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ABSTRACT

Phase I of a multiphase research program in progress at the Technical Education Research Center, Inc., was conducted to analyze needs and resources in terms of job performance tasks, career opportunities, and training requirements for nuclear medical technicians. Data were gathered through personal interviews with 203 persons, mostly physicians, and from 151 questionnaire respondents. Major findings were: (1) Nuclear medicine has grown rapidly, but more money, better equipment, and improved instructional programs for technicians would speed the growth, (2) Diagnosis is the major concern of every nuclear medicine department surveyed, although most are involved in some radiotherapy work, (3) The technician's tasks center upon scanning and the related activities of radiopharmaceutical preparation and oral administration to the patient, (4) Standardization of preparatory programs and certification requirements is needed, and (5) Need was expressed for a standard textbook written especially for the technician and for more careful instruction in clinical procedure, use of instruments, mathematics, and radiation physics. (SB)

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TERC Technical Education Research Center

Interim Report Number 1

Survey of Job Characteristics,

Manpower Needs and Training Resources,

July 1969.

Development of Career Opportunities for Technicians in the Nuclear Medicine Field

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INTERIM RESEARCH REPORT

Development of Career Opportunities
For Technicians in the Nuclear Medical Field
Phase I

August 1969

Technical Education Research Center, Inc.
44A Brattle Street
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PREFACE

This Research Report describes Phase I of the "NMT Program", a multiphase research program being carried on at Technical Education Research Center, Inc. (TERC) as a part of TERC's program to develop generalizable educational programs in several emerging technologies.

The overall objectives of the NMT Program are to assist both public and private institutions to plan, design and/or evaluate programs in nuclear medical technology that are keyed to identified needs, and anticipate future developments, in the field. The purpose of the Phase I study was to analyze the needs and resources of the field in terms of the job performance tasks, the career opportunities, and training requirements for nuclear medicine technicians. The purpose of Phase II will be to design and evaluate responsive instructional programs based on task analysis and performance criteria.

TERC is a non-profit research organization that is wholly devoted to the improvement of occupational and technical education throughout the U.S. The critiques of the report (Appendix I) by several well known experts in the practice of nuclear medicine reflect TERC's interest in receiving feedback both favorable and unfavorable, which will allow us to improve the quality of our work. We will welcome any comments you might have on the substance of the report or its format which would allow us to perform a better service to young people choosing careers as Nuclear Medical Technicians, to the institutions that train them, and to the public and private institutions that employ them.

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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I. Introduction

This report, completed as Project Number 7-0313 for the Bureau of Research of the United States Office of Education, concerns the career opportunities for young people as Nuclear Medicine Technicians (NMTs). Although the NMT has provided the focal point for research and occupies center stage in this report, the background for the technician is the present and future state of the field of nuclear medicine. Thus the report of necessity includes our findings concerning the field of nuclear medicine as well as the technician's place within it.

The survey has grown during the past year from preliminary planning conferences to the rough identification of behavioral objectives of an NMT, then to the design of a survey questionnaire instrument, and finally to the collection and analysis of information on the technician and nuclear medicine. There have been five specific objectives which have provided structure to the survey and which dictate the substance of this report. The five objectives are:

1. to provide an estimate of the number of NMTs now employed, the number now needed, and the number likely to be needed by 1975 in the United States;
2. to identify the performance objectives of an NMT, and from them to derive job descriptions for the NMT;
3. to discover the nature and extent of existing preparatory programs for NMTs;
4. to explore the feasibility of NMT preparatory programs involving cooperation among hospitals and educational institutions;
5. to consider what new instructional materials or new programs, if any, will be required to meet employment needs.

The outline of the report (exclusive of the appendices) tends to follow these objectives. An additional section has been added on the field of nuclear medicine as we have found it in our investigations. Because the survey has provided what amounts to a current picture of nuclear medicine, a comprehensive history of the development to this point in time is neither possible nor particularly useful. From the information we have gathered, however, we have attempted to identify the dynamic factors at work and their implications for the growth and direction of the field.

Several impressions have become clear as the investigations have proceeded. Nuclear medicine is a vigorous, dynamic activity, and although physicians and NMTs frequently disagreed on many subjects within the field, there was a consensus that the rate of growth of nuclear medicine has been unique. At the same time, ironically, a difficulty exists in defining exactly what nuclear medicine is and where it should be practiced in hospitals. The established definition of nuclear medicine is as follows:

> Nuclear Medicine is the scientific and clinical discipline concerned with the diagnostic, therapeutic (exclusive of sealed radiation sources), and investigative use of radionuclides. (Journal of Nuclear Medicine, Page 901, December, 1967)

The field overall seems to be fragmented, however, with nuclear medicine being conducted in departments of radiology, pathology, internal medicine, and independent nuclear medicine departments. Although trends and schools of thought are fairly clear, the exact direction of nuclear medicine seems uncertain. The activity of a nuclear medicine service in a particular hospital seems to bear a direct relation to the initiative, energy, and dynamism of the physicians, technologists, and physicists involved. Although we have developed terminal performance tasks for the total range of activities in which most Nuclear Medicine Technicians are engaged, the conception of what an NMT is or should be has varied widely, perhaps reflecting the present lack of definition in the field.

Besides identifying tasks and working conditions of the NMT, we have attempted to project the requirements for new NMTs over the next five years. Indications are that the field is growing not only in tests performed and equipment purchased, but in manpower needs as well. The preparatory programs for these technicians, like the entire field itself, appear to be uncoordinated. Existing programs, certification standards, and instructional needs constitute another section of the report.

A brief note of explanation concerning the terminology used in this report is necessary since many differences exist in the field. We have used the title "Nuclear Medicine Technician" (NMT) consistently throughout the report to describe the person who works as an assistant to a physician in performing nuclear medicine tests and operations in hospitals. The titles such persons presently hold vary considerably but frequently incorporate the term "technologist" rather than "technician." Where registries or organizations use the former term, we have tried to follow their usage. We understand "technologist" to imply, however, four years of higher education, with a baccalaureate degree. In selecting the title of "Nuclear Medicine Technician," we have assumed that two years of higher education and probably an associate degree would more accurately describe the educational qualifications of technicians involved in and required for nuclear medical work. A general agreement on the definition and use of these terms does not exist.

Among educators and others concerned with education there is a lack of agreement on terminology parallel to that within the health professions. In this report, rather than use "training" or "education" to modify "programs" designed for persons going into nuclear medicine technology, we have chosen the adjectives "preparatory" and "instructional". We define "preparatory programs" as including (in some unspecified ratio which may vary from case to case) both training for particular skills and education in the sense of broad underlying knowledge and individual fulfillment. "Training" has been used only where it was clearly so intended by respondents.

We have made every effort to refine the body of the report itself as much as possible. Consequently, much of the detailed information and substantive material have been placed in the appendices where they may be referred to readily. The report is intended to be as useful as possible to those concerned with nuclear medicine technology. Rather than to furnish only numbers and statistics, the report seeks to provide the physician who hires or instructs Nuclear Medicine Technicians with practical information. Also it should furnish a valuable framework to those interested or presently involved in establishing more formal preparatory programs for NMTs. Hopefully the report will reflect some sense of where the field stands at the moment and where it may be heading. Thus, by casting the report in a utilitarian mold, we hope that the survey objectives will provide helpful information.

The data on which this report is based were gathered in personal interviews and by mail. A single basic questionnaire instrument was developed over a period of several months and gradually refined by critical examination and practical experience in the field. A longer version provided the foundation for personal interviews, conducted by ten interviewers in twenty major cities over a period of three weeks in June, 1969. An abridged version of about one-half the full length was used in a mailed sample, sent to a random sample of hospitals listed by the Journal of the American Hospital Association as having nuclear medicine facilities. As we conducted interviews and as we have undertaken the analysis of the data obtained, a number of flaws in the questionnaire have become apparent. Undoubtedly it is always difficult to design a questionnaire that is simultaneously fully comprehensive, entirely clear in intent, and completely efficient in format. This questionnaire sought varieties of information which a single respondent was not always capable of giving. Indeed we sought information frequently requiring the respondent to be physician, technologist, administrator, education specialist, and medical prognosticator and visionary rolled into one! A full copy of the questionnaire along with a more detailed critique of the instrument and its use is contained in Appendix A.

The majority of those interviewed were physicians with backgrounds representing radiology, pathogy, and internal medicine.* Nuclear Medicine Technicians and physicists were also among the 203 interview respondents. The mailed questionnaires were sent to 618 hospitals in every state except Alaska. There were 151 replies and the data they contain have been integrated and/or compared with the interview data.

The assistance and cooperation of all respondents was rewarding and the level of enthusiasn for nuclear medicine and this survey has been high. Many physicians interrupted busy schedules to give generously of their time and insight. Those doctors who mentioned the number of questionnaires they received were often the most generous with their time. This report owes no small debt to the many respondents whose interest and assistance have made its completion possible.

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*For exact breakdown, see Appendix A, page 96

II. The Growth, Place, and Practice of Nuclear Medicine

The Development of Nuclear Medicine in Hospital Departments

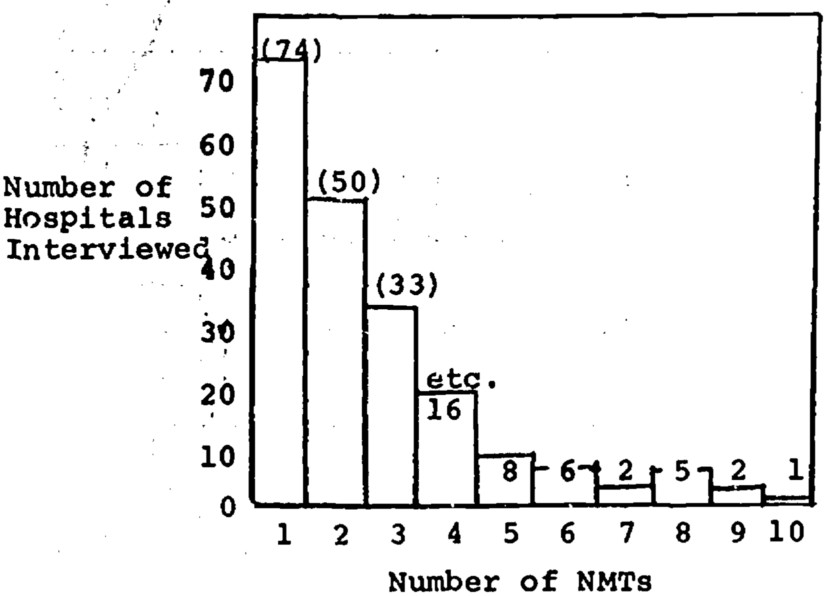
Radioactive isotopes have been the subject of research throughout most of the twentieth century. It has only been since the end of World War II, however, that they have been used extensively as a research tool. The use of nuclear radiation in medical diagnosis and therapy - called "nuclear medicine" - has also grown since the end of the War, and has become established in many hospitals.

In the 203 hospitals from which interview data were gathered, about five nuclear medicine facilities were established per year in the early 1950's. By 1953 this number rose to about ten departments per year, a growth pattern indicated in Graph 1 on the following page. The decline in numbers of new departments following 1965 is probably not characteristic of hospitals throughout the country, but reflects the types of hospitals we visited. In most cases we surveyed only well established nuclear medicine departments, since our interview sample was based on hospitals listed in the <u>1966 American Hospital Association Guide</u> as having radioisotope facilities.

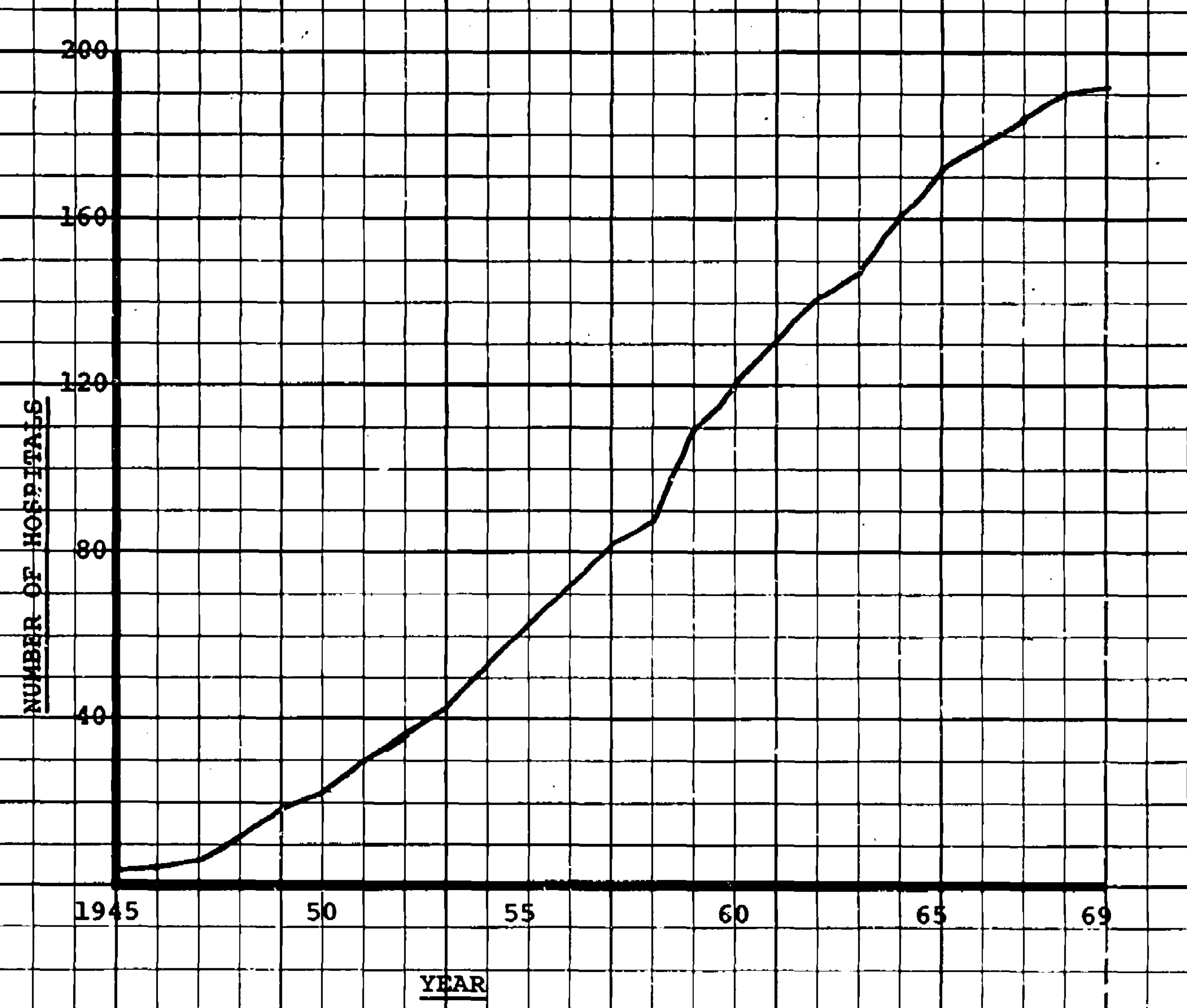
Nearly all nuclear medicine departments are quite small in terms of personnel. In only 24 cases (12%) were more than 4 technicians employed. In over thirty-seven percent (37%) of the hospitals only one (1) technician was employed.

Table 1

Numbers of Technicians in Departments Where Nuclear Medicine Operations Occur (n = 197)



Graph 1: The Establishment of Nuclear Medical Facilities



In most cases (62%) nuclear medical operations began in departments of radiology and in only thirteen percent (13%) of the cases was nuclear medicine originally established as a separate and independent department. Eleven percent (11%) of the departments were initially a branch of pathology and seven percent (7%) a branch of internal medicine; the remaining departments, notably in Veterans Administration hospitals, usually began as a part of research departments. Currently the same percentage of departments is subordinate to radiology, but an additional nine percent (9%) have become independent of pathology and internal medicine, bringing the number of independent departments to twenty-two percent (22%) of our sample.

Although a principal purpose of nuclear medicine is to provide a diagnostic aid for a variety of medical specialties, and several of the tests correspond to work in pathology, nuclear medicine has been and continues to be most closely linked to radiology. This affinity is evidenced by the percentage of departments subordinate to radiology, the fact that most Nuclear Medicine Technicians have come to their position by way of X-ray technology, and the fact that much of nuclear medical work concerns scanning or anatomic imaging. Many radiologists indicated that they thought their department was the appropriate place in the hospital organization for nuclear medicine.

In sixty percent (60%) of the hospitals which have either an independent department or one subordinate to pathology, all of the hospital's nuclear medical tests and operations are performed within that department. For these hospitals, laboratory tests associated with nuclear medicine (T-3 tests, blood volumes, etc.) tend to be performed by the same individuals who do the scanning. Where nuclear medicine is associated with radiology, however, only thirty-seven percent (37%) of the units performed all the tests, the majority sharing the work with pathology and other departments.

Table 2

Organizational Patterns in Nuclear Medicine

Status of Nuclear Medicine Department	Number of Departments	Number Sharing Nuclear Medical Operations	Number Performing All Nuclear Medical Operations
Independent	44	19 (44%)	25 (56%)
Under Pathology	11	3 (27%)	8 (73%)
Under Radiology	120	76 (63%)	44 (37%)
Other	20	5 (25%)	15 (75%)

Trends in Nuclear Medicine

If past trends continue, the number of independent departments of nuclear medicine will probably grow slowly over the next few years, most separating themselves from pathology and internal medicine. Departments of radiology will undoubtedly continue to sponsor nuclear medicine operations during the next few years; their interest in nuclear medicine operations remains positive and strong. We see some signs, however, that after a few years nuclear medicine may begin to branch from radiology as it has done from other departments. Some respondents indicated a desire to separate from radiology into an independent department. The recognition of nuclear medicine as a specialty rather than a subspecialty by the American Medical Association (AMA) would provide strong impetus for independent status. If physicians find their primary interest in the practice of nuclear medicine, some of the presently strong ties to radiology may be loosened. Several interview respondents suggested that the parallels between nuclear medicine and radiology are more apparent than real. Furthermore, some of the trends in instrumentation and technique foreseen by a number of those interviewed may have the effect of moving nuclear medicine farther from radiology. One trend is toward an increased number of dynamic function studies by means of such instruments as the scintillation camera. The application of computers to the scintillation camera and to data processing in general would seem to indicate a greater degree of complexity and specialization than has heretofore characterized nuclear medicine.

The preceding paragraph is not intended to be a certain prediction that departments of nuclear medicine will become separate from radiology. There are other signs that existing connections will be maintained. In smaller hospitals the present volume of nuclear medicine tests may require the part-time assistance of X-Ray Technologists. Indeed the preparation required by a Nuclear Medicine Technician and an X-Ray Technologist has a common base in anatomy and radiation physics. Also, a procedure used in a few of the hospitals surveyed combines X-Ray pictures with dynamic function studies in a sort of "overlay" fashion to give physicians a more comprehensive diagnostic tool.

The source of much of the energy and dynamism in nuclear medicine often appears to be in university hospitals and medical schools. Where respondents were asked with whom they would prefer to collaborate if a preparatory program for NMT's were established, many named university medical centers. Because of the prestige of these centers, and the fact that extensive research and development work is carried on there, staff physicians in surrounding hospitals tend to look to universities for leadership in nuclear medicine.

Factors Affecting the Growth of Nuclear Medicine

Respondents were asked to list the factors they thought would slow or limit the growth of nuclear medicine, and conversely, the factors which might speed its growth. The responses tended to fall into several categories. One factor mentioned as constraining growth was money for equipment, personnel and the necessary hospital space. The initial cost, technical sophistication, and the rapid obsolescence of equipment were cited by a number of respondents. More than a quarter of those surveyed also mentioned the poor quality of instructional programs for technicians, the inadequate formal preparation in nuclear medicine for physicians, and the general lack of familiarity of doctors with the potential of nuclear medicine. In many cases health insurance plans do not cover nuclear medicine tests on an out-patient basis, thus placing a burdensome cost on the individual. Although another significant factor mentioned was the bureaucratic "red tape" required by the Atomic Energy Commission (AEC) and the Food and Drug Administration for use of radionuclides and radiopharmaceuticals, some respondents felt that these regulations are essential to prevent the use of nuclear medicine by incompetent persons. Fear of nuclear radiation by the public was also cited as a consideration in the growth of nuclear medicine.

In speeding the growth of nuclear medicine, more money, better equipment, and improved preparation for NMT's and medical doctors were cited as significant factors. A number also felt more uniform certification standards and stronger organizations for NMT's would permit the growth of the field. A few respondents noted that nuclear medicine would grow as it became freed of its subordinate status to other departments.

A few felt that recognition of nuclear medicine as a specialty by the AMA might significantly speed its growth.* About ten percent (10%) of our respondents cited increased availability, shorter half-life, and ease in the use of new and improved radiopharmaceuticals as factors that would speed the field's growth. A subsequent section will discuss in more detail anticipated innovations in equipment and radiopharmaceutical use.

A feeling expressed by many was that the nuclear medicine field could benefit from better public relations in several ways. They felt that the general public should be made aware of the fact that nuclear medicine tests are quite safe and that the patient usually receives even less radiation exposure than in a normal X-ray. At the same time, radiopharmaceuticals make possible tests enabling the physician to diagnose many patient ills he would not be able to diagnose otherwise. The popular idea of radioactivity is probably most commonly associated with nuclear weapons and war and these popular fears are not limited to patients alone. Hospital staff including doctors and nurses, frequently lack an understanding of the functions of the nuclear medicine department in their hospital. As a result of this misunderstanding, some departments provide lectures and tours for new hospital staff who have to relate to patients or personnel involved in nuclear medicine.

Another feeling of concern to many, one which relates to the fear of radioactivity, is that many people outside the field consider it to be esoteric. Several respondents cited the need to develop counseling and student recruitment materials at the secondary school level for potential Nuclear Medicine Technicians. Apparently many counselors view the field as being extremely difficult and would only think of recommending a career in nuclear medicine to the "brightest" students. Needless to say, this type of student usually goes into a four-year degree program. The professional societies with interests in developing this field might consider how to dispel the fear among the general public and, at the same time, stimulate interest among young persons who might consider employment opportunities in nuclear medicine.

Nuclear Medicine Tests and Equipment

Most departments of nuclear medicine are primarily concerned with diagnostic work. The basic nuclear medicine instruments -- detector probe, scaler, well counter, monitor, rectilinear scanner, and automatic film developing facilities -- are designed to meet two major diagnostic objectives:

*See comment by C. Craig Harris, Appendix I, pages 262-263.

the description and localization of medical or organic disorders.* Interviews showed that a scaler and stationary detector probe were often the first major purchases of new departments of nuclear medicine, followed by a rectilinear scanner.

For the purpose of observing trends that may affect the NMT's role, the diagnostic work of most departments, allowing for some overlapping, can be classified into three categories: static studies, dynamic function studies, and *in vitro* tests. Static studies, which may also be described as "anatomic imaging," primarily include image or localization studies, commonly called "scans." They are usually done with a scanner, taking from thirty minutes to two hours or done with a camera in considerably less time. Rapid uptakes (e.g. renograms) and slow uptakes (e.g. thyroids) are examples of dynamic function studies and are usually done by a stationary probe. Nuclear medicine departments may combine the single measurement of a thyroid function with a scan of the thyroid, a brief operation. The renogram takes more time, whether scanned or probed, than a thyroid. *In vitro* tests can be done ten or more times as quickly as a scan. These three classes of procedures account for 54% of the number of tests performed in the average department, although there is a wide range in their frequency. Roughly 40% of the work time of the average nuclear medicine department of our survey is devoted to scanning.

Other dynamic function studies currently form a small proportion of the typical nuclear medicine department's work but many doctors reported that they expect to do more such studies in the future. Inhalation studies, brain blood flow, and cardiac blood flow were the areas of interest most often mentioned by these physicians. Dynamic function studies may be done by the scintillation camera with or without computers, as well as by the stationary detector probe. Many departments have this equipment now (49%) and many have cameras on order (9%) or anticipate eventual acquisition.

When nuclear medicine is independent or subordinate to radiology, *in vitro* tests are often performed in the

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*See Appendix G for a more thorough discussion of instrumentation.

department of pathology (see Table 2, page 8). Many separate nuclear medicine department, however, would like to assume responsibility for laboratory tests. These tests include T-3 and T-4 tests, absorption and excretion tests (e.g. Schilling, fat tests) and blood volume tests. In vitro work does not usually demand the amount of training and experience which distinguishes a separate technology. Medical Technologists easily pick up the nuclear medical in vitro techniques without a subspeciality occurring in their ranks.

Therapy is also a part of the work of most departments where nuclear medicine is practiced. Radiopharmaceutical therapy is performed in seven-eight percent (78%) of the departments interviewed; it almost always involves ^{131}I. Other forms of therapy, including other radionuclides, brachytherapy, and teletherapy are conducted less frequently. These forms of therapy do not change the organization, training, technique, or equipment required by the department. Nuclear Medicine Technicians are only occasionally involved in radiopharmaceutical therapy since the procedures are ordinarily performed by a physician.

Many respondents expected to be using new equipment and procedures in the near future. They mentioned computer applications for the scintillation camera and whole-body scanner, time sharing computers, inhalation studies, and the area of radioimmunoassay. These operations are now being performed in a few hospitals. Other trends mentioned in the development of nuclear medicine included the introduction of ultrasonic scanners, infrared scanners, and joint tests with electro-encephalographs and electrocardiographs. We have little information on these developments, since the practices are limited to very few hospitals and occur infrequently.

The major trends in nuclear medicine which may affect technicians over the next two or three years include scanning with faster scanners and cameras, an increased number of time dependent observations, the development of radionuclides of shorter half-life, greater use of prepackaged pharmaceuticals and materials, and more automated data handling. Most respondents anticipated a greatly expanded use of radionuclides of shorter half-life; this practice would increase the importance of chemical preparation of radiopharmaceuticals. In some ways these changes will simplify the tasks of the technician since there will be fewer steps to some routines. In other ways, however, tasks will become more complex, with more routines, tests, pieces of equipment, and radioactive materials. This dynamic character of nuclear medicine explains the premium now placed on intelligent people motivated to learn new techniques.

III. The Nuclear Medicine Technician: Occupational Information

Profile of the "Average" Nuclear Medicine Technician

The questionnaire used in the performance of this survey emphasized the "average" Nuclear Medicine Technician. The use of this term caused semantic difficulties. It was not the intent of the investigators to describe this "average" in the sense of a mathematical mean; rather, to employ it in its more colloquial usage as "common" or "ordinary". For example, the decision was made to largely exclude tasks performed by highly skilled Chief Technicians, since these tasks would hardly be assigned to those newly graduated from Associate Degree programs of the two-year variety. However, once having defined this restriction, the objective was to compile a list of tasks representing the total range within which such an entry-level NMT would operate, within the first year or two from his graduating date.

However, in some cases, departments had only a single, all-purpose NMT, while in other instances there was no clear dividing line between the "chief" technician and others working with him. In still other replies, it was apparent that the respondents were not describing their actual "average" technicians, but an average technician which would be "ideal" (i.e., for their situations), were he available. This introduced a confusion with the following item in the questionnaire, which did request this information. The latter, however, was then interpreted as some kind of a "super-ideal", not tied to the respondent's own institutional situation, necessarily.

Recognizing these difficulties, we have attempted in this section to delineate the profile of the "average" NMT now working in American hospitals. This profile is based upon analysis of the data and upon our collective impressions of the views expressed in the interviews. A fuller discussion of this profile and variations of it are contained in the following sections.

The "average" technician now working in hospitals does not always hold the title of "Nuclear Medicine Technician," although that name is common. "Technologist" may be preferred since it connotes a baccalaureate degree. Another fairly common title is "Radioisotope Technician," and where X-Ray Technologists perform double-duty with operations in nuclear medicine, they frequently maintain their title of "X-Ray" or "Radiologic Technologist."

Although the amounts of preparation technicians have received vary, the average NMT has had between two and three years of formal preparation, most of it as an X-Ray Technologist, or, in a few cases, in laboratory work. The average

NMT has usually learned nuclear medicine in an on-the-job situation from physicians or, as commonly, from other Nuclear Medicine Technicians. Besides on-the-job experience, the average technician has received some formal instruction in short seminars or special programs of perhaps a week's duration.

The average NMT has certification from the American Registry of Radiologic Technologists as a Registered Technologist (R.T.) usually in X-ray technology but occasionally in nuclear medicine technology. The salary received by technicians varies considerably, but the average is about $6,300.

The average NMT works in a department with two other technicians, although he may spend considerable time working by himself. The tasks he routinely performs are many, but he spends about forty percent (40%) of his time engaged in the operation of a rectilinear scanner for conventional scanning. In connection with this work, he makes simple dose calculations for <u>in vivo</u> studies. He also receives, positions, and attends to patients, besides abstracting simple data from their records. The average technician is also concerned with safety, and has responsibility for the disposal of radioactive waste, safe storage of radioactive material, and the inventory and control of radiopharmaceuticals.

Most of the Nuclear Medicine Technicians we talked to reported that they found their work varied and interesting, and it is probably safe to say that the average technician does not suffer from boredom. When technicians do leave their jobs, the most common reasons are marriage, pregnancy, or a better paying position elsewhere.

<u>Tasks of the Nuclear Medicine Technician</u>

On a gross level, it may be sufficient to state that, in carrying out the diagnostic tasks of the nuclear medicine department, the average Nuclear Medicine Technician is primarily occupied with scanning and related activities. However, since a basic premise of this report is that curriculum design for preparatory programs for any occupation must be based on the current and expected activities of people in that occupation, <u>all</u> NMT tasks must be thus identified in reasonably sure fashion. The part of the questionnaire which began this complicated task may be seen on pp. 58-59.

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*See pages 42-44.

In explanation of the task frequency table which appears on the next two pages (and in Appendix A), several points should be noted. First, the term "job description" can have several legitimate definitions, depending upon the purpose of the investigator. If one desires an overall profile of general characteristics, for informational or comparative purposes, the format employed in the Dictionary of Occupational Titles is useful. If, on the other hand, the intent is to describe progressive levels of preparation and responsibility, as for rating or certification purposes, a scheme such as that devised by the Duke University Medical Center is appropriate. However, if the descriptive materials are intended for direct use in developing instructional materials, a much more detailed analysis must be undertaken.

Second, in the latter case, the initial step is to develop a complete and verified listing of all tasks (i.e., operational outcomes) which the worker is, or may be, expected to perform. Successively, the task analyst determines task frequency, relative importance, relationships among tasks or a task hierarchy, skill and knowledge inputs, conditions under which the tasks are performed (e.g., degree of supervision), and socio-personal concomittants, among others. The resulting task network can then be superimposed on the certification-type job description, thus affording the investigator the benefits of both types.

Third, this survey has attempted systematically only the first two steps in the task analysis sequence described above: task frequency and relative importance. Unfortunately, replies concerning the latter were not in a form which permitted the same kind of tabulation as the frequency. The same is true of information regarding tasks which an average NMT might reasonably be expected to perform in the future. Consequently, while task frequency results are reproduced in tabular form, below, the questions of task importance and future task developments are reported in narrative form, throughout the text.

Finally, it should be noted that task frequency does not necessarily correspond to task importance. However, in most instances in this study, this correspondence existed. Important cases which deviated from the norm are noted in the text. Also, Table 3 summarizes data from personal interviews, only. For various reasons, the validity of responses to this particular item (1.1) in the mailed responses was questionable. However, numerous spot checks were made and the mailed responses indicated very similar frequency patterns to those in the table.

To facilitate calculations, somewhat arbitrary values were assigned to the letter codes described on page 63. This does not significantly distort the relative frequencies since the absolute frequency ranges of the original letter codes could, themselves, be open to debate. To avoid confusion, the equivalent values and code meanings are stated, as follows:

0 = task not performed in department (value assigned: 0)

a = task performed in department, but not by an <u>average</u> technician in that department (value assigned: 1)

b = 1-3 times per month (value assigned: 2)

c = 4-10 times per month (value assigned: 3)

d = 11 or more times per month (value assigned: 4)

<u>Table 3</u>

<u>Frequency of Tasks Performed by NMTs In Nuclear Medicine Departments, with Emphasis on Average Technician.</u>

<u>Preparation</u>	<u>Mean</u>	<u>S.D.</u>
1. Chemically prepare short-life isotopes: a) eluting the column	2.7	1.8
2. b) chemical preparation	1.0	1.5
3. c) sterilize	0.6	1.3
4. Calibrate isotopes against a standard	3.1	1.5
5. Prepare oral dose: measure from manufacturer's bottle	2.6	1.7
6. Prepare oral dose: mix, dilute to measure	2.1	1.8
7. Prepare injections: measure dose	3.7	1.0
8. Prepare injections: sterilize dose	0.7	1.4
9. Set up instruments for operation: a) in vivo studies	3.6	1.0
10. Set up instruments for operation: b) in vitro studies	3.0	1.6
<u>Tests & Patients</u>		
11. Administer isotopes to patients: a) orally	3.6	1.0
12. Administer isotopes to patients: b) by injection	2.5	1.6
13. Receive patients, explain tests to them and allay their fears	3.9	0.6
14. Position patient with respect to nuclear medical equipment	3.9	0.5
15. Superficial and specialized examination of patients	---	---
16. Attend to patient's comfort before and during scan	3.9	0.6
17. Understand operating room procedure	---	---
<u>Data Handling</u>		
18. Abstract simple data from patient's chart	3.0	1.4
19. Make simple dose calculations for a) in vivo examinations	3.6	1.0
20. Make simple dose calculations for b) in vitro examinations	2.8	1.6
21. Make simple dose calculations for c) tracer examinations	3.5	1.1
22. Accumulate and process data for MD's interpretation	3.6	1.0
23. Examine scan test results for general credibility	3.7	0.9
24. Perform preliminary interpretations of observations for MD	1.9	1.6

Table 3 (cont'd)

Equipment	Mean	S.D.
25. Operate a rectilinear scanner for conventional scanning	3.7	0.9
26. Operate a autofluorescope for static studies	0.1	0.4
27. Operate a scintillation camera for static studies	1.7	1.9
28. Operate an autofluorescope for fast dynamic studies (under one minute scan)	0.1	0.6
29. Operate a scintillation camera for fast dynamic studies	1.3	1.7
30. Operate a scanner for slow dynamic studies (over one minute scan)	1.9	1.8
31. Operate an autofluoroscope for slow dynamic studies	0.1	0.6
32. Operate a scintillation camera for slow dynamic studies	1.5	1.8
33. Calibrate nuclear medical instruments	3.0	1.4
34. Check performance of existing and new nuclear medical instruments against manufacturer's specifications	1.9	1.3
35. Determine if a nuclear medical instrument is in need of major repair	2.6	1.3
36. Perform minor maintenance on nuclear medical instrument	1.9	1.2
37. Evaluate nuclear medical instruments from manufacturer's literature and specify and rank those instruments that satisfy doctors' requirements	1.2	0.9
38. Advise doctors on the technicalities and procedures involved in operating a nuclear medical instrument	2.2	1.3
Safety		
39. Check monitoring instruments	2.5	1.3
40. Monitor personnel in compliance with hospital regulations	2.2	1.4
41. Monitor space in compliance with hospital regulations	2.5	1.2
42. Handle and store radioisotopes safely	3.8	0.7
43. Assay wet chemical solutions for activity and contaminants	2.3	1.7
44. Safely dispose of radioactive wastes	3.4	0.9
Clerical		
45. Handle secretarial work: appointments, type reports	2.8	1.4
46. Routinely check incoming equipment	2.2	1.3
47. Inventory and order radiopharmaceuticals and materials	3.3	1.0
48. Keep accounts of hospital licensing and isotope procurement	2.6	1.5

Frequency data contributing to the calculation of means in Table 3, plus parallel data from the mailed questionnaire, are shown more fully in Appendix J.

Other major points of interest regarding the average NMT's performance tasks are as follows:

Wherever the patient load justifies the cost, hospitals have obtained their own radionuclide generator. Technicians operate these generators, but so far little chemical preparation of the resulting radioactive material is performed. Chemical work is becoming simplified by kits for many procedures, although certain procedures continue to require some wet-lab skill and attention. Radionuclides and pharmaceuticals prepared by commercial firms usually are sterile and as a result sterilization is almost never done by NMTs. Technicians do calibrate radiopharmaceuticals against a standard, and some doses are calculated and diluted to measure; others come pre-measured by the manufacturer. Technicians usually set up their own instruments on a daily basis, checking voltages, concentrations, radiation levels, etc.

The technician usually administers oral doses to the patient. Many technicians draw blood, and in about forty percent (40%) of the hospitals surveyed, they also administer injections. Some MDs prefer to give injections themselves because of their responsibility and risk to the patient involved. Some MDs have expressed interest in knowing more about legal restrictions or insurance possibilities for technicians who would be eligible to administer injections.

Technicians, as well as doctors, find it beneficial to establish rapport with patients before and during the scan, which may last two hours or more. Ordinarily technicians read the patient's chart and abstract data from it. NMTs receive patients, explain the tests to them, allay their fears and tend to their comfort during a long scan. They may sometimes work in a recovery room, but instances of participation in surgery are rare.

Nuclear Medicine Technicians do not diagnose disorders or interpret results of tests, but some may point out an area of interest on a scan to the doctor. Most are capable of judging the quality of their scans, and in general exercise quality control over their work. Some physicians check their calculations or share this work with them, each checking the other's calculations. Slide rules and desk calculators are used in figuring such problems as half-life, but there is a trend toward more electronic calculation. Time-sharing computer terminals currently are operated by a few physicists or MDs who often are seeking technicians capable of using this type of equipment.

Nuclear Medicine Technicians operate rectilinear scanners, detector probes, well counters, scalers and scintillation cameras for static and dynamic studies. Although in some instances (usually in hospitals without cameras) is was felt that sophisticated studies involving the scintillation camera required an exceptional technician, the average NMT generally handles this task adequately. The NMT is not involved in any major maintenance of equipment, although he may perform minor maintenance, such as changing a fuse on a tracking motor or replacing a knob. He may also check the performance of instruments against manufacturer's specifications, and may decide when the repairman must be called. NMTs demonstrate nuclear medical instruments and procedures to doctors, often residents, and to students in radiologic technology and nuclear medicine.

Radiation safety responsibilities are often shared with a Radiation Safety Officer (M.D. or Ph.D. physicist) or with a Chief Nuclear Medicine Technician. Basic knowledge in handling, storing and disposing of radionuclides and cleaning lab ware is essential. Technicians routinely use monitoring instruments, film and ring badges, and are familiar with regulations and techniques for monitoring persons and hospital space.

The amount of clerical work done by the average NMT varies depending upon whether or not a department has its own secretary. It may include keeping of records of doses, dose calculations, and treatments, as well as the filing of scans. NMTs often inventory and order radiopharmaceuticals, routinely check incoming equipment and materials and handle appointments. Since NMTs often work unsupervised in the course of a day, they must be capable of planning and completing work on their own.

The discussion, thus far, of the tasks of the Nuclear Medicine Technician has been largely in terms of an "average" technician. These are the tasks which were reported as presently being performed by Nuclear Medicine Technicians in hospital departments. In other questions, respondents indicated for what task performance they believed a technician should be prepared, and what tasks he should be able to perform. In short, we received a range of impressions of what a Nuclear Medicine Technician should be, focusing both on their actual and desired abilities.

The expectations respondents had of the NMT's job varied considerably. However, we had the general impression upon completion of the interviews that there were, in effect, three types of technicians - the "knob turner," the "two-year person," and the "chief tech." The first would perform most of the mechanics of nuclear medicine tests and operations under close supervision, but would not know much about the theoretical or conceptual background of the tasks he performed. Preparation for this individual would be minimal, usually on-the-job, and would follow directly from high school. The principal requisite qualification would be a willingness and ability to perform, with competence,tasks which are routine and repetitive.

The "chief tech" described for us by many respondents more commonly was termed a Nuclear Medicine "Technologist," especially qualified for the field by a full four-year college program. In contrast to the first type, this Nuclear Medicine Technologist would have a firm grasp of the conceptual background of nuclear medicine, besides competence to perform the mechanics of tests and operations. In addition, such a person might have supervisory and instructional responsibilities.

A description of the tasks of the "two-year" Nuclear Medicine Technician would fall between these poles. This person would most commonly have completed a two-year program in an area other than - but related to - nuclear medicine (usually radiologic technology,) followed by a short formal or on-the-job preparatory program.

We believe that these three modal impressions reflect a desire for several levels of an NMT. Certainly paths for advancement should be considered for career-oriented persons, and different levels of preparation, experience, competence, and responsibility could provide an appropriate career ladder. However, as has been previously emphasized in this report, this type of job description must ultimately come from agreement within the field. This agreement does not currently exist. Furthermore, for the purposes of developing instructional materials rather than immediately hypothesizing a "paper" curriculum, the task performance analysis approach is more relevant and has been the foundation of this report.

Nevertheless, since this report will hopefully be used by schools which are faced with the immediate problem of developing a curriculum outline for a specific kind or level of technician, we are including one of the better, locally developed, set of job level descriptions in the field. This particular one was developed by the Duke University Medical

Center's Division of Nuclear Medicine. Since these descriptions presumably are based on the Medical Center's own manpower organization and needs, they are understandably more detailed than our own conclusions of this type, which are not only peripheral to our purpose at this stage, but also reflect the lact of clear national agreement previously noted.

Contrary to Duke's experience, our survey did not find that the lowest level technician is nearly as well prepared as their "NMT-I". However, with this single tentative qualification, we feel that the Duke classification scheme should be a useful guide in providing a prototype career ladder for the Nuclear Medicine Technician. Adjustments can be made in it, by prospective users, in order to reflect their own local conditions.

While the entire Duke classification can be found in this report's Appendix K (including nature of work, skills and abilities, and training and experience), only the first of these categories is placed in the body of the report, below, as a convenient aid to those readers who may wish a quick overview to determine the full scheme's possible usefulness.

The Duke job descriptions are as follows:

Nuclear Medicine Technician I*

A technician in this classification performs entry-level work as a trainee in nuclear medicine procedures. These tasks are carried out under the direction and guidance of higher level personnel. The individual is responsible for performing a limited number of procedures accurately, or assisting in setting up procedures, and for recording pertinent data. Assignments may be in specialized areas, such as: scanning, in vitro studies, or other areas as determined by the patient-care needs of the service or the aptitude of the technician trainee. Duties are performed under direct supervision of both senior technologists and physicians, although some phases may be performed without repeated instruction. The work is evaluated by observation.

Employment in a position of this classification provides, over an appropriate interval of instruction and experience, training to lead to certification as a Registered Nuclear Medicine Technologist.

Nuclear Medicine Technician II, Nuclear Medicine Technologist II

A technician or technologist in this classification performs routine technical work related to nuclear medicine procedures using radioactive tracers and instrumentation pertaining to the measurement thereof. The level of performance is above that of an entry-level technician, but does not call for completely unsupervised performance. The individual is responsible for performing a large number of procedures accurately, for setting up procedures and for recording pertinent data. Assignments may be in any area of the nuclear medicine laboratory, e.g. assignment to rectilinear scanners, thyroid uptake area, or *in vitro* studies. Supervision is of a general nature and performance is evaluated by observation, both by senior technologists and by physicians.

Nuclear Medicine Technician III, Nuclear Medicine Technologist III

A technician or technologist in this classification is capable of performing any of the usual procedures in the clinical nuclear medicine laboratory with only minimal or occasional supervisory guidance. This classification identifies the technician or technologist as a senior technician or technologist, and assumes that the individual is of a responsible nature, having had intensive training and adequate experience. The individual is responsible for performing a large number and variety of procedures accurately, to develop and evaluate new procedures and should be capable of developing optimal means for recording pertinent data. As a senior technician or technologist, assignments may be to perform or to supervise in any area of the nuclear medicine laboratory, including scanning, *in vitro* studies and radiopharmaceutical preparation. The work is performed under general supervision and is evaluated by observation.

Nuclear Medicine Technologist IV

A technologist in this classification carries out the supervisory responsibilities of an overall chief technologist. This position carries the responsibility of organizing the technologic staff of the Division of Nuclear Medicine and devising and maintaining an orderly approach to the completion of each day's work load. This work is accomplished with the advice and guidance of the Instructor and in coordination with the clinicians and other faculty members responsible for the clinical service of nuclear medicine.

(end of Duke University material)

NMT Working Conditions

The tasks of the Nuclear Medicine Technician and the hospital environment shape the NMT's working conditions. The tasks, tests, and equipment involving the technician have already been discussed. The hospital environment in which the technician works necessitates that he be able to relate to MDs, physicists, technicians, nurses, other hospital personnel, and last, but by no means least, the patient. Ideally, the NMT must function as a part of the health care team of the hospital. Several respondents noted that the NMT occupied a position of unusual responsibility and importance and should enjoy an associate relationship with the physician. Others noted that a "bedside manner" was every bit as important to the NMT as to the doctor.

Formal and informal instruction in hospitals also influences the NMT's working conditions, especially those new on the job. Some doctors prefer a "black box" approach in training technicians to operate the instruments; their concern is for reliable, uniform technical performance based on routine. This approach requires only a relatively short training time, and an individual of average intelligence and high reliability. It recognizes the high turnover rate of NMTs that some areas have experienced. Other doctors prefer an in-depth understanding of the radiopharmaceutical-physiological-physics-instrumentation aspects of what is being done. Their concern is for reliable performance plus ability to handle unusual situations and to learn new techniques with a minimum of supervisory instruction. This approach requires an individual of higher intelligence, initiative, interest in the work, possibly a longer preparatory program, and perhaps higher salaries and more than average career challenge and opportunity.

Most NMTs at present are prepared informally on the job, one or two people at a time, by the doctor in charge of nuclear medicine at the hospital. The physician's most important criterion for hiring a person as an NMT is intelligence enough to learn the work quickly. Many MDs instruct their technicians closely for awhile, checking their work and supervising them until they are confident of their ability. In the larger hospitals with long-established nuclear medicine departments there are commonly several technicians who are supervised directly by a chief NMT, who in turn is supervised by a doctor. In the smaller hospitals he is more likely to be on his own and there his role depends very much on the attitude of the MD and the responsibilities entrusted to him.

Communications on the Job

Many NMTs work without close supervision once their preparation is completed. Most of the procedures are routine and require little on-the-spot communication. Often there is an informal net of people who provide assistance as it is needed, such as moving a patient, explaining a point of technique, etc. The more involved communications can usually be deferred until it is convenient, such as discussions on background, theory, new products, and techniques. The record keeping is standardized, often in ledgers devised by the NMT to meet doctors', hospital, and AEC requirements. The NMT may write a note or fill out a form for the patient's chart describing the work done and dose given. On occasion a short report of the procedure and findings, with unusual items noted, is required.

Communications with nurses in wards is usually to convey routine messages about pre- and post-scan attention and care, to ensure that the message is fully understood, and to encourage the nurses to observe every detail. Many floor nurses are totally unfamiliar with nuclear medicine and its pre- and post-scan requirements. This process is a combination of informing, impressing others with the need to carry out all instructions, and occasional checking up. It may be done by mimeographed instructions, phone calls, and face-to-face conversations.

Communication with patients is to explain the need to remain immobile, to allay fears (sometimes extreme in the aged or those unfamiliar with medical aspects of radiation), to bolster morale, and to explain pre- and post-test procedures, such as avoiding high-iodine foods, vitamin pills and medicines before a thyroid scan. During tests, NMTs have to establish rapport with the patient to secure their total cooperation.

Communication with drug and instrument manufacturers is by telephone and personal contact for orders and repairs and for information on new products. Technicians often continue to read medical texts and booklets on procedures and to attend discussions and lectures. For a senior or chief technician, an ability to understand written technical material is essential. Conferences and review sessions are sometimes organized by NMTs to refresh and stimulate interest in the field. In some cities, NMTs organize preparation sessions for the certification examinations.

