying one electrostatic unit of quantity of electricity of either sign. This is equivalent to an energy absorption of 87.7 ergs per gram of air.

Table 9: Personnel Monitoring Instruments (Portable)

Instrument	Detector	Radiation Detected	Range	Application	Remarks
Film meter (badge)	Film, Au, In, S, silver phosphate glass, and chemical dosimeter	γ, β N_f, N_{th}	0.1-10,000 rad	Permanent record of dose of each type of mixed radiation. Au and In activated by criticality accident.	Film-density dependence on photon energy circumvented by filters. Orientation of film during exposure a problem.
Pocket Chamber (indirect reading) Victoreen Type	Ionization chamber (air)	γ	to 100 ± 5 mr, to 200 ± 10 mr	Measurement of day-to-day gamma exposure	Relatively energy independent for γ. Read by minometer.
Pocket Chamber (Direct reading)	Ionization chamber (air)	γ N_{th} (when coated with boron enriched in B^{10})	to 200 mr; available with higher ranges	Visual check on gamma and, when modified, thermal neutron exposure	Position of electrometer fiber read through magnifying lens.
Personal Radiation Monitor	G-M tube	γ, x high-level β	Maximum audible warning at 0.5 r/hr; flashing light becomes continuous at 10 r/hr	Visible (light) and audible warning of radiation field	Signal frequency proportional to radiation intensity. Available in higher rate ranges.
Chemical Dosimeter	Tetrachloroethylene + pH indicator	γ	5 rad to 2×10^6 rad	Measure gamma component of a mixed radiation field.	Being tested in film badges. Read by titration, measurement of conductivity change, measurement of pH colorimetrically or electrometrically.
Glass Dosimeter	Metaphosphate glass containing silver	γ	5 to several thousand rad	Dose measurement of gamma exposure over a wide range.	Loosely bound electrons freed by radiation form photoluminescent centers with silver; centers excited by ultraviolet light emit photons (~6400 A). Should not be read for 1 hr after exposure unless specially calibrated.

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Table 10: Portable Survey Instruments

(Battery or Electrostatically Powered)

Instrument	Detector	Radiation Detected	Range (Nominal)	Application	Remarks
Cutie Pie	Ionization Chamber (air)	γ, x High-energy β	5 to 10,000 mrad/hr	Dose-rate meter for γ and x (0.008 to 2 Mev) within 10%. With ORNL chamber measures with at least 50% efficiency the externally hazardous betas.	Most widely used instrument for these measurements. A "soft-shell" instrument (ORNL chamber) is made by cutting away sections from the detector housing and replacing them with a thin film. Adjusted to "zero" position through grid bias potentiometer.
Juno Survey Meter	Ionization Chamber (air)	α γ β	Three scales: 10,000, 100,000, and 1,000,000 d/min Three scales: 50, 500, and 50,000 mr/hr	Dose-rate meter for γ and β; relative-intensity meter for α.	Maximum error 10% full scale. Manually positioned shields used. Should be warmed up 1 min and carefully zeroed. For γ measurement should be oriented as to calibrating source. Zero may be adjusted in high radiation fields.
Samson Survey Meter	Ionization Chamber (air)	α β,γ	Three scales: x1, x5, x25 (500 counts/min, full-scale, x1)	Rate meter for α; with probe, monitor for β, rate meter for γ.	Calibrated only for alpha, although sensitive to β and γ radiation. Must be properly zeroed before use. Warm-up time: 2-3 min. External shield should be used to determine if radiation other than α is present. Sensitive area should almost touch surface being surveyed.
Geiger-Mueller Survey Meter (Thyac and Nuclear 2610)	G-M tube	$\beta > 0.2$ Mev, γ	Three scales: x1, x10, x100; x1 may be 600-800 counts/min full scale	Detection instrument for $\beta > 0.2$ Mev and γ. Rate meter and audible pulse. Indicates approximate γ dose rates between 0.05 and 20 mr/hr.	Energy dependent. Should be used with earphones for faster response. Sliding shield for β-γ discrimination. Some models saturate above 50-100 mr/hr and will not indicate higher dose rates. Commercial instruments insensitive to low β energies, unless equipped with thin window counter.