NMTs interviewed were appreciative of the responsibility they were entrusted with, the newness of the field, the skill required to obtain good results, and the mutual confidence and regard between doctors and technicians, especially in the area of new information and techniques. Technicians generally were pleased with their work situation. They desired better preparatory programs and more continuing instruction, especially for those NMTs who are working nearly full time. Technicians were piqued where they sensed a lack of interest by their hospital or department head in the nuclear medicine unit (when nuclear medicine was not an independent department and the chief of the department was not nuclear medicine-oriented). Other concerns were lack of space, need for another technician, a concern to show others in the hospital what nuclear medicine could do, and a desire for more equipment and better procedures.

Manpower Needs

Estimating future manpower needs in any field is always a hazardous undertaking. Such estimates are not only a function of present data, but are also dependent on future occurrences which may be unforeseeable. Whenever calculations are presented for manpower needs, they should be coupled with the assumptions on which they are based. Wherever a variety of assumptions is reasonable, more than one set of estimates is required.

For the field of nuclear medicine, respondents generally were of the opinion that the next decade would be a period of rapid expansion (although even this was not unanimous: two or three people felt that nuclear medicine would be completely obsolete by 1980, having been replaced by thermography, ultrasonics or other procedures). From the data compiled, we have attempted to isolate the most reasonable assumptions concerning future growth and relate them to the expected needs for Nuclear Medicine Technicians.

(The most basic premise of this method is that the demand for an occupation will be the major factor in determining the supply of people in that occupation. The recent emergence of the position of the NMT and the predominance of on-the-job instruction are both major reasons to believe that this premise is a valid one.)

The techniques used were not complicated, consisting essentially of multiplying values of "average number of NMTs per hospital" by "number of hospitals." To obtain the values used, however, numerous assumptions were made, each of which is incorporated into the explanation of that technique in Appendix B.

The results are summarized in Graph 2. The shaded area of the graph represents the range within which the need for Nuclear Medicine Technicians for any given year is most likely to fall. The circled results are our best estimates based on the assumptions which appear to be most reasonable.

From a present base of 4,000 - 4,600 NMTs, Table 4 summarizes in different form the future demand for Nuclear Medicine Technicians.

Table 4

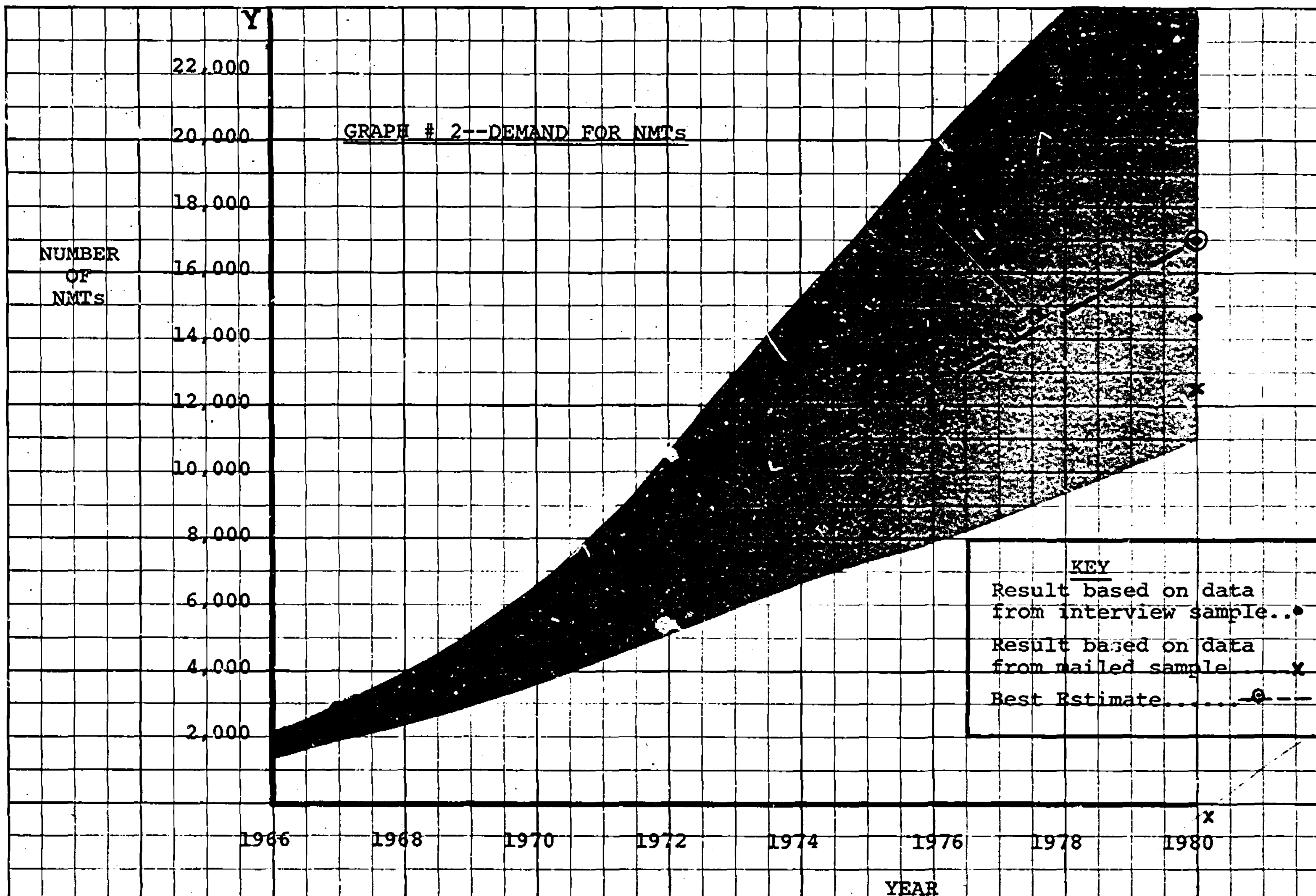
Demand for Nuclear Medicine Technicians

Year	Range	Best Estimate
1970	4,600 - 5,800	5,500 - 5,700
1972	6,300 -10,300	8,000 - 8,500
1975	10,000 -17,000	11,300 -12,300

Finally, the number of people who should be prepared to fill positions as NMTs is somewhat larger than the yearly increase due to deaths, retirement, pregnancies, and other causes which reduce the existing stock. Incorporating these factors we have concluded that there will be a need to prepare about 1,300 people per year to fill available positions as Nuclear Medicine Technicians.

Salary

Dissemination of information concerning the wage structure of an occupation is an essential process if market forces are to regulate effectively the supply and demand for people with that occupation. Nuclear Medicine Technicians are unfortunately under the same constraint as many hospital occupations in that demand is greater than supply, and yet salaries remain low. We have attempted in this survey to obtain data on present salaries under the assumption that such information would be useful to a person contemplating entering this field.



GRAPH # 2--DEMAND FOR NMTs

Nuclear Medicine Technicians in the U. S. with one year of experience are presently being paid anywhere from $4,000 to $12,000 with an average salary of $6,300 per year. These figures, unfortunately, are of little value because they include people with such a wide variety of backgrounds (our expectation that it would be possible to differentiate salaries based on the possession or nonpossession of "certification" proved to be impractical due to the many interpretations of the term).

Respondents were also presented with a description of possible candidates for a position as an NMT in their department and asked: a) to rank them in order of preference and, b) to suggest the salaries they would be willing to pay each individual. As indicated in Table 5, their first choice was for people with two years of nuclear medicine preparation, with or without an internship. A somewhat surprising finding, since most present NMTs have followed this route, is the relatively low ranking accorded to people with preparation in radiologic technology.

Respondents' answers to whether they would wish to hire an individual with four years of formal education (either a college science or a medical technologist program) exhibited the greatest variety; some refused even to consider anyone else; others felt that it was too unrealistic to expect someone with such high-level credentials to seek a job as a Nuclear Medicine Technician. The latter contention is further supported by the starting salaries respondents were willing to offer people with four-year backgrounds. Means were less than $7,000 and only $300-$400 more than salaries offered to those completing a two-year nuclear medicine program. Aggregating the data in this manner tends to conceal certain regional or other patterns; nevertheless, it is a highly exceptional hospital which offers competitive salaries to people with a B.S. degree.

The variety of responses to the above question was partly a function of the lack of standardization of certification requirements and instructional programs. Starting salaries offered NMTs with two years formal preparation range from less than $5,000 to more than $10,000. The variety was also due to real city-to-city differences, as shown by Table 6 which lists the mean salaries respondents in each city would offer people who have concluded "a two-year Nuclear Medicine Technician program involving hospital experience over several semesters" (this was first or second choice in all cities). It should be noted that respondents were often not responsible for the establishment of salary levels; the variety of figures within nearly every city suggests that their reliability is questionable.

Table 5

Preferences and Salary Offered to NMT Candidates

Comparison factors: Candidate has Completed	Preferred Ranking	Proportion Ranked in Top 4	Salary Offered	
			Median Range	Mean
(a) no post-secondary preparation or experience	10	10	4,750-5,250	$5140
(b) two years of on-the-job preparation in hospital medical laboratories other than in radiation	9	9	5,250-5,750	$5610
(c) two years of on-the-job preparation in a nuclear medicine department	3	3	5,750-6,250	$6270
(d) a two-year X-Ray Technician program involving hospital experience over several semesters	6	6	5,750-6,250	$6040
(e) same as (d) plus six-month hospital internship program	7	7	5,750-6,250	$6200
(f) a two-year nuclear medicine technician program involving hospital experience over several semesters	2	1	6,250-6,750	$6560
(g) same program as (f) plus six-month hospital internship program	1	2	6,750-7,250	$6680
(h) a registered nurse program	8	8	6,250-6,750	$6250
(i) a four-year college degree program in biology/chemistry/physics	5	5	6,750-7,250	$6820
(j) four-year Medical Technologist Program including hospital experience over several semesters	4	4	6,750-7,250	$6980

Table 6

Mean Salaries (by City) Offered to People Concluding Two-Year Nuclear Medicine Program

City	Salary	City	Salary
New York	$8,050	Baltimore	$6,600
Miami	$7,600	Cleveland	$6,500
Minneapolis-St. Paul	$7,100	St. Louis	$6,400
Los Angeles	$7,100	Denver	$6,050
San Francisco	$7,100	Washington	$6,000
Boston	$6,950	Atlanta	$6,000
Chicago	$6,850	Kansas City	$6,000
Dallas-Fort Worth	$6,700	Philadelphia	$5,750
Seattle	$6,650	New Orleans	$5,350

The reasons people leave positions as Nuclear Medicine Technicians is a useful guide to the problems of the job. Eighteen percent (18%) of the hospitals replied that their technicians left because the department could not offer sufficient opportunities for advancement. An additional eleven percent (11%) cited an inadequate salary schedule as the prime cause for leaving, although seventeen percent (17%) considered it an important cause. (For example, in one very large county hospital, the respondent asserted that he needed and would hire three competent NMTs at that moment, except that their pay scale, established by Civil Service, was not competitive. As a result, he could find no technicians to employ.) Less than five percent (5%) reported that technicians left because of lack of interest, supporting the frequently expressed idea that the Nuclear Medicine Technician's job is in general varied and interesting.

IV. Preparation of Nuclear Medicine Technicians

Summary of Findings

The report thus far has considered the growth and practice of nuclear medicine, and occupational information about the Nuclear Medicine Technician. The major objectives of this survey have also included the identification of the ways NMTs are presently being prepared and certified, and the need and feasibility for collaborative instructional programs. This section of the report focuses on our findings and impressions concerning certification and instructional programs for the technician.

We have indicated earlier in the report that the field of nuclear medicine is highly fragmented. This fact was no more apparent than in the answers to our inquiries concerning preparation and certification for Nuclear Medicine Technicians. Most technicians have entered nuclear medicine by way of an X-ray background or previous experience in some aspect of medical technology. It is thus not surprising that the majority of the survey respondents (53%) reported that their Nuclear Medicine Technicians are instructed informally on-the-job at the hospital, since this instruction is to alter the tasks of an existing employee. This arrangement can amount to an inefficient over-preparation for NMTs, since other technicians, also in short supply, must be replaced. Furthermore, the newly prepared NMT may not use all the instruction gained in other technologies.

It was difficult to determine exactly what constituted these informal instructional programs, but it was clear that they varied greatly both quantitatively and qualitatively. In a few cases, respondents maintained that as many as a half-dozen or more NMTs were prepared informally, on-the-job each year. On the other hand, most informal programs appeared at best to be makeshift, catch-as-catch-can operations, preparing one or two students per year.

Over one-fourth of the hospitals surveyed provide a formal preparation program for their Nuclear Medicine Technicians, although these also seemed to vary considerably. About sixteen percent (16%) have a program of their own, and another thirteen percent (13%) are involved in some form of collaborative program with other hospitals or schools. Of those who claimed to have some kind of formal program, collaborative or not, sixty-seven percent (67%) reported preparing fewer than three students per year. Again it is impossible to give an adequate descriptive breakdown of these programs in anything but the grossest terms of size, length, etc., since no uniform standards exist and we could determine none to act as a standard for comparison.

The distinction between a "formal" and an "informal" program is often a rather uncertain one. Regardless of the category in which they were reported, most programs emphasize on-the-job experience. This aspect of the technician's preparation is interspersed with formal classwork, occasional conferences and short courses. The essential difference between a "formal" and an "informal" program seems to revolve around the question of whether or not these aspects of the program are regularly scheduled. Qualitatively, it is difficult to believe in many cases that an important difference exists.

As there seemed to be some controversy over the value of an internship as part of (or appended to) a preparatory program for NMTs, we attempted to obtain respondents' opinions on this topic. An internship was defined as a period of time (at least several weeks) spent wholly in a hospital, usually for little or no pay. A clinical experience consisted of spending (on a regular basis) part of a day (or week) in a hospital, while continuing to do course work. Of those who expressed an opinion only on the idea of an internship (63), two-thirds favored it. When compared with a clinical experience, however, the overwhelming opinion favored the latter. About one-third of all respondents thought that an internship should be part of the preparatory program, but close to half felt that it was of little importance. Some were vehemently opposed to it, with one respondent referring to an internship as "slave labor". A clinical experience was considered to be an essential part of any program by about eighty percent (80%) and of little importance by less than ten percent (10%) of all respondents.

Existing Collaborative Programs

A relatively small number of the hospitals we visited are involved in collaborative instructional programs with other hospitals and/or educational institutions. Of the twenty-three hospitals that are so involved, fifteen participate in a full-time educational program (regular intervals of in-hospital clinical work alternating with regular intervals of classroom instruction at the educational institution) without an internship. Three have full-time programs with a following internship as part of the total program. There are a few hospitals which are involved in part-time school-based courses for employees who are either in a different medical field or who are already in the field of nuclear medicine.

Although the majority of these collaborative programs do not include an internship as part of the total program, many of them do involve clinical experience over the period of preparation. In fact, eighty-five percent (85%) of the respondents connected with various collaborative programs believed that clinical experience is of great importance in such programs. Although most of our respondents saw the utility of an internship, they nevertheless felt that clinical experience interspersed with course work throughout the instructional period is more expedient and relevant.

There is no standardized length of preparation for collaborative programs. Class work ranges from a few weeks to a full year while clinical work may be a few months to well over a year. Variation is such that no average figure has any validity.

Besides finding the type and length of existing collaborative programs, we were also interested in trying to understand some of the organizational problems involved in such cooperative efforts. We suggested six possibilities (question 4.19) and asked the respondent to indicate the degree of importance of each factor in establishing their collaborative program. Those that were considered to be of greatest importance were, in order: 1) that the program include on-the-job (clinical) experience over several semesters; 2) that the AMA or another professional association approve the curriculum; and 3) that the hospital's department of nuclear medicine be represented on an active advisory board to the educational program.

Additional Existing Programs

Thirty hospitals reported that they have a formal instructional program for NMTs which does not involve collaboration with any other institution. The duration and type of such programs vary too much for aggregate figures to be meaningful. The vast majority (84%) of hospitals with formal instructional programs reported that they prepared only one to three persons per year.

Other Background Factors

Persons who are prepared to be Nuclear Medicine Technicians have a variety of backgrounds, including X-Ray Technology, Medical Technology, laboratory assistant work, high school, nurse training, and college degrees in science. From 1967-69, more than half of the students were originally

X-Ray Technologists. An additional one-fifth of the NMTs prepared came directly to their program from high school. Medical Technologists accounted for about one-tenth of nuclear medicine students.

Our survey questionnaire did not specifically request the sex and age of technicians, but an impression is that the average Nuclear Medicine Technician is female, and probably in her middle to late twenties. Respondents were asked, however, whether they preferred males or females as Nuclear Medicine Technicians. More than half had no preference, and, of the remainder, males were preferred slightly over females. Some wanted to have at least one NMT of each sex because of the need to deal with patients' idiosyncracies. Reasons for preferring females were that they tended to be more accurate, more easily instructed, better with patients, less trouble and more willing to accept lower salaries. Males were preferred because they could work at odd hours, were better with equipment, were more career oriented, tended to stay longer, could lift heavy items, were faster, more dependable, and,in the colorful terminology of one respondent, weren't "bitchy".

Certification

It is difficult to say for sure how the average Nuclear Medicine Technician is certified since the definition of "certification" is as ambiguous as the adjective "average" applied to an NMT. Probably a majority of technicians have certification of one type or another, most of them in a specialty other than nuclear medicine. Although data were not obtained in the survey, it is our impression that a plurality of Nuclear Medicine Technicians are certified as Radiologic Technologists by the American Registry of Radiologic Technologists (ARRT).

A national total of between 600 and 700 people are presently certified as "Nuclear Medicine Technologists". The two organizations providing certification are the ARRT and the Registry of Medical Technologists (American Societv of Clinical Pathologists), with most certified technicians registered with the former group. Certification does not, however, imply uniformity of formal preparation or experience since basic eligibility requirements vary considerably.*

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*See Appendix C for ARRT and RMT eligibility requirements.

A substantial number of NMTs work with no formal certification, either in nuclear medicine or in an allied field. Without implying that their competence is any less than their certified colleagues, many respondents felt that standardization of certification requirements would assist the development of the field.

To a major extent, this lack of standardized certification requirements is responsible for the wide variety of instructional programs cited above. Respondents were asked to name the organization(s) they would like to see establish standards for proposed collaborative programs. Their replies suggest the continuing fragmentation of the field (see Table 7), although it should be noted that forty percent (40%) of the respondents favored some form of collaboration of organizations to establish standards (either by listing more than one organization or by citing the AMA as the standard-setting group).

Table 7

Organizations Which Respondents Would Like to Approve Curriculum for New Preparatory Programs

Organization	%*
American Medical Association	35%
Society of Nuclear Medicine	51%
American Registry of Radiologic Technologists	19%
American College of Radiology	15%
American Society of Clinical Pathologists	1%
Registry of Medical Technologists	4%
Society of Nuclear Medical Technologists	2%
Others	7%

*Total is greater than 100% because many respondents cited two or more organizations.

At the American Medical Association convention, on July 15, 1969, the House of Delegates took a large step toward establishing standards for programs for Nuclear Medicine Technicians. The House approved a paper entitled: "Essentials of an Accredited Education Program in Nuclear Medicine Technology". These Essentials provide for a Board of Schools of Nuclear Medicine Technology representing the technological groups and medical specialties with interests in nuclear medicine. The Board of Schools is charged in the Essentials with the evaluation of educational programs for Nuclear Medicine Technicians, the maintenance of high standards of education, and the development of new teaching programs. The Essentials are included in full in Appendix E.*

Possibility of Collaborative Programs

Most of the hospitals surveyed were not involved in collaborative nuclear medicine programs with other hospitals and/or educational institutions. Respondents in these hospitals were asked if they would consider establishing some type of collaborative effort; eighty-six percent (86%) responded affirmatively. Their responses, however, were marked by varying degrees of enthusiasm and interest. Some felt a need for collaborative programs to prepare more technicians, and some welcomed the idea although they did not think that with their facilities and personnel they could do much to help start a program.

Respondents were asked to rank their preference for working with various institutions if their department were considering establishing a collaborative educational program. The kinds of institutions chosen for collaboration were, in order of preference, 1) other hospitals and a university medical school; 2) other hospitals and a community college or technical institute; 3) a university medical school; 4) a community college or a two-year technical institute and 5) other hospitals only. Ninety-five percent (95%) of those who did not list collaboration with a community college or technical institute as their first choice nevertheless indicated in answering another question their willingness to work with such institutions.

As with the established collaborative programs, we presented a table of factors (question 4.28) and asked the respondent to indicate how important each would be for their participation in a collaborative program. First, there was considerable agreement (75%) concerning the inclusion of on-the-job experience. Second, there was nearly equal importance attached to the approval of the curriculum by the AMA (or another recognized professional organization) and

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*The survey interviews were conducted prior to the AMA's adoption of these Essentials. As a result the Board of Schools was not mentioned as an alternative to approve curriculum for preparatory programs. For a fuller description of this issue, see also the comment by C. Craig Harris in Appendix I.

the representation of the nuclear medicine department on an active advisory board to the program. Third, almost half of the respondents attached great importance to having control over the specialized content of the curriculum. It is interesting to note that, in the case of hospitals presently involved in collaborative programs, the importance attached to this factor was not as great. The great majority of respondents favored a collaborative program consisting of a full-time educational program with regular intervals of in-hospital clinical work alternating with the classroom instruction. A program of upgrading the skills of present employees appeared to be relatively unattractive.

As is true of present instructional programs, the length desired of collaborative programs varied considerably. The difference, however, was that respondents tended to prefer longer periods of preparation in a proposed collaborative program than in presently existing ones, whether collaborative or non-collaborative. Thus, while about a third of all currently existing programs are between six and twelve months long, more than half (52%) of the respondents preferred collaborative programs that are eighteen to twenty-four months long.

The overwhelming acceptance by respondents of the idea of collaboration is an accurate reflection of the demand for future preparatory programs. With the field of nuclear medicine presently fragmented, and with an apparent present and future need for increased numbers of NMTs, collaborative programs seem essential to the supply of well-prepared competent technicians. Programs with collaborative arrangements among hospitals, colleges, university hospitals and medical schools, offer the possibility of increased efficiency in the use of expensive equipment and valuable professional talent. Collaborative programs also will facilitate the placement of graduates, easing employment burdens for both employer and employee.

Collaborative arrangements seem central to the emerging concept of the "health team" and recent ideas on education for the health professions. The college or institute setting is perhaps the best place for didactic, classroom instruction, and clinical experience is best obtained in the appropriate hospital setting. Course and clinical work can be at least partially credited toward degree requirements when a college is involved, encouraging participation in health fields by individuals also desiring the advantages of a college program.

Some Program Descriptions

The evolution of preparatory programs for Nuclear Medicine Technicians has followed the growth of nuclear medicine. With its expansion into new hospitals during the last decade or more, technicians in related medical specialties have, largely in on-the-job situations, gained new skills to perform the tasks of the NMT. The initiation of formal instructional programs seems to have lagged somewhat behind the need for well prepared technicians. Even today most Nuclear Medicine Technicians receive their instruction primarily in an on-the-job, clinical setting. Undoubtedly many physicians practicing nuclear medicine prefer to instruct X-Ray Technologists or other experienced technicians to perform the specific tasks they desire.

The fact that wide concern exists regarding standardization of Nuclear Medicine Technician preparation and certification, and that formal and collaborative programs have recently begun or are presently being initiated, indicates that informal methods of instruction are no longer considered sufficient to meet the needs of the field.

Existing formal preparatory programs for Nuclear Medicine Technicians exhibit a great variability in almost any dimension. A useful, if arbitrary, categorization scheme might describe the types of programs by their purpose, student background, and length. Using these dimensions, the following pattern emerges.

There are essentially three types of formal preparatory programs: 1) In the first, present NMTs attend very short refresher courses or presentations of new techniques. Such programs are sponsored privately, by universities, or by professional organizations, and last from several days to a maximum of a month. A common variation is a semester-long single course given by an educational institution. Programs of this nature may be more correctly termed improvement rather than fully developed instructional programs; as such, they are not within the scope of this report. 2) The most common type of formal preparatory program is intended to turn Radiologic or Medical Technologists (or others with a significant scientific and/or medical background) into Nuclear Medicine Technicians. Such programs need not be comprehensive since the students have already had instruction in related areas. These six-to-twelve month programs tend to be offered either by an educational institution in conjunction with one or more hospitals or by a university hospital. 3) A third type of formal preparatory program for NMTs differs from the others in that its students usually have little or no background in medicine. Most come directly from high school. These programs are often collaborative programs involving an educational institution and one or more hospitals, and most commonly last about two years.*

A number of programs exist which fall into the latter two categories. Several will be described to provide a reference point for further comments on curriculum and materials. Exclusion from this discussion is not intended to imply criticism of an existing program since the information gathered in the survey did not emphasize the problems of preparation raised in this section. We did not visit hospitals or institutions primarily to evaluate the training programs they were conducting, nor did we ask our respondents to specify course content or evaluation criteria used in their programs. Wherever formal programs were conducted, however, we requested any written material available describing the program. As a result, we have compiled a number of papers on a variety of existing programs. These summaries outline, but in no way judge, the content or excellence of these programs.

The most common type of formal program conforms with the requirements established by the American Society of Radiologic Technologists (ASRT). This is a twelve-month program, and usually represents the student's third year of formal preparation. To be eligible for such a program, the potential student:

"1. Must be a graduate of AMA Approved School of X-Ray Technology or

2. Registered Technician (ARRT) or

3. Medical Technologist, (ASCP certified), (see NOTE), or

4. Registered Nurse with two years of college credits or with a baccalaureate degree, or

5. Bachelor of Science degree with a major in Biology, Chemistry or Physics, (see NOTE).

NOTE: In addition, applicants under section 3 and 5 must have completed a basic course in human anatomy and physiology of at least 60 clock hours."**

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*Formal programs with three or more students are outlined in Appendix D.

**ASRT requriements.

This curriculum allocates a total of 295 hours to thirteen different topics, adding that "all remaining hours should be devoted to experience in performing clinical radioisotopic procedures.* The role of theory in this curriculum is deemphasized; for example, a full 130 of the specified hours (44%) are devoted to "specific procedures" while less than sixty hours (20%) are concerned with the physics of radiation.

Numerous institutions run programs which generally conform with these requirements, while varying somewhat in specifics. To illustrate this curriculum approach, we have included in Appendix D the curriculum outlines both of the American Society of Radiologic Technologists and of the Radioisotope Technology program of the Indiana University Medical Center. Many other programs exist which vary somewhat differently from the ASRT requirements.

The Nuclear Medicine Institute (NMI) in Cleveland conducts one of the largest programs in the country for preparing NMTs. Its one-year courses are open to registered technologists (ARRT or ASCP), registered nurses, or those with a B.S. degree in biology, chemistry, or physics. The program is divided into three phases: twelve weeks of didactic and clinical training at NMI, thirty-eight weeks of internship at an affiliated hospital, and two weeks of review.

The preparatory program conducted at the National Naval Medical Center in Bethesda, Maryland, lasts for six months, yet is far more intense than ASRT programs. Most students in this program are naval medical corpsmen, although some other students are also accepted. Over 750 classroom hours are scheduled, and emphasis is placed far more on chemistry and physics than in ASRT programs.

Programs to prepare high school graduates to become NMTs are largely in the formative stages. Two promising collaborative efforts are expected to begin operations in the Fall of 1969, one in Colorado at the Denver Community College and one in Florida at Miami Dade Junior College. Both are two-year programs leading to an Associate Degree and both enroll high school graduates (although an option exists for X-Ray Technologists or others with a related medical and/or scientific background to enter the programs at the beginning of the second year).

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* ASRT requirements.

Many other similarities exist between the Denver and Miami programs. Both have found it essential to emphasize, continually, cooperation between the educational institutions and the collaborating hospitals. Advisory bodies consisting of both medical and educational personnel have helped establish each program and aid in continuing promotion. In each case there is a relatively large number of hospitals involved (at last count, 10 in Denver and 6 in Miami). Each program includes, in addition to classwork at the college, both a summer internship and clinical experience at the cooperating hospitals throughout the school year.

The content of both programs builds upon the existing courses offered in the colleges. At Miami Dade there is a greater number of courses created specifically for NMTs, whereas at Denver a core program is emphasized, in which students in nuclear medicine begin with some of the courses provided for allied health occupations. Outlines of the programs of study and descriptions of their course offerings are presented in Appendix D.

Similar programs, although apparently with less of a collaborative emphasis, exist or are being developed at Los Angeles City College, Chicago City College, and the British Columbia Institute of Technology. In Harrisburg, Pennsylvania, a unique collaborative effort exists involving the Harrisburg Hospital, the Pennsylvania Junior College of Medical Arts and the Harrisburg Area Community College. The curriculum for this program is based on the ASRT requirements and its graduates are eligible for certification as Registered Technologists. It differs from other programs in that it lasts only twelve months and yet is intended for students with no previous medical experience.

The only four-year training program for Nuclear Medical Technologists of which we are aware is located at the University of Cincinnati. Developed with the assistance of the Bureau of Radiological Health (U. S. Public Health Service) the program leads to a degree of Bachelor of Science in Medical Technology with a Nuclear Medicine Option. Graduates are eligible for certification by the Registry of Medical Technologists. Three of the four years are spent at the University with the student following a normal didactic program. The senior year consists of a twelve-month internship at the Cincinnati General Hospital, where a combination of didactic training, laboratory exercises and practical training prepares the student for his future occupation. An outline of this curriculum and a description of its technical courses are presented in Appendix D.

Curriculum Development Approaches

Except to belabor the theme of fragmentation, the course descriptions and certification requirements presented above and in Appendices C, D and E do not easily lead to generalizable conclusions. Their variety, however, does tend to reinforce our impression that typical NMT courses seem to "just grow". They may originally have been based on general statements of what the NMT needs to know, a general set of goals probably derived unsystematically, or from too limited an analysis of the occupation. Courses may have been added based on interest or influence in a program. Seldom if ever has the course content been rationalized in terms of the tasks the NMT actually does perform on the job. The AMA "Essentials" included in Appendix E provide an interesting case in point. They fail to define a Nuclear Medicine Technician and to specify the proficiency level on various tasks which graduates of a preparatory program are expected to achieve, and yet they include a breakdown of courses required as part of the program. Clearly, the wide variation in hours allowed for certain courses is indicative of this problematic method of establishing a curriculum.

We have taken the approach that the design of a curriculum for preparing NMTs must begin with a behavioral analysis of the occupation, specifying in detail the tasks, skills and performances it contains. From these occupational specifications, instructional objectives can then be developed and expressed in terms which more readily allow measurement of the skills, knowledge and attitudes the student is expected to learn and use. This survey, in outlining both the present and expected performances required of the NMT, has provided the first step in a more rational approach to curriculum development.

This discussion is not intended to give the impression that all present NMT preparatory programs, especially the ones we have considered, are of poor design and quality. Quite the contrary, we have been impressed with the calibre of elements in many programs. The emphasis given to practical clinical work, the collaborative use of resources and talents, and the emphasis placed on job performance, are recognized ingredients of effective programs. Furthermore, we do not mean to indicate that skill "training" aimed at increasing the NMT's ability to perform limited tasks is all that is necessary in his preparation. This misuse of the behavioral objective approach poses real dangers and must be judiciously avoided. Effective courses in fields such as psychology and English will certainly result in improving the technician's competence, both as a worker and as a citizen, although their specific contributions are not so easily measured.

We are not attempting here to develop detailed course content or program evaluation instruments. These tasks are a step beyond that represented by the survey and report undertaken thus far. A general approach and methodology, however, can be described in outline form and provide one possible framework for designing more systematic preparatory programs.

A first step in such a general methodology has been taken in this report, viz., the identification of the Nuclear Medicine Technician's occupational performance tasks. These must be central to the design of a basic NMT curriculum and/or instructional materials.

The next step is to determine the criterion behaviors which all students are expected to achieve by the conclusion of the preparatory program. From these, evaluative instruments are developed, which in turn form the basis for the preparation of instructional objectives.

Evaluation of students' success in the program might proceed as follows: different forms of a test involving both written and performance sections would be administered prior to, immediately after, and about six months following the program. (Other measures, such as aptitude and intelligence tests, should also be used to help control for variations in student performance not resulting from the instructional program itself.) In conjunction with these tests, follow-up reports from NMTs prepared in the program and physicians employing them should be solicited. From all of these evaluative instruments, feedback would be provided to suggest instructional topics where an individual (or, in aggregate, the program itself) is inadequate.

Advisory committees should also contribute to continuing evaluation, insuring that course content remains abreast of the rapid changes in the field. The entire point of this evaluative scheme is to place emphasis on the quality of occupational preparation the NMT has received. The focus is the NMT's ability to perform his job competently rather than the titles and hours included in his instructional program.

The only present means which we have discovered for evaluating the quality and effectiveness of programs seem less than ideal, although possibly providing some valid indicators. Programs approved by the ASRT or the AMA "Essentials" must include facilities such as libraries, laboratories, etc., a competent administration, affiliation with accredited institutions, as well as specified courses and hourly contents. The several registries certify NMTs upon the successful completion of an examination.

The examination and other evaluative measures which we are proposing would be more job oriented than the existing registry exams. The primary purpose would be to specify a minimum set of competencies without which an individual would not be qualified to act as a Nuclear Medicine Technician.

In the interim prior to the adoption of such an approach to curriculum development, two topics should be stressed as necessary additions to most programs. Many respondents maintained that the increased involvement of NMTs in the preparation of radiopharmaceuticals meant that more of an emphasis on chemistry was needed. Also, with computers expected to loom larger in the future of nuclear medicine, a basic knowledge of statistics and data processing should become part of the technician's preparation.

Instructional Materials

With a view to the content of new preparatory programs, we asked interview respondents to identify existing instructional materials which they felt could be useful. Some thirty-five to forty different books, manuals, films or other resources were mentioned in their replies. The diversity in these recommendations is perhaps again reflective of the lack of standardization and the fact that a consolidated set of educational and technical reference materials for the technician is not readily available. About one-third of the respondents failed to give any answer to this question or commented that they knew of nothing suitable. If anything approaches a "standard" textbook for the NMT at the present, it seems to be Henry Wagner's Principles of Nuclear Medicine. Several other texts mentioned frequently were those authored by Blahd, Quimby, and Chase and Rabinowitz. Most respondents felt, however, that these medical textbooks were too difficult for technicians.

Nearly as often as textbooks, physicians and Nuclear Medicine Technicians mentioned as excellent the literature, films, and materials published by the equipment manufacturers and pharmaceutical suppliers; some respondents stated emphatically that commercial firms produced some of the best material available for both NMTs and MDs. A more complete list of existing instructional aids is included in Appendix F.

Besides requesting information about presently available instructional material, we also asked respondents what new materials were needed. Perhaps half of those interviewed left this question blank, or their statements were so general and vague to be of little practical assistance. Apparently few respondents had ever considered the existing literature from the viewpoint of its utility for preparing their technicians to perform desired tasks.

Of the responses received, the need most often expressed was for a good standard textbook written with the instructional needs of the Nuclear Medicine Technician, rather than the physician, in mind. Although apparently in contradiction with some respondents' favorable comments on the quality of material provided by equipment manufacturers and pharmaceutical suppliers, others stressed the need for material, programs, procedures, etc., to prepare NMTs thoroughly on the use of specific nuclear medicine equipment (including calibration and maintenance of such instruments, as well as basic electronics). The need for careful instruction in clinical procedures was also widely voiced, and a number felt that manuals, some even of a "cookbook" format, were badly needed.

Other specific topics mentioned frequently were mathematics and nuclear physics. Most respondents felt that these were of central importance for the NMT and that too often their basic preparation and background in these subjects has been weak. In connection with mathematics, several doctors and physicists stressed the importance of instruction in using the slide-rule. Safety was another specific topic mentioned by a number of respondents.

Although most of the persons interviewed noted that there was a dearth of good resource material for the preparation of Nuclear Medicine Technicians, we are somewhat cautious about agreeing with this conclusion. Such a conclusion cannot yet be based on any rigorous analysis of available materials. It is equally possible that the fragmentation and lack of communication within the field are causing this response, rather than deficiencies in the resources themselves. The predominance of informal, on-the-job training, the variety of approaches to formal instruction, and even the differences in job requirements for the NMT may contribute to a poor knowledge of available materials. However, to our present knowledge, the complaint that no consolidated set of reference and instructional materials is available appears to be valid.

Our impression is that many learning resources and aids are available, but, like the field itself, are fragmented in form and format. The greatest training requirement may not necessarily be a new textbook for the NMT, but rather coordination, cataloging, testing, adapting, and retesting of the many materials now in use or available for use. Such a task would undoubtedly be sizeable, but certainly less difficult than devising all training materials from scratch. Furthermore, such consolidation and evaluation of existing materials must be completed before the second major task of identifying and developing new materials can rightfully be started.

Finally, all materials might well be packaged as "modules", so that users might combine them in somewhat varying configuration, according to individual needs.

These three important sequential tasks yet remain to be undertaken.

V. Mailed Questionnaire

The hospitals visited by interviewers were located within the major metropolitan areas of the U.S. and tended to be the leading hospitals within those areas. Therefore, in order to describe more accurately the state of nuclear medicine throughout the nation, it was necessary to survey hospitals in other areas as well. A number of hospitals from each state were selected at random from those listed in the 1966 AHA Guide as having facilities for nuclear medicine. A shorter version of the interview schedule was sent to these hospitals.

Response

From the sample of 619 hospitals, 151 replied within seven weeks. Of these, 104 answered the questionnaire; forty-one indicated that they had no nuclear medicine operations, or that the operations were of a very restricted nature; six replied that, although a nuclear medicine department existed, they were not willing to take part in the survey. It was clear from an inspection of the responses that the instructions for a few of the questions were ambiguous. These questions were deleted.

Findings

The responses concerning the work performed indicated that there was little difference in the type of work done by technicians in hospitals in the two samples. The principal differences were that technicians in the mailed sample used scintillation cameras less frequently and had less responsibility for advising physicians and checking incoming equipment. The nuclear medicine departments in the mailed sample share many characteristics with the interview sample. The type of organizational structure seems to be essentially the same.

The average size of the hospitals in the mailed sample (as measured by number of beds) was about seventy percent (70%) of the average size of the hospitals in the interview sample. This ratio reappeared several times (see Table 8) suggesting that the differences between the samples may only be a result of the fact that in the mailed sample the hospitals are somewhat smaller than in the other. Another possible explanation of the differences is suggested by the finding that the average age of nuclear medicine departments in the mailed sample was about two years less than that of the interview sample (8.7 vs. 10.8 years).

Table 8

Comparison Between Mailed and Interview Samples

Factor	a Mailed (average)	b Interview (average)	a/b %
Number of Beds	350	500	70%
Major Items of Equipment	2.8	4.1	68%
Number of NMTs in 1969	1.97	2.5	73%
Expected Number of NMTs in 1975	3.7	5.7	65%
Expected Number of NMT's in 1980	5.5	7.9	70%

Possibly because the departments are in general smaller and the equipment less sophisticated, the departments in the mail sample tend to employ more part-time technicians. However respondents again indicated that they would prefer to employ individuals who have completed a two-year nuclear medicine program. Salaries paid tended to be rather lower than those in the interview sample. This finding may be explained by the difference in proportion of hospitals in major cities, where both salaries and the cost of living tend to be somewhat higher. The mean starting salary which would be offered to a person who had completed a two-year NMT program in the mailed sample was $6,420.

Since the mailed questionnaire was sent to a different sample of hospitals with nuclear medicine operations than the interviews, we had expected to combine the data from the two samples for a manpower analysis. Unfortunately, an essential question (3.5) was not answered by enough respondents in the mailed sample to provide the necessary reliability. The questions for which responses were adequate suggest that the mean number of Nuclear Medicine Technicians per hospital in the mailed sample is seventy to eighty percent (70-80%) of that in the interview sample (see Table 9).

Employing data only from the interview sample for the manpower analysis has probably provided an upward bias to our results. Since we have no means to gauge the extent of this bias (although it probably is not more than ten percent (10%)), we have not attempted to alter the conclusions.

Table 9

Comparison of Number of Nuclear Medicine Technicians per Department in Mailed Vs. Interview Sample

Year	Mailed	Interview
1969 (Question 3.1)	1.97	2.48
1975 (Question 3.11)	3.73	5.66
1980 (Question 3.11)	5.51	7.95

VI. Summary of Conclusions

The Growth, Place, and Practice of Nuclear Medicine

1. Nuclear Medicine has grown rapidly since the late 1950's. In hospitals surveyed, departments of radiology initiated and still control over sixty percent (60%) of such operations, while twenty-two percent (22%) of nuclear medicine departments are independent. The latter figure appears likely to grow slowly depending on such factors as the interest of other departments and the energy and initiative of physicians in nuclear medicine.

2. Most respondents thought that more money, better equipment, and improved instructional programs for NMTs and physicians would speed the growth of the field. A few felt that the growth of nuclear medicine would be stimulated by a status independent of other departments. Others considered that the recognition of nuclear medicine as a specialty by the AMA also would contribute to the field. Education of the public concerning the usefulness and safety of nuclear medicine and less stringent AEC regulations were also considered important factors in speeding the growth of the field.

3. Costs of equipment, personnel, and hospital space were cited as factors which could constrain the growth of nuclear medicine. The technical sophistication of equipment was also mentioned along with the frequently poor quality of instructional programs for technicians, the inadequate formal preparation of physicians, and the general lack of familiarity of doctors with the potentials of nuclear medicine.

4. Diagnosis is the major concern of every nuclear medicine department surveyed, although most are involved in some radiotherapy work (mostly ^{131}I). Diagnostic tests performed fall into three categories: static studies (scans), dynamic function studies, and in vitro tests and blood volumes. Static studies and uptakes provide the bulk of the typical department's work. When nuclear medicine is subordinate to radiology, in vitro tests are often performed in the department of pathology. The major trends in nuclear medicine which may affect technicians over the next two or three years include scanning with faster scanners and cameras, an increased number of dynamic function studies, the development of radionuclides of shorter half-life, greater use of prepackaged pharmaceuticals and materials, and more automated data handling. Such trends are expected not only to affect the <u>type</u> of work done in nuclear medicine, but also to greatly increase the <u>quantity</u> of activity.

The Nuclear Medicine Technician: Occupational Information

1. The tasks the Nuclear Medicine Technician performs center upon scanning and the related activities of radiopharmaceutical preparation and administration (oral) to the patient. The NMT does not interpret the results of scans, but some may point out areas of interest to the doctor. Besides operating the rectilinear scanner, technicians use detector probes, well counters, scalers, and scintillation cameras for static and dynamic studies. Anything more than very minor maintenance on equipment is not done by the NMT, but he usually does share responsibility for radiation safety with other technicians or physicians.

2. The tasks of the NMT and the hospital environment shape the Nuclear Medicine Technician's working conditions. The hospital environment necessitates that he be able to relate to patients, doctors, physicists and technicians, nurses, and other hospital personnel. Formal or informal preparation and experience also define the working conditions of the NMT. In the larger hospitals with long-established nuclear medicine departments there are commonly several technicians who are supervised directly by a chief Nuclear Medicine Technician, who in turn is supervised by a doctor. In the smaller hospitals he is likely to be more on his own and his role depends very much on the attitude of the MD and the responsibilities entrusted to him.

3. It is estimated that the present number of NMTs in the United States is between 4,000 and 4,600. Some thirty percent (30%) of the survey respondents felt that their present number of NMTs was insufficient for their current level of operation; about half of these cited a lack of well-prepared technicians as the reason for this inadequacy. From 1966-1969 the number of NMTs has been increasing by about 800 to 900 per year. Our best estimate of the total number of Nuclear Medicine Technicians needed by 1972 is 8,000-8,500, and by 1975 is 11,300-12,300. There is a need to prepare about 1,300 new technicians per year.

4. Nuclear Medicine Technicians in the U.S. with one year of experience are presently being paid anywhere from $4,000 to $12,000 with an average salary of $6,300 per year. Respondents were also presented with a description of possible candidates for a position as NMT in their department and asked to rank them in their order of preference and indicate the salaries they would be willing to pay each choice. The first choice was for persons with two years of formal nuclear medicine preparation, and the mean salary offered such a person in his first year was $6,500.

Preparatory Programs for Nuclear Medicine Technicians

1. A majority of the respondents felt that standardization of preparatory programs and certification requirements for NMTs was essential if the technician's position in terms of skill and salary were to be improved. Standardization also would help attract better persons and ensure that the demand for technicians would be filled. At present there are two certifying organizations for NMTs: the American Registry of Radiologic Technologists (ARRT) and the Registry of Medical Technologists. Most Nuclear Medicine Technicians are not certified at all in nuclear medicine; a plurality of them are certified as X-Ray Technologists (ARRT). Still others have no certification of any kind. Eligibility requirements for certification as a Nuclear Medicine Technologist by the above organizations vary from a high school diploma and on-the-job experience to a baccalaureate degree.

2. Preparatory programs for Nuclear Medicine Technicians are at present even more diverse and fragmented than certification requirements. The most common method of preparation (53%) consists of informal, continuing, on-the-job instruction under the supervision of physicians and experienced technicians. Twenty-eight percent (28%) of the hospitals surveyed claim to have a formal instructional program of some sort for their NMTs. The interpretation which they give the term "formal," however, is questionable, since most of these programs prepare only one or two people each year. About one half of these programs are in collaboration with some other institution(s), either other hospitals, a community college, or a university medical school. In many cases, however, a hospital may be "collaborating" only to the extent of sending an individual to be prepared elsewhere.

3. When asked if they would be willing to participate in collaborative programs, most respondents (86%) replied in the affirmative. Collaboration in instructional programs appears to be desirable since it would provide greater resources and talents, allow for their more efficient use, and facilitate the recruitment and placement of students. Those who replied in the negative to this question either feared that such programs would inevitably be poor, or did not believe that NMTs needed much formal instruction. Respondents ranked collaboration with a university medical school first, followed by collaboration with community colleges or technical institutes. Very few, however, were able to name the institutions with which they would like to work. Fifty-two percent (52%) felt that two years would be an appropriate length for such a program. Nearly all respondents expressed a willingness to collaborate with community college or technical institute programs in nuclear medicine.

4. Formal programs may be separated into three types. (1) In the first, present NMTs attend very short refresher courses or presentations of new techniques. Such programs are usually sponsored privately, by universities, or by professional organizations and last from several days to a maximum of a month. (2) The most common type of formal preparatory program is indended to turn Radiologic or Medical Technologists (or others with a significant scientific and/or medical background) into Nuclear Medicine Technicians. These six-to-twelve month programs tend to be offered either by an educational institution in conjunction with one or more hospitals or by a university hospital. (3) A third type of formal preparatory program for NMTs differs from the others in that its students usually have little or no background in medicine. Most come directly from high school. These programs are often collaborative programs involving an educational institution and one or more hospitals, and most commonly last about two years.

5. Interview respondents were asked to identify instructional materials which they felt could be useful in preparatory programs for NMTs. Some thirty-five to forty different books, manuals, films or other resources were mentioned in their replies. If anything approaches a "standard" textbook for the NMT at the present, it seems to be Henry Wagner's Principles of Nuclear Medicine. Literature, films, and other materials published by the equipment and pharmaceutical firms were also described as being generally of excellent quality.

6. There was considerable uncertainty among respondents regarding new instructional materials which are presently needed. Most often expressed was the need for a good standard textbook written with the NMT, rather than the physician, in mind. Additionally, the need was also voiced for careful instruction in clinical procedures, use of instrumentation, mathematics, and radiation physics; chemistry and statistics were also mentioned. We are somewhat cautious in agreeing with the conclusion of many respondents that there is a dearth of good resource material for the preparation of NMTs. Our impression is that many learning resources and aids are available, but, like the field itself, are fragmented in form and format. The greatest training requirement may not necessarily be a new textbook for the NMT, but rather coordination, cataloging, testing, adapting, and re-testing of the many materials now in use or available for use.

Appendix A: The Questionnaire Instrument

The Survey Questionnaire: Critique

This appendix contains copies of the questionnaire instruments used as the basis for personal interviews and the mail survey. There were minor changes in the longer questionnaire, the result of initial experience and revision. These changes have been indicated, however, in the copy included here, and notes of explanation along with a brief critical evaluation follow. After the questionnaires, a summary of the statistical tabulations is presented.

Many parts of the questionnaire were quite successful in terms of the information they were designed to gather. The list of tasks in Question 1.1 was very helpful in defining the actual on-the-job performance objectives of the Nuclear Medicine Technician. Question 1.7 provided a good supplement to the behavioral description of the NMT with a catalog of the types and frequency of equipment used. Generally we found the responses to open-ended questions (e.g. 3.9, 3.10, 4.30, and section 6) especially useful in determining trends, verifying impressions, and corroborating patterns that emerged from the more structured data we obtained.

One of the general shortcomings of the interview questionnaire was its formidable appearance in length and complexity. Long and detailed instructions (see pages 1, 4, and 9 for examples) frequently contributed more to the respondent's confusion than clarity. The translation of instructions into number and letter codes to be placed in columns or tables seemed to be the source of much of the confusion. Several questions required a degree of discrimination among choices that was perhaps unreasonable. In Question 3.7, the respondent was asked to rank in order from one to ten his preference for hiring Nuclear Medicine Technicians. The time and difficulty initially experienced on this question required that we seek only the top four choices.

Question 2.4 also caused a problem; it contained a table of fifty-six blocks which the respondent had to complete with a code for the frequency of the NMTs "interaction." In our first interviews it became clear that this question was too long and that some responses were unclear. A revision simplified the question somewhat, but terms such as "reports" and "written information" still lacked clarity and specificity.

Question 3.5, another table requiring completion by the respondent, also caused some confusion. The aggregation of "equivalent full-time technicians" probably contributed more to confusion than to useful information, and the projection of needed Nuclear Medicine Technicians in categories (A) versus (B) frequently depended on several contingencies such as the quality of the instructional programs involved.

A real problem arose in Question 2.1, where we asked for the salary scale now paid to NMTs. The range of salaries was to be determined by certification and length of experience. The term "certification" was interpreted in so many ways, however, that we were unable to discriminate among salary levels by this criterion. This problem of "certification" is discussed more fully in the section on the preparation of NMTs and the appendix on certification requirements. This was not the only place in the questionnaire where money figures were a problem. Physicians and NMTs were often unsure of the salary that should be paid for varying levels of preparation, and frequently they stated that the establishment of salary and stipend figures was an administrative function.

The length of the questionnaire was certainly a liability and the average interview lasted at least an hour. In most cases, however, busy schedules were interrupted to accomodate interviewers. A number of respondents remarked that overall the questionnaire was comprehensive and complete. Some others were aware of the deficiencies in the survey instrument and helped us by calling them to our attention. Although the questionnaire was less than perfect in its form, we have been satisfied that it has provided data sufficient to accomplish the objectives of the survey.

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NUCLEAR MEDICAL TECHNICIAN INTERVIEW SCHEDULE

Interview Number_______________

Interviewer_______________

Name of Hospital:

Name of department or division
where nuclear medicine is practiced:

Title of Interview Respondent:

Please indicate the title you use for the technician of nuclear medicine to whom your responses will apply:

Title of Technician:

About how many months of formal or on-the-job training beyond a high school education has this person received, or the average technician in your department received?

Months of training beyond high school:_____months

Card 01

NMT INTERVIEW

SECTION 1 The following questions concern tasks performed by the average technicians in your nuclear medical department.

1.1 Please circle in Column 1.1 how many times per month the following tasks are performed by your technicians.

"Not in Hospital" means that the task is not performed in your Department.
"0 times per month" means that the task is performed in your Department, but not by your average technician.
"1-3 times/month" is up to and including once a week.
"4-10 times/month" is weekly or semi-weekly.
"11+ times/month" is almost daily or more often.

1.2 Please circle in Column 1.2 the 5 or 6 most important which you would like to see your technicians be able to do better, or in addition to those he performs now.

		1.1				1.2
	Not in Hosp.	Techs now do 0	1-3	4-10	11+	New or Additional Tasks
Preparation						
17 1. Chemically prepare short-life isotopes: a) eluting the column	0	a	b	c	d	1
2. b) chemical preparation	0	a	b	c	d	2
3. c) sterilize	0	a	b	c	d	3
4. Calibrate isotopes against a standard	0	a	b	c	d	4
5. Prepare oral dose: measure from manufacturer's bottle	0	a	b	c	d	5
6. Prepare oral dose: mix, dilute to measure	0	a	b	c	d	6
7. Prepare injections: measure dose	0	a	b	c	d	7
8. Prepare injections: sterilize dose	0	a	b	c	d	8
9. Set up instruments for operation: a) in vivo studies	0	a	b	c	d	9
26 10. Set up instruments for operation: b) in vitro studies	0	a	b	c	d	10
Tests & Patients						
27 11. Administer isotopes to patients a) orally	0	a	b	c	d	11
12. Administer isotopes to patients b) by injection	0	a	b	c	d	12
13. Receive patients, explain tests to them and allay their fears	0	a	b	c	d	13
14. Position patient with respect to nuclear medical equipment	0	a	b	c	d	14
15. Superficial and specialized examination of patients	0	a	b	c	d	15
16. Attend to patient's comfort before and during scan	0	a	b	c	d	16
33 17. Understand operating room procedures	0	a	b	c	d	17

Card 01

		1.1				1.2
	Not in Hosp.	Techs now do 0	1-3	4-10	11+	New or Additional Tasks
Data Handling						
34 18. Abstract simple data from patient's chart	0	a	b	c	d	18
19. Make simple dose calculations for a) in vivo examinations	0	a	b	c	d	19
20. Make simple dose calculations for b) in vitro examinations	0	a	b	c	d	20
21. Make simple dose calculations for c) tracer examinations	0	a	b	c	d	21
22. Accumulate and process data for MD's interpretation	0	a	b	c	d	22
23. Examine scan test results for general credibility	0	a	b	c	d	23
40 24. Perform preliminary interpretations of observations for MD	0	a	b	c	d	24
Equipment						
41 25. Operate a rectilinear scanner for conventional scanning	0	a	b	c	d	25
26. Operate an autofluoroscope for static studies	0	a	b	c	d	26
27. Operate a scintillation camera for static studies	0	a	b	c	d	27
28. Operate an autofluoroscope for fast dynamic studies (under one minute scan)	0	a	b	c	d	28
29. Operate a scintillation camera for fast dynamic studies	0	a	b	c	d	29
30. Operate a scanner for slow dynamic studies (over one minute scan)	0	a	b	c	d	30
31. Operate an autofluoroscope for slow dynamic studies	0	a	b	c	d	31
32. Operate a scintillation camera for slow dynamic studies	0	a	b	c	d	32
33. Calibrate nuclear medical instruments	0	a	b	c	d	33
34. Check performance of existing and new nuclear medical instruments against manufacturer's specifications	0	a	b	c	d	34
35. Determine if a nuclear medical instrument is in need of major repair	0	a	b	c	d	35
36. Perform minor maintenance on nuclear medical instrument	0	a	b	c	d	36
37. Evaluate nuclear medical instruments from manufacturer's literature and specify and rank those instruments that satisfy the doctors' requirements	0	a	b	c	d	37
54 38. Advise doctors on the technicalities and procedures involved in operating a nuclear medical instrument	0	a	b	c	d	38
Safety						
55 39. Check monitoring instruments	0	a	b	c	d	39
40. Monitor personnel in compliance with hospital regulations	0	a	b	c	d	40
41. Monitor space in compliance with hospital regulations	0	a	b	c	d	41
42. Handle and store radioisotopes safely	0	a	b	c	d	42
43. Assay wet chemical solutions for activity and contaminants	0	a	b	c	d	43
60 44. Safely dispose of radioactive wastes	0	a	b	c	d	44
Clerical						
61 45. Handle secretarial work: appointments, type reports	0	a	b	c	d	45
46. Routinely check incoming equipment	0	a	b	c	d	46
47. Inventory and order radiopharmaceuticals and materials	0	a	b	c	d	47
48. Keep accounts of hospital licensing and isotope procurement	0	a	b	c	d	48
64						
Others						
49.	0	a	b	c	d	49
50.	0	a	b	c	d	50
51.	0	a	b	c	d	51
52.	0	a	b	c	d	52

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Card 02 - Card 02

1.3 Please indicate, using the code given below, why the five or six additional tasks you would like to see your technicians perform, which you circled in the task list 1.2, are not now being done by them.

Code:	Number from Task List 1.2	Reason why task performed now (Code)
1 Technician not trained for task	______ 66-67	______ 68
2 Technician not well trained enough	______ 69-70	______ 71
3 Shortage of staff	______ 72-73	______ 74
4 Facilities not yet available	______ 75-76	______ 77
5 Legal requirement or prohibition	______ 17-18	______ 19
6 Other (please specify)	______ 20-21	______ 22

1.4 Please indicate below which of the tasks you checked off in question 1.1 as how being performed by your technician, you think may become obsolete by 1972, because of: (give task number from 1.1)

(a) technological innovations 23 - 26

______ 23-24 ______ 25-26

(b) change in your department's areas of interest and work

______ ______ 27 - 30

(c) hospital organizational changes (e.g., combining old or creating new departments)

______ ______ 31 - 34

1.5 Please indicate what new tasks you think may be performed by your technicians in 1972, because of: (give task number from 1.1, or a phrase)

(a) technological innovation

35 - 38

______ ______

(b) change in department's areas of interest

39 - 42

______ ______

(c) hospital organizational changes (e.g., combining old or creating new departments)

______ ______

43 - 46

1.6 What tasks, presently being carried out by you, would you turn over to your technicians, if they were better trained? (task number from 1.1, or a phrase)

______

______

______

1.7 Please indicate, in the Table opposite, in the column marked 1.7, the number of major items of nuclear medical equipment which your Department now possesses (or has on order). Please place number of items on order in parentheses following number now possessed. Example: 2 (1)

1.8 If there are any other items of nuclear medical equipment located elsewhere in the hospital, which do not belong or are not controlled by your Department, please indicate, in the Table opposite, in the column marked 1.8, the number and types of the equipment.

1.9 For each kind of equipment which you have checked off which you now possess please indicate, in the table opposite, in the column marked 1.9, the average number of man-hours per week your technicians work with those pieces. Example: 3 Single Probe Scanners used by 4 technicians 1/2 time - 3 x 4 x 20 hrs/week - 240 man-hours.

1.10 If there are any items of equipment not operated by your nuclear medical technicians, please indicate, in column 1.10, below, using the following code, the reason for this:

Code:
1. Technicians not sufficiently well-trained to use or work with the equipment.
2. Too responsible an operation/test to be performed by a technician.
3. Could be done by a technician but you have a specialist to do it.
4. Other.

1.10		1.11
Item of equipment (Number from Table)	Code	Will be operated by technician by 1972

1.11 Please check in column 1.11, above, if any of the items of nuclear medical equipment which you indicated in 1.10 as not now being operated by technicians, will be operated by your technicians by 1972.

Cards 02 - 04

> 1.7 Equipment have now: no parentheses (equipment on order: number in parentheses) Example: 2 (1)

MAJOR ITEMS OF NUCLEAR MEDICAL EQUIPMENT	1.7 Equip. in your Dept.	1.8 Equip. elsewhere in Hosp.	1.9 Tech. man-hrs per/wk on Equip.	
1. Single Probe Scanner -- 3", 5", or 8"	47 , 48	49	50-52	47-52
2. Dual Probe Scanner				53-58
3. Autofluoroscope				59-64
4. Scintillation Camera				65-70
5. Whole Body Scanner (radiation distribution)				71-76
6. Whole Body Counter (total radiation level)			17-19	Begin Card 03
7. Manual Well System				20-25
8. Automatic Well System				26-31
9. Dose Assay Ionization Chamber				32-37
10. Monitoring Ionization Chamber				38-43
11. Single Probe Renal System				44-49
12. Dual Probe Renal System				50-55
13. Computer Applications of Scintillation Camera				56-61
14. Liquid Scintillation System				62-67
15. Orthodensitometer				68-73
16. Multichannel Gamma Ray Spectrometer				74-79
17. T-3 Type or T-4 Type Measurement System	17 18			Begin Card 04
18. Automatic or Semi-automatic Blood Volume Measurement Systems				23-28
19. Automatic Film Developing Facilities				29-34
20. Other:				
21. Other:				

Cards 04 - 05

NMT INTERVIEW

Section 2 The following questions concern the working conditions which are characteristic of those experienced by your nuclear medical technicians.

2.1 Please circle the annual salary range which you now pay your technician.

(circle one letter in each row)

Certification & years of experience	4,000-4,999	5,000-5,999	6,000-6,999	7,000-7,999	8,000-8,999	9,000-9,999	10,000-11,999	Over 12,000	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
1. non-certified and first year	a	b	c	d	e	f	g	h	75
2. non-certified and second year	a	b	c	d	e	f	g	h	76
3. non-certified and fifth year	a	b	c	d	e	f	g	h	77
4. certified and first year	a	b	c	d	e	f	g	h	78
5. certified and second year	a	b	c	d	e	f	g	h	79
6. certified and fifth year	a	b	c	d	e	f	g	h	80

Begin Card 05

2.2 Do you prefer males or females in the role of a nuclear medical technician? 17

(1)___males (2)___females (3)___no preference

2.3 Does your NMT technician work 18

(1)___primarily alone

(2)___primarily with one other technician

(3)___with two other technicians

(4)___with more than two other technicians

NMT INTERVIEW

Equipment Repair and Maintenance:

1.12 How many service calls were made on all your nuclear medical equipment in the past year? ______

1.13 Approximately what percent of these repairs were done by personnel not from your hospital? ______

1.14 Approximately what percent of repairs were done by your hospital's equipment serviceman or maintenance people? ______

1.15 Approximately what percent of repairs were done by an NMT? ______

Total=100%

1.16 How many of the following are performed per month in your department?

1. Image or localization studies ______
2. Flow studies (e.g., brain blood flow) ______
3. Dilation studies (e.g., blood volume) ______
4. Absorption, Excretion tests (e.g., Schilling tests) ______
5. Rapid uptakes (e.g., renograms) ______
6. Slow uptakes (e.g., thyroid uptakes) ______
7. In vitro tests (e.g., T-3 tests) ______

1.17 Is radiotherapy performed in your nuclear medical unit?

Yes: Radioparmaceutical therapy ___
Brachytherapy ___
Teletherapy ___

No: ___

1.18 How many technicians in your nuclear medical unit are principally doing radiopharmaceutical therapy?

(None = 0) 0 1 2 3 4 5 6 7 8 __

 Card 05

NMT INTERVIEW

2.4 In the process of performing his tasks, the technician interacts with numerous people, in and out of the hospital. For each of the following categories, please indicate the frequency of the interaction by writing the appropriate letter from this scale:

(1) A = frequently
(2) B = seldom, but the interaction is very important
(3) C = seldom, and the interaction is relatively unimportant
(4) D = never or hardly ever
Blank = don't know

function of interaction	to-from-	doctors	nurses	other hospital technicians	hospital general administrative staff	maintenance personnel	eqpt. mnfrs., drug suppliers	departmental administrative staff	others (please specify)	PERSONS INSIDE HOSPITAL E.G. MD'S NURSES	PERSONS OUTSIDE HOSPITAL E.G. MAINTENANCE, COMMERCIAL PERSONS	
1. read reports	from	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				18-25
2. write reports	to	[illegible]						[illegible]				26-33
3. fill out forms	for	[illegible]						[illegible]				34-41
4. receive written instructions and/ or information	from	[illegible]						[illegible]				42-49
5. give written instructions and/ or information	to	[illegible]						[illegible]				50-57
6. receive verbal instructions and/ or information	from	[illegible]						[illegible]				58-65
7. give verbal instructions and/ or information	to	[illegible]						[illegible]				66-73

2.5 Can you give us some samples of the forms (administrative and specialized) the NMT has to work with?

2.6 The NMT technicians in your department report directly to: 75
(a) M.D.'s ____ (1)
(b) a Head Nuclear Medical Technician ____ (2)
(c) a Head Technician ____ (3) Please specify type ____________
(d) other ____ (4) Please specify ____________

Cards 05-06

Section 3

The following questions concern the hiring of Nuclear Medical Technicians and your projected manpower needs for these technicians.

If some, or all of your technicians work only part-time, please estimate the fraction of their working week devoted to nuclear medicine tests/operations and give the total in terms of numbers of full-time technicians. (For example, if you have two part time technicians, each working half time, and a third technician working three-quarter time, then you would answer question 3.1 as one and three-quarters technicians.)

3.1 How many nuclear medical technicians did your Department have at the beginning of 1969? ______ How many persons did this represent? ______ 76-79

3.2 If you have several technicians working part time, and their total time is equivalent to one person's normal working time, is it valid for us to assume that your needs could be satisfied by one nuclear medical technician? 80

(1) ________ yes (2) ________ no

If no, please explain.

3.3 Is this number sufficient for your Department's current needs? Begin Card 6

(1) ________ yes (2) ________ no 17

3.4 If your answer to 3.2 was no, please circle the importance of each of the following constraints which prevent your department from hiring more NMT technicians.

Possible constraints	Degree of importance				
	great	some	slight	none	
1. lack of funds for salaries	1	2	3	4	18
2. lack of trained technicians	1	2	3	4	19
3. lack of manpower to train technician candidates	1	2	3	4	20
4. lack of supervisors for technicians	1	2	3	4	21
5. lack of nuclear medical equipment	1	2	3	4	22
6. other (please specify below)	1	2	3	4	

Card 06 · 07

NMT INTERVIEW

3.5 Looking back over the past three years and also looking to the future, please answer, for each year, the following questions:

How many persons did you (or do you expect to):	1966	1967	1968	1969	1970	1971	1972	
(a) hire with some NMT training;								23 - 50
(b) hire with no NMT training, to be trained in your department.								51 - 78
(c) How many technicians left your department's employ?								Begin Card 07 17 - 32
(d) Of the technicians who left your department, how many left the field of nuclear medicine?								33 - 48

*For each box, answer as follows: number of people / number of equivalent full-time technician

Example: 5 people, all 1/2 time -

3.6 Please indicate below the most important reason(s) which you believe led to their leaving. 49

1. just want a change - or work, city, experiences ______
2. lack of opportunity to advance in position ______
3. inadequate salary schedule ______
4. lack of interest in the type of work ______
5. lack of competence to perform the tasks ______
6. interpersonal conflict ______
7. other (please specify) ______

Card 07

NMT INTERVIEW

3.7 Assume that to fill a position as Nuclear Medical Technician, you must choose among several candidates, all graduates of a high school who appear equal in basic intelligence. Please -

(a) establish a base salary for this position

(b) rank the following factors as you would value them in comparing the candidates (1 = most important)
RANK ONLY TOP FOUR (4)

(c) indicate the differential (amount in dollars plus or minus) from the base salary produced by each factor

Base salary for the position $__________ 50

Comparison factors: candidate has completed	Rank value	Salary diff. + or -
(a) no post-secondary training or experience	51	52
(b) two years of on-the-job training in hospital medical laboratories other than in radiation	53	54
(c) two years of on-the-job training in a nuclear medical department	55	56
(d) a two-year X-Ray technician program involving hospital experience over several semesters	57	58
(e) same as (d) plus six-month hospital internship program	59	60
(f) a two-year nuclear medical technician program involving hospital experience over several semesters	61	62
(g) same program as (f) plus six-month hospital internship program	63	64
(h) a registered nurse training program	65	66
(i) a four-year college degree program in biology/chemistry/physics	67	68
(j) four-year Medical Technologist Program including hospital experience over several semesters	69	70

Card 07

4T INTERVIEW

.8 Do you see any parallels in rate of growth of the use and practice of nuclear medicine and some other, now more developed, specialty of medicine? (1)____ yes (2)____ no 71

If yes, what field of medicine ____________________

.9 What do you see as the major factors which could slow or limit the growth of the use of nuclear medicine?____________________

____

____

.10 What do you see as the major factors which could speed the growth of the practice of nuclear medicine?____________________

____

____

.11 Please estimate how many nuclear medical technicians your Department will need in (a) 1975____ 72-75
(b) 1980____

.12 Suppose that your reputation depended on your success in predicting the percentage of hospitals in the United States that will have nuclear medical operations (a) by 1975, (b) by 1980. What percentages would you predict for each? (Presently about % of all hospitals listed in the AHA guide have a radioisotope facility). Please circle the appropriate figure for each year.

% by 1975	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	76-77
% by 1980	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	78-79

Card 10

NMT INTERVIEW

Section 5

These questions pertain to the development and growth of your Department.

5.1 In which department did nuclear medical operations begin? 20

1. Department of Radiology_____

2. Department of Pathology_____

3. Nuclear Medicine was established_____ as a separate department/ unit with its own rights.

4. Other (please specify) ______________________________

5.2 How long is it since nuclear medical tests/operations first started in your hospital? _____years 21-22

5.3 How many technicians did you have working in nuclear medicine at the end of the first year? (Count two half-time technicians as one technician, etc.) ________ 23-24

5.4 Are there any other nuclear medical tests/operations carried out elsewhere in the hospital, which are not under your Department's control? (1)_____yes (2)_____no 25

If so, please name Departments ______________________________

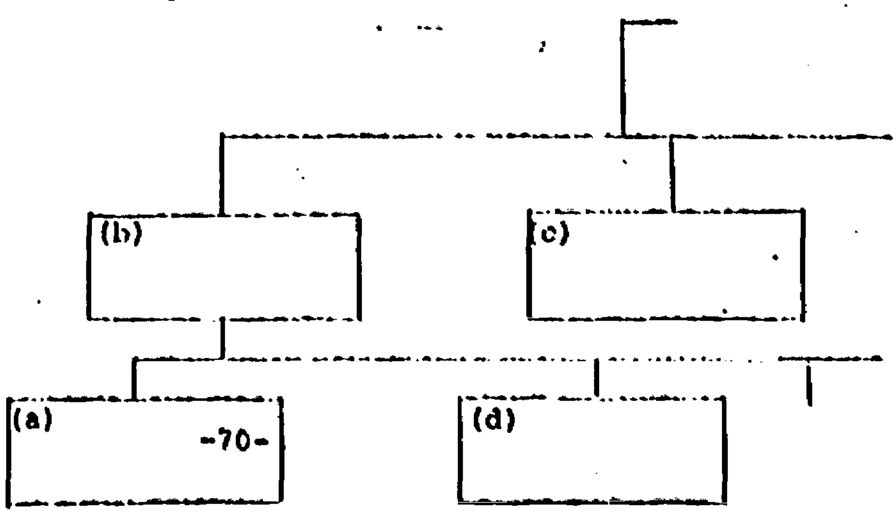
____

5.6 Please fill in the following organizational chart for your hospital. 26

1. Please locate and give the actual name of your Nuclear Medical Department in Block(a).

2. Please locate the Department/Unit/Division above the Nuclear Medical Department in Block (b).

3. If the Pathology or Radiology Departments are not mentioned above, how are they located in the organizational hierarchy in relation to the Nuclear Medical Department?



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Card 08

NMT INTERVIEW

Section 4

Begin Card 15

These questions concern your present training program, and/or the kind of training programs, that you would like to see developed to train nuclear medical technicians.

Part A

4.1 Please check below, how your technicians are now trained. 17

(a) (1) _____ informal hospital training program

(b) _____ formal hospital training program (ARRT Curriculum (2) _____ yes (3) _____ no

(c) (4) _____ formal training program in collaboration with other hospitals

(d) (5) _____ formal training program in collaboration with community college/technical institute

(e) (6) _____ formal training program in collaboration with a university medical school

(f) (7) _____ only hire trained or experienced technicians

If you checked (f), please skip to question 4.20, Part C

4.2 What is the length of your program? _____ (weeks) (months) 18-19

4.3 Who teaches it? (1) _____ M.D.'s (2) _____ Specialists (3) _____ Others 20

4.4 How many students/trainees were in this program last year? _____ 21-22

4.5 How many students/trainees graduated from this program during last year? _____ 23-24

4.6 How many students/trainees do you expect will graduate from the program during this year? _____ 25-26

4.7 What degree or certificate, if any, results from this program? 27
(1) _____ none; title of degree/certificate _____________________ (2)(3)(4)

4.8 Are the trainees who complete this program eligible to take:

(a) American Registry of Radiologic Technologists Certification examination? (1) _____ yes (2) _____ no 28

(b) Registry of Medical Technologists? (1) _____ yes (2) _____ no 29

4.9 Does the length of the program depend on the previous background of the trainee? (1) _____ yes (2) _____ no 30

If yes, please explain briefly:

NMT INTERVIEW

4.10 Does the content or clinical training of the program depend on the previous background of the trainee? ______yes ______no

If yes, please explain briefly:

4.11 Please indicate the present number of trainees, and recent graduates from the program, having the following backgrounds.

	Recent Graduates		Trainees
	1967	1968	1969
1. X-Ray technician			
2. Medical Technologist			
3. Laboratory Assistant			
4. High School graduate			
5. Nurse			
6. College graduate in Science			
7. Other			
8. Don't know			

Part B

Please answer the following questions of the program you are now involved in, or that is now being developed, is a collaborative training program with other hospitals and/or educational institutions. IF IT IS NOT, PROCEED TO PART C, PAGE 17.

4.12 What kind of education program is involved:

Full-time educational program (regular intervals of in-hospital clinical work alternating with regular intervals of classroom instruction at the educational institution) without internship as part of total program; ______ 1.
Full-time cooperative educational program with following internship as part of total program; ______ 2.
Full-time non-cooperative educational program, with post-graduate internship; ______ 3.
Part-time school-based courses for full-time hospital employees now in a different medical field; ______ 4.
Part-time school-based courses designed for upgrading full-time hospital employees already in the field; ______ 5.
Other. ______ 6.

Card 08 - 09

NMT INTERVIEW

4.13 How many months of the total program is spent in clinical or class work at a hospital?

(a) before graduation: class work ______ (weeks) (months) 75-76

clinical work ______ (weeks) (months) 77-78

(b) in a post-graduate internship program with a systematic educational design:

class work ______ (weeks) (months) 79-80

Begin Card 09

clinical work ______ (weeks) (months) 17-18

4.14 How many other hospitals and/or schools are collaborating in this program:

______ hospitals 19

______ schools 20

4.15 Please give in the Table below, the name(s) of the institution(s)/ hospital(s) involved in the program, and the distances and time to travel between your hospital and these other institution(s)/hospital(s).

Name of Institution	Location	Distance from your hospital in miles	Time to travel by public transportation
1.			
2.			
3.			

4.16 How many M.D.'s or specialists from your hospital are involved in this collaborative program?

(a) in teaching? ______ 21-22

(b) in advising on development? ______ 23-24

(c) in design and initiation? ______ 25-26

(d) in evaluation? ______ 27-28

4.17 Do you support the living costs of your staff while they receive training outside of your hospital? (1) ______ yes; (2) ______ no. 29

NMT INTERVIEW

4.18 Do you pay any of the tuition costs? $________total (not per person) tuition costs/year.

________% percentage paid by you

4.19 In the discussions both before and after you reached agreement to set up a collaborative program, which of the following factors apply and how important is each to you? Please circle the appropriate number in each case.

	Importance great	some	little
(a) That you have control over the specialized content of the curriculum	1	2	3
(b) That the program include on-the-job experience over several semesters	1	2	3
(c) Same as (b) followed by an internship program in a nuclear medical department	1	2	3
(d) That specialized courses be taught by MD's	1	2	3
(e) That your Department be represented on an active advisory board to the educational program	1	2	3
(f) That the AMA or another professional association approve the curriculum. Please specify the professional association ________	1	2	3
(g) Other			
(h) Other			

PLEASE PROCEED TO PART D, PAGE 18

Part C

PLEASE ANSWER THE FOLLOWING QUESTIONS IF YOU DID NOT ANSWER PART B. IF YOU ANSWERED PART B, PLEASE SKIP TO PART D, PAGE 18.

4.20 Would you consider establishing a collaborative nuclear medical training program with other institutions? _____yes _____no

If no, please very briefly give the reasons and then skip to Part D, question 4.30.

Card 09

NMT INTERVIEW

4.21 If your Department were considering establishing a collaborative educational program, please rank your preference for working with the following:

_____(a) Other hospitals only; 43

_____(b) Other hospitals and a University Medical School; 44

_____(c) University Medical School; 45

_____(d) Other hospitals and a Community College or Technical Institute; 46

_____(e) Community College or two-year Technical Institute; 47

_____(f) Other: 48

4.22 What kind of education program would you like to see? 49

_____1. full-time educational program (regular intervals of in-hospital clinical work alternating with regular intervals of classroom instruction at the educational institution) without internship as part of total program.

_____2. full-time program with following internship as part of total program.

_____3. full-time non-cooperative educational program, with post-graduate internship.

_____4. part-time school-based courses for full-time hospital employees now in a different medical field.

_____5. part-time school-based courses designed for upgrading full-time hospital employees already in the field.

_____6. other:

4.23 Assuming that the students entering the collaborative program are mainly high school graduates, what is the length of the formal training program that you would design, so that the graduate could assume responsibility for carrying out nuclear medical tests and operations in your Department? 50

Formal training program length __________ years.

4.24 How many months of the total program would be spent in clinical or class work at your hospital?

(a) before graduation: class work __________ (weeks) (months) 51-52

clinical work __________ (weeks) (months) 53-54

(b) in a post-graduate internship program with a systematic educational design:

class work __________ (weeks) (months) 55-56

clinical work __________ (weeks) (months) 57-58

Card 09

NMT INTERVIEW

4.25 Please give the names of the institutions/hospitals that you would prefer to collaborate with, the distances and time to travel between your hospital and the other institutions/hospitals, in the table below.

Name of Institution	Location	Distance from your hospital in miles	Time to travel by Public Transportation
1.			
2.			
3.			

4.26 Would you be willing to support the living costs of your staff while they received training outside of your hospital? (1)____ yes (2)____ no 59

4.27 Would you be willing to pay any of the tuition costs?

$____ total tuition costs/year 60-63

____ %paid by you 64-65

4.28 Which of the following factors would be important to you in setting up a collaborative program with your preferred choice. Please circle the appropriate number in each case.

	Importance great	some	little	
(a) That you have control over the specialized content of the curriculum.	1	2	3	66
(b) That the program include on-the-job experience over several semesters.	1	2	3	67
(c) Same as (b) but followed by an internship program in a nuclear medical department.	1	2	3	68
(d) That specialized courses be taught by MD's.	1	2	3	69
(e) That your Department be represented on an active advisory board to the educational program.	1	2	3	70
(f) That the AMA or another professional association approve the curriculum. Please specify the professional association ________	1	2	3	71
(g) Other:	1	2	3	
(f) Other:	1	2	3	

NMT INTERVIEW

SKIP TO PART D, PAGE ~~18~~ 21, IF YOUR ANSWER TO 4.21 WAS d) OR e).

4.29 If your local community college or technical institute were to seek your help in setting up a two-year nuclear medical training program, would you:

(a) be willing to collaborate with them? _____yes _____no

(b) if no, would you employ their graduates? _____yes _____no

(c) if you are willing to collaborate with them, which of the following factors would apply and how important is each to you? Please circle the appropriate number in each case.

	Importance great	some	little
(a) That you have control over the specialized content of the curriculum	1	2	3
(b) That the program include on-the-job experience over several semesters	1	2	3
(c) Same as (b) but followed by an internship program in a nuclear medical department	1	2	3
(d) That specialized courses be taught by MD's	1	2	3
(e) That your Department be represented on an active advisory board to the educational program	1	2	3
(f) That the AMA or another professional association approve the curriculum. Please specify the professional association ____________________	1	2	3
(g) Other:	1	2	3
(h) Other:	1	2	3

NMT INTERVIEW

Part D

These questions concern instructional materials, instructional aids and lab kits which are used, or could be used, in nuclear medical technician training programs. Here is a list of some of the media employed.

Media Code No.	Media
1	Teacher's manuals and/or source books
2	Commercially published textbooks
3	Manufacturers' manuals
4	Programmed instruction booklets
5	Your own booklets
6	Overhead projector transparencies
7	Film
8	Film loops
9	Film strips
10	Student lab kits
11	Simulation laboratories
12	Other ______________________

4.30 Please name the instructional materials, etc. which you use or believe that could be used for training nuclear medical technicians. Perhaps you have a syllabus or reading kit which you could give us.

Instructional Materials (Title and Author)	Media Code

4.31 How long ago were these materials updated? ______years
How often would you like to see them updated? ______years

4.32 Please name by topics, the new instructional materials, aids, etc. that you feel are most urgently needed for use in programs for training nuclear medical technicians. (Example: "Rapid uptake studies" 8)

Topics	Media Code

NMT INTERVIEW

Section 6

Is there any other information which you think could be important and useful to our study which we have not obtained through this questionnaire? If so, please comment below:

Remember!

Question 2.5: Can you give us samples of the forms (administration and specialized that NMT has to work with?

Section 4: Course syllabus and/or lists of materials.

Statistical Summary of Findings

Question 1.1

(coding explanation: 0=0; a=1; b=2; c=3; d=4)

Preparation	Mean	S.D.
1. Chemically prepare short-life isotopes: a) eluting the column	2.72	1.80
2. b) chemical preparation	1.02	1.53
3. c) sterilize	0.63	1.29
4. Calibrate isotopes against a standard	3.11	1.47
5. Prepare oral dose: measure from manufacturer's bottle	2.65	1.70
6. Prepare oral dose: Mix, dilute to measure	2.12	1.77
7. Prepare injections: measure dose	3.70	0.97
8. Prepare injections: sterilize dose	0.68	1.36
9. Set up instruments for operation: a) in vivo studies	3.65	1.01
10. Set up instruments for operation: b) in vitro studies	2.95	1.60
Tests & Patients		
11. Administer isotopes to patients: a) orally	3.60	0.95
12. Administer isotopes to patients: b) by injection	2.46	1.60
13. Receive patients, explain tests to them and allay their fears	3.88	0.56
14. Position patient with respect to nuclear medical equipment	3.92	0.52
15. Superficial and specialized examination of patients	----	----
16. Attend to patient's comfort before and during scan	3.88	0.63
17. Understand operating room procedures	----	----
Data Handling		
18. Abstract simple data from patient's chart	3.03	1.36
19. Make simple dose calculations for a) in vivo examinations	3.65	1.02
20. Make simple dose calculations for b) in vitro examinations	2.85	1.65
21. Make simple dose calculations for c) tracer examinations	3.50	1.12
22. Accumulate and process data for MD's interpretation	3.60	1.03
23. Examine scan test results for general credibility	3.69	0.94
24. Perform preliminary interpretations of observations for MD	1.89	1.58
Equipment		
25. Operate a rectilinear scanner for conventional scanning	3.74	0.94
26. Operate an autofluoroscope for static studies	0.09	0.43
27. Operate a scintillation camera for static studies	1.67	1.93
28. Operate an autofluoroscope for fast dynamic studies (under one minute scan)	0.13	0.58
29. Operate a scintillation camera for fast dynamic studies	1.32	1.71
30. Operate a scanner for slow dynamic studies (over one minute scan)	1.90	1.80
31. Operate an autofluoroscope for slow dynamic studies	0.13	0.58
32. Operate a scintillation camera for slow dynamic studies	1.46	1.76
33. Calibrate nuclear medical instruments	3.04	1.37
34. Check performance of existing and new nuclear medical instruments against manufacturer's specifications	1.91	1.34
35. Determine if a nuclear medical instrument is in need of major repair	2.61	1.27
36. Perform minor maintenance on nuclear medical instrument	1.86	1.23
37. Evaluate nuclear medical instruments from manufacturer's literature and specify and rank those instruments that satisfy the doctors' requirements	1.20	0.90
38. Advise doctors on the technicalities and procedures involved in operating a nuclear medical instrument	2.17	1.31

Question 1.1 (cont.)

Safety	Mean	S.D.
39. Check monitoring instruments	2.46	1.28
40. Monitor personnel in compliance with hospital regulations	2.24	1.37
41. Monitor space in compliance with hospital regulations	2.46	1.16
42. Handle and store radioisotopes safely	3.80	0.68
43. Assay wet chemical solutions for activity and contaminants	2.26	1.70
44. Safely dispose of radioactive wastes	3.39	0.94
Clerical		
45. Handle secretarial work: appointments, type reports	2.83	1.45
46. Routinely check incoming equipment	2.23	1.27
47. Inventory and order radiopharmaceuticals and materials	3.34	1.03
48. Keep accounts of hospital licensing and isotope procurement	2.56	1.47

Question 1.7

	Eqpt. in your dept		Tech man-hrs/wk on eqpt	
	Mean	S.D.	Mean	S.D.
1. Single Probe Scanner -- 3", 5", or 8"	1.36	0.91		
2, Dual Probe Scanner	0.30	0.58		
3. Autofluoroscope	0.04	0.22		
4. Scintillation Camera	0.53	0.59		
5. Whole Body Scanner (radiation distribution)	0.07	0.25		
6. Whole Body Counter (total radiation level)	0.07	0.26		
7. Manual Well System	1.43	1.56		
8. Automatic Well System	0.61	0.99		
9. Dose Assay Ionization Chamber	0.63	0.82		
10. Monitoring Ionization Chamber	1.57	2.13		
11. Single Probe Renal System	0.25	0.59		
12. Dual Probe Renal System	0.62	0.67		
13. Computer Applications of Scintillation Camera	0.13	0.36		
14. Liquid Scintillation System	0.54	1.11		
15. Orthodensitometer	0.05	0.21		
16. Multichannel Gamma Ray Spectrometer	0.39	0.95		
17. T-3 Type or T-4 Type Measurement System	0.39	0.60		
18. Automatic or Semi-automatic Blood Volume Measurement Systems	0.51	0.58		
19. Automatic Film Developing Facilities	1.44	1.07		
TOTAL	4.10	3.07	114.47	131.86

Question 1.16

How many of the following are performed per month in your department:

	Mean	S.D.
1. Image or localization studies		
2. Flow studies (e.g., brain blod flow)		
3. Dilution studies (e.g., blood volume)		
4. Absorption, Excretion tests (e.g., Schilling tests)		
5. Rapid uptakes (e.g., renograms)		
6. Slow uptakes (e.g., thyroid uptakes)		
7. *In vitro* tests (e.g., T-3 tests)		
TOTAL	494.67	262.03

	Proportion of Total
Static studies (scans) - #1	.27
Dynamic function studies - #2, 5, 6	.29
In vitro tests, etc. - #3, 4, 7	.44
	1.00

Question 2.1

(coding explanation: mid pt of 4000-4999 = 1;
mid pt of 5000-5999 = 2; etc.)

Please circle the annual salary range which you now pay your technician.

Certification & Years of Experience	Mean	S.D.	Dollar Value Mean	Dollar Value S.D.
Certified or non-certified & first year	2.79	1.17	$6290	$1170
Certified or non-certified & second year	3.52	1.33	$7020	$1330
Certified or non-certified & fifth year	4.60	1.25	$8100	$1250

Question 2.2

Do you prefer males or females in the role of a nuclear medical technician?

	Proportion
Males	.25
Females	.19
No preference	.56
	1.00

Question 3.1

	Mean	S.D.
How many nuclear medical technicians did your Department have at the beginning of 1969?	2.48	
How many persons did this represent?	2.54	1.86

Question 3.3

Is this number sufficient for your Department's current needs?

	Proportion
Yes	.69
No	.31
	1.00

Question 3.4

If your answer to 3.3 was no, please circle the importance of each of the following constraints which prevent your department from hiring more NMT technicians.

	Proportion each answer				
	Degree of importance				
Possible constraints	great	some	slight	none	Mean
1. lack of funds for salaries	.67	.10	.02	.21	1.77
2. lack of trained technicians	.67	.10	.02	.21	1.79
3. lack of manpower to train technician candidates	.20	.11	.09	.57	3.11
4. lack of supervisors for technicians	.00	.12	.15	.74	3.62
5. lack of nuclear medical equipment	.03	.19	.11	.67	3.42

Question 3.5 and 3.1 combined

How many persons did (you) (or do you expect to):

		1966	1967	1968	1969	1970	1971	1972	1973
a) appoint with or without NMT training in------	mean	0.76	1.10	1.33	0.88	1.09	1.02	1.02	
	SD	0.85	2.44	2.46	1.18	1.61	1.48	1.58	
b) leave your dept's employ in----------------	mean	0.35	0.47	0.68	0.49				
	SD								
c) leave your dept's employ and the field of nuclear medicine in------	mean	0.16	0.25	0.31	0.17				
	SD								
d) employ in------------	mean	1.22	1.64	1.97	2.48	2.87	4.01	4.93	5.98
	SD	2.40	2.02	1.94	3.47	2.35	3.33	3.97	5.23

Question 3.6

Please indicate below the most important reason(s) which you believe led to their leaving.

	Proportion
inadequate salary schedule	.17
other	.83
	1.00

Question 3.7

	Preferred Rank	Proportion Ranked in Top 4	Median Range $	Salary Mean $	S.D.
No post-secondary training or experience	10	10	4750 5250	5140	700
Two years of on-the-job training in hospital medical laboratories other than in radiation	9	9	5250-5750	5610	1020
Two years of on-the-job training in a nuclear medical department	3	3	5750-6250	6270	1400
A two-year X-Ray technician program involving hospital experience over several semesters	6	6	5750-6250	6040	1460
Same as above plus six-month hospital internship program	7	7	5750-6250	6200	1490
A two-year nuclear medical technician program involving hospital experience over several semesters	2	1	6250-6750	6560	1300
Same program as above plus six-month hospital internship program	1	2	6750-7250	6680	1580
A registered nurse training program	8	8	6250-6750	6250	1410
A four-year college degree program in biology/chemistry/physics	5	5	6750-7250	6820	1740
Four-year Medical Technologist Program including hospital experience over several semesters	4	4	6750-7250	6990	1840

Question 3.11

Please estimate how many nuclear medical technicians your Department will need in

	Mean	SD	Median
(a) 1975	5.66	3.71	5.00
(b) 1980	7.95	5.08	6.50

Question 3.12

Suppose that your reputation depended on your success in predicting the percentage of hospitals in the United States that will have nuclear medical operations (a) by 1975, (b) by 1980. What percentages would you predict for each? (Presently about 30% of all hospitals listed in the AGA guide have a radioisotope facility.) Please circle the appropriate figure for eacy year.

	Proportion
1975	.62
1980	.79

Question 4.1

Please check below, how your technicians are now trained.

	Number	Prop.
(a) _____ informal hospital training program	103	.53
(b) _____ formal hospital training program (ARRT Curriculum)		
_____ yes	26	.13
_____ no	4	.02
(c) _____ formal training program in collaboration with other hospitals	6	.03
(d) _____ formal training program in collaboration with community college/technical institute	9	.05
(e) _____ formal training program in collaboration with a university medical school	9	.05
(f) _____ only hire trained or experienced technicians	36	.19
	193	1.00

Question 4.2

What is the length of your program?

	Number	Proportion
0 - 2 weeks	2	.01
2 - 6 weeks	11	.08
6 weeks - 3 months	19	.14
3 - 6 months	16	.12
6 - 12 months	45	.33
> 12 months	13	.09
continuous	31	.22
	137	.99

Question 4.3

Who teaches it?

	Number	Proportion
MD's	22	.18
Technologists	26	.21
Other	7	.06
Combination	70	.56
	125	1.01

Questions 4.1 x 4.2

Length of Program

Type of Program		0-2 wks.	2-6 wks.	6 wks.-3 mos.	3-6 mos.	6-12 mos.	over 12 mos.	cont-inuous	
	informal hosp. training prog.	1	9	14	11	18	-	31	84
	formal hosp. training prog., ARRT curriculum	-	-	-	3	16	8	-	27
	formal hosp. training prog., not ARRT curr.	1	1	-	1	1	-	-	4
	collab. with other hosp.	-	1	2	-	3	-	-	6
	collab. with community coll. or tech. inst.	-	-	1	-	4	3	-	8
	collab. with university medical school	-	-	2	1	3	2	-	8
		2	11	19	16	45	13	31	137

Question 4.4

How many students/trainees were in this program last year?

	No. of Hospitals	Proportion	No. of stud/trnees
0	32	.28	0
1	33	.29	33
2	16	.14	32
3	14	.12	42
4	6	.05	24
5	4	.04	20
6	1	.01	6
7	0	.00	0
8	2	.02	16
9	0	.00	0
10	1	.01	10
11	1	.01	11
14	1	.01	14
20	3	.03	60
	114	1.01	268

Question 4.5

How many students/trainees graduated from this program during last year?

	No. of Hospitals	Proportion	No. of stud/trnees
0	41	.39	0
1	34	.32	34
2	14	.13	28
3	7	.07	21
4	2	.02	8
5	2	.02	10
6	1	.01	6
7	0	.00	0
8	1	.01	8
9	0	.00	0
10	0	.00	0
11	1	.01	11
15	1	.01	15
16	1	.01	16
	105	1.00	157

Question 4.7

What degree or certificate, if any, results from this program?

	No. of Hosps.	Proportion
none	77	.69
certificate received	34	.30
	111	.99

Question 4.8

Are the trainees who complete this program eligible to take:

(a) American Registry of Radiologic Technologists Certification examination?

Yes	66	.59
No	46	.41
	112	1.00

(b) Registry of Medical Technologists?

Yes	17	.17
No	83	.83
	100	1.00

Question 4.9

Does the length of the program depend on the previous background of the trainee?

Yes	75	.64
No	42	.36
	11/	1.00

Question 4.10

Does the content or clinical training or the program depend on the previous background of the trainee?

Yes	68	.59
No	48	.41
	116	1.00

Question 4.11

	1967				1968				1969			
	Mean	SD	No. of hosps.	No. of trnees.	Mean	SD	No. of hosps.	No. of trnees.	Mean	SD	No. of hosps.	No. of trnees.
X-Ray technician	1.19	1.92	57	68	1.34	1.82	70	94	1.65	2.20	72	119
Medical Technologist	0.24	0.73	42	10	0.48	1.62	54	26	0.44	1.56	59	26
Laboratory Assistant	0.05	0.22	40	2	0.08	0.34	51	4	0.07	0.32	56	4
High School graduate	0.70	3.38	40	28	0.59	2.34	53	21	0.85	2.70	58	51
Nurse	0.13	0.52	40	5	0.12	0.39	50	6	0.00	0.00	53	0
College graduate in Science	0.15	0.49	39	4	0.12	0.48	49	6	0.17	0.53	59	10
Don't know	0.00	0.00	37	0	0.02	0.15	47	1	0.04	0.28	52	2

Question 4.12

What kind of education program is involved?	Number	Proportion
a) Full-time educational program (regular intervals of in-hospital clinical work alternating with regular intervals of classroom instruction at the educational institution) without internship as part of total program;	15	.65
b) Full-time cooperative educational program with following internship as part of total program;	3	.13
c) Full-time non-cooperative educational program, with post-graduate internship;	1	.04
d) Part-time school-based courses for full-time hospital employees now in a different medical field;	2	.09
e) Part-time school-based courses designed for upgrading full-time hospital employees already in the field;	2	.09
	23	1.00

Question 4.13

How many weeks of the total program are spent in clinical or class work?

	Mean	SD
class work	18.58	15.37
clinical work	35.57	23.05

Question 4.17

Do you support the living costs of your staff while they receive training outside of your hospital?

	Number	Proportion
yes	14	.70
no	6	.30
	20	1.00

Question 4.19

(coding explanation: 1 = great; 2 = some; 3 = little)

	Mean	SD
(a) That you have control over the specialized content of the curriculum	2.00	0.92
(b) That the program include on-the-job experience over several semesters	1.25	0.64
(c) Same as (b) followed by an internship program in a nuclear medical department	2.21	0.92
(d) That specialized courses be taught by MD's	1.75	0.64
(e) That your Department be represented on an active advisory board to the educational program	1.65	0.81
(f) That the AMA or another professional association approve the curriculum. Please specify the professional association.	1.42	0.69

Question 4.20

Would you consider establishing a collaborative nuclear medical training program with other institutions?

	Number	Proportion
yes	135	.86
no	22	.14
	157	1.00

Question 4.21

If your Department were considering establishing a collaborative educational program, please rank your preference for working with the following:

	No. ranked #1
(a) Other hospitals only;	2
(b) Other hospitals and a University Medical School;	48
(c) University Medical School;	35
(d) Other hospitals and a Community College or Technical Institute	31
(e) Community College or two-year Technical Institute	16
(f) Other	6
	138

Question 4.22

What kind of education program would you like to see?