Table 10: (continued)

Instrument	Detector	Radiation Detected	Range	Application	Remarks
Alpha Proportional Counter (air) "Poppy"	Proportional counter (air)	α	May detect as little as 50 d/min α in presence of 1 rad/hr γ.	Analysis of mixed γ, β, and α radiation; discriminates between α and β-γ.	Less stable than the gas-flow instrument, particularly in area of high relative humidity. Probe face must be very near source of radiation, and moved slowly for low activities.
Alpha Proportional Counter (gas) (PAC-3G)	Proportional counter (gas)	α	May detect as little as 50 d/min α in presence of 1 rad/hr γ; range to 500,000 d/min.	Analysis of mixed γ, β, and α radiation; discriminates between α and β-γ.	More stable than air proportional counter. Reading not dependent on section of probe face receiving radiation, as with scintillation counter. Grade or type of gas used should not be changed without recalibration.
Alpha Scintillation Counter (Q 1975)	Phosphor and and photomultiplier	α	To ~500 c/min	Assay of α emitters; registers accumulated counts. Audible signal and meter.	Requires less maintenance than proportional counter. Probe face must be very near source of radiation, and moved slowly for low activities.
Disc Air Sampler	None	α, β, γ later counted		Air drawn through filter by AC-operated blower.	Collection time and airflow rate should be noted.
Thermal Neutron Proportional Counter (Q-2004)	(BF_3 enriched in B^{10}). Proportional counter, gas.	N_{th}	20 to 20,000 $N_t/cm^2 \cdot sec$	Can discriminate against intense γ radiation (measure 200 N_{th}/cm^2 sec in field of 10-rad/hr γ).	Employs $B^{10} + N \rightarrow Li^7 + \alpha$ reaction.
Fast Neutron Proportional Counter (Rudolph)	Proportional Counter, gas	N_f	0.1 to 100 mrad/hr	Measure first-collision tissue dose of N_f from 0.2 to 14 Mev. Discrimination a problem in γ fields above 2 r/hr.	Tissue-equivalent walls and gas.

Table 10: (continued)

Instrument	Detector	Radiation Detected	Range	Application	Remarks
Gamma Scintillation Counter	NaI crystal	γ	Low-level	Used for very low-level γ monitoring, 0.001 to 1 mr/hr	Sensitivity dependent on size of crystal.
Beta Scintillation Counter	Phosphor	β		Very few applications in portable instruments.	G-M tube generally preferable.
Neutron Scintillation Counter	Zn S(Ag), molded in Lucite.	N_f		Fast neutron detection where dose rate is not required.	

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Table 11: Area Monitoring Instruments

Instrument	Detector	Radiation Detected	Range	Application	Remarks
Continuous Beta-Gamma Air Monitor (Particulate)	G-M tube (shielded)	β, γ	Includes MPC level	Continuous recording of β-γ particulate radiation. Amber light and bell alarms for preset level.	Count-rate and strip-chart recorder incorporated. Does not distinguish between β and γ.
Continuous Alpha-Particulate Air Monitor	ZnS (Ag) for α	α, β		Provides alarm when permissible exposure is exceeded.	Alarm may be based on rate of increase of activity, rate of sample decay, change of normally constant α-β ratio due to radon decay. Radon is a problem.
Continuous Gaseous Air Monitor	Ionization chamber (gas-flow, shielded)	Tritium	1/100 to 10 x MPC for tritium	Tritium monitor	
Fast Neutron Dosimeter (Radsan)	Proportional counter lined with polyethylene and filled with ethylene	N_f	From 1/10 permissible exposure	Fast neutron dosimetry. Insensitive to γ less than 5 r/hr.	Can be checked with internal α source. Tissue-equivalent chamber.

Table 11:(continued)

Instrument	Detector	Radiation Detected	Range	Application	Remarks
Monitron	Ionization chamber	γ if chamber is coated with carbon only, γ and N_{th} if coated with B^{10}-enriched boron.	To 125 mr/hr	Dose-rate meter for γ background monitoring; measures only the relative intensities of N_{th}. Requires Ac power input. Several ion chambers can be placed 150 ft or more from central unit.	Zero setting should be checked daily. Should be operated only on high-sensitivity setting unless users are warned of low-sensitivity setting. Where background permits, alarm should sound at 7.5 mr/hr. Calibrated with Ra source.
Threshold Detector Unit	Series of foil detectors.	N_{th}, N_f.	High-intensity neutron flux.	Provides data which, when analyzed with special counting equipment, gives the dosage of high-intensity neutron bursts.	Should supplement, but never be substituted for, alarm-type instruments which warn of dose rate, but which do not measure dose.
Alpha Gas-Flow Proportional Counter	Proportional Counter (gas)	α and β-γ	May detect as little as 0.1 d/min α.	Analysis of mixed γ, β, and α radiation; discriminates between α and β-γ.	Requires timer and scaler for power. Contamination of counter walls and loop electrode a problem.