	Number	Proportion
(a) Full-time educational program (regular intervals of in-hospital clinical work alternating with regular intervals of classroom instruction at the educational institution) without internship as part of total program	56	.44
(b) Full-time program with following internship as part of total program	56	.44
(c) Full-time non-cooperative educational program, with post-graduate internship	2	.02
(d) Part-time school-based courses for full-time hospital employees now in a different medical field	5	.04
(e) Part-time school-based courses designed for upgrading full-time hospital employees already in the field	4	.03
(f) Other	3	.02
	126	.99

Question 4.23

(coding explanation: if on a border, choose the lower code)

Assuming that the students entering the collaborative program are mainly high school graduates, what is the length of the formal training program that you would design, so that the graduate could assume responsibility for carrying out nuclear medical tests and operations in your Department?

	Number	Proportion
0-6 months	1	<.01
6-12 months	18	.14
12-18 months	2	.02
18-24 months	68	.52
24-30 months	6	.05
30-36 months	22	.17
36-42 months	13	.10
42-48 months	0	.00
> 48 months	1	<.01
	131	1.00

Question 4.6

Would you be willing to support the living costs of your staff while they received training outside of your hospital?

	Number	Proportion
Yes	51	.49
No	54	.51
	105	1.00

Would you be willing to pay any of the tuition costs?

Yes	44	.42
No	40	.38
Maybe	15	.14
Don't know or no authority	7	.07
	106	1.01

Question 4.28

(coding explanation: 1 = great; 2 = some; 3 = little)	Mean	SD
(a) That you have control over the specialized content of the curriculum.	1.72	0.74
(b) That the program include on-the-job experience over several semesters.	1.33	0.62
(c) Same as (b) but followed by an internship program in a nuclear medical department.	2.11	0.85
(d) That specialized courses be taught by MD's	2.00	0.75
(e) That your Department be represented on an active advisory board to the educational program	1.39	0.61
(f) That the AMA or another professional association approve the curriculum. Please specify the professional association.	1.43	0.73

Question 4.29

If your local commu: ·· college or technical institute were to seek your help in setting up a two-year nuclear medical training program, would you:

(a) be willing to collaboate with them?	Number	Proportion
Yes	72	.95
No	4	.05
	76	1.00

Question 4.29 c

	Mean	SD
(a) That you have control over the specialized content of the curriculum	1.68	0.70
(b) That the program include on-the-job experience over several semesters	1.32	0.62
(c) Same as (b) but followed by an internship program in a nuclear medical department	2.08	0.87
(d) That specialized courses be taught by MDs	1.95	0.77
(e) That your Department be represented on an active advisory board to the educational program	1.33	0.54
(f) That the AMA or another professional association approve the curriculum. Please specify the professional association	1.48	0.76

Question 5.1

In which department did nuclear medical operations begin?

	Number	Proportion
1) Department of Radiology	122	.62
2) Department of Pathology	22	.11
3) Nuclear Medicine was established as a separate department unit with its own rights.	25	.13
4) Department of Internal Medicine	13	.07
5) Other or >1 department	14	.07
	196	1.00

Question 5.2

How long is it since nuclear medical tests/operations first started in your hospital?

	Number	Proportion
0-5 years	45	.23
6-10 years	58	.30
11-15 years	48	.25
16-20 years	29	.15
21-25 years	11	.06
26+ years	1	.01
	192	1.00

Question 5.4

Are there any other nuclear medical tests/operations carried out elsewhere in the hospital, which are not under your Department's control?

	Number	Proportion
Yes	105	.54
No	91	.46
	196	1.00

Question 5.5

What is the current status of your department?

Nuclear Medicine is:	Number	Proportion
equal to Radiology, Pathology	42	.22
a subunit of Radiology	120	.62
a subunit of Pathology	12	.06
other	20	.10
	194	1.00

Respondents to Survey Interviews

	Number	Proportion
MD	96	.48
Physicist	17	.08
Chief Technician	56	.28
Other Technician	13	.06
Combination	19	.09
Other	1	.00
	202	.99

Appendix B: Manpower Needs

Introduction

In the appendix which follows, we have attempted to determine the number of Nuclear Medicine Technicians needed (and needed to be prepared) for future years. Data for these projections were gathered in an interview sample of 202 hospitals and a mailed questionnaire sample of 104 hospitals, although only the former provided enough reliable data to serve this purpose (see page 53 for further explanation).

Since respondents were not in total agreement as to the extent of future growth in nuclear medicine, no single set of assumptions proved sufficient for the prediction of Nuclear Medicine Technician needs. The assumptions were related to the year(s) for which the estimates were made; thus, results were obtained within the following categories: 1966-68, 1969, 1970-73 and 1975 and '80. For the first three time spans, the number of Nuclear Medicine Technicians in each year (N_i) was a function of the number of hospitals with nuclear medicine operations in that year (h_i) and the average size of these operations (m_i). Thus:

$$N_i = h_i m_i .$$

For 1975 an additional factor was added to account for the assumption that hospitals just beginning nuclear medicine operations would have fewer NMT's than hospitals with established departments.

Part I of this appendix describes in detail the techniques used. Section A lists the assumptions which were relevant to <u>all</u> the calculations. Section B explains the techniques and presents the different assumptions used to produce values for the average number of hospitals with nuclear medicine and the average number of Nuclear Medicine Technicians in these hospitals for each year. In section C, these values are combined in different ways to provide estimates of the total number of NMT's needed in those years. Section D summarizes these findings, while section E takes these conclusions one step farther by suggesting a relationship between the number of technicians <u>needed</u> in any year and the number <u>needed to be prepared</u>.

Part II is based on the data collected from the mailed sample. Sections A and B above are assumed to apply and values for manpower needs for certain years were determined. It proved impossible to summarize these results, since significant information was lacking.

Part I: Manpower - Interview Data

A. General Assumptions

1. The data we have collected via interview and questionnaires are essentially accurate reflections of the situation in these hospitals.

2. The interview sample is representative of all hospitals with nuclear medicine operations (see comment pages 53-54).

3. There are no significant differences between hospitals that agreed and did not agree to be included in the samples.

B. Raw Data

1. The Number and Proportion of Hospitals in the U.S. with a Nuclear Medicine Facility.

a. The mailed sample was sent to hospitals listed in the Journal of the American Hospital Association's 1966 Guide as having either a radioisotope facility or a radiotherapy facility or both. Of 117 responses from hospitals listed as having a radioisotope facility, 102 (87%) indicated that they really had such a facility while the remaining 15 (13%) reported having no nuclear medicine operations. For purposes of determining the number of hospitals in the U.S. with nuclear medicine operations, it is therefore assumed that the proportion of hospitals listed in the guide as having a radioisotope facility should be reduced by 13% (the "correction factor").

b. The total number of hospitals reported by the AHA guide has recently been extremely stable (an average increase of .15% per year from 1964-67). It is assumed that the number of hospitals through 1975 will not significantly change and will remain at about 7,150.

c. i)* The proportion of hospitals with radioisotope facilities listed in the AHA guides in 1964-66 (1965-67 guides) has changed as follows:

---

* c i) and c ii) represent mutually exclusive sets of assumptions.

1964 - 24.9%

1965 - 26.5%

1966 - 25.8%

Since more recent comparable data are not available, and since the above represents no clear trend, it is assumed that the average of these figures (25.7%) is a reasonable estimate of the proportion of hospitals which would continue to be listed in the guide as having a radioisotope facility. Incorporating the correction factor, the number of hospitals in the U.S. with a radioisotope facility (1967-1980) is

$$h_i = (7,150)(.257)(1.00 - 0.13)$$

$$= \underline{1,592} \qquad (i = 1967\text{-}80)$$

ii) Of 203 hospitals surveyed, the number beginning nuclear medicine operations each year from 1950-65 was extremely stable,(10 hospitals, or about 5% of those surveyed, per year.) If we accept the 1966 data (from the 1967 AHA guide) as a base, incorporate the correction factor, and add 5% of this figure each year, the number of hospitals in the U.S. with a nuclear medicine facility (1966-80) is:

$$h_i = h_{66}(1.00 - 0.13) + (.05)(h_{66})(1.00 - 0.13)\sum_{i=1}^{15} i$$

(i=1-15= 1966-1980

The resulting number of hospitals (and the proportion of all hospitals) for each year through 1980 is the following:

Year	Number	Proportion
1966	1,603	.22
1967	1,684	.24
1968	1,764	.25
1969	1,844	.26
1970	1,925	.27
1971	2,005	.28
1972	2,085	.29

Year	Number	Proportion
1973	2,165	.30
1974	2,245	.31
1975	2,326	.32
1976	2,406	.34
1977	2,486	.35
1978	2,567	.36
1979	2,646	.37
1980	2,727	.38

2. The Average Number of Nuclear Medicine Technicians in a Hospital with Nuclear Medicine Operations

a. Respondents were asked the number of people they have hired or expect to hire in 1966-72, as well as the number who left their employ and the field of nuclear medicine from 1966-69 (Question 3.5). Respondents were also asked the number of Nuclear Medicine Technicians in their department as of the beginning of 1969 (Question 3.1).

1)* The average number of technicians employed in a department with nuclear medicine operations was obtained by the following methods:

for 1969: m of Question 3.1

prior to 1969: $m_i = m_{i+1} - m_{a+b-c}$**

after 1969: $m_i = m_{i-1} + m_{a+b}$**.

By this method the average number of Nuclear Medicine Technicians (1966-73) is:

---

* a 1) and a 2) represent mutually exclusive sets of assumptions.

** For interpretation of letters, see Question 3.5.

1966: $m_{66} = 1.22$

1967: $m_{67} = 1.64$

1968: $m_{68} = 1.97$

1969: $m_{69} = 2.48$

1970: $m_{70} = 2.87$

1971: $m_{71} = 4.01$

1972: $m_{72} = 4.93$

1973: $m_{73} = 5.98$.

2) Unfortunately, it was uncertain whether respondents' replies concerning the number of people they expected to hire did or did not incorporate turnover. Since about half of those hired from 1966-69 represented replacements for those who had left, it can be assumed that this proportion will be continued. The previous section assumed that those appointed (a+b)* included this turnover rate. Without making this assumption the number of new employees should be reduced by half; thus the average number of Nuclear Medicine Technicians (1970-73) is:

$$m_i = m_{i-1} + \frac{m_{a+b^*}}{2} .$$

1970: $m_{70} = 2.92$

1971: $m_{71} = 3.47$

1972: $m_{72} = 3.98$

1973: $m_{73} = 4.49$

Expressed algebraically, the above sets of conclusions, a 1) and a 2), can be understood more clearly:

For both, $N_i = N_{i-1} + h_{i-1} - f_{i-1}$, where

---

* For interpretation of letters, see Question 3.5.

N_i = number of NMT's in year i

h_i = number of NMT's hired in year i

f_i = number of NMT't leaving in year i.

For the first, $f_i = 0$ because it is assumed to be included in h_i. For the second,

$$f_i = \frac{h_i}{2}.$$

b. Respondents were asked to estimate the number of NMT's they would need in 1975 and 1980 (Question 3.11). Averages of these figures are:

$m_{75} = 5.66$

$m_{80} = 7.95.$

It should be noted that the form of Question 3.11 differed somewhat from Question 3.5. The former asked for the number "needed," while the latter requested the number they "expect to hire."

C. Manpower Needs for Specified Years

1. 1969

a. Direct Expansion of Number of Nuclear Medicine Technicians in Sample to Entire Population (1969)

Explanation

This method consists of a simple multiplication of average number of Nuclear Medicine Technicians in a hospital by number of hospitals with nuclear medicine operations.

Technique

m_{69} = average number of NMT's in a department

h_{69} = number of hospitals with nuclear medicine operations

N_{69} = number of NMT's in 1969

$$N_{69} = m_{69}\, h_{69}$$

Calculations

i)* hospitals with nuclear medicine constant

$m_{69} = 2.48$ (from pages 106-107)

$h_{69} = 1,592$ (from pages 104-105)

$N_{69} = (2.48)(1,592)$

$= \underline{3,948}$

ii)** hospitals with nuclear medicine increasing

$m_{69} = 2.48$ (from pages 106-107)

$h_{69} = 1,844$ (from pages 105-106)

$N_{69} = (2.48)(1,844)$
$= \underline{4573}$

2. 1966-1968

a. Number of Nuclear Medicine Technicians Based on Respondents' Reports of Hiring History (1966-1968)

Explanation

Beginning with the present number of Nuclear Medicine Technicians, the number hired each year was successively deducted to determine the number extant for each target year.

Technique

m_i = average number of NMT's in year i

---

* Under each technique in this section, more than one set of calculations is presented, each based on different assumptions. The page(s) on which those assumptions are stated are provided for reference; in addition, each set of calculations is preceded by a brief description of the assumption(s) which distinguish(es) it from its neighbors.

** "Best estimate" (see graph 2 page 32) is based on this value.

h_i = number of hospitals with nuclear medicine operations in year i

N_i = number of Nuclear Medicine Technicians in year i

$$N_i = m_i \ h_i$$

Calculations

i) hospitals with nuclear medicine constant

$m_{66} = 1.22$ (from pages 106-107)

$m_{67} = 1.64$ "

$m_{68} = 1.97$ "

$h_{66} = h_{67} = h_{68} = 1,592$ (from pages 104-105)

$N_{66} = (1.22)(1,592) = \underline{1,942}$

$N_{67} = (1.64)(1,592) = \underline{2,611}$

$N_{68} = (1.97)(1,592) = \underline{3,136}$

ii)* hospitals with nuclear medicine increasing

$m_{66} = 1.22$ (from pages 106-107)

$m_{67} = 1.64$ "

$m_{68} = 1.97$ "

$h_{66} = 1,603$ (from pages 105-106)

$h_{67} = 1,684$ "

$h_{68} = 1,764$ "

$N_{66} = (1.22)(1,603) = \underline{1,956}$

$N_{67} = (1.64)(1,684) = \underline{2,762}$

$N_{68} = (1.97)(1,764) = \underline{3,475}$

---

*"Best estimates" (see graph 2, page 32) are based on these values.

3. 1970-1973

a. Needs Based on Respondents' Estimates of Hiring Patterns of New Nuclear Medicine Technicians

Explanation

This method is similar to the above, except that the data are respondents' estimates of expected hiring patterns rather than their reports of past hiring patterns. Although we expect that the average number of Nuclear Medicine Technicians in departments created within the next few years will be less than the average number of Nuclear Medical Technicians in long-established departments, we are assuming that the difference is not significant.

Technique

m_i = average number of NMT's in a hospital with nuclear medicine operations in year i

h_i = number of hospitals with nuclear medicine operations in year i

N_i = number of Nuclear Medicine Technicians in year i

$$N_i = u_i\ h_i.$$

Calculations

i) hospitals with nuclear medicine constant; average number of Nuclear Medicine Technicians includes turnover rate

$m_{70} = 2.87$ (from pages 106-107)

$m_{71} = 4.01$ "

$m_{72} = 4.93$ "

$m_{73} = 5.98$ "

$h_{70} = h_{71} = h_{72} = h_{73} = 1{,}592$ (from pages 104-105)

$N_{70} = (2.87)(1{,}592) = \underline{4{,}569}$

$N_{71} = (4.01)(1{,}592) = \underline{6{,}384}$

$N_{72} = (4.93)(1{,}592) = \underline{7{,}849}$

$N_{73} = (5.98)(1{,}592) = \underline{9{,}520}$

ii) hospitals with nuclear medicine increasing; average number or Nuclear Medicine Technicians includes turnover rate

$m_{70} = 2.87$ (from pages 106-107)

$m_{71} = 4.01$ "

$m_{72} = 4.93$ "

$m_{73} = 5.98$ "

$h_{70} = 1{,}925$ (from pages 105-106)

$h_{71} = 2{,}005$ "

$h_{72} = 2{,}085$ "

$h_{73} = 2{,}165$ "

$N_{70} = (2.87)(1{,}925) = \underline{5{,}525}$

$N_{71} = (4.01)(2{,}005) = \underline{8{,}040}$

$N_{72} = (4.93)(2{,}085) = \underline{10{,}279}$

$N_{73} = (5.98)(2{,}165) = \underline{12{,}947}$

iii) hospitals with nuclear medicine constant; average number of Nuclear Medicine Technicians reduced by turnover

$m_{70} = 2.92$ (from page 107)

$m_{71} = 3.47$ "

$m_{72} = 3.98$ "

$m_{73} = 4.49$ "

$h_{70} = h_{71} = h_{72} = h_{73} = 1{,}592$ (from pages 104-105)

$N_{70} = (2.92)(1{,}592) = \underline{4{,}649}$

$N_{71} = (3.47)(1{,}592) = 5{,}524$

$N_{72} = (3.98)(1{,}592) = \underline{6{,}336}$

$N_{73} = (4.49)(1,592) = \underline{7,148}$

iv)* hospitals with nuclear medicine increasing; average number of Nuclear Medicine Technicians reduced by turnover

$m_{70} = 2.92$	(from page 107)
$m_{71} = 3.47$	"
$m_{72} = 3.98$	"
$m_{73} = 4.49$	"
$h_{70} = 1,925$	(from pages 105-106)
$h_{71} = 2,005$	"
$h_{72} = 2,085$	"
$h_{73} = 2,165$	"

$N_{70} = (2.92)(1,925) = \underline{5,621}$

$N_{71} = (3.47)(2,005) = \underline{6,957}$

$N_{72} = (3.98)(2,085) = \underline{8,298}$

$N_{73} = (4.49)(2,165) = \underline{9,721}$

4. 1975, 1980

a. Needs Based on Respondents' Estimates of Departmental Needs for Nuclear Medicine Technicians

Explanation

This method uses as data the respondents' estimates of the number of Nuclear Medicine Technicians their department will need in 1975 and 1980 and the proportion of hospitals expected to have nuclear medicine operations in those years. The latter is introduced because respondents have indicated that they expect a significant increase in hospitals conducting nuclear medicine operations.

---

*"Best estimates" (see graph 2, page 32) are based on these values.

Technique

m_i = average number of NMT's in those hospitals which presently have nuclear medicine operations in year i

a_i = average number of NMT's in those hospitals which do not have nuclear medicine operations but which will have nuclear medicine operations in year i

H_i = the total number of hospitals in year i

p_{69} = proportion of all hospitals which presently have nuclear medicine operations

p_i = proportion of all hospitals which will have nuclear medicine operations in year i

N_i = number of NMT's in year i

(i = 1975, 1980)

$$N_i = m_i p_{69} H_{69} + a_i (p_i H_i - p_{69} H_{69})$$

Calculations

i)* proportion of hospitals with nuclear medicine based on past data

m_{75} = 5.66	(from page 108)
m_{80} = 7.95	"
a_{75} = 2.52	(from Questions 3.1 and 5.2: average number of NMT's in hospitals reporting that NM operations began 0-5, 0-10 years ago)
a_{80} = 2.57	"
$H_{69} = H_{75} = H_{80}$ = 7,150	(from page 104)
p_{69} = .26	(from pages 105-106)
p_{75} = .32	"
p_{80} = .38	"

---

* "Best estimates" (see graph 2, page 32) are based on these values.

$$N_{75} = (5.66)(.26)(7,150) + (2.52)(.32 - .26)(7,150)$$
$$= \underline{11,592}$$
$$N_{80} = (7.95)(.26)(7,150) + (2.57)(.38 - .26)(7,150)$$
$$= \underline{16,984}$$

ii) proportion of hospitals with nuclear medicine based on respondents' estimates

$m_{75} = 5.66$	(from page 108)
$m_{80} = 7.95$	"
$a_{75} = 2.52$	(From Questions 3.1 and 5.2; average number of NMT's in hospitals reporting that NM operations began 0-5, 0-10 years ago.)
$a_{80} = 2.57$	"
$H_{69} = H_{75} = H_{80} = 7,150$	(from page 104)
$p_{69} = .26$	(from pages 104-105)
$p_{75} = .62$	(from Question 3.12)
$p_{80} = .79$	"

$$N_{75} = (5.66)(.26)(7,150) + (2.52)(.62 - .26)(7,150)$$
$$= \underline{16,996}$$
$$N_{80} = (7.95)(.26)(7,150) + (2.57)(.79 - .26)(7,150)$$
$$= \underline{24,519}$$

Note: In answering Question 3.12, respondents were incorrectly informed that the present proportion of hospitals with nuclear medicine operations was 30%. This undoubtably stimulated an upward bias in their responses.

iii) proportion of hospitals with nuclear medicine constant

$m_{75} = 5.66$	(from page 108)
$m_{80} = 7.95$	"

$a_{75} = 2.52$	(from Question 3.1 and 5.2: average number of NMT's in hospitals reporting that NM operations began 0-5, 0-10 years ago.)
$a_{80} = 2.57$	"
$H_{69} = H_{75} = H_{80} = 7{,}150$	(from page 104)
$p_{69} = p_{75} = p_{80} = .26$	(from pages 104-105)

$$N_{75} = (5.66)(.26)(7{,}150) + (2.52)(.26 - .26)(7{,}150)$$

$$= \underline{10{,}511}$$

$$N_{80} = (7.95)(.26)(7{,}150) + (2.57)(.26 - .26)(7{,}150)$$

$$= \underline{14{,}779}$$

(iv) can also be calculated for values of m_i obtained by extrapolating from both sets of values listed on page 107; combined with three different "p" values above, six other results can be obtained.)

5. A Different Method

An attempt was made to determine future manpower needs using only present and recent data. It was hypothesized that certain hospitals could be indentified as being further advanced than others with respect to the quantity of their use of nuclear medicine operations and that the rate at which their use of nuclear medicine was growing would differ from the rate at which less advanced hospitals were increasing their nuclear medicine operations. If hospitals could be so ranked, it would be reasonable to assume that the less advanced hospitals would, over time, approach the occupational distribution (defined as the number of Nuclear Medicine Technicians per hospital or hospital size) of the more advanced hospitals. Given such a categorization of hospitals, the need for Nuclear Medicine Technicians could be derived without using data based on future estimates. The data, however, proved intractable on this point. None of the expected trends materialized and this method had to be abandoned.

D. Summary of Manpower Needs

By the techniques described above, numerous values were derived for manpower needs for certain years. These results can be combined in many ways; through linear and curvilinear regression analysis, almost an infinite number of lines can be made to fit these data points. We feel that such an exercise is not very valuable, and that our findings can be portrayed more clearly simply by plotting the data points and allowing them to define a range. Thus, the need for Nuclear Medicine Technicians for any given year is most likely within the shaded area in graph 2, page 32.

To narrow this range to a more specific figure it is necessary to make certain judgments concerning the assumptions listed in sections 1-3 above. The data points circled on the graph represent our "best estimate" of future Nuclear Medicine Technician needs. The assumptions on which they are based are that:

a. hospitals with nuclear medicine facilities will increase at a rate of about 80/year; and

b. the average number of Nuclear Medicine Technicians/department will increase at a rate determined by the respondents' estimates of their hiring patterns, combined with their reports of past turnover rate.

E. <u>Number of Graduates of Preparatory Programs Needed</u>

Were every existing Nuclear Medicine Technician to remain indefinitely in the field, there would be a need each year to prepare the difference between the present number and the number needed for the following year. Since NMT's have a tendency to become pregnant, or to leave for other reasons, it is necessary to prepare a somewhat larger number than this yearly increase.

The data we have obtained indicated that roughly a third of those who leave a position as a Nuclear Medicine Technician completely foresake the field of nuclear medicine. Since the number of new Nuclear Medicine Technicians in any given year has tended to be about twice the number of employees leaving, the following relationship obtains:

G_i = number of graduates of a Nuclear Medicine training program in year i

N_i = number of Nuclear Medicine Technicians in year i

$$G_{i-1} = N_i - N_{i-1} + (1/3)(1/2)(N_i - N_{i-1})$$
$$= 7/6\ (N_i - N_{i-1})$$

Thus, for preparatory programs to produce enough new Nuclear Medicine Technicians to fill both the expected increase and the replacement need in any year, the number of graduates should be approximately one-sixth greater than the expected increase.

For the data points circled (graph 2, page 32), this means that there will be a need to graduate about 1,300 new Nuclear Medicine Technicians per year through 1975.

Part II: Manpower - Mailed Survey Data

A. Manpower Needs for Specified Years

1 1969

a. Direct Expansion of Number of Nuclear Medicine Technicians in Sample to Entire Population (1969)

Explanation

This method consists of a simple multiplication of average number of Nuclear Medicine Technicians in a hospital by number of hospitals with nuclear medicine operations.

Technique

m_{69} = average number of NMT's in department

h_{69} = number of hospitals with nuclear medicine operations

N_{69} = number of NMT's in 1969

$$N_{69} = m_{69}\ h_{69}$$

Calculations

i) hospitals with nuclear medicine constant

$m_{69} = 1.97$ (from Question 3.1)

$h_{69} = 1,592$ (from pages 104-105)

$N_{69} = (1.97)(1,592)$

$= \underline{3,136}$

ii) hospitals with nuclear medicine increasing

$m_{69} = 1.97$ (from Question 3.1)

$h_{69} = 1,844$ (from pages 105-106)

$N_{69} = (1.97)(1,844)$

$= \underline{3,633}$

2. <u>1975, 1980</u>

a. <u>Needs Based on Respondents' Estimates of Departmental Needs for Nuclear Medicine Technicians</u>

<u>Explanation</u>

This method uses as data the respondents' estimates of the number of Nuclear Medicine Technicians their department will need in 1975 and 1980 and the proportion of hospitals expected to have nuclear medicine operations in those years. The latter is introduced because respondents have indicated that they expect a significant increase in hospitals conducting nuclear medicine operations.

<u>Technique</u>

m_i = average number of NMT's in those hospitals which presently have nuclear medicine operations in year i

a_i = average number of NMT's in those hospitals which do not have nuclear medicine operations but which will have nuclear medicine operations in year i

H_i = number of hospitals in year i

p_{69} = proportion of all hospitals which presently have nuclear medicine operations

p_i = proportion of all hospitals which will have nuclear medicine operations in year i

N_i = number of NMT's in year i

(i = 1975, 1980)

$$N_i = m_i p_{69} H_{69} + a_i (p_i H_i - p_{69} H_{69})$$

<u>Calculations</u>

i)

$m_{75} = 3.73$	(from Question 3.11)
$m_{80} = 5.51$	"
$a_{75} = 2.52$	(from Questions 3.1 and 5.2: average number of NMT's in hospitals reporting that NM operations began 0-5. 0-10 years ago.)
$a_{80} = 2.57$	"
$H_{69} = H_{75} = H_{80} = 7{,}150$	(from pages 104-105)
$p_{69} = .26$	(from pages 105-106)
$p_{75} = .32$	"
$p_{80} = .38$	"

$$N_{75} = (3.73)(.26)(7{,}150) = (2.52)(.32 - .26)(7{,}150)$$
$$= \underline{8{,}009}$$

$$N_{80} = (5.51)(.26)(7{,}150) + (2.57)(.38 - .26)(7{,}150)$$
$$= \underline{12{,}441}$$

[ii) can also be calculated for other values of "p"]

Appendix C: Certification Requirements

Registration In Nuclear Medicine Technology

(Reprinted by Permission of
The American Registry of Radiologic Technologists
2600 Wayzata Boulevard
Minneapolis, Minnesota 55405)

General Qualifications of Trainees

Applicants for training leading to registration in nuclear medicine technology must be citizens of the United States or shall have filed a Declaration of Intention or a Petition for Naturalization for United States citizenship; may be male or female, must have had a high school education, or the equivalent thereof, as witnessed by such documentary evidence as the Board of Trustees shall deem acceptable, and must be of good moral character. Applicants who have been convicted of a crime must have served their entire sentence, including parole, and have had their civil rights restored.

Basic Eligibility Requirements (for NMT examination)

Candidates shall have at least one year of full time experience in clinical radioisotope work, including didactic experience equivalent to the radioisotope curriculum recommended by the American Society of Radiologic Technologists jointly with the Commission on Technologist Affairs of the American College of Radiology or proposed by the Registry of Medical Technologists (ASCP). In addition, applicants must meet at least one of the following sets of conditions:

1. Graduation from an A.M.A. approved program in x-ray technology.
2. Certification as an x-ray technologist by the American Registry of Radiologic Technologists (ARRT).
3. Certification as a medical technologist by the Registry of Medical Technologists (ASCP).
4. Registration as a professional nurse.
5. A baccalaureate degree from an accredited institution.

Alternate Qualifications

As an alternative to the basic eligibility requirements, candidates may meet one of the following:

1. The successful completion of a course of at least two years in radioisotope technology accepted by The American Registry of Radiologic Technologists.
2. Graduation from a four year high school course plus at least five (5) years of full time (40 hours per week) experience in a clinical radioisotope laboratory or department accepted by The American Registry of Radiologic Technologists.
3. Certification as an x-ray technologist by The American Registry of Radiologic Technologists plus at least two (2) years of full time (40 hours per week) experience in a radioisotope laboratory or department accepted by The American Registry of Radiologic Technologists.

The Alternate Qualifications may be altered or discontinued at the discretion of the Registry Board.

Certification in Nuclear Medical Technology*

[Reprinted by Permission of
The Registry of Medical Technologists
of
The American Society of Clinical Pathologists
P. O. Box 2544
Muncie, Indiana 47302]

The examination in this field is being sponsored by the ASCP Council on Radioisotopes and the American Society of Medical Technologists Special Committee on Nuclear Medical Technologists. Applicants must meet at least one of the following requirements:

a. Certification in Medical Technology by the Board of Registry of Medical Technologists of the American Society of Clinical Pathologists, plus one year of satisfactory experience in an acceptable clinical radioisotope laboratory.

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*The qualifications for certification by the Registry of Medical Technologists are under review at the present time. There is a possibility that these requirements may be altered.

b. Baccalaureate degree in biologic sciences or chemistry from a college or university accredited by a recognized accrediting agency, plus 2 years of satisfactory experience in an acceptable clinical radioisotope laboratory.
c. Two years (60 semester hours or 90 quarter hours) in a college or university accredited by a recognized accrediting agency. During the two years, at least 12 semester hours or 18 quarter hours of biology and one full year of chemistry (including lectures and laboratory acceptable toward a major in the field), and a minimum of 3 semester or 4 quarter hours of qualitative analysis, organic chemistry or biochemistry, plus 4 years experience in an acceptable clinical radioisotope laboratory.
d. Baccalaureate degree in the physical sciences (including the courses listed in "c") from a college or university accredited by a recognized accrediting agency, plus 2 years of experience in an acceptable clinical radioisotope laboratory.
e. High School diploma plus 6 years experience in an acceptable clinical radioisotope laboratory.

Appendix D: Preparation for Nuclear Medicine Technicians

Page

Programs Reported by Hospitals Interviewed

The preparatory programs which are listed below are limited to the hospitals which were interviewed and indicated having a formal program graduating a minumum of three students per year. This rather arbitrary break-off point is intended to imply that there is a difference in the methodology of teaching small and large numbers of students. This does not necessarily imply that there is a qualitative difference in the products of these programs; given the right combination of individuals, it is entirely reasonable to believe that some of the students prepared informally are better Nuclear Medicine Technicians than others who underwent a formal preparatory program. However, given the need to prepare increased numbers of Nuclear Medicine Technicians efficiently, we feel that formal programs, with at least a minimum number of students, are essential.

City Name of sponsoring institution; address; collaborating hospitals or institutions; other remarks	Length of Program in months	Approximate number of students/year	Certificate* or degree granted	Eligible for ARRT-RT certification exam**
Atlanta				
Grady Memorial Hospital; 80 Butler Street SE, Atlanta, Georgia 30303; program for students who have had 2-year X-ray training course; may be shortened to 6 months for students who have had several college science courses.	6 or 12	3	--	Yes

* C stands for certificate of completion only, not for recognition by a society.

** There are two titles designated RT. (Registered Technologist). One is for Radiologic Technologists (X-Ray Technologists) and the other for Nuclear Medicine Technologists. One need not complete the X-ray examination before taking the nuclear medicine examination. The examination indicated above is the Nuclear Medicine Technologist examination.

	Length of program in months	Approximate number of students/year	Certificate or degree granted	Eligible for ARRT-RT certification exam
Baltimore				
Johns Hopkins Hospital; 601 North Broadway, Baltimore, Maryland 21205; program for graduates of AMA-approved Schools of radiologic Technology.	12	3	C	Yes
University of Maryland Hospital; Redwood and Greene Streets, Baltimore, Maryland 21201	3	5-6	--	No
Boston				
Children's Hospital Medical Center; 300 Longwood Avenue, Boston, Massachusetts 02115	36	3	C	Yes
Chicago				
Cook County Hospital; 1825 West Harrison Street, Chicago, Ill. 60612	12	3	C	Yes
Cleveland				
Nuclear Medicine Institute; Box 4562 Cleveland, Ohio 44106; program combines class and clinical work; students do clinical work at Hillcrest Hospital, Cleveland Heights, Ohio, at St. Vincent Charity Hospital, Cleveland, Ohio, and others. (See also under Washington, D.C.)	12	20	C	Yes

	Length of program in months	Approximate number of students/year	Certificate or degree granted	Eligible for ARRT-RT certification exam
Dallas				
Methodist Hospital of Dallas; 301 West Colorado, Box 5999, Dallas, Texas 75208; program lasts 6 months for Radiologic Technologists, 30 months for others.	6 or 30	--	--	--
Denver				
Colorado General Hospital (part of University of Colorado Medical Center); 4200 E. 9th Avenue, Denver, Colorado 80220; program in collaboration with Denver Community College and 9 other hospitals (see entries which follow) under the sponsorship of Colorado-Wyoming Regional Nuclear Medical Training Program; program lasts 12 months for students who have already completed a diagnostic X-ray program, 24 months for others; Denver collaborating hospitals include: Denver General Hospital Fitzsimons General Hospital General Rose Memorial Hospital Lutheran Hospital and Medical Center Mercy Hospital Porter Memorial Hospital Veterans Administration Hospital	12 or 24	20	A.A.	Yes
Presbyterian Medical Center; East 19th Avenue and Gilpin St., Denver, Colo.	12	4	--	Yes

	Length of program in months	Approximate number of students/year	Certificate or degree granted	Eligible for ARRT-RT certification exam
Detroit				
Henry Ford Hospital; 2799 West Grand Blvd., Detroit, Michigan 48202; program lasts 12 months for students with Radiologic Technologist certification, 24 months for others.	12 or 24	4	C	Yes
Kansas City, Kansas				
University of Kansas Medical Center; 39th and Rainbow Blvd., Kansas City, Kansas 66103	12	4	C	Yes
Los Angeles (and vicinity)				
Loma Linda University Hospital; 1105 Anderson Street, Loma Linda, Calif. 92354; program lasts 12 months for students with Radiologic Technologist certification, 24 months for others.	12 or 24	3	A.A.	Yes
Los Angeles County General Hospital and University of Southern California Medical Center; 1200 North State Street, Los Angeles, California 90033	12	3	C	Yes
Miami				
Miami Dade Junior College; 11380 NW 27th Ave., Miami, Fla.; program expected to start with 15 students in August 1969 and to expand to 30 students in its second year; 1 year	12 or 24	15	A.A.	Yes

	Length of program in months	Approximate number of students/year	Certificate or degree granted	Eligible for ARRT-RT certification exam
program for Registered X-Ray Technologists who have graduated from a 2-year program, for ASCP Medical Technologists with a B.A. or B.S., and registered nurses with a B.A. or B.S.; 2 year program for high school graduates with a C+ average and courses in chemistry, physics and math. Collaborating hospitals include: Dade Brower Hospital Hollywood Hospital Jackson Memorial Hospital Mercy Hospital Mt. Sinai Hospital St. Francis Hospital				
Minneapolis				
Veterans Administration Hospital; 48th Ave. and 54th Street S., Minneapolis, Minnesota 55417; program in collaboration with the University of Minnesota; first two years of program make students eligible for Radiologic Technologist certification; after third year they become eligible for the Nuclear Medicine Technologist certification examination.	36	3	C	Yes
Philadelphia				
American Oncologic Hospital (Cancer and Allied Diseases); 3234 Powelton Avenue, Philadelphia, Pennsylvania	12	6	C	Yes

	Length of program in months	Approximate number of students/year	Certificate or degree granted	Eligible for ARRT-RT certification exam
19104; program also qualifies students to take Registry of Medical Technologists examination, if they are not Medical Technologists (ASCP) already.				
Jeanes Hospital; Hasbrook Avenue and Hartel Street, Philadelphia, Pennsylvania 19111; students receive a certificate from the Philadelphia County Medical Society.	18	8	C	Yes
Misericordia Hospital; 54th and Cedar Avenue, Philadelphia, Pennsylvania 19143	10	5	C	Yes
St. Louis				
Mallinckrodt Institute of Radiology, Barnes Hospital, 510 South Kings Highway, St. Louis, Missouri 63130.	12	4	C	Yes
St. Louis University Hospital; 1325 South Grand Blvd., St., Louis, Missouri 63104; program for students who are already Radiologic Technologists.	9 or 12	3	--	Yes
Washington, D. C. (and vicinity)	12	8-10	--	Yes
Georgetown University Hospital; 3800 Reservoir Road, N.W., Washington, D.C. 20007; collaborative program with George Washington University, Howard University, and the Nuclear Medicine				

	Length of program in months	Approximate number of students/year	Certificate or degree granted	Eligible for ARRT-RT certification exam
Institute in Cleveland; student spend 3 months in Cleveland and 9 months in Washington hospitals (to begin in September, 1969).				
U. S. Naval Hospital, National Naval Medical Center; Rockville Pike, Bethesda, Maryland 20014; most students are naval medical corpsmen; students must have 6 months additional hospital work to be eligible for ARRT examination.	6	20	C	No

Programs Reported in Correspondence

The following formal training programs are in institutions which were not interviewed. They have come to our attention in correspondence and the background study preceding the survey. We are sure that many others exist throughout the country which have not been called to our attention.

Duke University Medical Center; Division of Nuclear Medicine, Department of Radiology, Durham, North Carolina 27706; 1 year program; 4-10 students per year; ARRT curriculum (graduates eligible for both ARRT and RMT certification).

Harrisburg Hospital, Section of Nuclear Medicine, South Front Street, Harrisburg, Pennsylvania 17101; collaborative program with Harrisburg Area Community College and Pennsylvania Jr. College of Medical Arts; 12 month program for high school graduates.

The Harrisburg Polyclinic Hospital; Harrisburg, Pennsylvania; students must be registered Radiologic Technologists before entering the program; 12 months; graduates eligible for ARRT certification.

Indiana University Medical Center; 1100 West Michigan Street, Indianapolis, Indiana 46207; program in collaboration with School of Radiologic Technology; grants AA degree.

Oak Ridge Associated Universities, Special Training Division; P.O. Box 117, Oak Ridge, Tennessee 37830; holds periodic 4-week courses for experienced nuclear medicine technologists.

The Penrose Cancer Hospital; 2215 North Cascade Avenue, Colorado Springs, Colorado 80907.

St. Mary's Hospital, School of Nuclear Medicine; 720 South Brooks Street, Madison, Wisconsin 53715.

Tampa General Hospital, School of Nuclear Medicine; Tampa, Florida; 1-year program for students who have at least 1 year of full-time experience in clinical radioisotope work, and who have had a background as X-Ray Technologists, or Registered Nurses, or who have a B.S. degree; 3 students per year; graduates eligible for ARRT certification.

University of Cincinnati College of Medicine, Radiology Department; sponsored by the U.S. Public Health Service; two and four year programs leading to A.A. and B.S. degrees respectively; graduates eligible for ARRT certification; catalog may be obtained from Registrar, McMicken College of Arts and Sciences, University of Cincinnati, Cincinnati, Ohio 45221.

University of Mississippi Medical Center; 2500 North State Street, Jackson, Mississippi 39216; all students are either Registered Radiologic Technicians or are eligible for Registry Examination; one-year program; 3 students per year.

University of Tennessee, College of Medicine, School of Nuclear Medical Technology; Walter F. Chandler Building, 865 Jefferson Avenue, Memphis, Tennessee 38103; one-year program for graduates of schools of Radiologic Technology of B.S. holders (around whom program is being revised); program is currently in process of reorganization, will be part of a new School of Health Related Sciences.

University of Virginia Hospital, School of Nuclear Medicine Technology, Department of Radiology; Charlottesville, Virginia; program for ARRT certified technologists, ASCP Registered Medical Technologists, nurses with two years of college or baccalaureate and holders of the B.S. degree.

Vanderbilt University, Division of Nuclear Medicine and Biophysics; Nashville, Tennessee 37203; program for students with either 1 or 2 years of X-ray training or with backgrounds as Medical Technologists or nurses; program is part of the Regional Medical Program of the Southeastern Chapter of the Society of Nuclear Medicine.

American Society of Radiologic Technologists Minimum Radioisotope Curriculum

Prepared and Presented by:
The American Society of Radiologic Technologists

Length of Course: 12 Months

Eligibility of Applicants:

1. Must be a graduate of A.M.A. approved school of X-ray Technology or
2. Registered Technician (A.R.R.T.) or
3. Medical Technologist, (A.S.C.P. certified, (see note), or
4. Registered Nurse with two years of college credits, or with a baccalaureate degree or
5. Bachelor of Science degree with a major in Biology, Chemistry or Physics, (see note).

Note: In addition, applicants under section 3 and 5 must have completed a basic course in human anatomy and physiology of at least 60 clock hours.

Curriculum

A.	Introduction to Course	2 hours
B.	Radiological Mathematics	30 hours
C.	Basic Radiation Physics	20 hours
D.	Interaction of Radiation with Matter	10 hours
E.	Interaction of Radiation with Physiological Systems	10 hours
F.	Radiation Units	5 hours
G.	Protection and Shielding	10 hours
H.	Introduction to Radioisotopes	20 hours
I.	Instrumentation (including Laboratory)	40 hours
J.	Clinical Laboratory Equipment and Procedures	10 hours
K.	Specific Procedures	130 hours
L.	Records and Administrative Procedures	5 hours
M.	Records, Coding and Filing	3 hours
N.	Clinical Application (All remaining hours should be devoted to experience in performing clinical radioisotope procedures.)	
	Total:	295 hours

I. Introduction to the Course — 2 hours
   A. Description of text material
   B. Professional relationships
      1. Physician-Technologist-Patient-Family
      2. Medico-legal aspects
      3. Ethics
II. Radiological Mathematics — 30 hours
   A. General
      1. Review of fractions, decimals
      2. Review of algebra
      3. Exponents and powers
   B. Logarithms
   C. Graphs
   D. Slide Rule (demonstration and practice)
   E. Calculators (demonstration and practice)
III. Basic Radiation Physics — 20 hours
   A. Review of atomic structure and particles
   B. Ionizing radi· ions
      1. Electrom tic
         a. Production of X-radiation
            (1) Continuous and characteristic
            (2) Secondary
         b. Gamma radiation
            (1) Natural occurring sources
            (2) Artificially produced sources
      2. Corpuscular
         a. Alpha
         b. Beta
IV. Interaction of Radiation with Matter — 10 hours
   A. Photo-Electric
   B. Compton
   C. Pair production
   D. Coherent and incoherent scattering
   E. Photodisintegration
   F. Total and component absorption coefficients
V. Interaction of Radiation with Physiological Systems — 10 hours
   A. Systems sensitive to radiation
   B. Biological effects of radiation
      1. Acute effects
         a. Local
         b. Systemic
      2. Delayed effects
         a. Genetic

b. Increased tumor incidence
c. Life-span shortening
d. Growth and developmental defects

VI. Radiation Units — 5 hours
- A. Roentgen
- B. Absorbed dose--Rad
- C. Relative-biological-effecc
- D. Roentgen-equivalent-man
- E. Curie

VII. Protection and Shielding — 10 hours
- A. Protective regulations
  1. Permissible exposure limits
  2. Monitoring and surveying
  3. State and local regulations and registration requirements
  4. A.E.C. regulations
- B. Techniques for reducing hazards to operator
  1. Shielding
  2. Distance
     a. Review of Inverse Square Law
     b. In re: source and scatteiing media
     c. Remote handling equipment

IX. Introduction to Radioisotopes — 20 hours
- A. Nature and characteristics
  1. Sources
  2. Methods of production
  3. Decay
  4. Half-life
  5. Specific activity
- B. Useful radioactive isotopes
  1. Diagnostic
     a. Internal dose calculations
     b. External dose calculations
  2. Therapeutic
     a. Internal dose calculations
     b. External dose calculations

X. Instrumentation (Including laboratory instruction) — 40 hours
- A. Statistics of counting
- B. Counting equipment and detectors
  1. Geiger-Mueller tubes
  2. Scintillation detectors
  3. Scalers
  4. Count rate meters
- C. Survey Instruments
  1. Geiger-Mueller survey meter
  2. Ionization chamber survey meter
- D. Personnel monitoring equipment

1. Dosimeter or pocket chamber
2. Film badge

E. Standardization and calibration (general)

XI. Clinical Laboratory Equipment and Procedures — 10 hours

XII. Specific Procedures — 130 hours

A. Radioactive iodine
1. Standardization
2. Diagnostic applications
3. Therapeutic applications
4. Equipment and administration
5. Measurements
6. Calculations and interpretations

B. Radioactive gold
1. Standardization
2. Diagnostic applications
3. Therapeutic applications
4. Equipment and administration
5. Measurements
6. Calculations and interpretations

C. Radioactive phosphorus
1. Standardization
2. Diagnostic applications
3. Therapeutic applications
4. Equipment and administration
5. Measurements
6. Calculations and interpretations

D. Radioactive chromium
1. Standardization
2. Diagnostic applications
3. Therapeutic applications
4. Equipment and administration
5. Measurements
6. Calculations and interpretations

E. Radioactive cobalt
1. Standardization
2. Diagnostic applications
3. Therapeutic applications
4. Equipment and administration
5. Measurements
6. Calculations and interpretations

F. Radioactive strontium
1. Standardization
2. Diagnostic applications
3. Therapeutic applications
4. Equipment and administration
5. Measurements
6. Calculations and interpretations

G. As additional radioactive isotopes become available for clinical use, hours should be added to correspond to breakdowns noted in all sections under "XII."

XIII. Records and Administrative Procedures — 5 hours

A. A.E.C. rules and regulations
B. Application forms
C. Sources of supply

XIV. Records, Coding and Filing — 3 hours

A. Inventory - receipt and disposal
B. Personnel monitoring
C. Surveys

XV. Clinical Application

All remaining hours should be devoted to experience in performing clinical radioisotopic procedures.

Radiologic Technology School of Indiana University Medical Center-Radioisotope Technology Curriculum

I. Introduction — 2 hours
   A. Description of course
   B. History of nuclear medicine
   C. Professional and patient relationships
      1. Ethics: Physician-technologist-patient
      2. Medical-legal aspects

II. Mathematics and Statistics in Nuclear Medicine — 22 hours
   A. General mathematics
      1. Review of fractions, decimals
      2. Review of algebra
      3. Exponents and powers
   B. Logarithms
   C. Means of notation
      1. Digital
      2. Analog
         a. Graphs-arithmetic, log and semilog
         b. Tables
   D. Mathematic instrumentation
      1. Slide rule
      2. Calculators
      3. Computers
   E. Statistics
      1. Definition
      2. Rates, ratios and percentages
      3. Frequency distribution
         a. Mean, median, mode
   F. Reliability of data
      1. Standard deviation, coefficient of variation
      2. Standard error
      3. Range
   G. Counting statistics

III. Basic Nuclear Radiation Physics — 8 hours
   A. Review of atomic and nuclear structure
      1. Periodic system
      2. Elements of quantum theory
      3. Valence theory
      4. Atomic structure and particles
         a. Atomic number
         b. Atomic weight
         c. Atomic particles
            (1) Alpha particles
            (2) Deutrons
            (3) Protons
            (4) Electrons

(5) Positrons
(6) Neutrons

B. Ionizing radiation
  1. Corpuscular and wave theories
    a. Electromagnetic
    b. Particles
      (1) Uncharged
      (2) Charged
  2. Production of x-irradiation
    a. Continuous and characteristic
    b. Secondary
  3. Photons
    a. Gamma radiation
      (1) Natural sources
      (2) Artificially produced sources

IV. Interaction of Radiation and Matter, Energy Transfer — 10 hours
  A. Introduction-linear energy transfer from corpuscular and photon sources
    1. Photoelectric effect
    2. Compton effect
    3. Pair production
    4. Scatter radiation
    5. Internal conversion
    6. Relationship of half value layer to density, atomic number and type and energy of radiation

V. Interaction of Radiation with Biologic Systems. — 10 hours
  A. Radiochemical and photochemical reactions
  B. Radiobiologic reaction
    1. Reaction with water
    2. Interaction with biomolecules
    3. Radiation effects upon cells
      a. Latency
      b. Recovery
      c. Mitosis
      d. Viability
    4. Radiation effects upon organs and organ systems, blood forming organs, G.I. tract, etc.
    5. Radiation effects upon organisms
      a. Effects of dosage and type of radiation
      b. Acute radiation syndrome
      c. Chronic effects
        (1) Malignancy
        (2) Genetic
        (3) Effect on life span

6. Modification of radiobiologic effect
   a. Water, temperature, oxygen, chemicals

VI. Radiation Units — 5 hours
   A. Roentgen
   B. Rad
   C. Relative biological effect
   D. Roentgen-equivalent-man
   E. Curie

VII. Safe Handling of Radioisotopes — 10 hours
   A. General principles
      1. Shielding, distance, exposure time
   B. Consequences of poor technique
   C. Permissible exposure-internal, environmental
   D. Procedures
      1. Monitoring and surveying
      2. Laboratory usage
      3. Hospital usage
      4. Contamination
      5. Radioactive waste disposal
   E. Protective regulation
      1. AEC, state, local, hospital

VIII. Isotopes — 20 hours
   A. Stable
   B. Radioactive
      1. Sources
      2. Production methods
         a. Reactors, accelerators, n, gamma; gamma, n; by other particles
      3. Properties
         a. Emission-alpha, beta, gamma; positron, neutron, deutron, k-capture, x-ray
         b. Decay
            (1) Half life; effective life
         c. Units of activity; specific activity
   C. Useful radioactive isotopes
      1. Diagnostic
      2. Therapeutic

IX. Measure of Radiation — 40 hours
   A. Counting equipment and detectors
      1. Ionization chamber
      2. Proportional counters
      3. Geiger-Mueller counter
      4. Scintillation counters
      5. Liquid phosphors
      6. Semiconductor detectors

7. Photographic emulsion
8. Biologic detectors

B. Auxiliary instruments
   1. Scalers, amplifiers, discriminators
   2. Count rate meters
   3. Pulse height analyzers, single and multiple channel
   4. Read out devices

C. Geometry
   1. Collimation and shielding
   2. Distance and Inverse Square Law

D. Measurement application
   1. Counting
   2. Scanning
   3. Autoradiography
   4. Surveying
   5. Monitoring of personnel and work areas

E. Fundamentals of instrument measurements
   1. Characteristics of instrumentation and calibration
      a. Voltage
      b. Energy level measurements-resolution
      c. Sensitivity
      d. Efficiency
      e. Pre-set time and count
      f. Resolving time
      g. Read out methods
      h. Background
   2. Principles of in vitro counting
      a. Standardization
         (1) Absolute standards
         (2) Relative standards, dry, solutions, etc.
         (3) Geometric considerations
            (a) Isodose, isosensitivity, attenuation, 4 pi and 2 pi geometry
            (b) Particulate emitters
            (c) Detector type
      b. Characteristics and preparation of samples
         (1) Physical state
         (2) Type of emission
         (3) Type of detector
   3. Principles of in vivo counting,
      a. Quantitative
         (1) Whole body
         (2) Regional or compartmental
      b. Distributive
         (1) Automatic and manual scanning

c. Time clearance and accumulation studies
   (1) Compartmental, regional

X. Specific Procedures — 110 hours
   A. Radioactive iodine-including colloidal albumin forms
      1. Standardization
      2. Diagnostic applications
      3. Therapeutic applications
      4. Equipment and administration
      5. Measurements
      6. Calculations and interpretations
   B. Radioactive gold
      1. Standardization
      2. Diagnostic and therapeutic applications
      3. Equipment and administration
      4. Measurements
      5. Calculations and interpretations
   C. Radioactive phosphorous
      1. Standardization
      2. Diagnostic and therapeutic applications
      3. Equipment and administration
      4. Measurements
      5. Calculations and interpretations
   D. Radioactive chromium
      1. Standardization
      2. Diagnostic and therapeutic applications
      3. Equipment and administration
      4. Measurements
      5. Calculations and interpretations
   E. Metastable technetium
      1. Standardization
      2. Diagnostic applications
      3. Equipment and administration
      4. Measurements
      5. Calculations and interpretations
   F. Radioactive metastable indium
      1. Standardization
      2. Diagnostic applications
      3. Equipment and administration
      4. Measurements
      5. Calculations and interpretations
   G. Radioactive cobalt
      1. Standardization
      2. Diagnostic and therapeutic applications
      3. Equipment and administration
      4. Measurements
      5. Calculations and interpretations

H. Radioactive strontium
   1. Standardization
   2. Diagnostic and therapeutic applications
   3. Equipment and administration
   4. Measurements
   5. Calculations and interpretations
I. New radiopharmaceuticals

XI. Records and Administrative Procedures — 5 hours
   A. A.E.C. rules and regulations
   B. Application forms
   C. Sources of supply

XII. Records, Coding and Filing — 3 hours
   A. Inventory-receipt disposal
   B. Personnel monitoring
   C. Surveys

XIII. Clinical Application
All remaining hours will be devoted to experience in performing clinical radioisotopic procedures.

Community College of Denver
Nuclear Medicine Technology Training Program

[The following is quoted from a paper entitled "Radiation Therapy-Nuclear Medicine Technology Training Programs," by William R. Hendee, Ph.D., Colorado-Wyoming Regional Medical Program]

Although many health professions are experiencing a manpower shortage, a critical shortage of trained personnel exists in the fields of radiation therapy and nuclear medicine technology. The Rocky Mountain region has an unusual scarcity of well-trained technical personnel in these fields, primarily because few training programs in nuclear medicine and radiation therapy technology are available within this geographical area. To help alleviate this shortage of trained technologists, the Colorado-Wyoming Regional Medical Program has provided a grant to establish two-year training programs in Denver. William R. Hendee, Ph.D., is project director for the grant.

Under the direction of a Policy Committee composed of radiologists, technologists and other persons, representatives from Denver Community College and a number of Denver hospitals have developed training programs in radiation therapy and nuclear medicine technology. These programs are scheduled to begin in September, 1969. Students enrolled in the programs attend classes and lectures at Denver Community College and receive on-the-job training in hospitals participating in the programs. Entrance requirements, curriculum and clinical training are established by the Policy Committee.

Who Is Eligible?

To be eligible for admission, a student must (1) be a high school graduate, (2) fulfill college entrance requirements and (3) receive recommendation by the Policy Committee.

....

Students who earn an Associates Degree after completing either of the two-year training programs are eligible for examination and certification in radiation therapy or nuclear medicine technology by the American Registry of Radiologic Technologists.

During the second year of study, a stipend is furnished to students who have demonstrated academic ability.

No stipend will be furnished during the first year.

Persons already certified in diagnostic radiologic technology are admitted, as space permits, into the second year of the training programs. These persons must satisfy entrance requirements identical to those established for two-year students and, additionally, may be required to take first-year courses which were not included in their previous training. An Associates Degree is awarded if these students satisfy the degree requirements established by Denver Community College. The Policy Committee attempts to find part-time employment for diagnostic technologists enrolled in the second year of the programs.

Registered diagnostic radiologic technologists who complete the second year of one of the training programs are eligible for examination and certification by the American Registry of Radiologic Technologists in either nuclear medicine or radiation therapy technology.

Advantages of the Program

1. Unlike existing programs requiring three years of training beyond high school, these training programs require only two years. Also, specialized training in nuclear medicine or radiation therapy is provided during both years of the programs, whereas specialized training is offered only during one year in most other programs.

2. College credits received for participating in most of the courses in either program may be credited toward a Bachelor of Science or Bachelor of Arts degree at most four-year colleges and universities. Efforts are underway to develop a second two-year program leading to a bachelor's degree.

3. The Denver training programs offer many courses not included in the curricula of most other programs. Some of these courses, such as "chemistry of nuclear medicine," "electronics," "introduction to data processing," "radiation biology and pathology," "nuclear medicine methodology" and "radiation therapy methodology," improve the students' technical competence. Other courses, such as composition, public speaking and psychology, increase the students' capabilities to communicate and relate effectively with other persons.

4. Since there are full-time coordinators for both programs, it is possible to assist graduates in finding interesting, professionally rewarding positions.

5. Personnel and facilities of several institutions

are used to increase the effectiveness of the training program.

6. Students are exchanged among participating hospitals to increase the exposure of the students to different instrumentation and techniques.

7. Nationwide recruiting, plus a stipend during the second year of the programs, draw good students into the programs.

8. Technologists certified in diagnostic radiologic technology can become eligible for examination and certification in nuclear medicine or radiation therapy technology by completing only the second year of one of the programs.

Course Outline

Core Curriculum (First Year) for All Specialties

R.T. = radiation therapy students only
D.T. = diagnostic students only
N.M. = nuclear medicine students only

Fall	
English Composition	3 hours
Medical Terminology	2 hours
Basic Health Science	4 hours
Survey of Radiologic Technology	3 hours
Fundamentals of Mathematics	3 hours
Winter	
English Composition	3 hours
Anatomy/Physiology	4 hours
Fundamentals of Chemistry	4 hours
Psychology	3 hours
College Algebra	3 hours
Spring	
English Composition	3 hours
Anatomy/Physiology	4 hours
Nursing Procedures and Ethics	3 hours
Radiation Physics	3 hours
College Trigonometry	5 hours
Summer	
Radiation Physics	3 hours
Introduction to Data Processing--R.T.	3 hours
or	
Electrical Instruments and Measurements--N.M.	3 hours

or	
Diagnostic Methodology--D.T.	4 hours
Clinical Technology	4 or 6 hours

Nuclear Medicine (Second Year)

Fall	
General Chemistry	5 hours
Nuclear Medicine Methodology	3 hours
Clinical Technology	6 hours
Winter	
General Chemistry	5 hours
Nuclear Medicine Methodology	3 hours
Clinical Technology	6 hours
Spring	
Chemistry of Nuclear Medicine	3 hours
Nuclear Medicine Methodology	6 hours
Clinical Technology	6 hours
Summer	
Clinical Technology	10 hours

Description of Courses

DCC = Denver Community College
other courses are given in hospitals

Composition I (English 121) (3) DCC: English 121 and 122 constitute a two-quarter sequence designed for students intending to transfer to a four-year degree granting institution. The student will prepare themes frequently to develop skill in expository writing.

Composition II (English 122) (3) DCC: Continuation of English 121 with further study and practice in written composition emphasizing logical organization and clarity of expression.

Basic Health Science (Biology 130) (4) DCC: A core biological science course for health science students. Subject matter from anatomy, physiology, bacteriology, microbiology, and pathology are studied with reference to the appropriate health science program. One laboratory session per week.

Nursing Procedures and Professional Ethics (3) DCC: The nursing procedures relative to patient and services to be offered. The organization of hospitals and public health nursing services. Practical demonstrations in nursing and professional obligations to the patient.

Fundamentals of Mathematics (Mathematics 100) (3) DCC: A review of mathematics involving whole numbers, fractions, decimals and percentages. This course is intended to develop background for students who have had little or no previous training in mathematics.

Algebra I (Mathematics 105) (3) DCC: Intended for the student who has not had high school algebra or who needs review. An introduction to the basic concepts of algebra sets, properties of the real number system, operations on algebraic expressions, linear equations and systems of quadratic equations. Prerequisite: Developmental Mathematics or equivalent mathematics background.

Algebra II (Mathematics 111) (3) DCC: Fundamentals of algebra, linear functions, exponents and radicals, quadratic equations, ratio and proportion, probability, theory of equations and determinants. Prerequisite: Introductory Algebra or High School Algebra.

Anatomy/Physiology I (Biology 123) (4) DCC: Detailed study of gross and microscopic anatomical structure of the human body and the function to structure relationships.

Anatomy/Physiology II (Biology 124) (4) DCC: A continuation of Anatomy and Physiology. Prerequisite: Biology 123.

Medical Terminology (Health Service Terminology) (3) DCC: A study designed to acquaint the student with the origin and structure of medical terms. The intent of this course is to help the student interpret and understand medical terms, medical reports and medical requests applicable to his field.

Public Speaking (Speech 102) (3) DCC: Instruction and intensive practice in essential speech processes and skills. Organization and effective oral presentation of reports and speeches related to the student's career interests.

Radiation Physics I (3) DCC: Structure of matter, production and nature of radiation, interactions of radiation with matter, radiation detection and measurement, nuclear instrumentation, radiation exposure and dose, introduction to therapy treatment planning, radiation protection and safety.

Radiation Physics II (3) DCC: Continuation of Radiation Physics I.

Psychology 111 (3) DCC: Introduction to basic principles and methods in the scientific study of human behavior, including perception, motivation, learning, emotions, maturation and psychological development. Intended to meet occupational studies and college transfer requirements.

Electronic Devices (4) DCC: A study of electronic devices; how they work, nomenclature, materials, apparatus, and characteristics. Both tube characteristics and solid state device characteristics are covered. This course utilizes the mathematical tools as they become available. Laboratory techniques and skills are taught by extensive use of a variety of devices and equipment.

Principle of X-Ray Technique (3) DCC: Radiographic and fluoroscopic instrumentation and procedures, darkroom technique, evaluating image quality and special techniques of diagnostic radiology.

Introduction to Data Processing (3) DCC: An introduction to basic methods, techniques, and systems of manual, mechanical, and electronic data processing. Covers manual and machine accounting equipment and systems, punched tape or integrated data processing, and electronic or automatic data processing.

Nuclear Medicine Methodology I (3) CGH: Radiation units, properties of nuclides, detectors and instrumentation, counting procedures, identifying nuclides, absolute counting, calibrating nuclides, scintillation spectrometry, diagnostic and therapeutic isotope procedures, scanners and cameras, patient dose, radiation shielding and safety, administration and record keeping, slide rule, mechanical and electronic calculators, digital computers, etc. Most of this course is devoted to laboratory work.

Nuclear Medicine Methodology II (3) CGH: Continuation of Nuclear Medicine Methodology I.

Nuclear Medicine Methodology III (6) CGH: Continuation of Nuclear Medicine Methodology II.

Inorganic Chemistry I (Chemistry 111) (3) DCC: Introductory study of principles of inorganic and organic chemistry; properties of matter, nature and chemical changes. This course may be taken by the student wishing to improve his background before taking General Chemistry but is required for chemistry majors.

Inorganic Chemistry II (Chemistry 112) (3) DCC: A beginning general college chemistry course which includes the laws of chemical combination, states of matter, atomic and molecular structure, bonding and other basic principles. Prerequisite: Chemistry 111.

Chemistry of Nuclear Medicine (3) CGH: Hematology, radionuclide generators, dilution analysis, sterility and pyrogenicity tests, chemical, radiochemical and radioisotopic purity, labeling procedures, calibration of nuclides, literature of nuclear medicine, regulations, equipment and nuclide suppliers.

Clinical Technology (PH): Credit hours granted for supervised participation in radiation therapy or nuclear medicine programs at participating hospitals.

Miami Dade Junior College
Nuclear Medical Technology Program

First Semester

		Cr.	Hrs/wk.	Hrs/sem.
NMT 201	Nuclear Medical Technology	1	1	16
NMT 202	Physics for Nuclear Medical Technologists	4	5	80
NMT 203	Procedures in Nuclear Medical Technology I	4	5	80
NMT 210	Radiochemistry and Radio-pharmaceuticals	2	2	32
	Elective (Recommend Math 110, 112)	3	3	48
NMT 212	Seminar	1	2	32

Second Semester

		Cr.	Hrs/wk.	Hrs/sem.
NMT 220	Instrumentation and Laboratory Equipment	4	5	80
NMT 221	Radiobiology	1	1	16
NMT 206	Procedures in Nuclear Medical Technology II	4	5	80
	Externship	?	20	320
	Elective	3	3	48
NMT 221	Seminar	1	2	32

Spring and Summer

		Cr.	Hrs/wk.	Hrs/sem.
	Externship	?	40	480

Description of Courses

Nuclear Medical Technology (NMT 201), 1 cr., 16 hrs/sem.: Intended to provide the student with an introduction to the basic concept of the Nuclear Medical Technology Laboratory. Ethics, terminology, personnel protection and administrative records and coding are among the material covered. Proposed course outline follows:

I.	Ethics	1
II.	Terminology	3
III.	Laboratory Rules	1
IV.	Personnel Protection	2
V.	Examination	1
VI.	Records	3
VII.	Administration	2
VIII.	Coding	2
IX.	Filing	1

Physics for Nuclear Medical Technologists (NMT 202), 4 cr., 80 hrs/sem.: Intended to provide the student with a thorough understanding of the nuclear physics applicable to Nuclear Medical Technology. Atomic and nuclear structure, radioactivity, interactions of radiation with matter and shielding methodology are among the subjects covered. The laboratory experiments are structured as to provide maximum correlation with the lecturer. Proposed course outline follows:

	Hrs. Lect.	Hrs. Lab.
I. Atomic structure	3	2
A. Nuclear structure		
1. Nuclear constituent		
2. Nuclear models		
3. Nuclear energy levels		
II. Radioactivity	18	12
A. Natural radioactivity		
B. Induced radioactivity		
C. Modes of decay		
D. Properties of nuclear radiations		
E. Mathematics of radioactive decay		
III. Interaction of radiation with matter	21	14
A. Charged particle interactions		
B. Uncharged particles and quanta		
C. Interaction coefficients		
IV. Radiation protection and shielding	6	4

Laboratory

I. Statistics of counting	2
II. Counting of background radiation	2
III. Propagation of error	2
IV. Scintillation counting - effect of H.V.	2
V. Linear amplifier and PHA	2
VI. Differential gamma ray spectra	2
VII. Integral counting and optimum counting	2
VIII. Resolving time studies - sample volume and count rate	2
IX. Quantitative gamma determination	2
X. Backscatter and sidescatter - half value layer	2
XI. Evaluation of collimators	2
XII. Radioactive decay and half-life	2
XIII. Effect of crystal size on gamma energy and pulse height resolution	2
XIV. Shielding requirements	2
2 lab exams	4

Procedures in Nuclear Medical Technology I (NMT 203), 4 cr., 80 hrs/sem.: Intended to provide the student with the basic and procedural information on each examination routinely performed in the nuclear medicine laboratory. The several types of procedures are presented along with rationale which promotes their usage. Laboratory experiences are provided to reinforce procedural methodology. Proposed course outline follows:

	Hrs. Lect.	Hrs. Lab.
I. General laboratory procedures	15	10
A. Lab rules		
B. Basic laboratory math		
1. Units of radioactivity		
2. Decay		
3. Specific activity		
4. Dilutions		
5. Percentages		
6. Sources of error		
C. Modes of tracer administration		
1. Oral		
2. Intravenous		
3. Inhalation		
4. Other		
D. Sample preparation		
E. PHA calibrations		
F. Window settings		
II. Therapeutic procedures	6	4
A. I^{131}		
1. Functional		
2. Neoplastic		
B. Au^{198} colloid		
C. P^{32} colloid		
D. P^{32} phosphate		
E. Interstitial		
F. Applicators		
III. Diagnostic procedures	9	6
A. Thyroid anatomy and physiology		
B. Thyroid pathologies		
1. T-3 studies		
2. T-4 studies		
3. Thyroid uptake and variations		
4. Others		
C. Dilution studies	9	6
1. Dilution theory		
a. Anatomy and pathophysiology of the vascular compartment		
(1) RIHSA plasma volume		
(2) Tagged red cell volume		

	Hrs. Lect.	Hrs. Lab.
(3) Sources of error		
b. Anatomy and pathophysiology of other body compartments		
(1) H_2O, others		
(2) Potassium		
(3) Sodium		
D. Hematologic studies	6	4
1. Anatomy and pathophysiology or erythrokinetics		
a. Ferrokinetics		
b. Fecal blood loss		
c. RBC survival		
2. Anatomy and pathophysiology of Vitamin B_{12} metabolism		
E. Miscellaneous studies	3	2
1. Anatomy and pathophysiology of fat metabolism		
a. Trioleic acid		
b. Oleic acid		
2. Protein losing enteropathologies		

<u>Radiopharmacology and Radiochemistry</u> (NMT 210), 2 cr., 32 hrs/sem.: Intended to provide the student with an overview of the basic problems and concepts of the radiochemical and radiopharmaecutical laboratory. A review of basic principles is provided followed by an overview of the various methodologies and common practices of the radiopharmacy. Proposed course outline follows:

I.	Review of chemical principles and procedures	3
II.	The principles of radiopharmaceuticals	2
III.	Pharmacology	1
IV.	Toxicology	1
V.	Bacteriology and pyrogenicity	1
VI.	Chemistry and stability	1
VII.	Sterilization and asepsis	1
VIII.	Characteristics of radiopharmaceuticals	2
IX.	Methods in quality control	3
X.	Personnel protection in the radiopharmacy	1
XI.	Generator systems	2
XII.	Preparation and control of colloids	2
XIII.	Red cell labeling	1

		Hrs. Lect.	Hrs. Lab.
XIV.	Protein labeling	1	
XV.	Radioactive gases	1	
XVI.	Methods of preparing and dispensing radiopharmaceuticals	6	
XVII.	Record keeping in the radiopharmacy	1	
	2 exams	2	

<u>Instrumentation and Laboratory Equipment</u> (NMT 220), 4 cr., 80 hrs/sem.: Intended to provide the student with a thorough grounding in the operation and limitations of all equipment in common use in the nuclear medical laboratory. The simplest through the most sophisticated systems are studied and evaluated. A careful correlation of lectures and laboratories provides the student with practical application of each system studied. Proposed course outline follows:

		Hrs. Lect.	Hrs. Lab.
I.	Gas ionization detection systems	6	4
	A. Principles of ionization		
	B. Ionization chambers		
	C. Proportional counters		
	D. Geiger-Mueller counters		
	E. Laboratory instruments		
	1. Survey meters		
	2. Radiopharmaceutical survey instruments		
	F. Sources of error with gas detectors		
II.	Counting statistics	6	4
III.	Scintillation detectors	9	6
	A. Principles of scintillation detection		
	1. NAI (TL)		
	2. Plastic scintillators		
	3. Liquid scintillators		
	B. Scintillation detection electronics		
	C. Instrument using scintillation detection		
	D. Sources of error with scintillation detection		
IV.	Other radiation detectors		
V.	Organ visualization instruments	21	14
	A. Principles of organ visualization		
	B. Principles of collimation		
	C. Probe systems		
	D. Rectilinear scanning systems		
	E. Camera systems		

		Hrs. Lect.	Hrs. Lab.
	F. Other systems		
VI.	Data display systems	3	2

Radiobiology (NMT 221), 1 cr., 16 hrs/sem.: Intended to provide the student with a compacted view of the present state of knowledge in radiobiology. A brief review of pertinent biological systems is given followed by selected topics in the effects of radiation on biological systems. Proposed course outline follows:

I.	Review of pertinent radiation physics	1	
II.	The cell	1	
	A. The nucleus		
	B. The cytoplasm		
	C. The extranuclear organelles		
III.	Mitosis and meiosis	1	
VI.	Genetic material		
V.	The target theory	1	
VI.	The aqueous system	1	
VII.	Relative sensitivity of the nucleus and cytoplasm	1	
	Exam	1	
VIII.	Organs and organ systems	1	
IX.	Effects in the total organism		
	A. Immediately lethal effects	1	
	B. Bone marrow syndrome	1	
	C. Gastro-intestinal syndrome	1	
	D. Central nervous system syndrome	1	
	E. The late effects	1	
X.	Factors influencing the effects of radiation	1	
XI.	Low level radiation effects	1	

Procedures in Nuclear Medical Technology II (NMT 206), 4 cr., 80 hrs/sem.: A continuation of the material and philosophy of NMT 203. The dynamic studies and gamma imaging systems are given maximum stress. Proposed course outline follows:

I.	Gamma imaging (rectilinear)	9	6
	A. Rectilinear scanning		
	1. Theory of rectilinear scanning		
	2. Production of the photoscan		
	3. Scan configurations		
	B. Thyroid scanning		
	1. Anatomy and pathophysiology		
	2. Radionuclides		

	Hrs. Lect.	Hrs. Lab.
3. Chemical form		
4. Tracer amount		
5. Positioning and scan production		
C. Brain scanning		
1,2,3,4, and 5 as above		
II. Dynamic studies	12	8
A. Renogram		
1,2,3,4 and 5 as above		
B. Cardiac output		
1,2,3,4 and 5 as above		
C. Cerebral blood flow		
1,2,3,4, and 5 as above		
D. Lung perfusion and ventilation		
1,2,3,4 and 5 as above		
III. Gamma imaging (camera and rectilinear)	24	16
A. Hepatic scanning		
1,2,3,4 and 5 as above		
B. Splenic scanning		
1,2,3,4 and 5 as above		
C. Pancreatic scanning		
1,2,3,4 and 5 as above		
D. Renal scanning		
1,2,3,4 and 5 as above		
E. Brain scanning		
1,2,3,4 and 5 as above		
F. Lung scanning		
1,2,3,4 and 5 as above		
G. Bone scanning		
1,2,3,4 and 5 as above		
H. Other organs and systems		
IV. Data handling and computer applications	3	2

University of Cincinnati - A Program of Study and Training Leading to the Bachelor of Science Degree in Medical Technology with a Nuclear Medicine Option

Freshman Year

1st Quarter	Cr.	2nd Quarter	Cr.	3rd Quarter	Cr.
Eng. 101 (Comp.)	3	Eng. 102 (Comp.)	3	Eng. 103	3
Chem 101	3	Chem 102	3	Chem 103	3
Chem 111 (Lab.)	2	Chem 112	2	Chem 113	2
Math. elective	3	Math. elective	3	Math. elective	3
Foreign lang.	5	Foreign lang.	5	Foreign lang.	5
Phys. Ed.	1	Phys. Ed.	1	Phys. Ed.	1

Sophomore Year

1st Quarter	Cr.	2nd Quarter	Cr.	3rd Quarter	Cr.
Eng. (Lit. elective)	3	Eng. (Lit. elective)	3	Eng. (Lit. elective)	3
Chem. 204 (Org.)	4	Chem 205 (Org.)	4	Biochem 206 or elective	4
Biology 101	5	Biology 102	5	Biology 103	5
Soc. Study (soc., econ., hist., poli. sci.)	3	Soc. Study	3	Soc. Study	3
Phys. Ed.	1	Phys. Ed.	1	Phys. Ed.	1

Junior Year

1st Quarter	Cr.	2nd Quarter	Cr.	3rd Quarter	Cr.
Phil. or Psych.	3	Phil. or Psych.	3	Phil. or Psych.	3
Anal. Chem 341	3	Anal. Chem. 342	3	Lit., Psych. or social study	3
Anal. Chem 351	2	Anal. Chem. 352	2	Biol. 203 (Anat. and Physiol.)	3
Lit., Psych or social study	3	Lit., Psych or social study	3	Physics 103	5
Biol. 201 (Anat. and Physiol.)	3	Biol. 202 (Anat. and Physiol.)	3	Bacteriol. 271	4
Physics 101	5	Physics 102	5	Elective	4

Senior Year

The senior year is a 12 month hospital internship program during which the student receives both formal training and practical experience in the Radioisotope Laboratory of the Cincinnati General Hospital.

	Credits Per Quarter			
	Summer	Fall	Winter	Spring
Nuclear Physics and Instrumentation	6			
Radioisotope Measurements		6		
Radiation Protection			3	
Tracer Methodology and Radiopharmaceuticals				3
Hematology and Laboratory Chemistry Lectures		1	1	
Clinical Application of Radioisotopes		1	1	1
Technical Evaluation of Nuclear Medicine Procedures	2	2	2	2
Clinical Nuclear Medicine and Hematology Practicum	6	6	6	6
	14	16	13	12

Since the above are newly developed specialized courses, they are outlined in some detail.

Nuclear Physics and Instrumentation: This course is designed to provide the student with the fundamentals in physics, mathematics, and principles of nuclear instrumentation necessary for him to understand the physical aspects of the use of radioisotopes in medicine. Course content is as follows:

I. Atomic structure
  A. Electron configuration
  B. Nucleus
    1. Nuclear particles and their properties
    2. Nuclear binding energy
II. Radioactive decay
  A. Modes of decay
  B. Units of activity
  C. Mathematical decay law
III. Interaction of radiation with matter
  A. Corpuscular
  B. Electromagnetic
IV. Principles of radiation detection instruments
  A. Gas ionization instruments
    1. Ion chambers
    2. Proportional counters
    3. G-M counters
  B. Photographic emulsions
  C. Scintillation detectors
  D. Semiconductor detectors
  E. Thermoluminescent media

Radioisotope Measurements: This course is a continuation of the instrumentation part of the "Basic Nuclear Physics and Instrumentation" course which is prerequisite. The "principles of radiation detection instruments"section is used as a stepping stone to discuss various nuclear counting systems with emphasis on operating characteristics. Course content is as follows:

I. Operating characteristics and associated electronics of each of the following instrument systems
   A. G-M counters
   B. Ion chambers
   C. Proportional counters
   D. Scintillation detectors
      1. Integral counters
      2. Spectrometers (includes scanners)
II. Principles of in vitro counting
   A. Absolute
   B. Relative
III. Principles of in vivo counting
   A. Whole body
   B. Distributive
      1. Scanning
      2. Quantitative measurements
   C. Kinetic studies
IV. Statistics of nuclear radiation counting
V. Quality control of counting systems

Laboratory sessions for these courses include:

1. Determination of operating voltage for an integral laboratory counter.
2. Determination of counting efficiency.
3. Determination of the half-life of a radionuclide.
4. Calibration of a single channel pulse height analyzer.
5. Calibration of a multichannel pulse height analyzer.
6. Interpretation of a gamma spectrum.
7. Five two hour sessions on organ scanning using phantoms.

Radiation Protection: In this course safe handling of radioactive materials is stressed. Emphasis is placed on maximizing the diagnostic information obtained from a procedure while minimizing the radiation exposure to both the technician and patient. The course content is as follows:

I. Units of radiation exposure and dose
   A. Roentgen
   B. Rad
   C. Rem
   D. RBE
   E. Quality factor
   F. Dose equivalent
II. Biological effects of radiation
   A. Cellular effects
   B. Macroscopic effects
III. Radiation protection guides
IV. Radiation protection instrumentation
   A. Survey instruments
      1. Beta - Gamma
      2. Alpha
   B. Personnel instruments
      1. Film badges
      2. Pocket chambers
      3. Thermoluminescent dosimeters
V. Basic principles of radiation protection
   A. External
      1. Time
      2. Distance
      3. Shielding
   B. Internal
      1. Good housekeeping practices
      2. Protective clothing
      3. Proper pipetting techniques
VI. Emergency procedures

<u>Tracer Methodology and Radiopharmaceuticals:</u> The chemical and biological basis for using the radioisotope as a tracer are discussed in this course. Properties and methods of production of radioactive tracers are also covered. Course content is as follows:

I. Tracer methodology
II. Properties of radioactive tracers
   A. Physical properties
      1. Half-life
      2. Type and energy of emissions
   B. Chemical properties
   C. Biological localization
III. Methods of production of radioactive tracers
   A. Nuclear reactors
      1. Fission products
      2. Neutron activation
   B. Cyclotron
   C. Generators

<u>Clinical Applications of Radioisotopes:</u> This course consists of a series of lectures on varied topics

of interest. Each one is presented by a specialist in his subject. Lecture titles include:

1. Diagnostic Use of ^{131}I (2 lectures)
2. Therapeutic Use of ^{131}I
3. Radioisotopes in Ophthalmology
4. Regulations for Radioisotope Use
5. Technical Aspects of Scanning
6. Liquid Scintillation counting
7. Hematologic Studies with Radioisotopes
8. Metabolic Studies with Radioisotopes
9. Dynamic Function Studies
10. Lung and Cardiovascular Blood Pool Scans
11. Brain Scanning
12. Bone Scanning
13. O.B. and Gyn Radioisotope Studies
14. Liver Scanning
15. Spleen and Pancreatic Scanning
16. Therapeutic Use of ^{32}P and ^{198}Au
17. Whole Body Counter Applications
18. Cyclotron Production of Radionuclides
19. New Developments in Radiopharmaceuticals and Short Lived Isotopes
20. Principles of Radiopharmaceutical Preparation

<u>Technical Evaluation of Nuclear Medicine Procedures:</u>
This portion of the training consists of sessions held at the end of each day in which a staff physician, along with other staff members, reviews and interprets the studies performed on that day. These sessions (approximately one hour each day) provide a much needed correlation between the work the technologist performs and its significance in the practice of medicine. The student is able to see directly how the work he has done each day fits into the overall diagnosis of each patient. Also the importance of the technical factors and how they affect the final interpretation of a study is stressed in these sessions.

<u>Clinical Nuclear Medicine and Hematology Practicum:</u>

This portion of the curriculum will provide the student with practical experience in diagnostic and therapeutic procedures performed with radioisotopes. Approximately 30 hours per week will be spent in this activity. The students work under the close supervision of staff physicians and experienced nuclear medical technologists and learn, <u>by doing</u>, all of the procedures performed in the Radioisotope Laboratory. These include metabolic studies, thyroid tests, diagnosis of gastrointestinal, cardiovascular, and urogenital diseases, localization of tumors, hematologic studies, etc.

The student also spends time in the clinical hematology laboratory where he performs differential blood counts and other hematologic procedures.

Appendix E: Essentials of an Accredited Education Program in Nuclear Medicine Technology (AMA)

Essentials of an Accredited Educational Program in Nuclear Medicine Technology

Approved by the AMA House of Delegates
on 15 July, 1969

PREAMBLE

The organization primarily concerned with the maintenance of acceptable standards for educational programs for nuclear medicine technologists and technicians is the Council on Medical Education of the American Medical Association. The American College of Radiology, the Society of Nuclear Medicine, the American Society of Clinical Pathologists, the American Society of Medical Technologists, the American Society of Radiologic Technologists, and the Society of Nuclear Medical Technologists have obvious interest and concern in such training. To organize their concerns and provide an orderly mechanism for preparation of recommendations to the Council on Medical Education, a single Board of Schools of Nuclear Medicine Technology shall be concerned with the evaluation and survey of educational programs for Nuclear Medicine Technologists and Technicians, the maintenance of high standards of education, and the development of new teaching programs.

The Board of Schools of Nuclear Medicine Technology shall consist of two representatives each from the American College of Radiology, the American Society of Clinical Pathologists, and the Society of Nuclear Medicine; and two representatives each, registered in nuclear medicine technology, from the American Society of Radiologic Technologists, the American Society of Medical Technologists, and the Society of Nuclear Medical Technologists.

The Board of Schools shall serve as the reviewing body for all educational programs for Nuclear Medicine Technology and make recommendations to the Council on Medical Education of the American Medical Association concerning approval status.

Nuclear Medicine Technologists and Technicians are trained in these programs to work under the direction of physicians qualified in the clinical use of radionuclides, and not to work as independent practitioners.

I. ORGANIZATION

A. Acceptable schools for training in nuclear medicine technology may be conducted in approved medical schools, accredited colleges or universities, accredited general hospitals or other acceptable laboratories suitably organized in accordance with present educational standards. Facilities providing clinical services in nuclear medicine must be maintained, and must provide an adequate volume and variety of procedures in relation to student enrollment. Under special circumstances, programs may be developed in specialty hospitals, laboratories, or in general hospitals where experience may not be possible in the full range of radionuclides. In such cases, the institution may arrange for affiliation with some other facility to provide training and experience in desired procedures with the approval of the Board of Schools of Nuclear Medicine Technology.

B. Affiliation with an accredited college, community college, university, or medical school is desirable but not essential. When such an affiliation exists, an advisory committee should be established including representatives from the sponsoring institution and from the department of the college, university, or medical school which participates in the training program.

C. All training of technologists and technicians shall be under competent medical supervision.

D. Resources for continued operation of the school should be assured through regular budget, gifts, or endowments. A monthly stipend to the student may be permitted.

II. ADMINISTRATION

A. The nuclear medicine faculty shall comply with federal, state, and hospital regulations for safety procedures. Adequate space, light, and modern equipment should be provided in the training area.

B. A library containing up-to-date references, texts, and scientific periodicals pertaining to nuclear medicine technology should be readily accessible to students.

C. Satisfactory records must be kept for all work accomplished in the department.

D. Transcripts of college credits and other credentials must be available. Records must be kept of each student's attendence and grades, as well as the number and types of technological procedures performed.

E. A current outline of the curriculum and the rotation of assignments must be available in the office of the program director.

F. Approval of a program may be withdrawn if no students are enrolled for a period of two consecutive years.

G. Institutions sponsoring programs for nuclear medicine technology should submit an annual report to the Council on Medical Education and to the Board of Schools of Nuclear Medicine Technology.

H. Periodic resurvey will be conducted by the Board of Schools of Nuclear Medicine Technology in collaboration with the Council on Medical Education. If the physician director in charge of the training program or the curriculum is changed, the Council shall be notified, and reevaluation may be required.

III. FACULTY

A. The program must have a competent and adequate teaching staff. The director must be a physician qualified in the clinical use of radionuclides. He must be eligible for certification by a medical specialty examining board recognized by the American Medical Association, or have qualifications acceptable to the Council on Medical Education. He shall take part in and be responsible for the actual conduct of the training program and shall be in daily attendance for sufficient time to supervise properly the work and teaching in the department.

B. The teaching staff should include qualified instructors in radiation physics and radiation biology adequate for both group and individual instruction. It should also include at least one instructor who is a registered nuclear medicine technologist and who is actively engaged in nuclear medicine technology.

IV. ADMISSION REQUIREMENTS

Applicants must be at least eighteen years of age at the time they reach the training period when they will be working with radionuclides. Candidates for admission must satisfy one of the following minimal requirements:

A. For a Baccalaureate Degree Program; Technologists: Registered as a Medical Technologist, M.T. (ASCP); Radiologic Technologist, R.T. (ARRT); or Registered Nurse, R.N.; and have earned at least three years (90 semester hours) of college credit from an accredited college, university, or medical school, including credit acceptable toward a major in the biological or physical sciences.

B. For Associate Degree Programs; Technicians: Applicants must have successfully completed four years of high school or have passed a standard equivalency test for admission to a college. Successful completion of two years study, including the twelve month training program, may qualify the individual for an associate degree. For those who have successfully completed one year of college, including at least three credit hours in chemistry and mathematics, the twelve month training program may qualify the individual for an associate degree.

C. Those registered as M.T. (ASCP); R.T. (ARRT); or R.N. may, by completing the twelve month training program, qualify for registration in Nuclear Medicine Technology.

V. CURRICULUM

A. The following suggested basic minimum curriculum is presented as a guide for an educational program in nuclear medicine technology. The designation of technologist applies to those holding a bachelor or higher degree in science. Only the minimum essentials or requirements for a program of nuclear medicine technology education are suggested, so a curriculum beyond that necessary for an associate degree (technician) is not suggested in these essentials. The final distinction between technologist and technician lies in the purview of the certifying registry.

B. The training program must be at least twelve months in duration, should be uninterrupted, and should include approximately 300 didactic hours, or more where the clinical training is part of a total integrated educational program leading to an associate degree or baccalaureate.

C. Adequate clinical experience should be provided. The instruction should follow a planned outline and include text assignments, lectures, discussions, demonstrations, supervised practice, practical examinations, and quizzes.

Curriculum:

1. Orientation and Introduction (4 hours)
2. Basic Anatomy, Physiology, and Pathology (40-100 hours.)
3. Mathematics (20 hours)
4. Radiation Physics (10-20 hours)
5. Nuclear Physics and Instrumentation (60-100 hours)
6. Radiation Biology (20-30 hours)
7. Radiation Protection (15 hours or minimum for Federal or State laws)
8. Basic Laboratory Procedures and Techniques (10-50 hours)
9. Clinical Application of Radionuclides (100-150 hours)
10. Records and Administrative Procedures (5 hours)
    Presentation of regulatory requirements relating to licensing and inspection.
11. Therapeutic Radionuclides (10 hours)
12. Radiochemistry and Radiopharmaceuticals (25 hours)

The hours indicated are only suggestions and not essential provided an adequate total educational program is offered.

VI. ETHICS

Excessive student fees and commercial advertising are considered unethical. Educational programs must not substitute students for paid technologists and technicians.

VII. HEALTH

Applicants for admission to an acceptable educational program shall be required to submit evidence of good health and successful vaccinations, and a report of a medical examination should be a part of student records. This examination shall include an x-ray of the chest. Health care and hospitalization shall be available to the student.

VIII. ADMISSION TO THE APPROVED LIST

Application for approval of an educational program in nuclear medicine technology should be submitted to the Department of Allied Medical Professions and Services, Division of Medical Education, American Medical Association, 535 North Dearborn Street, Chicago, Illinois 60610. Forms will be supplied for this purpose on request and should be completed by the director of the institution requesting approval.

Approval may be withdrawn whenever, in the opinion of the Council on Medical Education, a school does not maintain an educational program in accordance with the minimum standards stated above.

Appendix F: Existing Films, Books and Materials on Nuclear Medicine

[Prepared by A. Bertrand Brill, M.D., for the Committee on Education, Southeastern Chapter Society of Nuclear Medicine, April, 1969]

Introductory Statement

This appendix contains a summary of materials, emphasizing films and books, which may provide useful resources for training in nuclear medicine. The major effort in preparing the annotated bibliography and film list was made by Dr. A. Bertrand Brill of the Division of Nuclear Medicine and Biophysics at Vanderbilt University in Nashville. This bibliography was prepared in April, 1969 by Dr. Brill for the Committee on Education of the Southeastern Chapter of the Society of Nuclear Medicine. A few additions have been made to the basic list, but for the most part thanks must be given to Dr. Brill for this contribution.

Several points should be made about this appendix. First, these resource materials are concerned almost exclusively with nuclear medicine. A training program for Nuclear Medicine Technicians would undoubtedly include other courses such as mathematics, chemistry, anatomy, or English. Material for other courses is not of primary concern, although some references are given. A second point is that many resources included here, notably some books, may have particular relevance to the specialized interests of physicians. Titles and notes give some indications of the content and intended audience. Certainly many entries, including some of the more specialized subjects, would be appropriate and useful for the NMT.

This appendix is intended to be neither complete nor comprehensive. It should be looked upon as a start in an effort to consolidate a catalog of resources for training programs in nuclear medicine. This list has most certainly missed many materials being used locally in training programs. The existence of additional training resources should be made known in order that training efforts can be as effective and efficient as possible. Technical Education Research Center would appreciate receiving additions to or comments to this appendix. The basic bibliography and resource list will be updated, and additional information furnished to all those concerned with the training of Nuclear Medicine Technicians.

1A - RADIATION FUNDAMENTALS, POPULAR

"A" Is For Atom - 15 minutes; 16 mm; color.

An amusing character called Dr. Atom takes the audience through "Element Town" to explain the atomic structure of the 92 naturally occurring elements. An understandable explanation of the principles of nuclear fission is given in an intersting and entertaining manner. In cartoon animation, the film goes on to explain principles of atomic energy, and how this energy can be applied to peacetime uses in industry, medicine, agriculture, and science. AEC.

Taking the X out of X-Ray - 10 minutes; 16 mm; black and white.

With narration by Coolidge, this film describes the nature and development of x-rays from their discovery by Roentgen to the present day. Included is a description of the mechanisms by which x-rays are produced from both hot and cold cathode tubes. The theory of fluoroscopy and the production of radiographs is covered. AEC

Of Man and Matter (1963) - 29 minutes; 16 mm; sound, color.

This film describes the design, development and operation of the alternating gradient synchrotron (AGS) at Brookhaven National Laboratory. Shows the various major components of this 33 billion-electron-volt particle accelerator, and explains how the high energy protons produced in the machine are used in physical research. An actual experiment is seen, in which the particle beam is guided into a bubble chamber and the resultant interactions with the target nuclei are photographed. The methods adopted in scanning and analyzing the photographs are also shown. By means of a brief lecture, a Brookhaven physicist explains that such gigantic and complex machines as the AGS are necessary in order to study the fundamental particles and the forces within the atomic nucleus that are the basic components of all existing metter. AEC

The High Energy People (1963) - 5 1/4 minutes; 16 mm; sound color.

This film offers a brief description of the problems and tools of high energy physics, illustrated by some of the work being done with Zero Gradient Sychrotron. Scientists and technicians who work with this giant atom smasher describe various phases of their work. Aside from the Synchrotron itself, the Spark Chamber is shown and explained, as are the automatic cameras which photograph the tracks of sub-atomic particles. Examination and analysis of the photographs are also described. AEC

1B - RADIATION FUNDAMENTALS, TECHNICAL

ATOMIC AND NUCLEAR PHYSICS

Nuclear Structure, Part III, Atomic Physics Series - 19 minutes; 16 mm; black and white, sound.

This film begins with the discovery of natural radioactivity by Henri Becquerel in 1896, showing the effect of radiation on a photographic plate. This is followed by a review of the work of the Curies in isolating radium, the various types of radiation and their behavior in a magnetic field, and Rutherford's experiments showing that alpha particles are helium nuclei and how the pattern of their scatter by a gold foil served as a basis for the classical concept of the atom. The structure of selected simple atoms is then shown and the importance of the atomic number of elements, rather than the atomic weight is developed through a review of the results of Moseley's experiments with characteristic x-rays. The film concludes by showing the realization of the dream of the alchemist to change one element to another, when Rutherford bombarded atoms of nitrogen with alpha particles, forming oxygen and hydrogen. AEC

Atomic Physics (1948) - 90 minutes; 16 mm; black and white, sound.

This film discusses the history and development of atomic energy, stressing nuclear physics. Dalton's basic atomic theory, Faraday's early experiments in electrolysis, Mendeleev's periodic table, and early concepts and size of atoms and molecules are discussed also. The film demonstrates how cathode rays were investigated and how the electron was discovered; how the nature of positive rays were found and put to use. The film also presents research tools of nuclear physics, explains work of Joliot Curie and Chadwick in discovery of neutron, and splitting of lithium atom by Cockcroft and Walton. Einstein tells how their work illustrates his theory of equivalence of mass and energy. Uranium fission is explained, as well as why it is possible to make an atomic bomb. AEC

Atomic Theory, Part I, Atomic Physics Series - 10 minutes; 16 mm; black and white, sound.

This film developes the rebirth of the atomic theory of matter beginning with the discovery of the law of definite proportions and Dalton's basic atomic theory. Mendeleeff's periodic table, Brownian movement, and the early experiments of Michael Faraday, showing that electric current must be composed of unit particles of electricity, are reviewed. The film concludes with a summary by Lord Rutherford. AEC

Rays from Atoms, Part II, Atomic Physics Series - 10 minutes 16 mm; black and white, sound.

This film reviews the early investigations of cathode rays showing that they are small particles which possess mass and charge and which travel in straight lines. Included are the basic principles of the experiments by J. J. Thompson. The film concludes with a review of the nature of positive rays and the discovery of x-rays by Roentgen. AEC

Fundamentals of Radioactivity (The Radioisotope - Film I Part 1) - 45 minutes; 16 mm; black and white.

This film opens with a sequence tracing uranium, the raw material of atomic energy, from the prospector to the Atomic Energy Commission. The film shows how uranium changes into other elements through the natural processes of radioactive decay and nuclear fission. Einstein's equation $E=mc^2$ is cited. Mention is made of the atomic bomb and the use of nuclear power for industry. Stable and radioactive isotopes are also discussed. AEC

Fundamentals of Radioactivity (The Radioisotope - Film I Part 2) 35 minutes; 16 mm; black and white.

Charts and energy-level diagrams are employed to illustrate the decay of radionuclides. The various radiations resulting from nuclear changes are described in detail. The nuclear reactor is described in terms of fission and moderation. Several scenes show target materials introduced into a typical nuclear reactor and withdrawn as radionuclides. The processing of fission products is also shown. AEC

Understanding the Atom: Alpha, Beta, and Gamma (1962) - 44 minutes.