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Table 12: Personnel and Area Contamination Monitoring Instruments (Fixed)

Instrument	Detector	Radiation Detected	Range	Application	Remarks
Hand and Foot Monitor	Halogen-quenched G-M tube	β, γ	Low-level	Simultaneous detection of β and γ contamination of hands and shoes. Will not detect α.	Most models have auxiliary probe for monitoring clothing.
Water Effluent Monitor	Cluster of G-M tubes or NaI scintillator	γ, β		Monitoring water wastes or coolants. May be connected to rate-meter, recorder, and alarm systems, or to check and diversion valves for control of water flow.	Thin films of water (or other material) will absorb α. Monitoring for any radiation may be complicated by silt, algae, radioactive contamination of the detector, variability in water flow rate and surface levels.
"Stack" Monitors for Gaseous Effluents	Combinations of monitors listed above for gaseous and particulate activity.	Depends upon detectors chosen.		Rough estimate of the radioactivity of effluent from a multi-use stack.	Requires complicated and expensive sampling, collecting, detecting, counting, and data-interpreting equipment.
Portal Monitors (Quintector)	Five or more G-M tubes	β, γ		Monitoring exits from areas of suspected contamination.	Slow passage through narrow portal required for maximum instrument response.

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FOOD IRRADIATION TECHNICIAN TRAINING NEED SURVEY
University of Connecticut
Storrs, Connecticut 06268

As a part of a U.S. Office of Education study, this survey is being conducted to determine the special training needs of the technician class of personnel responsible for future food irradiation operations in government and commercial organizations. It will be greatly appreciated if you will complete the following survey form to help establish the level and criteria needed for training these technicians. Please feel free to express your personal opinion regarding the training program in the area provided for comment.

Your Name ____________________, Employer ____________________

Work level: Administrative _________, Supervisory ____________

Professional _________, Technician ____________

Please return this form by November 1, to:

Dr. Philip P. Stiles
Poultry Science Department
University of Connecticut
Storrs, Connecticut 06268

1. What education level is realistic for food irradiation technicians? (Please check the appropriate value blank.)

	Large Need	Moderate Need	No Need	Comment
High school	____	______	____	________
Vocational Post High School	____	______	____	________
Some college training	____	______	____	________
Graduate college training	____	______	____	________
Other____________	____	______	____	________

2. What would you suggest as being the optimum training program for food irradiation technicians?

	Large Need	Moderate Need	No Need	Comment
Special courses added to a standard curriculum	_____	_____	_____	_____
On-the-job training	_____	_____	_____	_____
Special school	_____	_____	_____	_____
Short courses (2 or 3 weeks by government agencies)	_____	_____	_____	_____
Other_____	_____	_____	_____	_____
Other_____	_____	_____	_____	_____

3. What are the relative values for the following courses for food irradiation technicians?

	Large Need	Moderate Need	No Need	Comment
Fundamentals				
English & composition	_____	_____	_____	_____
Mathematics	_____	_____	_____	_____
Chemistry	_____	_____	_____	_____
Physcis	_____	_____	_____	_____
Government	_____	_____	_____	_____
Economics	_____	_____	_____	_____
Other_____	_____	_____	_____	_____
Food Courses				
Food processing	_____	_____	_____	_____
Equipment	_____	_____	_____	_____
Food microbiology	_____	_____	_____	_____
Quality control	_____	_____	_____	_____
Food identification	_____	_____	_____	_____
Food merchandising	_____	_____	_____	_____
Food packaging	_____	_____	_____	_____
Food chemistry	_____	_____	_____	_____
Unit operations	_____	_____	_____	_____
Other_____	_____	_____	_____	_____

	Large Need	Moderate Need	No Need	Comment
Irradiation Skills				
Irradiation equipment	____	____	____	____
Irradiation hazards	____	____	____	____
Health physics	____	____	____	____
Safety	____	____	____	____
Physical chemistry	____	____	____	____
Nuclear physics	____	____	____	____
Electronics	____	____	____	____
Irradiation mathematics	____	____	____	____
Toxicology	____	____	____	____
Other____________	____	____	____	____
Other____________	____	____	____	____
Social Skills				
Public speaking	____	____	____	____
Sociology	____	____	____	____
Psychology	____	____	____	____
Physical education	____	____	____	____
Business management	____	____	____	____
Merchandising	____	____	____	____
Other____________	____	____	____	____