This film gives some insight into the origin and nature of alpha, beta, and gamma radiation. After a short discussion of the methods of describing atoms and the introduction of the energy-level concept, the lecturer introduces the potential energy well model of the nucleus. This, together with the barrier model, is used as the frame of reference for a variety of other nuclear concepts. The energetics in alpha emission and the Gamow tunneling effect are used to describe alpha-ray emission and the energy levels in the nucleus. The lecturer discusses neutron absorption leading to the formation of nuclei having neutron-proton ratios differing from stable or naturally occurring nuclei. The transformation of excess neutrons into negative beta radiation and the return to stability are considered in some detail. Similarly, gamma radiation arising from a nuclear cooling process is described. The nuclear well model is then used to introduce decay schemes. AEC

Understanding the Atom: Nuclear Reactions (1963) - 29 1/2 minutes.

This segment of the series continues the discussion of Film No. 1 ("Understanding the Atom: Alpha, Beta and Gamma") and involves some of the basic concepts of nuclear reactions. Use is made of the nuclear well model which was introduced in Film No. 1 as a useful teaching diagram. Neutron capture processes are described with the gamma emission and particle ejection reactions being studied. Nuclear fission is also discussed. As an example of the calculations involved in nuclear reactions, the film describes the activation of a gold sample in a nuclear reactor. Emphasis is placed on the minute quantities which can be detected with the subsequent applications to the technique of activation analysis. It is shown that hundredths of a part per billion of certain materials can be detected by nuclear techniques. AEC

Understanding the Atom: Properties of Radiation (1962) - 30 minutes

This film includes a discussion of general problems of radiation decay, such as the laws of radioactive decay, including the concept of half life, Statistical considerations are introduced and the basic notion of the standard deviation in counts expected in various experiments is described. The energy spectrum from alpha and beta emitters is considered, and the use of absorption curves to study the energy distribution of beta radiation is introduced. The density thickness expressed in milligrams per square centimeter is introduced as a useful term. The film also considers problems of self-absorption, special activity, and backscattering of radiation. AEC

Understanding the Atom: Radiation and Matter (1962) - 44 minutes

This film, which considers the interaction of radiation with matter, develops the various processes by which alpha, beta, and gamma radiation give up energy to their surroundings. The similarities and differences of alpha and beta particles are considered, with emphasis on the methods by which ionization occurs. It is pointed out that since the interaction of radiations in the absorption process takes place essentially only with orbital electrons on the atoms, the density of electrons in matter is the determining factor. The relation between energy of a particle and the number of ion pairs formed is also explained. The lecturer follows with a discussion of gamma, or electromagnetic radiation, which is described as a non-ionizing event in terms of the initial interaction between photons and atoms. Four possibilities of gamma-ray absorption (Excitation, photo-electric effect, Compton effect, and pair production) are discussed. The viewer, however, is alerted to the fact that there is only a certain probability that one particular process may take place rather than another, depending upon the energy of the gamma ray. This probability, expressed as absorption coefficient, is then related to each of the four absorption processes. AEC

REACTORS

Atomic Furnaces (Challenge Film No. 4)

The operation, principles, and scientific applications of nuclear reactors, used as research tools in various projects are briefly described. Types of research that reactors and associated equipment make possible are shown at length. The Gamma Ray Spectrometer, the Neutron Chopper, and a new reactor designed specifically for high-and low-radiation experiments in biology are also described.

Criticality - 22 minutes; 16 mm; color.

This film discusses the theory of criticality, and describes the conditions which will produce it, emphasizing the importance of mass, shape and moderation. Included are many examples of precautions which must be taken in industry to assure that fissionable material will not become critical. AEC

<u>Medical Research Reactor</u> (1958) - 22 minutes; 16 mm; color and sound

This film, prepared primarily for those concerned with the design and utilization of reactors for medical research demonstrates the need for such a reactor and defines the design criteria. The reactor and its components are shown during construction and assembly. Operation of the reactor and shutters controlling its neutron beam are shown by animation. There is also a neutron-capture therapy experiment sequence at the Brookhaven graphite reactor which can be compared with the patient treatment facility at the new medical reactor. AEC

ACCELERATORS

<u>High Energy Particle Accelerators</u> (1958) - 30 minutes; 16 mm; color and sound.

This technical film surveys the work of particle accelerators in high-energy physics, shows the major accelerator installations in the U. S., major accelerators under construction, and a series of typical experiments with high-energy particles. It explains, with both live action and animation, the components and operations of various types of accelerators and gives a description of bubble chambers. The film features information on the following operating accelerators: the Brookhaven National Laboratory Cosmotron (proton-synchrotron), the University of California Radiation Laboratory's Bevatron (largest proton-synchrotron operating in the U.S., as of the fall of 1958), the California Institute of Technology electron-synchrotron, the Cornell University electron-synchrotron, and Stanford University's linear accelerator; also, construction work and principles of the Princeton University - University of Pennsylvania synchrotron (Cosmotron type), Argonne National Laboratory's proton-synchrotron (up to 12 Bev), Brookhaven's alternating Gradient Synchrotron (25-30 Bev), and the Harvard-MIT Alternating Gradient Electron Synchrotron (6 Bev). Also included are brief data on studies at Stanford, Oak Ridge, and Midwestern Universities Research Association on the linear, spiral magnet, and fixed-field alternating gradients types, respectively. AEC

<u>High Energy Radiations for Mankind</u> (1958) - 16 minutes
16 mm, sound, color.

This semi-technical film, for high school and college-level audiences, describes the principles, assembly and uses of the Van de Graaff particle accelerator to produce intense stable controlled beams of all basic radiation for basic and applied research, industrial processing, chemistry, metallurgy, and biology and medicine. It shows stages of assembly, testing and use of vertical and horizontal machines ranging from 1 to 6 million electron volts; the Microwave Linear Accelerator; and the 10-Mev Tandem Van de Graaff for exploring the binding energy of heavier elements. Examples include use for basic research, nuclear engineering, petrochemistry, drug sterilization, food preservation, radiography, and cancer treatment. AEC

<u>Atom Smashers</u> (1954)

Explains purposes, principles and methods of particle accelerators. Shows how swift atomic projectiles "smash" atomic nuclei apart for scientific examination of subatomic particles. Views of various particle accelerators, including the first 4-inch Cyclotron, the giant Bevatron, the Cosmotron, and of photographic trails left by smashed atoms. AEC

<u>Searching for the Ultimate</u> (Challenge Film No. 3)

Atomic structure, one of the most basic forms of nuclear research, permits the scientist to discover the nature of the universe through the use of atom smashers or particle accelerators. The machines produce intense beams of radiation which enable study of the structure of the atom, the nucleus, and the basic components of the nucleus. This film explains how accelerators operate and shows one of the world's largest particle accelerators being constructed. Sub-nuclear particles and the concept of matter and anti-matter are also explained. AEC

DETECTION AND MEASURMENT OF IONIZING RADIATION

<u>Properties of Radiation</u> (PMF-5145-B) - 68 minutes.

This film shows a Geiger counter used to compare penetrations of alpha, beta, and gamma radiation and to derive their characteristic absorption curves. The beta-radiation section of the film presents the cloud-chamber electrostatic generator and beta-ray spectrometer as well as the concepts of ionization, electron volt, beta-ray spectrum, neutrino, scattering, nonlinear absorption, and density thickness (mg/cm^2). The gamma-radiation section explains bremsstrahlung, photoelectric effect, Compton Scattering, pair production, exponential absorption, absorption coefficient, and half thickness. The final section concerns the interpretation of composite absorption curves. ARMY

Understanding the Atom: Radiation Detected by Ionization (1962) -30 minutes

The basic principles of ionization detectors are described, particularly in relation to the pulse height as a function of voltage curves. Brief descriptions of ionization chambers, proportional counters, and Geiger counters are included, and examples of instruments operating in these regions are shown. Special consideration is given to Geiger counters, including the mechanism of gas quenching and the determination of a counting-rate plateau. The resolving time of a counter is discussed, as well as various components of a practical instrument, including amplifiers and scalers. AEC

Understanding the Atom: Radiation Detection by Scintillation (1962) - 30 minutes

A short review of gamma interactions with matter is shown, with particular reference to useful scintillation crystals. The scintillation process is described, and the efficiency of the conversion of gamma radiation to visible light in the scintillator is discussed. Solid and liquid scintillators are shown along with special detection devices using this principle. A description of the operation of a photomultiplier tube is given, and the concept of pulse height is developed. The principle of operation of a pulse-height analyzer is shown, and the spectrum obtained with such an instrument is shown and discussed. Brief mention is made of solid state radiation detectors. AEC

The Roentgen - 15 minutes; 16 mm; black and white, sound.

This film develops the concept, definition, and measurement of the Roentgen unit. By way of introduction, the relative penetrating and ionizing abilities of the various types of ionizing radiation are compared. This is followed by illustrations of the production of ion pairs by x- and gamma radiation and a pictorial demonstration of the concepts of secondary electron equilibrium and air equivalent walls. AEC

Introduction to Radiation Detection Instruments - 19 minutes; 16 mm; black and white.

This film presents the fundamentals necessary to an understanding of the theory of operation of radiation detection instruments. Emphasis is on the need for instruments for detection as our senses are unable to detect ionizing radiation. It includes a brief description of a dosimeter, pocket chamber, ion chamber survey meter, alpha portable survey meter, Geiger-Mueller tube and a Geiger-Mueller-type survey meter. A discussion is included of the penetrating ability of alpha, beta, and gamma rays, calibration of instruments, and their use in the event of disaster. Laboratory instruments are shown as used in more detailed analysis. A brief description of film-badge monitoring is also included. A radiological monitoring group is shown in action as they evaluate various radiological hazards. AEC

Practical Procedures of Measurement (The Radioisotope - Film III) 48 minutes; 16 mm; black and white.

The user of radionuclides must be concerned with radiation measurements for safety and experimental purposes. Several sequences cover the principles and use of various types of instrumentation, with emphasis on the Geiger counter, and illustrate background, threshold value, plateau, and counting statistics. The remaining part of the film is devoted to absolute measurement, wherein the true activity of a sample is determined by using a calibrated standard, and comparative measurement, wherein the activity of a sample is compared with that of a control sample in order to determine the quantitative change in activity which resulted from decay or dilution. AEC

Beta Ray Spectrometer (1963) - 7 minutes; 16 mm color and sound.

By animation and live action, this film explains the principles and working of the Coincidence Beta Ray Spectrometer, a device which is used to measure to intensity and direction of electron emissions known as beta particles. Components of the device are shown and assembled. A source is introduced. Mashing for beam direction and size is demonstrated. Detectors are shown and explained. AEC

RADIOCHEMISTRY

The Atomic Pharmacy (1954)

Describes the storage and handling of radioisotopes, and illustrates remote-control devices for safe manipulation of radioactive liquids. Explains use of radioisotopes in hospitals, research laboratories, and industrial facilities. AEC

Tagging the Atom (1954)

Describes the use of radioisotope "tracers" as scientific research tools. Shows details of radioisotope production, methods of handling, purification, and packaging. AEC

The Art of Separation (Challenge Film No. 12)

This film deals with the separation of chemical compounds into basic substances in the purest form possible by the process known as chromatography and with the importance of that process in chemistry work. Using radiation, the chemist is able to work with much greater speed and ease in the field of chromatography. The basic principles and various methods of modern chromatography are explained and demonstrated. Actual separation of a chemical compound is shown. AEC

Isotopes (1959) - 20 minutes ; 16 mm; color and sound

This film describes the production of stable isotopes and radioisotopes and the separation of fission products. The first part of the film explains, in layman's language, radioactivity, half life, and the three methods of producing radioisotopes. Live photography and animation tell the story of radioisotopes production at the Oak Ridge National Laroratory (ORNL). The remainder of the film explains, in semitechnical language, the large-scale separation of long-life fission products at ORNL's pilot plant. Animation illustrates in detail the separation of fission products from wastes derived during the processing of spent reactor fuels. AEC

GENERAL PRINCIPLES

Radiation Protection in Nuclear Medicine (1962)- 45 minutes
16 mm; color and sound.

This semitechnical film demonstrates the procedures devised for naval hospitals to protect against the gamma radiation emitted from materials used in radiation therapy. However, its principles are applicable in all hospitals. The practices demonstrated are based on three principles established at the outset. The film explains the nature of gamma radiation relative to how time, distance, and shielding are used to provide protection from its harmful effects. Time is considered in two ways: (1) the half life of the radioactive materials used and (2) the speed in handling them. The film shows the continuous application of these principles from the moment radioactive materials are received at a hospital, through their storage, their preparation for use, their therapeutic administration, the nursing care of radioactive patients, and the disposal of radioactive human waste. The film details the special techniques and equipment used in the handling of radium and radioactive gold, iodine, and iridium as representing the variety of such materials that hospital personnel encounter and the consequent variations in time, distance and shielding employed as protection against them. The use of monitoring devices and the maintenance of records of their readings form a recurrent theme throughout the film. It makes the dual point that radiological-safety records are used (1) to provide immediate protection for hospital personnel and (2) as a basis on which the staff can reevaluate and improve techniques, always with the purpose of keeping the exposure of each person below the established maximum permissible levels. AEC

Radiation in Perspective (1963) - 43 minutes; 16 mm; sound, color.

The film, in the form of a lecture by Commission Safety Engineer Francis L. Brannigan, presents the salient points of an approach to the understanding of the radiation problem which has been found useful for persons requiring a layman's understanding of the nature of radiation -- such as teachers groups, public safety officials, transportation executives, insurance executives, service clubs, colleges and universities, etc. The film will also be useful to those technically qualified, since it demonstrates proven techniques for explaining the radiation hazard to the layman. Since is it basic to the acceptance of any hazard that we expect to get some benefit from it, the lecture-film briefly summarizes some of the beneficial uses of radioactive materials -- in medicine, agriculture, industry, systems for nuclear auxiliary power, food sterilization -- that justify acceptance of the hazard. The lecturer then explains briefly the internal radiation problem, and in detail the external radiation problem. Information is given on ionization, background levels of radiation, the roentgen, the radiation levels required to produce immediate injury and low-level radiation exposures over long periods of time. The lecturer discusses the somatic effects (on the individual) and genetic effects (on future generations), and makes a comparison of the acceptable-versus-dangerous levels for radiation with that of the levels for carbon monoxide, to show the conservative nature of radiation regulations. An explanation is given of time, distance and shielding and how they are used to control external radiation exposure. The lecturer points out that the question is not radiation versus no radiation, but rather how much more radiation people can accept consistent with the other hazards of our environment -- all balanced against the tremendous industrial, medical and research benefits of the nuclear age. He summarizes and concludes: "Radiation is another of the hazards with which we must deal as we make progress in our industrial age. Radiation energy in quantity can damage living tissue. However, within limits we can live with this problem so that we can obtain the benefits of the atomic age. This parallels our acceptance of other hazards. There is a tremendous spread between the routinely acceptable operating radiation levels and the dangerous levels -- many thousands of times greater than the corresponding spread for other hazards. All radiation contributes to but is not the sole cause of mankind's genetic problems. The proportion due to atomic energy is very small. The conclusion is clear: we can enjoy the benefits of the nuclear age with safety to employees and the public." AEC

<u>Understanding the Atom: Radiological Safety</u> (1963) - 30 Minutes; 16 mm; black and white, sound.

Part seven of this series examines the field of radiological safety or health physics, and tries to give a basis for a perspective on potential biological radiation damage. It first considers background radiation and the nature of the difference in this radiation. Larger doses of radiation can be a potential cause of both somatic (direct bodily) damage and genetic (hereditary) damage, and consideration is given to the maximum permissible limits or radiation guide levels which have been established by various radiological protection committees and the Federal Radiation Council. Various units are described, with these including the roentgen, the rad, and the rem. The latter unit is a measure of the biological dose equivalent and considers the relative biological effectiveness (RBE) of the radiation. Consideration is also given to the maximum permissible concentration of radioisotopes in air or water, and the problems involved in the localization of radioactive materials in the body. Various factors that must be controlled in reducing the radiation hazard include the quantity of radioactive material, the distance, the time of exposure and shielding. Internal exposure must be minimized by the use of special laboratory facilities and techniques which are required to minimize the admission of radioactive isotopes into the body. The importance of having calibrated instruments available is stressed in any program involving the use of radiation sources. AEC

<u>Practice of Radiological Safety</u> (PMF-5145-F) - 33 minutes.

This film depicts a visit through a radioisotope laboratory and discusses handling of radioisotope shipments; preparation of therapeutic doses; need for, and function of a local radioisotope committee; laboratory design; decontamination; use of shielding; measurement of personnel exposure, an other topics pertinent to health safety. ARMY

<u>Atomic Biology for Medicine</u> (1956)

Explains experiments to discover effects of radiation on mammals, including effects on lungs, eyes, bones and other tissues, cell division, and tumors. AEC

<u>Living with the Atom</u> (1960) - 18 minutes; 16 mm sound, color.

This nontechnical film for intermediate through college-level audiences, explains the radiation safety devices and procedures used to protect workers in the atomic industry, which is among the safest of U. S. heavy industries. Through the viewpoint of a community representative talking with the health physicist of a nearby atomic installation, the film also details the precaution taken for the protection of the communities. AEC

Living with Radiation (1958) - 28 minutes; 16 mm; sound, color.

This semitechnical film, for intermediate through college-level audiences, documents in detail the radiation safety program of the U. S. atomic energy program, using procedures at the National Reactor Testing Station in Idaho as typical, illustrative examples. It explains: separation-distance factor; storage and/or disposal of radioactive waste; protection of populations, water, crops and livestock by monitoring of air and environment; remote-control devices, radiation counters, decontamination procedures, and bio-medical studies. AEC

A matter of Contamination Sense - 10 minutes; 16 mm; Black and white.

This is a short relatively humorous film showing a case of contamination in a nuclear installation. It stresses common sense and points out several possible ways a person might become unknowingly contaminated. AEC

Principles of Radiological Safety (PMF-5145-E) - 51 minutes.

This film introduces concepts of internal and external and acute and chronic radiation exposure by means of a historical sequence on hazards associated with X-ray and radium therapy and radium-dial painting. A discussion of ionization from external and internal sources of alpha, beta and gamma radiation, with detailed explanations of roentgen and "equivalent" or "energy" roentgen, is presented. Maximum permissible exposure and the theory of radiation-measuring instruments are also discussed. Formulas are developed for computing dosage rates from internal sources. Concepts of single and continued uptake, physical decay and biological elimination of activity, biological half life and effective half life are considered. The responsibility of the radioisotope user to other members of the laboratory and to the public is emphasized. ARMY

Bikini Radiological Laboratory (1949) - 22 minutes; 16mm; sound, color.

This nontechnical film, for intermediate through college-level audiences, explains studies of effects of radioactivity from the 1496 atomic tests at Bikini Atoll, on plants and marine life in the area three years latter. AEC

Building Blocks of Life (Challenge Film No. 8)

Unique fragments of molecules caused by radiation in living systems, which are known as free radicals, either kill or seriously damage living cells. The how and why of both the particles and the damage they cause is the topic of this film. AEC

Radiation and the Population (Challenge Film No. 5)

Because genetic damage is one of the most serious effects of radiation, the U. S. Atomic Energy Commission genetics program is designed to learn how radiation damages cells and what the long term effects of such damage might be. This film explains how radiation causes mutations and how these mutations are passed on to succeeding generations. Mutation research is illustrated with results of experimentation on generations of mice and includes discussion of work with fruit flies and induced mutations. Fallout and its implications are also discussed. AEC

Radiation as a Cause of Cancer - 20 minutes; 16 mm color.

This film presents an explanation of the histological step-by-step formation of cancer in various experimental animals and man after exposure to ionizing radiations. A brief review is made of basic atomic structure, radioactivity, and interaction of radiation with tissue; free radical formation is discussed in some detail. Also shown is an interesting experiment in which rats are fitted with jackets lined with strontium-90 beads. After a suitable exposure and ensuing latent period, skin cancer appears in the test animals. The carcinogenic hazards of external skin exposure are compared with internal exposures resulting from the uptake of radioactive materials by the gastrointestinal tract and the respiratory system. AEC

Tale of Two Cities (1947) - 20 minutes; 16 mm; sound, black and white.

This nontechnical film, for intermediate through college-level audiences, shows the destructive results of atomic bombings of Hiroshima and Nagasaki, with close-ups of effects on buildings and materials. AEC

MONITORING

Primer on Monitoring (1953) - 30 minutes; 16 mm; sound, color.

This semitechnical film, for high school and college-level audiences, describes the different types of radiation, various devices for monitoring each type, and the basic principles of health monitoring procedures. AEC

Offsite Monitoring of Fallout During Nuclear Tests - 29 minutes; 16 mm; color.

This film describes the radiological safety activities of the Public Health Service in the offsite area of the U. S. Atomic Energy Commission's Nevada Test Site - a 300-mile radius, including portions of Nevada, California, Utah, and Arizona. Included is a description of the training provided PHS Commissioned Reservists from state health departments, universities, and industry; monitoring and public information activities of representative PHS Zone Commanders; methods of collection, and laboratory analysis of environmental samples. AEC

Protecting the Atomic Worker (1954)

Explains safeguards used to protect men and women working closely with radiation: film badges, ionization pencils, shielding, decontamination, laundry, health monitors, blood counts, breath testing, and health records. AEC

X-Ray Inspection - 21 minutes; 16 mm; black and white.

The theory of x-ray production and the application of the principle of differential absorption of x-rays in a medium to radiographic inspection of metallic artifacts are briefly discussed. The procedures of simple radiographic inspection of a cast gear blank are shown in detail, from the technician's viewpoint. Some x-ray protection principles are mentioned. Released by United World Films, Inc. AEC

Radiation and Public Health (1965)-25 minutes; 16 mm; sound, color. (M731)

Describes the current activities of the Division of

Radiological Health, U. S. Public Health Service, directed toward the development of a nation-wide Federal-State Health Agency program capable of insuring that the benefits of radiation are accrued with a minumum of health risks to the public. It depicts the measurement and surveillance of environmental radiation to determine the extent of human radiation exposure; the development of methodology for exposure reduction control; research in radiology; epidemiology and environmental sciences training of scientific manpower; assistance to State and local Health Departments. Scientific projects featured in the film include: institutional diet sampling, radiochemical analyses of environmental samples, X-ray exposure assessment, thyrotoxicosis followup, training, and assistance to State radioactive materials control programs. U. S. PUBLIC HEALTH SERVICE

PROTECTION

Modification of Radiation Injury in Mice (1958) - 10 minutes; 16 mm; color and sound.

This film shows the effects on mice of chemical protection by mercaptoethylguanidine (MEG) before irradiation and bone-marrow transplant after exposure to lethal doses of 900 r, as well as possible implications regarding treatment of some human diseases. The irradiation that kills 50 per cent of mice in 30 days can be doubled with MEG protection and nearly doubled with bone-marrow treatment. With chemical protection followed by bone-marrow treatment, the dose of irradiation that it takes to kill 50 percent of mice in 30 days can nearly be tripled. MEG reduced the effect of a lethal dose of 900-r X irradiation on the bone marrow, spleen, thymus, and body weight by about a factor of 2. MEG is not effective when given after irradiation. Bone-marrow injection was primarily responsible for replacing the destroyed bone marrow. It is not effective when given before irradiation. In combined treatment, the animal received the advantages of both types of therapy and survived much greater exposure. AEC

You Can Be Safe From X-Rays - 10 minutes; 16 mm; black and white.

This film is intended for those whose occupations necessitate frequent exposure to x-radiations. Emphasized are the facts that penetrating radiation cannot be detected by one's five senses and radiation damage is cumulative and may not be noticed until permanent harm has been done. With illustrations in animation, the film is primarily designed for photofluorographic operators making mass chest x-ray surveys. It has many well-illustrated public health principles equally of interest to anyone engaged in x-ray work. AEC

Radioactive Waste Disposal (1961) M-443 - 24 minutes; 16 mm; sound, color

Shows extreme precautions used at the National Institutes of Health in handling radioactive waste and the care used in its ultimate disposal in the océan. U. S. PUBLIC HEALTH SERVICE

Radiation Safety in Nuclear Energy Explorations M-461 (1962) 24 minutes; 16 mm; sound, color.

Depicts the activities of the Division of Radiological Health of the Public Health Service, showing public health programs designed for protection against radiation. U. S. PUBLIC HEALTH SERVICE & AEC

3A - BIOLOGICAL APPLICATIONS

The Atom and Biological Science (1953) - 12 minutes; 16 mm; sound, black and white.

This is a technical film for intermediate through college-level audiences. It identifies and illustrates uses of radioactivity in several areas of biology; effects of radiation on growth and heredity of plants and animals; tracer studies; photosynthesis studies; and measures to protect the investigating scientists. AEC

Chromosome Labeling By Tritium (1958) - 15 minutes; 16 mm; color and sound.

This film discussed the advantages of tritum over other radioisotopes as labeling material in autoradiography. AEC

The Immune Response (Challenge Film No. 7)

This film is concerned with the mechanism by which the body builds antibodies against disease and other foreign substances. The effects of irradiation of rabbits with X-rays are shown and conclusions are discussed. AEC

The Living Solid (Challenge Film No. 9)

This film shows that bone is not a fairly stable substance but is active, living matter, constantly remodeling and reforming itself. The importance of bone to the entire body as a supplier of calcium is emphasized, and the systems by which this calcium gets from bone to blood and vice versa are illustrated. Effects of radiation are illustrated in photographs of bone cross-section. AEC

Liquid Scintillation Counting (1958) - 14 minutes; 16 mm; sound and color.

This film describes the use of a liquid scintillator for counting low-energy beta emitters commonly used in biological and medical tracer experiments. It also explains the advantages of the single- and double-photomultiplier tube liquid scintillation counters over the solid-phase and gas-phase counters, e. g. the ease of sample preparation, high efficiency, and excellent sensitivity. The film describes counting techniques, how the counters work, and how a sample is prepared. Liquid scintillation counting is an extremely useful technique, particularly for weak beta emitters, such as C^{14} and tritium, where the number of samples to be counted places a premium on the ease of sample preparation. AEC

The Radioisotope: Methodology (PMF-5145-D) - 40 minutes.

This film contains a historical sequence showing the early work of Hevesy in studying plant metabolism with naturally occurring radiolead, after which it explains seven criteria for setting up a tracer experiment: (1) radiochemical purity, (2) single chemical state, (3) elimination of exchange error, (4) knowledge of the degree to which the labeled molecules remain intact, (5) avoidance of isotope effect, (6) avoidance of chemical effects and (7) avoidance of radiation effects. The film also illustrates the relative importance of economy of time and materials and accuracy by depicting a typical biological tracer experiment from the formation of an idea to the final results. ARMY

Time -- The Surest Poison (Challenge Film No. 6)

This film explores the natural process of aging and the methods used in its study. Aging might be considered one of the deleterious side effects of radiation since radiation injury resembles natural aging in so many ways. Results of study of the aging process involving the use of radiation are presented. The conduct of research on animals using low-level gamma irradiation is illustrated. AEC

Micropuncture of Cells by U. V. Microbeam (624) - 20 minutes; black and white, sound.

Marcel Bessis, M.D. - A pictorial record showing in motion picture form the results obtained from irradiating various cells, either wholly or in part. SQUIBB

Death of a Cell (571) - 15 minutes; black and white, sound.

Marcel Bessis, M. D. - Uses phase contrast microscopy and time lapse photography to show the complex anatomical changes that occur in cells during death produced by various mechanisms. SQUIBB

Anatomy of the Cell (612) - 20 minutes; black and white, sound.

Marcel Bessis, M. D. - Uses phase contrast microscopy and time lapse photography to show how cells function, multiply, suffer and having served their purpose, die. SQUIBB

3B - MEDICAL APPLICATIONS

MEDICAL RESEARCH APPLICATION OF RADIOISOTOPES

Tracing Living Cells (Challenge Film No. 11)

Radioactivity is often mankind's servant. In recent years, the use of radioactive isotopes in the study of cell division and in medical therapy has helped man overcome disease. This film demonstrates some of the many helpful and healthful uses of atomic energy, including use of radioactive tracers in blood and cancer research. AEC

Ionizing Radiation in Humans (1958) - 15 minutes; 16 mm; color and sound.

This film shows the design and operation of Argonne National Laboratory's whole body counter for determining identification, quantity, and location of internally deposited radioelements. Various techniques in accumulation of data, the tilting chair, one meter arc, and collimating the crystal are also shown. AEC

Human Radioactivity Measurements (1958) - 9 minutes; 16 mm; color and sound.

This film shows a method developed at Los Alamos Scientific Laboratory to monitor personnel exposed to the possible intake of gamma-emitting materials and to study the retention and excretion of radioactive isotopes by the body. The liquid scintillation counter is large enough to contain a man and sensitive enough to detect even the minute amounts of his natural gamma radioactivity. AEC

The Atomic Apothecary (1954) - 38 minutes; 16 mm; black and white, sound.

This film discusses radioisotope research in biology and medicine, including research in radioactive dust, calcium absorption in animals and effects of radioiodine in their diet; use of astatine, effect on blood flow, oxygen tension studies, radioactive iron in bone marrow, arteriosclerosis, and the use of cyteine. AEC

CLINICAL APPLICATIONS OF RADIOISOTOPES

GENERAL APPLICATIONS

Too Hot To Handle -- The Two Faces of Radiation - 1 hour, black and white.

Excellent survey of diagnostic and therapeutic medical uses of radioisotopes. Also covers radiation biology in a very effective set of presentations by some of the major researchers in this field. ROBECK

The Atom in the Hospital (1961)

At the City of Hope Medical Center, the following facilities are shown: (1) the stationary cobalt source that uses radioactive cobalt to treat various forms of malignancies; (2) a rotational therapy unit called the "cesium ring," which revolves around the patient and focuses its beam on the diseased area; and (3) the total-body irradiation chamber for studying the effects of radiation on living things. Studies can be carried out to determine the effects of massive doses of radiation. Data from these studies will be used for civil defense purposes, for investigating skin grafts and organ transplants, etc. At the UCLA Medical Center the total-body counter facility, which measures the slight radioactivity normally present in the animal or human body, is shown. The counting facility makes it possible to employ new diagnostic procedures requiring much smaller amounts of radioactive materials by eliminating practically all background radiation. AEC

The Atom and the Doctor (1954)

Shows three applications of radioisotopes in medicine; testing for leukemia and other blood disorders with radioiron; diagnosis of thyroid conditions with radioiodine "cocktails," and cancer research with radiogallium. AEC

Medicine (1957) - 20 minutes; 16 mm; sound, color.

This nontechnical film gives four illustrations of the use of radioactive materials in diagnosis and therapy; exact pre-operative location of brain tumor; scanning and charting of thyroids; cancer therapy research and the study of blood diseases and hardening of the arteries. AEC

Radioisotopes: Their Application to Humans (1954)

32 minutes; 16 mm; color and sound.

This film is a comprehensive review of the uses of radioisotopes in human applications as tracer studies and for therapeutic use. Uses of radioactive iodine, sodium, iron, calcium, lanthanum, strontium, cobalt, phosphorus, gold, and the neutron-capture therapy involving boron for treatment of brain tumors are also discussed. AEC

Radiation: Physician and Patient - 45 minutes; 16 mm; color.

This film is essentially an informal talk by Dr. Richard

H. Chamberlain (of the University of Pennsylvania School of Medicine and member of the National Committee on Radiation Protection and Measurements) about medical radiology -- the problem it raises; its biological effects; its physical behaviour; and its proper use in clinical examination. Many eminent authorities in the radio-biological field, who are interviewed in their own laboratories, discuss such matters as radiation effects on chromosomes, somatic effects of radiation, and dosage problems in radiation and clinical application. AEC

<u>The Atom Comes to Town</u> - 27 minutes; color 21st Century Television Series, "CBS Presents", Walter Cronkite.

Popular level film which surveys the following topics in language which is easily understood by non-technical as well as technical workers: Whole body counting, reactors used for isotope production, different types of labelled compounds and their use in scanning procedures, Carbon-14 breath studies, and radioactive isotope power supplies. Different forms of radiotherapy including ^{131}I, extracorporeal irradiation, pituitary irradiation with radioactive seeds, cobalt therapy, and the uses of computers in treatment planning are presented in a well done non-technical film.

<u>Radiation: Silent Servant of Mankind.</u> (1956)

Depicts four uses of controlled radiation to benefit mankind: bombardment of plants from a radioactive cobalt source, to induce genetic changes for study and crop improvement; irradiation of deep-seated tumors with a beam from a particle accelerator; therapy of thyroid cancer with radioactive iodine; and possibilities for treating brain tumors. AEC

<u>Radiopharmaceuticals: From Reactor to Physician</u> (1958) 20 minutes; 16 mm; color and sound.

This film illustrates the purification and processing of radioisotopes to render them suitable for use by the physician. Emphasis is placed upon the production of various radiopharmaceuticals in encapsulated form, together with methods used for their assay and standardization. A clinical section deals with the newest methods of thyroid uptakes, new iodine therapy, and the use of Racobalamin (R) (radiocyanocobalamin) and Raolein (radioiodinated triolein) for the diagnosis of pernicious anemia and faulty fat absorption, respectively. AEC

From Head to Toe

Documentary type film. ABBOTT

PARTICULAR APPLICATIONS

Iodine - 131 (1958) - 15 minutes; 16 mm; color and sound.

This film shows the diagnostic and therapeutic uses of the radioisotope I^{131} for hyperthyroidism, thyroid cancer, and heart disease. The characteristics, techniques, and results are discussed, as well as the problems of standardization and calibration of scanning devices for I^{131}, which is probably the most used isotope in the field of medicine. AEC

Clinical Organ Photoscanning - 3 reels; 25 minutes each; 16 mm;

Dr. Henry Wagner, (The Johns Hopkins Hospital), presents examples and discusses the role of radionuclide organ scanning in different clinical situations. Thyroid, lung, blood flow, liver, spleen scans and bolus studies are presented and discussed. This film is an excellent presentation for residents and practitioners as an introduction to the role of scanning studies in medicine. NAVY

The Radioisotopic Renogram in Renovascular Hypertension
20 minutes; 16 mm; color, sound. James L. Quinn III, M.D. and Joseph E. Whitley, M.D.

The authors indicate that the radioisotope renogram can contribute significantly to the diagnosis of renovascular hypertension. The acceleration of the vascular phase of the renogram to monitor the inflow pattern of radioactivity into the renal bed, has increased the diagnostic accuracy of the renogram in their hands, especially in bilateral renal artery disease. The method of performing and interpreting the "modified renogram" or renovasculogram is described. The attendant artifacts and pitfalls of interpretation are discussed. The coordinated role of the contrast urogram, radioisotope renogram and renal arteriogram in the diagnosis of renovascular hypertension is stressed. The more common abnormalities of each of these examinations are illustrated. SQUIBB

RISA Cysternography and Ventriculography (1968) - 20 minutes 16 mm.

An excellent film by Dr. DiChiro describing the dynamics of cerebrospinal fluid production and distribution in normal and abnormal situations. Illustrates the way in which this technique can be used clinically. (Author, NIH)

P-32 Therapy and Joint Scanning-3 reels; 25 minutes each 16 mm.

Dr. Bill Maxfield discusses the biological turnover of P-32 and the different ways in which it is used in the therapy of polycethemia vera. The relationship between P-32 therapy and the subsequent appearance of leukemia is discussed in the light of the most recent knowledge derived from the studies of large numbers of patients so treated. The use of P-32 plus testosterone for the treatment of patients with breast cancer metastases to bone is presented. Therapeutic regimenc and expected outcome are presented. The 3rd reel describes the use of scanning techniques for the study of joints in patients with arthritis. NAVY

Detection of Occult Bone Metastases - 3 reels; 25 minutes each; 16 mm.

Dr. David Charkes (Albert Einstein Medical Center) describes the clinical use of bone scanning with radioisotopes. Normal and abnormal bone metabolism are discussed along with the way in which isotopes have contributed to knowledge in this area. Emphasis is placed on evaluating patients with neoplasms for metastases to bone. NAVY

Teletherapy and Brachytherapy (1958) - 18 minutes; 16 mm; color and sound.

This film shows the diagnostic and therapeutic uses of such radioisotopes as Co^{60}, Cs^{137}, Eu^{152-4}, I^{131}, and Y^{90} in teletherapy and brachytherapy by using machines that aim a high-energy beam at a tumor or by using implants of radioactive materials in the form of needles, beads, sterile tubing, seeds, etc. AEC

Iridium -192 Implant for Cancer of the Floor of the Mouth (631) - 15 minutes 16 mm; color, sound.

This film, from the Tumor Institute of the Swedish Hospital, Seattle, Washington, demonstrates an iridium-192 implant for cancer of the floor of the mouth. A 62 year old male with large submandibular metastases bilaterally from a squamous cell carcinoma under the tongue is implanted with iridium-192 seeds in nylon tubing as a part of the radiation therapy for his disease. SQUIBB

4 - INDUSTRIAL APPLICATIONS

The Atom Comes to Town - 29 minutes; 16 mm; color and sound. A survey of the peacetime uses of atomic energy. Included: How heat from nuclear fission in a reactor can be used to make electricity, and what nuclear power will mean to the man on the street and to all of America: Scenes of various experimental and prototype power plants, with discussion of types, kilowatt capacity, principles and future developments: Explanation of radioisotopes - how they are made and how they are used to alleviate suffering and raise the standard of living; Uses of radioactive materials in diagnosis and treatment of disease: Use of radionuclides in agriculture for production of better crops: Atomic energy as a means of quality control in manufacturing and industrial operations (studies on washing machines, engine wear, tires, toothpaste, plastics): Food preservation by radiological techniques. AEC

The Atom and You (1953) - 16 minutes; 16 mm; sound, black and white.

This nontechnical film, for all audience levels, consolidates three newsreels covering the use of radioisotopes in biology, medicine, agriculture and industry, and also the development of atomic power. AEC

Foundations for the Future (Challenge Film No. 13)

Problems that are still to be solved by nuclear scientists are discussed in this film. Areas of particular interest to the scientist in his work now and in the future are identified as being the effects of radiation, the peaceful uses of radiation, and the dangers of radiation. AEC

Gauging Thickness with Radioisotopes - 4 1/2 minutes; 16 mm; black and white, sound.

This brief film explains how beta gauges are used for precise measurement and control of feedback apparatus in steel, plastics, rubber, and paper manufacturing. AEC

Industrial Applications of Radioisotopes - 57 minutes; 16 mm; color.

This semi-technical film surveys the current widespread uses of radionuclides throughout American industry. Three major areas of use are described: nuclear gaging (thickness, density and level), radiography and tracing. Luminescence, static elimination, isotopic power and uses of high intensity radiation are covered briefly. Basic principles are explained by animation, followed by examples of in-plant uses. The film is designed to acquaint industrial management with the versatility, economy and ease with which radioisotope techniques can be adapted to plant requirements. AEC

The Mighty Atom - 27 minutes, color. 21st Century TV Series, "CBS Presents" - Walter Cronkite.

Popular level film which surveys the following topics in language which is easily understood by nontechnical as well as technical workers: Operation Plowshare, reactors used as a source of electrical power and for propulsion of vehicles, food sterilization, whole body irradiation in the treatment of leukemia, the basic concepts involved in controlled fission reactions, isotope production and breeder reactors.

AVAILABLE SOURCES:

Atomic Energy Commission

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Reference List of Books in Nuclear Medicine

The following list of books is divided under four main headings although many of the books deal with a wide variety of topics and cannot really be categorized.

I. General

Principles of Nuclear Medicine, Wagner. W. B. Saunders Company, 1968.

Latest, most comprehensive book published in nuclear medicine.

Atomic Medicine, Behrens. Williams & Wilkins, 4th Edition, 1964.

Comprehensive textbook including both radiation biology and nuclear medicine.

Radioisotope Techniques in Clinical Research and Diagnosis, Veall and Vetter. Butterworth, London, 1958.

Good introductory text. Reads easily and is clinically oriented.

Radioaktive Isotope in Klinik und Forschung. Papers presented at biennial International Symposium, 1964. Urban and Schwarzenberg, Munich and Berlin.

Many excellent fundamental and some clinical papers, most of which are in English.

Nuclear Medicine, William H. Blahd. Blackstone Div. of McGraw-Hill Book Co., 1965.

Comprehensive text with excellent section on renal disease, among others.

Manual of Isotopes in Radiology and Nuclear Medicine, Bogardus. Warren H. Green, 1968.

Announced. Not yet reviewed locally.

Progress in Atomic Medicine - Volume II, Lawrence. Gruen and Stratton, 1967.

Recent Advances in Nuclear Medicine, Croll and Brady Appleton Press, 1966.

Yearbook of Nuclear Medicine, Quinn (Ed.). Yearbook Publishing Co.

Annual synopsis of important new clinical and technical advances in the field.

_1. Imaging

Clinical Radioisotope Scanning, Wang. Charles C. Thomas 1967.

Covers all the major organ scanning topics in a simple lucid, somewhat superficial aspect.

Progress in Medical Radioisotope Scanning.

(Proceedings of Symposium at the Medical Division of Oak Ridge Institute of Nuclear Studies - October 22-26, 1962.)

Description of collimator properties, data acquisition and display systems for use in isotope scanning. Good discussions of thyroid, brain, liver, kidney and spleen scanning. Still worthwhile in 1968 at both technical and clinical levels.

Medical Radioisotope Scanning - Vol. I. International Atomic Energy Agency, 1964.

This volume deals with the technical aspects of instrumentation in nuclear medicine and fundamental analyses of systems performance.

Medical Radioisotope Scanning - Vol. II. International Atomic Energy Agency, 1964.

Deals with the choice of radioisotopes and labelled compounds, clinical applications, and interpretation of results. Includes discussions by the leading authorities in the field.

Scintillation Scanning in Clinical Medicine, Quinn. Charles C. Thomas Co., 1964.

Report of papers presented at a meeting in 1964. Timely in 1964. Still of interest in several areas where good illustrations and back-up material are shown--for example, McAfee's section on Brain Scanning.

Fundamental Problems in Scanning, Gottschalk and Beck (Eds.) Charles C. Thomas Co., 1968.

An excellent technical presentation of the basic problems in radionuclide imaging.

III. Biological Aspects

Dynamic Clinical Studies with Radioisotopes. (Proceedings of Symposium at the Medical Division of Oak Ridge Institute of Nuclear Studies, October 21-25, 1963. Available from Office of Technical Services, U. S. Department of Commerce, Washington D. C.)

Mathematical techniques for the analysis of tracer kinetic data are described and results of research investigations utilizing these formulisms presented. Excellent compendium but difficult for the novice to follow in detail.

Compartments, Pools, and Spaces in Medical Physiology. (Proceedings of a Symposium held at the Oak Ridge Institute of Nuclear Studies, October 24-27, 1966. Available as Conf-661010 from Clearing House for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Va. 22151)

Presentations of methods of compartmental analysis and results of applications to body space, and pool turnover studies are given. Excellent, up to date review for the sophisticated reader and fellow researchers.

Clinical Aspects of Iodine Metabolism, Wayne, Koutras, and Alexander. Blackwell Scientific Publications 1964.

Excellent, succinct, typically British textbook with a strong physiologic approach. Easy reading.

The Thyroid and its Diseases. Means, DeGroot, and Stanbury. McGraw-Hill Book Co., 1963.

A second edition of a classic in the field which has lost little of its original flavor.

Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. (Supplement #16 -A/5216 - Available from the United Nations, New York City)

An excellent review of current knowledge of the effects of irradiation on man and his environment. An excellent summary review of necessary background information in physics, biology and radiobiology.

The Use of Isotopes in Hematology. Lajtha. Charles C. Thomas Co. 1961.

Very short book, well written, which includes information on red cell volume, red cell life span, Vitamin B-12 metabolism, iron metabolism, and autoradiography.

Radioactive Nuclides in Medicine and Biology - Vol. II. Silver. Lea and Febiger Co. 1968.

Comprehensive textbook on nuclear medicine with heavy emphasis on thyroid physiology, the author's specific field of interest.

Radioactive Pharmaceuticals. (Proceedings of Symposium at Oak Ridge Institute of Nuclear Studies, Nov. 1-4, 1965. Available as Conf-651111 - See #5 for address.)

Only book of any comprehensive magnitude dealing with this subject.

Radioisotopes in Medicine: In Vitro Studies. United States Atomic Energy Commission - Division of Technical Information - June 1968. Available as Conf-671111 from Clearing House for Federal Scienfific and Technical Information - See #5 for Address.

Annual Oak Ridge Symposium - Presents up to date information on radioimmunoassay method and applications, activation analysis, and findings derived from cytologic and chromosome labelling studies.

Report of the United Nations Scientific Committee on The Effects of Atomic Radiation. (Supplement #14 -A/5814 - Available from United Nations, New York City (1964).

Excellent two-page summary on radiation carcinogenesis in man. More detailed explanation of summary in annex.

The Thyroid, Sidney Werner. Hoeber Medical Book, 1962.

This book is the most comprehensive text on the thyroid available. Encyclopedic.

Radioisotopes in Medicine.
The United States Army - United States Atomic Energy Commission. Available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C., 1953.

IV. Physical Aspects and Instrumentation.

Radio-tracer Methodology in Biological Science. Wang and Willis. Hall, Inc., 1965.

Good, lucid presentation of basics of radiation measurements.

Organic Scintillation Detectors, Schram. Elsevier Publishing Co., 1963.

This deals primarily with liquid scintillation counting of low energy beta emitters by means of organic fluorescent substances. Excellent description of fundamental aspects of radiation counting systems, per se.

Safe Handling of Radioactive Isotopes in Medical Practice. Quimby. McMillian Co., 1960.

Excellent treatise on the health physics of clinical nuclear medicine.

The Measurement of Clinical Radio-Activity. D.A. Ross and C. C. Craig. (ORNL-4153 - Available from Clearing House for Federal Scientific and Technical Information - See #5 for address)

Excellent discussion of clinical gamma-ray spectrometry addressed to physicians, x-ray technicians, and para-medical personnel.

Nuclear Radiation Physics. Lapp and Andrews. Hall, Inc. 1954.

An old book which has excellent thought-provoking diagrams.

Instrumentation in Nuclear Medicine. Hine. Academic Press, 1967.

A detailed book on instrumentation used in nuclear medicine.

The Basic Physics of Radiation Therapy. Selman. Charles C. Thomas Co., 1960.

Chapter 15, "Medical Use of Radioactive Isotopes," is easily read and is the one of particular interest for nuclear medicine.

Radioactive Nuclides in Radiation and Biology - Vol. I Physics. Quimby and Feidelburg. Lea and Febiger, 1963.

Good basic introduction to radiation physics and instrumentation.

Nuclear Instruments and their Uses. Volume I. Arthur H. Snell. Wiley, 1962.

Excellent.

Source Book on Atomic Energy. Samual Glasstone. D. Van Nostrand Co., Inc., 1950.

Excellent glossary of terms used in nuclear medicine.

Radiological Health Handbook. Edited by Division of Radiological Health, U.S. Department of Commerce, Office of Technical Services, Washington, D.C. (25)

Contents: Glossary of Terms - Physical, chemical and mathematical data - Radioisotope, decay and radioassay data - Radiation protection data - Table of Isotopes (Deacy Schemes).

MIRD - Supplement #1 - Journal of Nuclear Medicine February 1968.

A schema for absorbed-dose calculation for biologically distributed radionuclides. Absorbed fractions for photon dosimetry.

MIRD - Supplement #2 - Journal of Nuclear Medicine March 1969.

Radioactive Decay Schemes.

Nuclear Radiation Detection - Second Edition. William J. Price. McGraw Hill Book Co., New York.

In depth presentation on the principles of operation

of radiation detectors including some electronics. A good chapter on statistics of radiation counting.

Scintillation Spectrometry. Second Edition. R. L. Heath. Clearing House for Federal Scientific and Technical Information. U. S. Department of Commerce, Washington, D. C. (25)

(AEC Report IDO-16880-2)
Volume I - Scintillation Spectrometry
Volume II - Gamma-Ray Spectrum Catalogue

Radioisotopes in the Human Body- Physical and Biological Aspects. F. W. Spiers.

Authoritative work directed particularly to the internal dosimetry of alpha and beta emitters in bone.

V. The Following Four Textbooks are Used in NMT Training at the Nuclear Medicine Institute, Cleveland, Ohio.

Algebra: First Course. Mayor and Wilcox. Prentice Hall

Illustrated Physiology. McNaught and Callander. The Williams and Wilkins Co.

Introductory Chemistry - Third Edition. Lillian Hoagland Meyer. MacMillan.

Structure and Function in Man. Jacob and Francone. Saunders.

VI. Materials Published by Commercial Firms

Abbott Radio-Pharmceuticals. Abbott Laboratories, Inc. 14th and Sheridan Rd. N. Chicago, Ill. 60064.

Fundamentals of Nuclear Medicine. Frank Low. Picker Nuclear, 1275 Mamoraneck Ave. White Plains, N.Y. 10605

Medotopes. E. R. Squibb & Sons, New Brunswick, N.J.

Nuclear Medicine Handbook, The Nucleus. Nuclear Chicago Corp, 333 E. Howard St. Des Plaines, Ill. 60018.

Vignettes in Nuclear Medicine. Marshall Brucer. Mallinckrodt, St. Louis, Mo.

VII. Additional Materials Recommended by Survey Respondents

Basic Concepts of Nuclear Chemistry. R. T. Overman. Reinhold Pub. Corp., 1963.

Basic Principles of Scintillation Counting for Medical Investigators. C. C. Harris, D. D. Hamblen and J. E. Francis. Office of Technical Services, Dept. of Commerce, Washington, D.C.

Clinical Nuclear Medicine. C. Douglas Maynard. Lea and Febiger, 1969.

Clinical Use of Radioisotopes. T. Fields and L. Seed. Yearbook Publishers.

Laboratory Guide to Nuclear Medicine. Revised Edition. U.S. Naval Medical School. National Naval Medical Center. Bethesda, Md. 1969.

A Manual for Nuclear Medicine. King and Mitchell. Charles C. Thomas Co. 1961.

Nuclear Chemistry and its Application. M. Haissinsky. Addison-Wesley, 1964.

Nuclear Chemistry, Technique of Inorganic Chemistry, Volume II. N. R. Johnson, E. Eichler and G. D. O'Kelley. Interscience Publishers, 1963.

Nuclear and Radiochemistry. G. Friedlander, J. W. Kennedy and J. M. Miller. John Wiley and Sons, 1964.

Principles of Radioisotope Methodology - Third Edition. Grafton D. Chase and Joseph L. Rabinowitz. Burgess, 1967.

A Training Manual for Nuclear Medical Technologists. Guy H. Simmons and George W. Alexander. U. S. Dept of Health, Education and Welfare. PHS Bureau of Radiological Health Training and Man-Power Development Program, Rockville, Md.

This manual (247 pages) was prepared for use in the didactic portion of a training program in Nuclear

Medicine Technology taught at the university of Cincinnati. The program was developed under a training grant from the Public Health Service, Bureau of Radiological Health. The purposes of the grant project are to investigate, through pilot programs, various approaches to training NMT's and to develop training materials which can be used by others. The program in which this manual is used leads to the B.S. degree in Medical Technology with a Nuclear Medicine option.

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The Nuclear Medicine Laboratory at Bowman Gray has developed a self-instructional unit in nuclear medicine designed primarily to teach medical students, technicians and residents on an individual basis. It consists of a front viewing carousel-type projection 8mm Fairchild loop projector, and closed-circuit television. All the soft-ware presently being used was made for the laboratory's own use and is not commercially available at this time.

Appendix G: "Radiopharmaceuticals and Instrumentation"

Chapter 1 from Clinical Nuclear Medicine
by C. Douglas Maynard, M.D.

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Clinical Nuclear Medicine

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353 illustrations on 194 figures

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radiopharmaceuticals and instrumentation

Introduction

During the past 5 to 10 years, nuclear medicine has progressed from a minor sub-specialty under the jurisdiction of several fields, primarily radiology, pathology, and internal medicine, to a position in which full recognition as a separate specialty is under consideration. This rapid growth has been due to many factors: the simplicity and low morbidity associated with the procedures; the valuable information not attainable by any other means; the awareness of the clinician as to the worth of the tests; and the increased accessibility due to the introduction of nuclear medicine into hospitals of all sizes. Without question, however, the two major causes for this surge have been the introduction and availability of many new and better radiopharmaceuticals and the development of improved radioisotopic imaging devices.

All persons interested in the application of nuclear medicine in clinical practice should have at least a limited acquaintance with radiopharmaceuticals and instrumentation. With a basic understanding of these subjects, the physician can more logically select the appropriate tests, more skillfully supervise the procedure, and more wisely interpret the results he obtains.

RADIOPHARMACEUTICALS

To understand the principles involved in all radioisotopic procedures, one must have a working knowledge of the composition of the radiopharmaceuticals employed, how they are obtained, their desirable and undesirable characteristics, and how they are utilized to obtain the information sought. Radiopharmaceuticals differ from other medically employed drugs in two ways: (1) they are not generally used to produce a pharmacological effect, and (2) they all contain a radionuclide (radioisotope) which is used for localization and/or measurement in diagnostic procedures and for radiation effects in therapy. No pharmacological response is elicited with the majority of drugs used in nuclear medicine because only very minute quantities are necessary. Radiation effects are apparent only with therapeutic doses.

RADIONUCLIDES

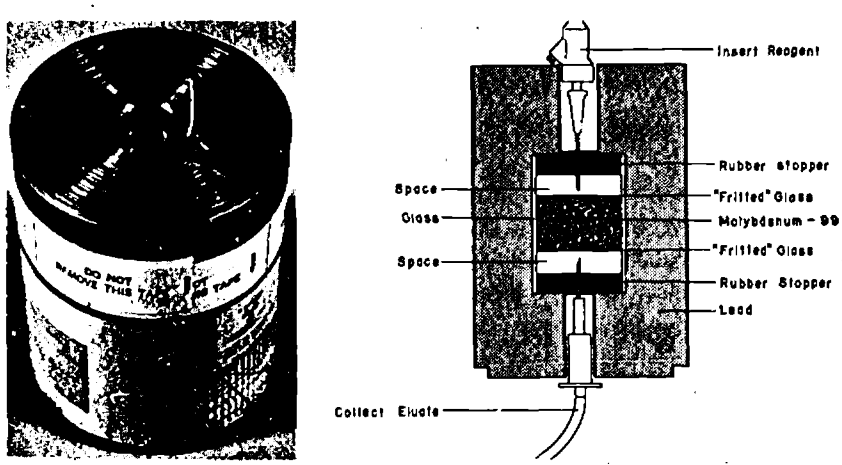
A radionuclide (radioisotope), which is essential to all radiopharmaceuticals, behaves chemically in a manner similar to its nonradioactive counterpart. The difference lies in the fact that the binding energy of the nucleus of the radioactive atom is not sufficient to hold it together, and it disintegrates. In so doing, it emits energy of two types: either *particulate*, such as alpha and beta particles, or *electromagnetic*, such as gamma or X rays. The electromagnetic radiations are employed in most diagnostic tests, particularly with external detection systems (liver scanning, thyroid uptake determination), while the particulate radiations are utilized for internal therapy (treatment of hyperthyroidism) although they can also be satisfactorily employed for sample counting (urine, plasma, etc.) with specialized equipment.

Radionuclides *disintegrate* at a constant rate, with the time required to reach 50% of the original number of atoms referred to as the *physical half-life*. Every radionuclide has a fixed half-life ranging from seconds to years. Most of those used in clinical nuclear medicine have half-lives in the range of minutes to days. Radionuclides generally are measured in terms of the amount of radioactive substance that disintegrates in 1 second. The specific units employed are referred to as curies, named after Marie Curie, and a single curie equals 3.7×10^{10} disintegrations per second. The most commonly employed units in nuclear medicine are the *millicurie* (mCi), which is 3.7×10^7 disintegrations/second, and the *microcurie* (μCi), which is 3.7×10^4 disintegrations/second.

There are a limited number of naturally occurring radioactive elements, mainly among the heavier elements, and these are of little importance in nuclear medicine today. The majority of the radionuclides utilized clinically are obtained by converting stable elements into radioactive forms by means of nuclear reactors or cyclotrons. These unstable forms are "created" by bombarding stable elements with other particles, mainly neutrons. Since most hospital laboratories employing radionuclides in daily practice are not near such installations, the radionuclides available to them are "half-life" limited; that is, their half-life must be long enough to allow for transportation from the maker to the user since radioactive decay naturally occurs during this transit period. Radionuclides with short half-lives, such as fluorine-18 with a half-life of 1.8 hours, are therefore available only to institutions located near these devices.

NUCLIDE GENERATORS

Because of the desirability of short-lived nuclides to reduce patient exposure and to allow the administration of larger amounts to achieve better counting statistics, the *nuclide generator* (Figure 1-1), commonly referred to as a "cow", has been introduced to help solve this problem. These generators consist of a longer-lived parent nuclide that produces a short-lived daughter in its decay scheme (Figure 1-2). The daughter can be separated as needed from the parent and utilized in diagnostic procedures. The necessity for replacement of the generator depends upon the half-life of the parent.



A B

FIG. 1-1. *A. Replaceable "cow" obtained commercially. B. Schematic drawing of the main components of the generator system.*

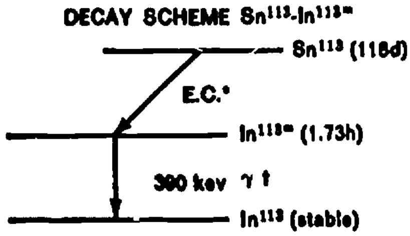
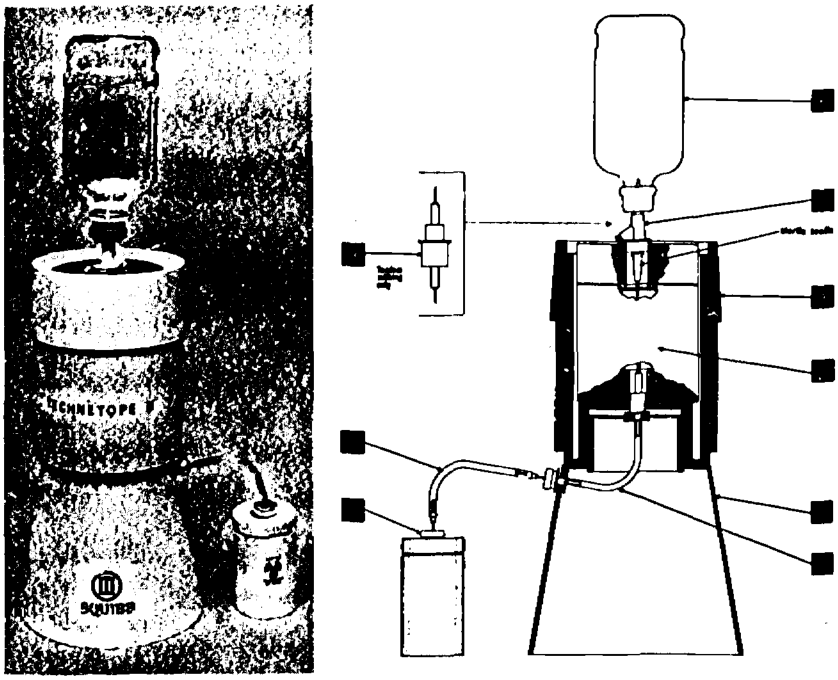


FIG. 1-2. *Decay scheme of tin-113—indium 113m. Tin-113 (the parent) changes by electron capture to indium-113m (the daughter) which decays by emission of a monoenergetic gamma photon of 390 Kev to stable indium-113.*

A generator is comprised of a small container of powdered aluminum on which the parent is firmly attached. As the daughter is "produced", it may be separated from the parent ("milked") by passing the proper reagent through the alumina column and collecting the eluate. The "cow" may be "milked" more than once a day with improved total yields. Most systems come equipped with lead shielding to avoid excessive exposure during the "milking" process (Figure 1-3).

The eluate is then checked for "breakthrough" of the parent (undesirable because of the longer half-life and different energy of the parent) and radioassayed. If obtained from a "closed", sterile generator, it is ready for immediate use or for the preparation of tagged compounds. Presently a number of "open" generators (non-sterile) are available, and the material obtained is neither sterile nor pyrogen-free. In these cases sterilization must be accomplished prior to use, but pyrogen testing, due to the short physical half-life of the nuclide, can be done only after the fact. The systems most commonly employed clinically today are molybdenum-99—technetium-99m, tin-113—indium-113m, yttrium-87—strontium-87m, tellerium-132—iodine-132, and germanium-68—gallium-68.

Although some radionuclides are employed in the ionic form (^{131}I, ^{85}Sr), in the majority of cases the radionuclide is only a part of the radiopharmaceutical, serving as the "tag" to make measurement or detection possible. In these instances, the chemical and biological behavior of the material labeled determines its use in the procedure. In ^{99m}Tc sulfur colloid employed for liver scanning, the ^{99m}Tc plays no role in its localization in the liver. The colloidal material is phagocytized by the reticuloendothelial system in the liver, and this is responsible for its deposition in the organ; the presence of ^{99m}Tc permits its demonstration in the organ by external scintillation detectors. Other radionuclides, such as ^{113m}In and ^{198}Au, can also be prepared in colloidal form and can therefore be satisfactorily employed for liver scanning.



A B

FIG. 1-3. *A. One of several commercially available generators and milking systems. The lead is provided to reduce personnel exposure. The inside system is replaced weekly. B. A cross sectional view of the system. 1. Connector from "cow" to outside system. 2. Lead stand. 3. Replaceable "cow". 4. Lead shielding. 5. Connector to milking reservoir. 6. Reservoir of eluent 7. Multidose vial to collect the eluate. 8. Milking tube (replaced at each milking). 9. Double needle to milk two "cows" in tandem. (Courtesy E. R. Squibb and Sons.)*

The mechanisms of localization are numerous, and the most commonly employed have been outlined by Wagner[1] (Table 1·1). In some instances there are several tagged compounds with different biological behavior which will give similar scans of a specific organ. In these situations, it is extremely important to know the clinical problem involved. An example of this is liver scanning with both radioactive colloid, which gives a picture related to the reticuloendothelial system, and radioiodinated rose bengal, which provides information concerning polygonal cell function and biliary patency. A tagged colloid would be preferred

Table 1-1. *Methods of Localization*

1. Active transport	(example, thyroid scanning with radioiodide)
2. Phagocytosis	(example, liver scanning with tagged colloidal particles)
3. Cell sequestration	(example, spleen scanning with heat damaged tagged red blood cells)
4. Capillary blockage	(example, lung scanning with labeled macro-aggregated albumin)
5. Simple or exchanged diffusion	(example, bone scanning with strontium-85)
6. Compartmental localization	(example, cardiac scanning with tagged human serum albumin)

to determine the presence of a space-occupying lesion, whereas ^{131}I rose bengal would be the agent of choice to evaluate the presence of a patent biliary tract. In cases such as these, multiple tests employing different mechanisms of localization may be used to obtain complementary information.

In organ system visualization, two general types of "pictures" are obtained. The first is that in which the administered tagged compound localizes in the abnormal area and thus appears as a region of increased uptake or a "hot" area, as in brain and bone scanning. The second is that in which the scanning agent localizes in the normal tissue of an organ or organ system, with the abnormal areas presenting as areas of decreased to absent activity or "cold" areas, as in liver and thyroid scanning. In general, the scans are more satisfactory if the abnormal area concentrates the tagged material.

SELECTION OF A RADIOPHARMACEUTICAL

No single group of characteristics can be utilized in the selection of a radiocompound for all uses in clinical nuclear medicine since a desirable characteristic in one instance may be undesirable in another. For example, the beta radiation from ^{131}I is useless in thyroid scanning, but essential in ^{131}I therapy for hyperthyroidism. Certain factors, however, should be considered in choosing a radiopharmaceutical for use in a given laboratory: the type of radioactive decay and physical half-life of the radionuclide; the biological behavior of the tagged material; the specific activity of the radiopharmaceutical; the type of instrumentation available for use; the radiation exposure to the patient; and certainly the cost to the patient.

The *type of radioactive decay* is of considerable importance since only gamma rays, X rays, and annihilation radiation are suitable for external detection. Practically speaking, gamma rays under 500 Kev are preferable since higher energy radiations may penetrate the shielding of the crystal and the septa of the collimators, causing a decrease in spatial resolution (maximum ability of a detection system to separate small changes in the distribution of radioactivity). A radionuclide with extremely low energy (less than 20 Kev is unsatisfactory) may also present problems since many photons may be absorbed by the tissue prior to reaching the detector, and some instruments are not constructed to handle them with any efficiency. Radionuclides with multiple gamma ray energies are also less desirable since generally only one "peak" is utilized and the others add radiation exposure to the patient and may distort the count rate or image due to scattered radiation. In diagnostic procedures associated emissions of beta particles, conversion electrons, and low energy photons, which have a limited range in tissue, are likewise undesirable since they add to the patients' exposure without contributing useful information. Consequently, in most diagnostic procedures, a radionuclide with a pure gamma or X ray emission without particulate radiation is desirable. In therapy the particulate radiation, usually beta, contributes a major portion of the absorbed dose and is therefore essential.

The *physical half-life* (previously discussed) is of obvious importance, but of equal importance is the *biological half-life* (time required for 50% of the original substance to be removed from an organ or the body by means of excretion, exhalation, etc.), since the combination of these two results in the *effective half-life* (time for 50% of the administered radionuclide to be removed from an organ or the body) and determines radiation exposure. An effective half-life of 1 to $1\frac{1}{2}$ times the time required to perform the test is generally accepted to be ideal for diagnostic procedures.

The *biological behavior* is important in determining the radiation exposure to each individual organ system as well as in interpreting the results. Where the radiopharmaceutical accumulates, what its turn-over rate is in these areas, and when and how it is eliminated from the body all play a part in establishing the exposure rate to individual organ systems. The "critical" organ is that one which receives the highest absorbed dose from a given radiopharmaceutical. Information concerning biological behavior is also necessary to interpret many tests adequately. For example, the excretion of ^{85}Sr by the bowel is important in determining when a bone scan of the pelvis should be performed since shortly after administration the normal presence of the radionuclide in the colon may cause some difficulty in interpretation. By waiting several days, excretion of this material makes interpretation easier.

Specific activity refers to the number of radioactive atoms in relation to the number of non-radioactive atoms of the same material. This is usually expressed in millicuries per gram. Specific activity is of particular importance in instances when it is desirable to administer only that amount of a substance that is essential since untagged material does not contribute photons for detection. An example of this is in the study of the cerebrospinal fluid flow with tagged (^{131}I or ^{99m}Tc) human serum albumin. Large amounts of albumin administered intrathecally may cause aseptic meningitis;[2] therefore, a high specific activity material is mandatory. "Carrier-free" material refers to those cases in which all of the material is tagged, and the specific activity is the highest possible.

The *type of instrumentation* available must definitely play a role in the selection of the radiopharmaceutical for a specific laboratory, since certain instruments are designed to be more effective with radionuclides within a specific energy range. Most camera systems, for example, are not satisfactory with low energy radionuclides such as ^{125}I. Also, the effective half-life of the radiopharmaceutical must be considered in relationship to the equipment available since a compound with a 1-minute half-life cannot be satisfactorily utilized with a device that takes hours to perform the procedure.

Another factor to be considered is the *cost of the procedure*. At times this is difficult because of the many factors involved in selecting a radiopharmaceutical. Generally in practice, an attempt must be made to achieve the most information at the least possible cost to the patient, in expense as well as in radiation exposure.

INSTRUMENTATION

Just as it is necessary to have some understanding of radiopharmaceuticals to select, supervise and interpret radioisotopic procedures, it is equally important to have some basic knowledge concerning the instrumentation involved. After the administration of the appropriate radiopharmaceutical, radiation detection devices are necessary to perform five broad categories of tests: (1) *dilution, absorption,* and *excretion studies*, where a known amount of radiopharmaceutical is administered to a patient and the dilution which occurs or the percentage that is absorbed or excreted in a specific time period is determined by collecting a sample of blood constituents, urine, stool, or other body fluid and comparing it to a known amount of the original substance administered (Schilling test, blood volume, Triolein absorption); (2) *concentration studies*, where a radiopharmaceutical is given to the patient and the percentage localization in an organ or region is measured by comparing it to a known sample of the material (thyroid uptake); (3) *dynamic function studies*, where the administered radiopharmaceutical is observed as it arrives and/or leaves a particular organ or region (cerebral blood flow, renogram); (4) *organ system or "pool" visualization*, where following administration, the distribution of the radiocompound is displayed in pictorial fashion (brain and cardiac blood pool scanning); and (5) *"in vitro" tests*, where the radiopharmaceutical is added not to the patient but to a sample of the patient's blood constituents to indirectly determine the amount of a specific substance present (T-3, T-4 tests). Often two or more of these tests are used jointly to obtain complementary information, as with the thyroid uptake (a concentration study) and the thyroid scan (an organ system visualization).

It is obvious that, with the diversity of performance necessary to achieve satisfactory results with all these different tests, no one instrument is available which can do them all. Although there are a large number of radiation detection devices which operate on several different basic principles (gas ionization chamber, cloud chamber, etc.), the scintillation counter is by far the most widely employed in everyday clinical nuclear medicine.

SCINTILLATION COUNTERS

The scintillation counter basically consists of a *detector system* and a *processing and display unit* (Figure 1-4). The detector system is generally made up of a sodium iodide crystal (thallium activated), optically coupled to a photomultiplier tube (Figure 1-5). When photons strike this crystal, flashes of blue-violet light or scintillations occur. The crystal is shielded and collimated, usually with lead, so that only incoming photons from the source can strike it. The crystal itself is transparent to light and is enclosed in a light-tight container. Between it and the surrounding container is a powder to reflect light out only through the area of the crystal adjacent to the photomultiplier tube. When these flashes of light reach the sensitive surface of the photomultiplier tube (usually made of substances such as cesium and antimony whose electrons are easily dislodged by light), a pulse of electrons is released. These are amplified in the photomultiplier tube and are transmitted through a preamplifier to the main unit to be further amplified. From here the pulses are ready for processing and display. The output signal from the detector system is directly related to the total light emitted, and this is proportional to the energy released in the crystal by the gamma photon.

An integral part of most detector systems is a *collimator*. It is designed to allow the detector to "see" only those photons coming from a specific area

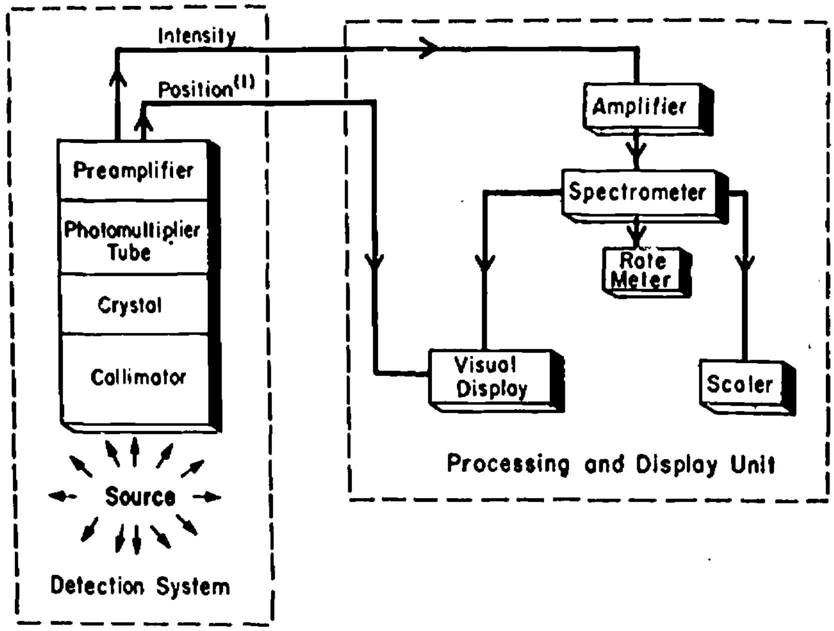


FIG. 1-4. *Block diagram of a scintillation counter in simplified form.*[1] *Only necessary for camera systems.*

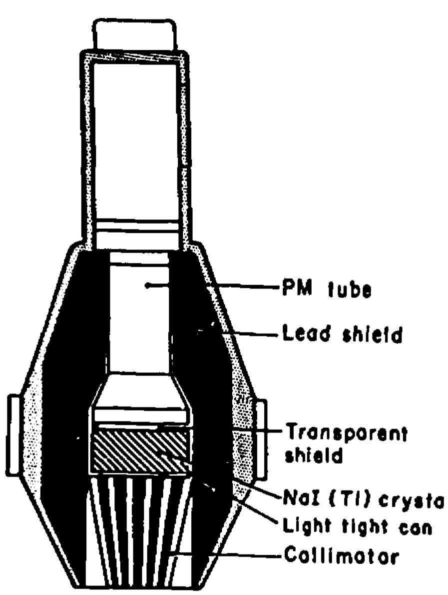


FIG. 1-5. *Simplified drawing of the basic components of most scintillation detection units.*

in the patient while rejecting others. There are several types of collimators, with the most commonly employed being the wide angle, the parallel multichannel, and the focusing multichannel (Figure 1-6). Each type is designed for a specific purpose. The wide angle, for instance, is used when only counts from a large field of view are desired, such as with the thyroid uptake. Parallel multichannel collimators are employed mainly with the camera systems, which also view a large area but are designed to help produce an image of the distribution of the radiopharmaceutical, as with liver imaging. Focusing collimators are commonly employed with scanning devices and are used to view a small area, usually at a depth within the patient, as in brain and liver scanning. The focusing collimator is constructed to increase the number of photons utilized from a given region. Most commercial imaging devices come equipped with several interchangeable collimators with varying numbers of holes and depths of focus. Since the shielding requirements for low energy photons are much less than for high energy ones, the septa have to be thicker with the higher energy photons, allowing less of the crystal to be used. In general terms, the collimator with more holes has

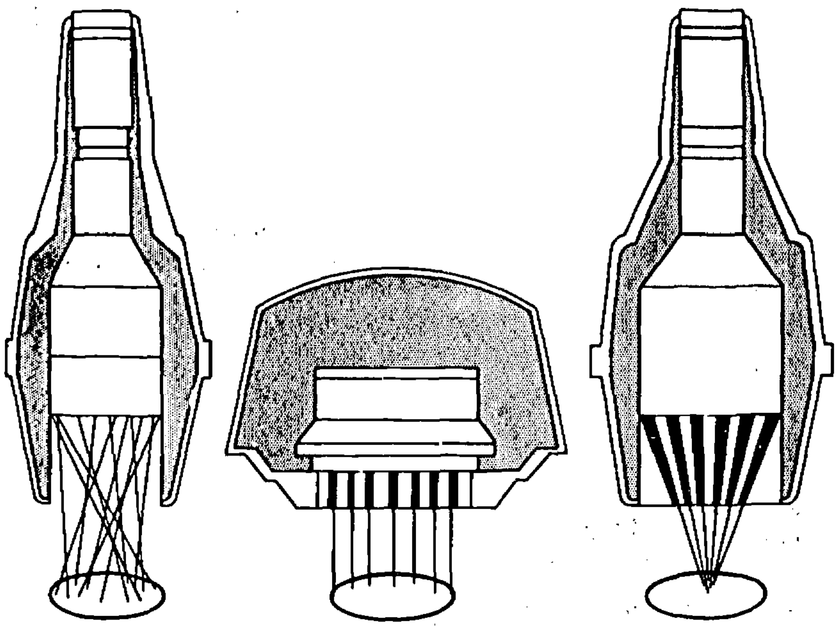


FIG. 1-6. *The three types of collimators commonly utilized in nuclear medicine.*

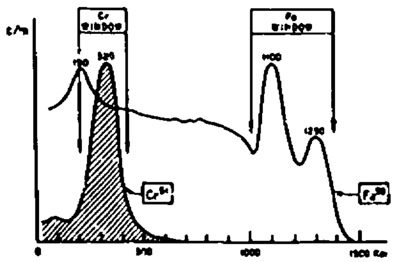


FIG. 1-7. *Schematic indicating the manner in which a spectrometer "window" can be adjusted to see either the major peak of one isotope or to count two separate peaks in the presence of each other. In the case of the Fe window no Cr will be counted; with the Cr window there is contribution from the Fe. From ORNL-4153.*[4]

increased resolution, but decreased sensitivity (number of counts measured in relation to the number emitted), and vice versa for a collimator with less holes.

From the detector system, the electrical pulses are generally directed to a *processing unit*. Usually the gamma spectrometer is a part of this unit. It is an instrument which can be preset to sort the spectrum of gamma energies and accept or reject those of a specific pulse height (energy). This allows the "counting" of only those photons desired, thus eliminating those which have been somewhat attenuated in the patient (scattered radiation) or which may be photons of different energies emitted by the nuclide administered. It also permits the measurement of one gamma emitting isotope in the presence of a second if their energies are somewhat apart (Figure 1-7). The "window", as the spectrometer setting is commonly called, may be adjusted to reject all pulses both below and above certain energy levels. it can usually be moved up and down the spectrum and adjusted in width to encompass only one or more "peaks" of the nuclides administered.

From the spectrometer, the selected information is sent forward to be *displayed* in some form, either as counts on a scaler, a needle deflection on a rate meter, a "dot" on special types of paper, a specific color on paper, or a flash of light on a photographic film or an oscilloscope. Often more than one type of presentation is possible in the same instrument.

The instruments currently available can be divided into four major categories: stationary probes, well counters, scanners, and cameras. Obviously they are designed to be employed for somewhat different purposes.

STATIONARY PROBES

Stationary probes are used mainly for tests of concentration in an organ or a region and for dynamic function studies. A large number are available commercially, commonly equipped with one or more probes of varying sizes (Figure 1-8) and wide angle collimators. The information is normally presented

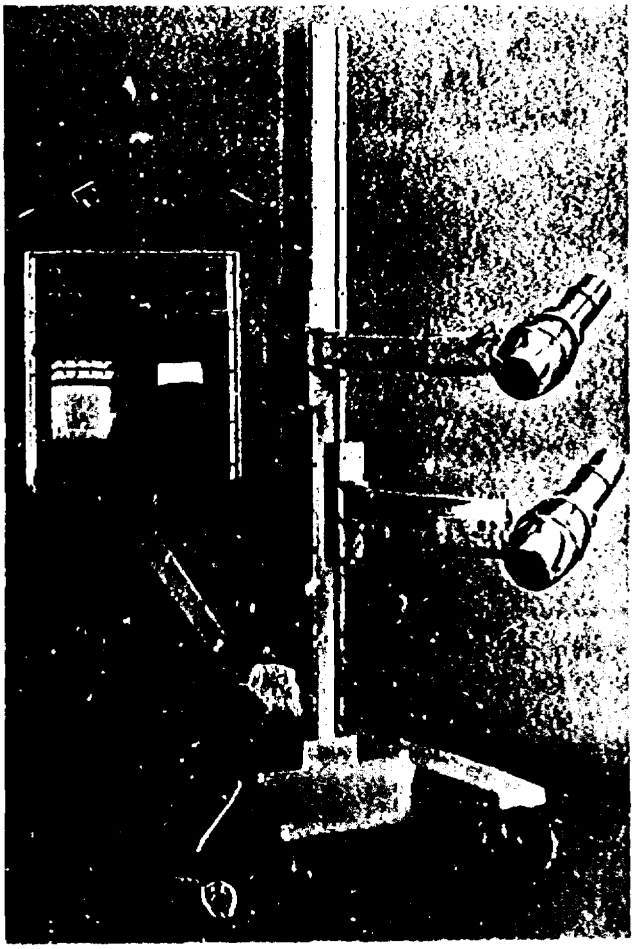


FIG. 1-8. *Commercially available two probe detector designed mainly for renography (Courtesy Nuclear-Chicago Corporation.)*

as counts per/unit time, time required to obtain a preselected number of counts, or a tracing on a paper chart recording.

WELL COUNTERS

These operate on the same basic principle but are constructed mainly for counting samples of urine, blood constituents, feces, etc. They are commonly

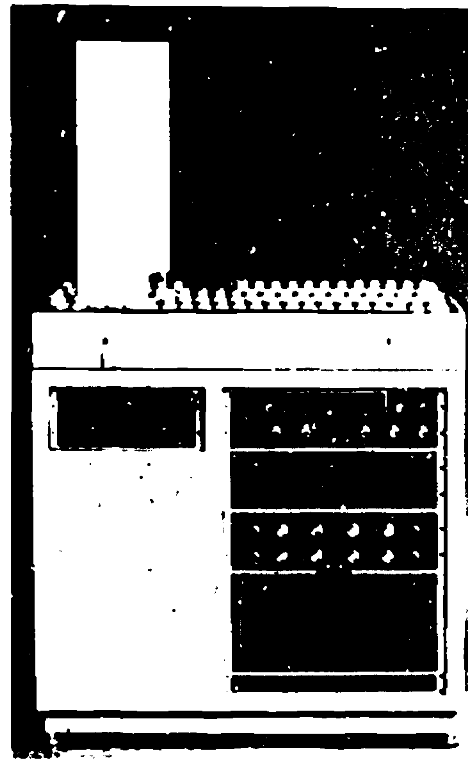
FIG. 1-9. Manual well counter designed to count vials or larger containers. Note considerable lead shielding to decrease background counts. (Courtesy Nuclear Division, Picker X-Ray Corporation.)

used in dilution, absorption and excretion studies, in *in vitro* tests, and in counting samples of tissue removed at surgery. Manual single vial units (Figure 1-9) are available as well as automatic scintillation gamma counters in which 50 to 100 vials can be loaded and systematically counted (Figure 1-10). They normally express the results in counts per minutes or record the time required to achieve a pre-selected number of counts.

SCANNERS

Widely employed, these instruments are designed to produce two-dimensional "pictures" of the distribution of a radiocompound in an organ system. They can also be used to do some tests of concentration, dilution, excretion, and absorption. Organ scanning is accomplished by the systematic movement of a scintillation detection assembly, generally equipped with a focusing collimator, scanning back and forth across the area of interest (Figure 1-11). The detector "sees" only a small region at a time, and the total "picture" is built up line by line until the preset pattern is completed. This is displayed on a photographic film, an oscilloscope, or a special type of paper with the differences in concentration of the nuclide depicted by changes in density on the film, in brightness on the oscilloscope, or in different colors or numbers of "dots" on the paper recordings.

FIG. 1-10. Automatic well counter. (Courtesy Nuclear-Chicago Corporation.)



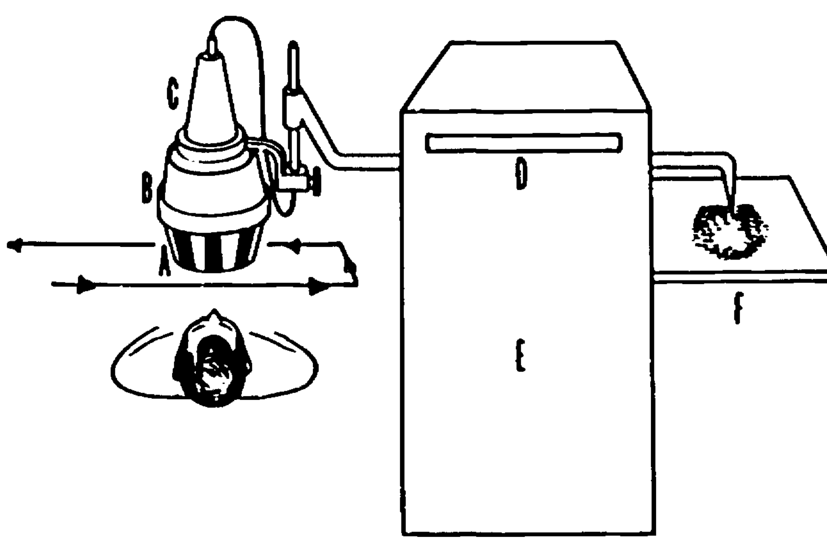


FIG. 1-11. Schematic of a mechanical rectilinear scanner. A. Collimator. B. Scintillation detecting unit. C. Photomultiplier tube. D. Photo recording aspect. E. Processing unit. F. "Dot" recording unit.

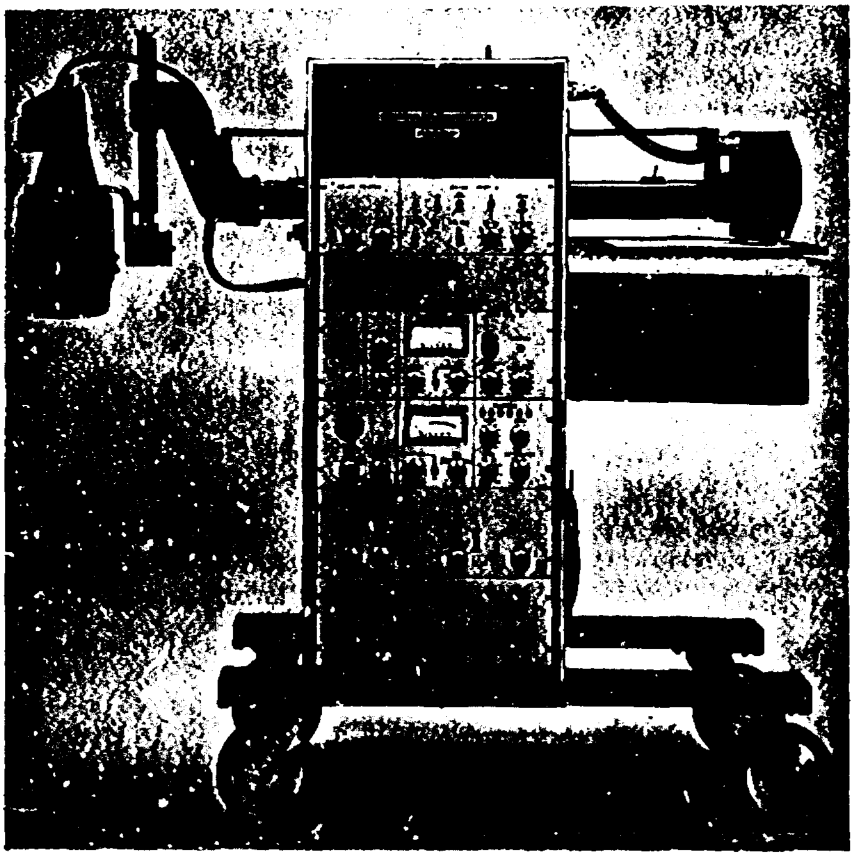


FIG. 1-12. *Commercially available 5 x 2 inch rectilinear scanner with color attachment. (Courtesy Nuclear Division, Picker X-Ray Corporation.)*

Scanners are available in many types, with the principal differences being in the size and number of the sodium iodide crystals they possess. The most commonly employed is the single detector system with a crystal 3 inches in diameter by 2 inches thick; however, 5 x 2 inch (Figure 1-12) and 8 x 2 inch single and dual detector systems (Figure 1-13) are increasing in popularity. Also available is one multiprobe scanner (Figure 1-14) with 10 separate sodium iodide crystals 6 x $\frac{3}{4}$ x 2 inches in size, each coupled to a photomultiplier tube (Figure 1-15). As a region is scanned, ten lines are drawn with each passage instead of one as with the commonly employed 3 x 2 inch scanner. Complete "pictures"

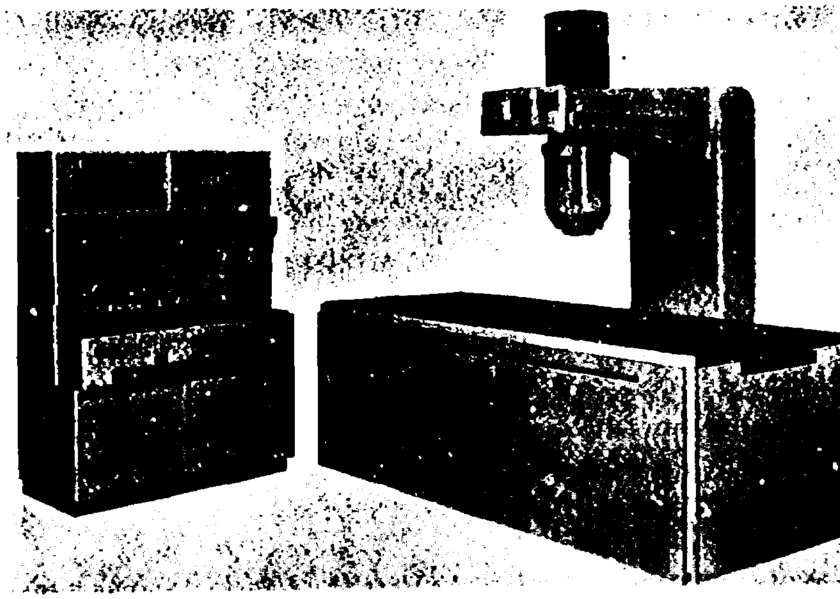


FIG. 1-13. *Dual head scanning system with one detection system above the table and the second mounted under the table (not visualized). They move as a paired unit and produce two views at one time. Example: both lateral brain projections. (Courtesy Ohio-Nuclear, Inc.)*

FIG. 1-14. *A Multiprobe scanner (Dynapix) with detecting and processing units. (Courtesy Picker X-Ray Corporation.)*

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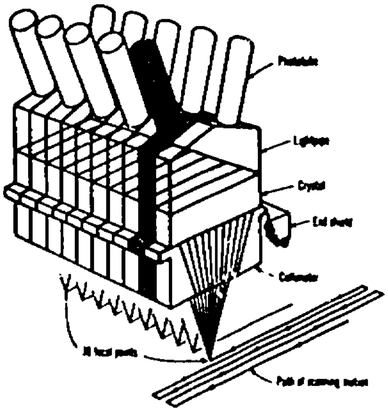

FIG. 1-15. *Schematic of detector/collimator assembly of the unit in Figure 1-14. (Hindel and Gilson, Multicrystal Scanner is Rapid and Versatile. Nucleonics 25:52, 1967.)*

may be achieved in 4, 8, or 16 sweeps of the detector unit. In scanning instruments, the size and number of crystals is of importance in that they are closely related to the time required to perform the procedure. Generally speaking, with the larger crystals and/or increased number of detectors, the time required to perform a scan is decreased.

CAMERAS

A radioisotope camera is an imaging device that can produce a "picture" without movement of the detector. It has the ability to "see" some organs in their entirety and to display visually changes in an organ during a dynamic function test. Most are constructed so the detector head can be positioned to do organ imaging either in the recumbent or the sitting position.

Presently there are three commercially available cameras which utilize the basic principle of the scintillation counter and come equipped with several types of collimators for use with different radionuclides or organ systems.[3,4] Two consist of a large sodium iodide crystal coupled with multiple (19) photomultiplier tubes (Figure 1-16). The photomultiplier tubes view overlapping areas so that the light created in the crystal by a scintillation is divided among the 19 tubes (Figure 1-17). The photo tubes are connected to an analog computer which identifies the position and brightness of each scintillation. The scintillations are then reproduced on an oscilloscope in the same X-Y coordinates as they occur in the crystal. They may be stored on an oscilloscope or photographed and reproduced on film (usually Polaroid) for visualization.

The second camera system consists of a rectangular matrix of 294 small

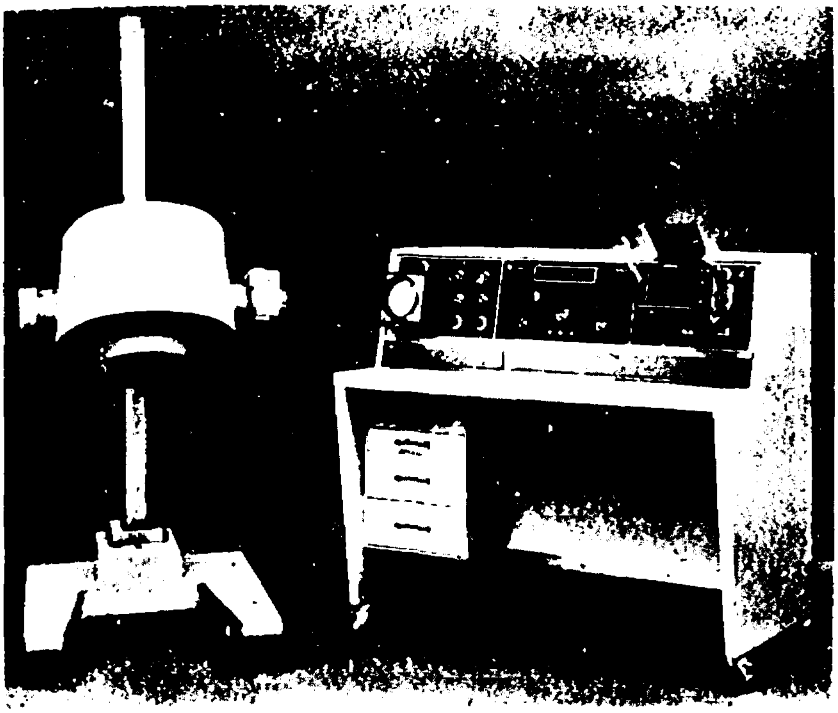

FIG. 1-16. One of the commercially available camera systems with detecting unit (left) and processing console (right). (Courtesy Nuclear-Chicago Corporation.)

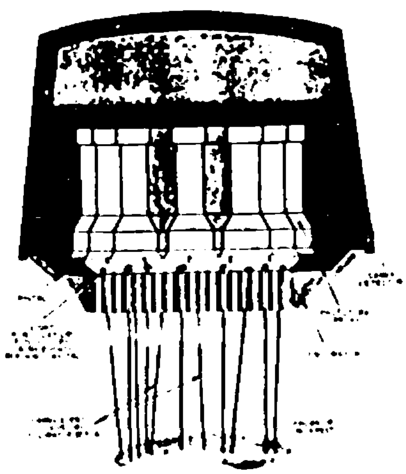

FIG. 1-17. Schematic of the detector/collimator assembly of the system depicted in Figure 1-16. The crystal is 11 inches in diameter and ½ inch thick backed by a hexagonal array of 19 photomultiplier tubes. (From Instructional Manual-Nuclear-Chicago Corporation.)

FIG. 1-18. *Autofluoroscope. (Courtesy Baird-Atomic Corporation.)*

individual crystals, each linked electronically to its own magnetic core memory (Figure 1-18). The resulting picture can be reproduced on an oscilloscope by displaying the data collected by each crystal individually.

Recently introduced is another camera which does not employ the scintillation crystal principle but is an image intensifier similar to those employed in diagnostic radiology.[5] It is at present in limited use and can only be employed with low energy isotopes (preferably below 150 Kev).

POSITRON DETECTING SYSTEM

The use of the positron should be mentioned since considerable investigation is now under way in this area. Annihilation of a positron is usually accompanied by the emission of two 0.51 Mev photons in opposite directions. The basic concept is to use two opposing detector systems, constructed to record data only when "hit" simultaneously by the photons derived by annihilation. This allows for adequate collimation without the need for lead collimators. Both scanning and camera systems have been constructed on this principle.

Conclusion

There are large numbers of different types of radiopharmaceuticals, each designed to localize in a specific organ system. Likewise, there are several types of radiation detection devices available which are constructed to perform specific functions. An understanding of these two areas is essential to the proper application of nuclear medicine to clinical practice. Since there is constant change in the radiocompounds available due to their development by both commercial radiopharmaceutical houses and research personnel in medical centers, a reassessment should be made periodically to decide if the radiocompound being employed is the best one to provide the information desired with the least radiation to the patient. With the design of other radiation detection systems, it is also apparent that not only will the procedures be improved in the future, but more information may be derived as well.

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Appendix H: Hospitals Participating in Survey

Alabama
- Huntsville
  - Huntsville Hospital
- Mobile
  - Providence Hospital
- Montgomery
  - Jackson Hospital and Clinic

Arizona
- Phoenix
  - Veterans Administration Hospital
- Tucson
  - Tucson Medical Center
  - Veterans Administration Hospital

Arkansas
- Little Rock
  - Arkansas Baptist Medical Center
  - University Hospital, University of Arkansas Medical Center

California
- La Jolla
  - Scripps Clinic and Research Foundation Hospital
- Lancaster
  - Antelope Valley Hospital
- Los Angeles Metropolitan Area (Interviews)
  - Holy Cross Hospital
  - Huntington Memorial Hospital
  - Loma Linda University Hospital
  - Long Beach Community Hospital
  - Los Angeles County General Hospital and University of Southern California Medical Center
  - Memorial Hospital of Long Beach
  - St. John's Hospital
  - St. Mary's Long Beach Hospital
  - St. Vincent's Hospital
  - University of California at Los Angeles Hospital
  - White Memorial Medical Center
- Napa
  - Queen of the Valley Hospital
- San Francisco Metropolitan Area (Interviews)
  - Alta Bates Community Hospital
  - French Hospital
  - Letterman General Hospital
  - Marin General Hospital
  - Mount Zion Hospital and Medical Center
  - Presbyterian Hospital and Medical Center of San Francisco
  - Samuel Merritt Hospital
  - San Francisco General Hospital
  - U.S. Public Health Service Hospital
  - University of California Hospitals (University of California Medical Center)

Veterans Administration Hospital

Colorado

Denver Metropolitan Area (Interviews)

Colorado General Hospital (part of University of Colorado Medical Center)

Denver General Hospital

Fitzsimons General Hospital

General Rose Memorial Hospital

Lutheran Hospital and Medical Center

Mercy Hospital

Porter Memorial Hospital

Presbyterian Medical Center

St. Anthony Hospital

St. Luke's Hospital

Swedish Hospital

Veterans Administration Hospital

Connecticut

Bridgeport

Bridgeport Hospital

Middletown

Middlesex Memorial Hospital

Norwalk

Norwalk Hospital

Delaware

Wilmington (Interview)

Wilmington Medical Center, Memorial Hospital

District of Columbia

Metropolitan Area (Interviews)

District of Columbia General Hospital

Doctor's Hospital

Georgetown University Hospital

Morris Cafritz Memorial Hospital

St. Elizabeth's Hospital

Sibley Memorial Hospital

Veterans Administration Hospital

Walter Reed General Hospital

Washington Hospital Center

Florida

Miami Beach

St. Francis Hospital

Miami Metropolitan Area (Interviews)

Doctor's Hospital

Jackson Memorial Hospital

Mercy Hospital

Miami Heart Institute

Mount Sinai Hospital of greater Miami

North Miami General Hospital

North Shore Hospital

South Miami Hospital

Veterans Administration Hospital

Victoria Hospital

Tampa

Tampa General Hospital

Georgia
- Atlanta (Interviews)
  - Crawford W. Long Memorial Hospital of Emory University
  - Emory University Hospital
  - Georgia Baptist Hospital
  - Grady Memorial Hospital
  - South Fulton Hospital
  - Veterans Administration Hospital
- Savannah
  - Warren A. Candler Hospital

Hawaii
- Hilo
  - Hilo Hospital
- Honolulu
  - St. Francis Hospital
  - U.S. Army Tripler General Hospital

Illinois
- Alton
  - Alton Memorial Hospital
- Champaign
  - Burnham City Hospital
- Chicago (Interviews)
  - American Hospital of Chicago
  - Augustana Hospital
  - Chicago Wesley Memorial Hospital
  - Children's Memorial Hospital
  - Columbus Hospital
  - Cook County Hospital
  - Franklin Boulevard Community Hospital
  - Grant Hospital of Chicago
  - Holy Cross Hospital
  - Illinois Central Hospital
  - Illinois Masonic Medical Center
  - Jackson Park Hospital
  - Louis A. Weiss Memorial Hospital
  - Mercy Hospital
  - Michael Reese Hospital and Medical Center
  - Mount Sinai Hospital Center of Chicago
  - Northwest Hospital
  - Presbyterian-St. Luke's Hospital
  - Provident Hospital and Training School
  - Ravenswood Hospital
  - St. Elizabeth's Hospital
  - St. Joseph Hospital
  - St. Mary of Nazareth Hospital
  - Swedish Covenant Hospital
  - South Chicago Community Hospital
  - University of Chicago Hospitals and Clinics
  - University of Illinois Research and Educational Hospitals
  - Veterans Administration Research Hospital
  - Veterans Administration West Side Hospital

Evanston
St. Francis Hospital
Kankakee
Riverside Hospital
Pekin
Pekin Memorial Hospital
Rockford
Swedish-American Hospital
Urbana
Carle Memorial Hospital

Indiana
Greenfield
Hancock County Memorial Hospital
Lafayette
St. Elizabeth Hospital
Richmond
Reid Memorial Hospital

Iowa
Cedar Rapids
St. Luke's Methodist Hospital

Kansas
Dodge City
St. Anthony Hospital
Kansas City (Interviews)
Providence Hospital
University of Kansas Medical Center

Kentucky
Louisville
John N. Norton Memorial Infirmary
South Williamson
Williamson Appalachian Regional Hospital

Louisiana
New Orleans (Interviews)
Charity Hospital of Louisiana at New Orleans
Hotel Dieu Sisters' Hospital
Mercy Hospital
Methodist Hospital
Ochsner Foundation Hospital
Southern Baptist Hospital
Tuoro Infirmary
U.S. Public Health Service Hospital
Veterans Administration Hospital

Maine
Augusta
Augusta General Hospital
Portalnd
Maine Medical Center
Waterille
Thayer Hospital

Maryland
Baltimore (Interviews)

Church Home and Hospital of the City of Baltimore
Johns Hopkins Hospital
North Charles General Hospital
St. Agnes Hospital of the City of Baltimore
St. Joseph Hospital
Sinai Hospital of Baltimore
University of Maryland Hospital

Bethesda (Interviews)
Clinical Center, National Institutes of Health
U.S. Naval Hospital

Camp Springs
U.S. Air Force Hospital

Fort George G. Meade
Kimbrough Army Hospital

Frederick
Frederick Memorial Hospital

Massachusetts

Beverly
Beverly Hospital

Boston Metropolitan Area (Interviews)
Beth Israel Hospital
Carney Memorial Hospital
Children's Hospital Medical Center
Faulkner Hospital
Mount Auburn Hospital
New England Deaconess Hospital
Norwood Hospital
Peter Bent Brigham Hospital
St. Elizabeth's Hospital
New England Medical Center
Veterans Administration Hospital

Fall River
St. Anne's Hospital

Holyoke
Providence Hospital

Framingham
Framingham Union Hospital

Lowell
St. Joseph's Hospital

Methuen
Bon Secours Hospital

North Adams
North Adams Hospital

Pittsfield
St. Luke's Hospital

Springfield
Mercy Hospital

Stoneham
New England Sanitarium and Hospital

Taunton
Taunton State Hospital

- Worcester
    - St. Vincent Hospital
- Michigan
  - Detroit (Interviews)
    - Grace Hospital - Northwest Unit
    - Harper Hospital
    - Henry Ford Hospital
    - Mount Carmel Mercy Hospital
    - Sinai Hospital of Detroit
  - Flint
    - Hurley Hospital
  - Midland
    - Midland Hospital
- Minnesota
  - Minneapolis-St. Paul (Interviews)
    - Bethesda Lutheran Hospital
    - Charles T. Miller Hospital
    - Fairview Hospital
    - Lutheran Deaconess Home and Hospital
    - Midway Hospital
    - Mount Sinai Hospital
    - North Memorial Hospital
    - Northwestern Hospital of Minneapolis
    - St. John's Hospital
    - St. Luke's Hospital
    - St. Mary's Hospital
    - University of Minnesota Hospital
    - Veterans Administration Hospital
- Missouri
  - Kansas City (Interviews)
    - Baptist Memorial Hospital
    - Kansas City General and Medical Center
    - Menorah Medical Center
    - Research Hospital and Medical Center
    - St. Luke's Hospital of Kansas City
    - St. Mary's Hospital
    - Veterans Administration Hospital
  - St. Louis (Interviews)
    - St. Louis City Hospital - Max C. Starkloff Memorial
    - Daconess Hospital
    - DePaul Hospital
    - Homer G. Phillips Hospital
    - Lutheran Hospital
    - Mallinckrodt Institute
    - Missouri Baptist Hospital
    - St. John's Mercy Hospital
    - St. Louis University Hospital
    - St. Luke's Hospital
    - Veterans Administration Hospital
  - Springfield
    - St. John's Hospital

Montana
- Billings
  - Billings Deaconess Hospital
- Butte
  - St. James Community Hospital
- Great Falls
  - Columbus Hospital
- Missoula
  - St. Patrick Hospital

Nebraska
- Lincoln
  - St. Elizabeth Hospital

Nevada
- Las Vegas
  - Sunrise Hospital
  - Southern Nevada Memorial Hospital

New Jersey
- Orange
  - Orange Memorial Hospital Unit
- Somerville
  - Somerset Hospital

New Mexico
- Albuquerque
  - Bernalillo County-Indian Hospital
- Hobbs
  - Lea General Hospital

New York
- Binghamton
  - Our Lady of Lourdes Memorial Hospital
- Buffalo
  - Veterans Administration Hospital
- Ithaca
  - Tompkins County Hospital
- Mount Vernon
  - Mount Vernon Hospital
- New York City (Interviews)
  - Beth Israel Hospital
  - French Hospital
  - Hospital for Special Surgery (Cornell School of Medicine)
  - Jewish Memorial Hospital
  - Lenox Hill Hospital
  - New York Medical College - Flower and Fifth Avenue Hospitals
  - New York University Medical Center
  - Presbyterian Hospital in the City of New York
  - Roosevelt Hospital
  - St. Vincent's Hospital and Medical Center of New York
  - Nathan B. Van Etten Tuberculosis Hospital
  - Veterans Administration Hospital
- New York City (Mailed Sample)
  - Maimonides Hospital of Brooklyn

Mt. Sinai Hospital
U.S. Public Health Service Hospital
Willowbrook State School
Schenectady
St. Clare Hospital of Schenectady
Yonkers
St. John's Riverside Hospital
North Carolina
Charlotte
Charlotte Memorial Hospital
Durham
Duke University Medical School
Raleigh
Rex Hospital
North Dakota
Bismarck
St. Alexius Hospital
Minot
St. Joseph's Hospital
Ohio
Akron
Akron City Hospital
Canton
Mercy Hospital of Canton
Cleveland Metropolitan Area (Interviews)
Cleveland Clinic Hospital
Hillcrest Hospital
Lakewood Hospital
Mount Sinai Hospital of Cleveland
St. Vincent Charity Hospital
Suburban Community Hospital
University Hospitals of Cleveland
Veterans Administration Hospital
Woman's Hospital
Columbus
Riverside Methodist Hospital
Kettering
Charles F. Kettering Memorial Hospital
Sandusky
Good Samaritan Hospital
Troy
Dettmer Hospital
Oklahoma
Oklahoma City
Presbyterian Hospital
Tulsa
St. Francis Hospital
Oregon
Portland
Good Samaritan Hospital and Medical Center
Pennsylvania
Altoona
Mercy Hospital
Bradford
Bradford Hospital

Drexel Hill
- Delaware County Memorial Hospital

Harrisburg
- Harrisburg Hospital

Lancaster
- Lancaster General Hospital

New Kensington
- Citizens General Hospital

Oil City
- Oil City Hospital

Philadelphia (Interviews)
- Albert Einstein Medical Center (Northern Division)
- American Oncologic Hospital (Cancer and Allied Diseases)
- Graduate Hospital of the University of Pennsylvania
- Hahnemann Medical College and Hospital of Philadelphia
- Jeanes Hospital
- Jefferson Medical College Hospital
- Methodist Episcopal Hospital
- Misericordia Hospital
- Northeastern Hospital of Philadelphia
- Pennsylvania Hospital
- Philadelphia General Hospital

Pittsburgh
- Allegheny General Hospital

Somerset
- Somerset Community Hospital

Rhode Island

Providence
- Roger Williams General Hospital
- Veterans Administration Hospital

Woonsocket
- John E. Fogarty Memorial Hospital

South Dakota

Sioux Falls
- Sioux Valley Hospital

Tennessee

Knoxville
- East Tennessee Baptist Hospital
- St. Mary's Memorial Hospital

Memphis
- Baptist Memorial Hospital
- Veterans Administration Hospital

Nashville
- Vanderbilt University Hospital

Texas

Dallas Metropolitan Area (Interviews)
- Baylor University Medical Center
- Collin Memorial Hospital

Methodist Hospital of Dallas
Parkland Memorial Hospital-Dallas County Hospital District
Presbyterian Hospital of Dallas
St. Paul Hospital
Veterans Administration Hospital

Fort Worth (Interviews)
Fort Worth Radiation Center (The Radiation Center and Medical Research Foundation of the Southwest)
Harris Hospital
St. Joseph Hospital

Houston
Ben Taub General Hospital
University of Texas M.D. Anderson Hospital and Tumor Institute

San Antonio
Baptist Memorial Hospital
Wilford Hall U.S. Air Force Base Hospital

Utah

Salt Lake City
Holy Cross Hospital

Virginia

Norfolk
DePaul Hospital

Roanoke
Roanoke Memorial Hospitals

Washington

Seattle (Interviews)
King County Hospital
Northgate General Hospital
Northwest Hospital
Providence Hospital
St. Frances Xavier Cabrini Hospital
Swedish Hospital Medical Center
University Hospital
Veterans Administration Hospital
Virginia Mason Hospital

West Virginia

Huntington
Veterans Administration Hospital

Wheeling
Wheeling Hospital

Wisconsin

Eau Claire
Sacred Heart Hospital

Madison
St. Mary's Hospital

Manitowoc
Holy Family Hospital

Milwaukee
Milwaukee County General Hospital

Sheboygan

Sheboygan Memorial Hospital

Wyoming

Casper

Memorial Hospital of Natrona County

Appendix I: Reviewers' Comments on First Draft Report

Upon completion of the first draft of this report, copies were sent to several physicians and NMTs for their comments and recommendations. We were most gratified by their responses, as they proved invaluable in helping to focus and improve many sections. Their statements varied from detailed corrections of terminology to general appraisals of our approach, methodology and conclusions. Most of their remarks have been incorporated into the body of the report, although they are by no means responsible for any of the report's remaining inadequacies. To the following individuals, we thus acknowledge a major debt of gratitude.

Millard N. Croll, M.D.
Hahnemann Medical College and Hospital of Philadelphia, Pennsylvania.

Howard J. Dworkin, M.D.
U.S. Naval Hospital, National Naval Medical Center, Bethesda, Maryland.

C. Craig Harris, M.S.
Duke University Medical Center
Durham, North Carolina.

William Hendee, Ph. D.
University of Colorado Medical Center, Denver, Colorado.

Merle Loken, M.D.
University of Minnesota Hospital, Minneapolis Minnesota.

Will B. Nelp, M.D.
University of Washington Hospital, Seattle, Washington.

E. James Potchen, M.D.
Washington University, St. Louis, Missouri.

Mrs. Bev Lee, R.T. (ARRT)
St. Anthony Hospital
Denver, Colorado.

Many of the comments which we received provided insights on topics which went somewhat beyond the scope of this report. Others either supported or contradicted our findings. As if to emphasize one of the major themes of the report, the fragmented aspect of the field of nuclear medicine, many of the comments tended to contradict each other. We feel that inclusion of some of these remarks will provide a valuable asset in understanding both the dilemmas and the dynamism of nuclear medicine and the preparation of Nuclear Medicine Technicians.

Comments listed below have been sorted by topic to provide a framewark within which to view them. They have not been otherwise edited except to conform with page changes from the first draft.

Several comments were made concerning terminology used in the report. The distinction between "technician" and "technologist" and the various types of "programs" ("education," "training," "preparatory," "instructional") have already been mentioned. The following discussion of other terms is also of value.

> I have penciled in red pencil a number of comments within the body of the copy that has been returned to you enclosed. One correction that you will see throughout is a correction of the word, "medical" in the expression, "nuclear medical technician," to read "nuclear medicine technician." This does not represent a morbid preoccupation on my part, but rather an appeal to you to help us continue to straighten out a very difficult semantic situation. Unfortunately, the Medical Technology Registry has a sort of "squatter's rights" on the term, "Medical Technician or Medical Technologist." When they additionally certify a person in nuclear medicine technology, they call this person a Registered Nuclear Medical Technologist. I am not exactly certain at this point what the American Registry of Radiologic Technologists calls the person that it certifies in nuclear medicine technology. (medicine, see Appendix C).
>
> It was a rather necessary, inherent part of the Essentials to use the term, "nuclear medicine technician" and "nuclear medicine technologist," because it was felt that the use of the word "medicine" as distinguished from "medical" would provide a properly, generally descriptive term.
>
> My repeated correction of this phrase in the draft copy does not reflect an obsession with this matter, but rather an attempt to

help you find the places that would have to be corrected if you were to accept this suggestion.

--Harris.

Page 5: I would suggest that you put the word, "radioisotope" in quotes, because the use of that term is certain to decline in the future... Let me submit to you a polemic on this terminology. I can document my point of view with substantial statements from many responsible persons in the field of nuclear medicine, and in the field of utilization of radioactive materials in general. A specimen of a nuclear species is called a "nuclide;" hence a nuclide is anything that occupies a block on a "chart of the nuclides." Example: iodine-127, copper-65, and hydrogen-3 and gold-198 are examples of nuclear species and are therefore called, "nuclides." Example: hydrogen-3 and gold-198 are radioactive; thery are therefore "radionuclides." It is never proper to speak of an "isotope" unless the context is one of referring that particular nuclear species to another of the same chemical kind. In other words, one may speak of "isotopes of an element" but to say, "we injected the isotope into the patient" is an improper statement. What was injected was either a "radionuclide" (in elemental or inorganic compound form) or a "radiopharmaceutical." (If it is injected or otherwise administered to man it is a drug. by order of the FDA.)

--Harris

Some of the major criticisms concerned the validity of the statistical conclusions, citing the inadequacy of our sampling techniques. Some of the points in question have been discussed in the report and manpower appendix in sections which were unavailable for the first draft. Others continue to be valid criticisms.

I am curious to know more than is submitted regarding the characteristic of the population that you interviewed. I think that it would be essential to correlate the results of the interview information with the source of that information. for instance, of those interviewed how many were physicians and what were their backgrounds in speciality and training. [see Appendix A, Statistical Summary] What fractions were technicians and at what level in training or experience were these individuals. I get the impression that the sample was rather heterogeneous and no where in the discussion of the initial results and impressions from the questionnaire is it clear which opinions were primarily physician generated and which opinions were primarily technician generated.

In addition, it might be useful to more completely characterize the hospitals from which completed questionnaires were received. The current practice of nuclear medicine appears to be linked closely with hospital size, the type of medicine practiced within the hospital as to speciality, etc. [see list of hospitals, Appendix H]

--Nelp

I think the most serious question that comes to my mind and, I am sure will come to the mind of readers who are closely familiar with the field, is the fact that there is no explanation of the manner in which the data were accumulated (with regard to efforts made to examine a truly representative cross-section of Nuclear Medicine departments.) I do not know personally how you selected the hospitals or the respondents and to my mind comes the question of the statistical significance of the results and whether they are skewed because of the selection of the respondents. Please understand, I am not saying that this is true--only that as a reader of the report I would have no way of knowing if the data truly represent the Departments throughout the United States or whether inadvertently the examining team has talked to a biased group and obtained a false or statistically inaccurate picture. I sincerely think that the report must contain statements as to selection of departments, the volume and type of work the departments are doing, and preferably an actual listing of the institutions and the names of the individual respondents giving the answers to the interviewer.

While on the same topic, I would call your attention to page 55 under the heading "The Growth of Nuclear Medicine". The first paragraph is interesting but there is reason to contest its accuracy and, this becomes more difficult because there is no reference source listed for your information. As you will realize, physicians are programmed to carefully substantiate any statements that they make or conclusions they draw by accurate references to source. They are just as programmed to look for documentated substantiation of any statements that they read and expect to fully believe. I think this is a serious deficit in the report itself. Again, I would emphasize that this in no way implies any falsefication of data but only that serious doubt will come into the mind of the critical reader. On page 4 it becomes apparant that those respondents who were not always capable of giving the variety of information requested but who did complete the questionnaire were guessing. This would suggest some alteration in the statistical significance of the results.

--Croll

The comment that nuclear medicine might become obsolete (page 30) elicited a strong reaction from some reviewers.

Wow! This is a curious observation and reflects on your sample population. I have had considerable experience in thermography, ultrasonics and nuclear medicine and I must say that your respondents are not very familiar with the facts. This should be kept in the report since it does point out one important aspect of the survey population.

--Potchen

On page 30 statements in the third paragraph such as the field would be obsolete, etc. is, of course, highly unlikely but including this type of information in report is a distraction. I notice throughout the report many physician statements of similar minor importance have been included. I think these should be curtailed as much as possible.

--Nelp

Reaction was mixed concerning the validity of the manpower section. It should be noted that this section has been changed considerably from its first draft form.

Starting on page 30 and going through 32 you make manpower projections which are rather critical for the nature of this report. Your assumptions (in Appendix B) that the samples you have chosen are representative of all hospitals with nuclear medical operation has a high risk in being incorrect. It appears you chose hospitals in metropolitan centers and probably larger and a good number of teaching hospitals. Of the 7,200 [7150] hospitals in the United States many of them will have characteristics quite dissimilar from your interview hospitals. Many will have no nuclear medical facilities and many (smaller community hospitals and speciality hospitals) may have no need for nuclear medicine facilities in the immediate future, possibly within the next ten years of your projection. In addition, the third assumption that you made (in Appendix B) that there were no significant differences between hospitals which did and did not return questionnaires seems inappropriate. There probably are significant differences between these hospitals where those with the most interest, need and insight may have responded.

--Nelp

As indicated in the introduction, this survey had five objectives relating to training of techicians in nuclear medicine. The first objective related to determination of the number of technicians currently employed, the number currently needed and the increase in numbers of trained technicians in the future. The data obtained appear valid in estimating an increase in technician requirements from the present number of 3900 [4000 - 4600] approximately 5400 [5500-5700] by 1970 and almost a four fold increase during the next decade.

--Loken

Congratulations also for the section on basic assumptions for manpower projections. Without this qualifying section, the report would have been crippled.

--Harris

Our profile of the "average" NMT elicited contradictory comments.

> Page 18: This is excellent information, well written and most interesting.
>
> --Potchen

> As I indicated in my response to the questionnaire, it may well be that the concept of the "average" technician was a mistake. Recognizing that it has already been done, I am still curious as to why this was done. It has been my experience that there are all levels of nuclear medicine technicians and technologists. They range from the med tech, who does the normal laboratory tests and incidentally does T-3's and the X-ray tech, who once in a while does a scan, to the highly skilled, professional-level, full-time nuclear medicine technologist. Perhaps it is premature to elicit these various levels at this time. I should think, however, that subsequent questionnaires would provide an opportunity to identify levels of technician accomplishment.
>
> Recognizing that the report must reflect the information gained from the questionnaire actually used, I would still say that the term "average" can be handled poorly if you try hard. On page 39, I would definitely suggest removing the statement, "the average Nuclear Medicine Technician is female." That is about as bad as saying that the average social science student is "hippie", but some are female and some are male and some leave us to wonder.
>
> In contrast, however, on page 13 the last paragraph is excellent and will go a long way toward communicating some knowledge of the actual task of the technologist to the lay person who would read this report.
>
> --Harris

Most of the reviewers' comments on nuclear medicine tests and equipment have already been incorporated into the body of this report. Several miscellaneous statements are included here.

Regarding the difficulty of a scanner vs. camera; Dr. Potchen wrote:

Page 15, fourth paragraph, second sentence: This is erroneous and I'm not sure exactly why, but I think anyone who has had any experience in the field appreciates the camera operation, if anything, is considerably easier than learning to run a rectilinear scanner. I don't necessarily favor cameras but there is no question that it is easier for technicians to run and requires a less knowledgeable technician to perform the camera studies.

On the statement that an NMT "may point out an area of interest on a scan to a doctor (page 15, third paragraph)":

The redlined statement in the middle of the page could stand the hair up on the back of somebody's neck. I would suggest that it be removed.

--Harris

Concerning new tasks for the NMT:

Page 12, paragraph 2, lines 7-10: Chemical preparation of radioactive compounds promises to become in the near future a very significant part of a technician's responsibility.

--Hendee

In response to our request for a review of the first draft of the report, Mrs. Lee developed a model of the needs of nuclear medicine.

The indeterminate destination of nuclear medicine in status among the other medical professional fields is due to the different physician supervisions and to its youthfulness in comparison to radiology and/or pathology. It must be recognized as being very dynamic (as mentioned in the draft) at its early age and thus has a great future ahead.

Requisites to progress in nuclear medicine are: 1) recognition by the AMA, 2) dedication to nuclear medicine alone, by the physician in charge, and 3) publicity of the values of nuclear medicine procedures. These requisites would bring about a) more financial funds for availability of advanced, more sophisticated equipment, and b) improve the educational opportunities which are so desired and desperately needed. Suggestions for educational improvements other than the actual training program curriculum are outlined below:

I. METHODS OF GENERAL EDUCATIONAL IMPROVEMENTS IN THE FIELD OF NUCLEAR MEDICINE.

A. Publicity.

1. Hospital staff physicians.

The physician in charge of the nuclear medicine department should keep the hospital staff physicians aware of all the different procedures and their values. This can be done by presenting periodic conferences and display exhibits. This arouses much interest and less traumatic procedures can be performed on the patient in deriving a diagnosis.

2. The general public.

By educating the general public to these procedures and their values, apprehension is less and more cooperation on their part enables the departments to function better, I believe, improving status.

3. Academic students.

a. Through "career days" or counselors, information regarding or pertinent to nuclear medicine would open the field to more students and increase interest in this medical profession.

b. College and university programs offering special courses toward degrees would improve professional status.

B. Teaching references.

1. Text books.

a. Improvement with more current information.

b. Teaching manuals of training program subjects.

2. Films.

a. Many films are now available but

outdated. These could show certain areas of the field or demonstrations where the subject is unobtainable or not available due to the locale.

3. Mock laboratory technique kits.

   a. Some kits are beginning to come on the market at the present. These would increase technical efficiency with less possibility for errors.

C. Post graduate courses.

   1. Subjects could include pharmacology, computers, etc. that apply to this specific field.

I realize that some of these educational improvement suggestions may be available at the present but the awareness of their availability is lacking. Better communications or publicity could be improved through a service which might be offered by one of the nuclear medicine societies.

--Lee

The problems of certification and standardization resulted in a variety of comments, some of which derived from the fact that the first draft of this report was written prior to the July meeting of the AMA. Mr. Harris' statement proved to be especially enlightening in clarifying the various aspects of AMA "recognition" of nuclear medicine.

Page 8, Mid-portion. The recognition of nuclear medicine as a tripartite subspecialty is pretty well underway with the American Medical Association. At the July meeting the nuclear medicine board application was approved in principle but the exact structure and relative position was left for further clarification.

--Potchen

Page 10: Please recognize that the establishment of a "speciality" by the AMA is a slightly complicated thing, and has several stages and aspects. First of all, there was some element of recognition of nuclear medicine in allowing board certified medical specialists to list the initials, S N M as a part of their biographies in the Directory of Medical Specialists. Here the recognition of the Society of Nuclear Medicine constituted something of a recognition of the "field of nuclear medicine." A second level of recognition is implicit if, and when, the AMA establishes a Section on Nuclear Medicine to present a part of its scientific program. For several years now there have been sessions on nuclear medicine presented under the Section on Miscellaneous Topics or the Section on Special Topics. In time this activity, together with certain others, will result in the establishment of a Section on Nuclear Medicine in AMA programs. A third level of recognition of nuclear medicine as a speciality will occur when, and if, an American Board of Nuclear Medicine is given sanction by the Advisory Board for Medical Specialities and the Council on Medical Education of the AMA. Steps are currently being taken in that direction also. The two or three places that "recognition of nuclear medicine as a speciality by the AMA" as they tend to affect growth of the field and profession are mentioned, seem to be a little out of touch with the foregoing facts.

--Harris

Page 39: Certification discussion is very good and when appended with the recent American Medical Association report makes a real contribution. Perhaps additional emphasis of the need to fix the uniform code could be helpful.

--Potchen

Page 2, paragraph 2: Fragmentation of the field of nuclear medicine is apparent not only among various hospitals, but also within the AMA and among the various Boards which are attempting to establish criteria for certification of specialists (physicians and technicians) in nuclear medicine. Because of this fragmentation, essentially no standardization of training in nuclear medicine has been established. This lack of standardization, and the confusion it causes, should be emphasized strongly and clearly.

--Hendee

Reviewers also commented on the role of other organizations in reducing or contributing to the fragmentation of nuclear medicine.

> On page 40, Table 6 is most revealing. As you and I have discussed, this points out the significant and important role that the Society of Nuclear Medicine plays in the training of Nuclear Medical Technologists.
>
> --Croll

> A problem closely associated with training programs is that of certification. As was pointed out, presently certification is available through two groups with somewhat different requirements. Your findings show that more than 50 per cent of those interviewed felt that it would be best to unify certification under one agency, namely the Society of Nuclear Medicine. I am surprised that this percentage is not significantly higher (approximately 90 per cent).
>
> --Loken

> Page 12: In a recent statement of the American College of Radiology, the field of Radiology has been defined by them to include the field of radiation, including ultrasound, thermography and X-rays. It also addresses attention to nuclear medicine, but the American College of Radiology is admittedly putting only a temporary roof over the field of nuclear medicine.
>
> --Harris

Related to the discussion of organizations is the tie of nuclear medicine to radiology.

> In my opinion, trends quoted do not support your conclusion that nuclear medicine is not related closely to radiology. The incentive for separation seems to be the recognition by a growing number of physicians that nuclear medicine is a reputable medical discipline.
>
> --Hendee

On page 11, there is a very serious breach of accurate data and what we might loosely term "medical politics". The relationship of "radiation therapy" to Nuclear Medicine is an extremely sensitive affair in the minds of all physicians who are practicing full-time Nuclear Medicine. Historically, the early development of the field of Nuclear Medicine came about, as the survey reports, as a third area of activity in the field of radiology. Diagnostic radiology, of course, was the initial and largest area, and radiation therapy was the secondary area. Nuclear Medicine then became a third area smaller than the other two and in many instances because of limitations of space and personnel, Nuclear Medicine was physically located in an area adjacent to the Radiation Therapy Department. It even developed that administratively Nuclear Medicine was lumped with radiation therapy. This concept is now disappearing as it rightly should. Nuclear Medicine has far less in common with radiation therapy than it has with diagnostic radiology.

--Croll

On Pages 9 and 10 some valuable points are brought out: The fact, that Nuclear Medicine as a speciality will expand as it becomes freed of its subordinate status to other departments, is most astute. Those of us who have been in the field long enough and in an academic environment are well aware of this, but the general Nuclear Medical population is not. The concept that a career in Nuclear Medicine is most difficult is not true, as the survey points out, although it does require some very important qualifications in the individual. I think this area needs further evaluation.

--Croll

Not only is the field of nuclear medicine tied to radiology but--as has been emphasized earlier--most NMT's have also begun as X-ray technicians. Reviewers' opinions on this situation differed radically.

Of those trained during the year 1969, approximately 62 per cent were initially trained as X-ray technicians pointing out the common features of performance of X-ray technicians and nuclear medicine technicians.

--Loken

Page 33, paragraph 2: The low rating given to technicians trained in diagnostic radiology may reflect dissatisfaction of physicians with this type of preparation.

--Hendee

Page 11: The statement about medical technologists picking up _in vitro_ techniques is certainly a true one. _It is_ also true that the _in vitro_ work does not demand the amount of _training requisite_ in a separate technology. However, it has been our experience and that of many others, that the medical technologist is much more adept at the systematic calculation of results than is the X-ray technologist, who in general is oriented away from numbers.

--Harris

Page 33: X-ray techs have the excellent attributes, in general, of being very good with patients, being able to operate equipment on a push-button or routine basis and they have some feeling for scan-record production. They even, on occasion, have some knowledge of anatomy and physiology. They suffer in general, from lack of motivation in going deeper than the "black box" approach to instrumentation and many of them go into complete shock at being faced with a mathematical calculation. They tend to routine and rote rather than to thinking in many cases. Medical technologists, on the other hand, are generally excellent at thought processes, mathematics, and assuming responsibility. They have to be taught virtually from scratch about instrumentation and the actual care of patients.

--Harris

The various expectations of the NMT were reflected in reviewers' comments on the section entitled "Working Conditions" (pages 25-29). Dr. Loken expanded on the need for different levels of NMT's with different levels of training.

The statement on NMT working conditions is good.

--Harris

Page 28: Second paragraph is outstanding and clearly dispalys an excellent understanding of the situation. It is well written and should be read by anybody interested in training nuclear medicine technologists (technicians).

--Potchen

Your study showed that the majority of those interviewed felt that the training of nuclear medicine technicians could be carried out in two years, providing the individual had some background in X-ray technology with certification in that field. It was somewhat surprising that so few (less than 1 per cent) felt the necessity of obtaining a bachelor of arts degree in order to function most effectively as a technician in nuclear medicine. At this point I think it deserves mentioning that it may be worthwhile to consider two levels of training for technical individuals with the first group including those covered in this report (training leading to certification as a nuclear medicine technician) and the second program for training individuals whose training would lead to a bachelors and possibly masters degree. This latter group is certainly needed in order to provide competent technical leadership in nuclear medicine.

--Loken

To the statement that NMT's need good "bedside manner" (page 28) Mr. Harris commented: "Good! especially in allaying fear of radioactivity.

To the idea of an NMT in an associate relationship with the M.D. (page 28) Dr. Dworkin's comment was: "ridiculous; perhaps a Ph.D. in nuclear medicine."

Several comments were made on the section concerning salaries for NMT's.

> As expected, there is a wide range in salaries being paid to technicians varying all the way from about $4,000 to $12,000 per year. This is not surprising because of the tremendous differences in the responsibilities and training of the individuals involved.
>
> --Loken

> Page 31: Discussion on salaries is very well done and should be very useful to people in the field of nuclear medicine. Undoubtedly, this leaves one with the impression that increase in salaries will be essential if we are ever to obtain the goals of a reasonable number of people entering this field. Perhaps this should be emphasized.
>
> --Potchen

The section on training of NMT's was in very rudimentary form when sent to reviewers. Thus they were unable to make substantive comments on this most important section. Nevertheless, certain of their statements are useful additions to the report.

> The final objective of your survey was to explore the feasibility of nuclear medicine training programs in cooperation among hospitals and educational insitutions. Your survey concludes that most of the individuals interviewed were in agreement with this concept, which I feel is indeed the proper approach in order to provide sufficient numbers of trained nuclear medicine technologists to fill the projected needs for the future of this rapidly growing field.
>
> --Loken

> I think your information on the current training of nuclear medicine technologists is well presented and the routes available for

certification, the AMA guide lines, etc. are useful in obtaining a perspective for the overall study.

--Nelp

Parenthetical thought: Now that the Essentials have been approved by the House of Delegates it might be in order to put out a questionnaire on curriculum content; maybe we can get a handle on reasons for the "poor quality of training programs for technicians" (page 9).

--Harris

The third objective was to determine the nature and extent of existing training programs for NMT's. Your finding that approximately 50 per cent of those employed as technicians today were trained on-the-job appears somewhat low to me because of the dearth of training programs. It was of interest to note that approximately 20 per cent of those interviewed state that they hire only trained technicians. I wonder where these trained technicians come from.

--Loken

Only one comment concerned the idea of an internship. "The wage fits the service value. These interns may do more damage than good." --Dworkin.

Finally criticisms of the interview protocol were common, with most statements critical of its bulk. Comments on the report as a whole were generally favorable.

The questionnaire was felt to be a most difficult one to comply with, mainly due to the method of classifying or stating degrees of evaluations.

--Lee

The questionnaire is comprehensive, somewhat cumbersome in design and I would imagine you to have a tremendous amount of data available from its answers.

--Nelp

I have some criticism of the survey form, but to dwell on that would serve no useful purpose. No instrument is perfect, but the questionnaire elicited a great deal of information that is vitally needed at this point in spite of its imperfections. Most of the problems relate to an outsider's lack of familiarity with the language of nuclear medicine.

--Harris

The following are some general comments made on the report.

In general, I believe you have developed an excellent survey of the current and future requirements for technologists in nuclear medicine.

--Hendee

I have read, in detail, the "draft final report" project No. 7-0313 entitled "Development of Career Opportunity for Technicians in the Nuclear Medicine Field -Phase I." I think it contains much valuable information which was heretofore inaccessible...In summary, the report contains much valuable information and should prove most useful in assessing and establishing nuclear medicine technologists (technicians) training program.

--Potchen

I have read the final draft of "Development of Career Opportunities for Technicians in the Nuclear Medicine Field" with great interest. TERC is to be commended for this effort since it is the first I know of. In general I feel the factual data is quite accurate. The conclusions and projections are undoubtedly overly optomistic.

--Dworkin

Inasmuch as I am about to be very candid and blunt in my constructive criticism of this document, let me say that is is an excellent report, lucid and informative. This document is the first intelligent compendium of information on this subject that has come out...In summary, I feel that the report shows a remarkable understanding cf the field of nuclear medicine by the TERC group. Certain anomalies of the language, however, tell me that additional familiarization can be found profitable. I am extremely pleased with the content of this most vital report. None of my "nit-picking objections have altered the general presentation of your major findings, impressions, and conclusions.

--Harris

In summary, I would again emphasize, as I did at the beginning of this report, that in general the survey appears to be fulfilling its objectives, and I am sure that it will become an extremely useful tool in developing the training program. I have purposefully been critical and candid in my remarks about it --bouquets would be of little value at this stage.

--Croll

Appendix J: Duke University Medical Center Job Specifications for Nuclear Medical Technicians and Technologists

Nuclear Medicine Technician I

Nature of Work

A technician in this classification performs entry-level work as a trainee in nuclear medicine procedures. These tasks are carried out under the direction and guidance of higher level personnel. The individual is responsible for performing a limited number of procedures accurately, or assisting in setting up procedures, and for recording pertinent data. Assignments may be in specialized areas, such as: scanning, *in vitro* studies or other areas as determined by the patient-care needs of the service or the aptitude of the technician trainee. Duties are performed under direct supervision of both senior technologists and physicians, although some phases may be performed without repeated instruction. The work is evaluated by observation.

Employment in a position of this classification provides, over an appropriate interval of instruction and experience, training to lead to certification as a Registered Nuclear Medicine Technologist.

Illustrative Examples of Work

Performs thyroid uptakes, T-3 serum binding tests and similar basic nuclear medicine laboratory procedures; calculates results under supervision.

Operates rectilinear scanners, including adjustment of the instrumentation, positioning of the patient; obtains development of film record and reloads film cassette.

Operates other radiation detection and measurement instrumentation.

Maintains working area and surfaces in proper state of cleanliness.

May be assigned to accompany higher level technician or technologist on night call rotation.

Performs other related work as assigned.

Knowledge, Skills and Abilities

Working knowledge of the principles of instrumentation and radiopharmaceuticals used in nuclear medicine procedures; this may be gained by on-the-job training.

Ability to follow procedures, instructions and regulations precisely.

Ability to communicate instructions and explanations effectively to patients.

Ability and aptitude to perform routine, repetitive procedures.

Ability to maintain effective working relationships with other employees and with patients.

Acceptable Training and Experience

1. Graduation from high school and graduation from a school of radiologic technology accredited by the Council on Medical Education of the American Medical Association with eligibility for certification as a Registered Radiologic Technologist by the American Registry of Radiologic Technologists.

   Experience in nuclear medicine techniques during above X-Ray technology training is desirable, OR,

2. Graduation from high school and completion of at least three years of a program in medical technology leading to the degree of Bachelor of Science of Medical Technology, OR,

3. Graduation from high school and ninety or more college credit hours, including courses in mathematics, chemistry and biology. Some exposure to principles of radioactivity detection in this training is desirable.

Nuclear Medicine Technician II, Nuclear Medicine Technologist II

Nature of Work

A technician or technologist in this classification performs routine technical work related to nuclear medicine procedures using radioactive tracers and instrumentation pertaining to the measurement thereof. The level of performance is above that of an entry-level technician, but does not call for completely unsupervised performance. The individual is responsible for performing a large number of procedures accurately, for setting up procedures and for recording pertinent data. Assignments may be in any area of the nuclear medicine laboratory, e.g. assignment to rectilinear scanners, thyroid uptake area, of *in vitro* studies. Supervision is of a general nature and performance is evaluated by observation, both by senior technologists and by physicians.

Illustrative Examples of Work

Performs thyroid uptakes, T-3 serum binding tests, blood volume determinations and similar basic nuclear medicine laboratory procedures; calculates results subject to checking by supervisory personnel as the need is indicated.

Operates all radiation detection instrumentation used in the diagnostic clinical laboratory. This includes rectilinear scanners; with film processing and patient setup. Some of this work may be carried out under supervision.

Performs special studies, with supervision, such as renograms and operates complex equipment such as the scintillation camera and its associated instruments.

On occasion, with supervision, calculates and draws up radiopharmaceutical material for patient injection; with close supervision, may formulate certain radiopharmaceuticals from pre-prepared kits.

Calculates results of patient studies and radio-active decay using calculations requiring the use of algebra and occasionally logarithms.

Performs specially designed tracer studies as outlined in specific protocols.

May be assigned to night call for emergency procedures.

Performs daily instrumentation calibration and enters results in log.

Makes entries in radiopharmaceutical receiving, dispensing and disposal log books.

Performs other related work as assigned.

Knowledge, Skills and Abilities

Considerable knowledge in the principles of operation of certain specific instrumentation used in nuclear medicine procedures; considerable understanding of radiopharmaceuticals used in certain nuclear medicine procedures.

Working knowledge of use of instrumentation used occasionally.

Working knowledge of enough chemistry and laboratory procedure to prepare, from kit materials, certain radiopharmaceuticals with little or occasional supervision.

This requires the ability to maintain aseptic technique in pharmaceutical preparations and the maintenance of clean radioactive conditions.

Ability to follow procedures, instructions and regulations precisely, with the additional ability to participate to a limited extent in formulation of new procedures and instructions.

Ability to communicate instructions and explanations effectively to patients.

Ability and aptitude to perform routine, repetitive procedures with reliable results under limited supervision.

Ability to maintain effective working relationships with other employees and patients.

Helpful: Knowledge in the use and operation of X-Ray equipment, OR,

Knowledge of equipment and procedures used in general medical clinical laboratories.

Acceptable Training and Experience (Order of preference is neither expressed nor implied)

1. Graduation from high school, with completion of accredited training with certification as a Registered Radiologic Technologist by the American Registry of Radiologic Technologists and certification as a Registered Nuclear Medicine Technologist, OF,

2. Graduation from high school, completion of accredited training with certification as a Registered Radiologic Technologist of the American Registry of Radiologic Technicians and at least two years' experience as a technician in a clinical practice of nuclear medicine, OR,

3. Completion of accredited training and certification by the American Society of Clinical Pathologists as a Registered Nuclear Medicine Technologist, OR,

4. Completion of accredited training and certification by the American Society of Clinical Pathologists as a Registered Medical Technologist with two years' experience as a technician in a clinical practice of nuclear medicine, OR,

5. A Bachelor of Science degree in one of the life sciences with some experinece as a technician in

clinical nuclear medicine. Both the content of the academic training and of the technician experience in nuclear medicine are subject to review, OR,

6. Other conbinations of preliminary training and accredited programs of technologies, formal academic training in the life sciences and in clinical experience as a technician in nuclear medicine may be found acceptable for this classification upon review of the applicant's credentials.

NOTE: Identification of an individual as a technician or as a technologist will be made upon an evaluation of registry or formal training credentials. In general, the title technologist requires registry as a technologist in the specified occupation or a baccalaureate degree in same.

Nuclear Medicine Technician III, Nuclear Medicine Technologist III

Nature of Work

A technician or technologist in this classification is capable of performing any of the usual procedures in the clinical nuclear medicine laboratory with only minimal or occasional supervisory guidance. This classification identifies the technician or technologist as a senior technician or technologist, and assumes that the individual is of a responsible nature, having had intensive training and adequate experience. The individual is responsible for performing a large number and variety of procedures accurately, to develop and evaluate new procedures and should be capable of developing optimal means for recording pertinent data. As a senior technician or technologist, assignments may be to perform or to supervise in any area of the nuclear medicine laboratory, including scanning, in vitro studies and radiopharmaceutical preparation. The work is performed under general supervision and is evaluated by observation.

Illustrative Examples of Work

Supervises, coordinates, and performs such studies as thyroid uptakes, T-3 serum binding tests, blood volume determinations; is responsible for the calculated result by himself or those under his supervision.

Operates, with general supervision only, all radiation detection instrumentation used in the diagnostic clinical laboratory including rectilinear scanners, stationary imaging devices and apparatus for in vitro counting.

Assists in the devising of, the supervision of and the performance of special studies such as renograms and rapid-sequence dynamic function studies with the scintillation camera.

Supervises and performs the calculation and drawing up of radiopharmaceutical material for patient injection; supervises and performs formulation of certain radiopharmaceuticals from pre-prepared kits.

Supervises and performs calculations of the results of patient studies and radioactivity decay using calculations requiring the use of algebra, logarithms and transcendental functions.

Supervises and teaches students in the program of nuclear medicine technology training or other specific trainees, assigned to his area.

Maintains appropriate stock levels of supplies required in his assigned work area.

Performs daily instrumentation calibration, enters results in log, and is responsible for review of calibration data to detect trends indicating malfunction.

Is assigned to night call for emergency procedures.

Performs and assists in the devising of specially designed tracer studies to meet the needs of specific protocols. Supervises and participates in the keeping of entries in radiopharmaceutical receiving, dispensing and disposal log books. Maintains record of bacteriologic culture reports.

On assignment by chief technologist or by physician, may consult with physicians and investigators from other disciplines on applications to tracer techniques to specific projects anticipated or existing.

Assumes the responsibility of seeing that appropriate nursing care is provided for the patients in his care and that supplies for same are made available.

Performs other related work as assigned.

Knowledge, Skills and Abilities

Considerable knowledge in the principle of operation of all specific instrumentation used in nuclear medicine procedures; considerable understanding of radiopharmaceuticals used in all routine nuclear medicine procedures; working knowledge of radiopharmaceuticals used in special procedures.

Considerable knowledge in chemistry and laboratory procedures, sufficient to supervise the preparation and formulation, from pre-prepared kits, of all commonly used radiopharmaceuticals. This requires the ability to provide means for, and maintenance of, aseptic technique in pharmaceutical preparation and in the maintenance of clear radio-active conditions.

Ability to interpret and follow procedures, instructions and regulations with the additional responsibility to see that these are carried out in the clinical operations.

Ability to participate actively in the formulation of new procedures, instructions and regulations.

Ability to perform well-defined, technologically oriented research projects.

Ability to train and advise subordinates, evaluate their work and help resolve technological problems they encounter.

Ability to perform a reasonable number of non-routine nuclear medicine procedures.

Ability to communicate instructions and explanations effectively to patients.

Ability to supervise effectively subordinates in the performance of routine, repetitive procedures, and to maintain effective co-worker relationships with others.

NOT ABSOLUTELY REQUIRED IN ALL APPLICANTS, BUT EXTREMELY DESIRABLE:

Considerable knowledge in the use and operation of X-Ray diagnostic equipment, OR,

Considerable knowledge of equipment and procedures used in general medical clinical laboratories.

Some knowledge of data processing methods or orientation to computer methodology.

<u>Acceptable Training and Experience</u> (Order of preference is neither expressed nor implied)

1. Graduation from high school, with completion of accredited training with certification as a Registered Radiologic Technologist by the American Registry of Radiologic Technologists and certification as a Registered Nuclear Medicine Technologist, plus a broad experience in all aspects of nuclear medicine technology, OR,

2. Graduation from high school, and subsequent completion of accredited training and certification by the American Society of Clinical Pathologists as a Registered Medical Technologist with subsequent certification as a Registered Nuclear Medicine Technologist, plus broad experience in all aspects of nuclear medicine technology, OR,

3. A Bachelor of Science degree in Nuclear Medicine Technology in an accredited program of nuclear medicine technology training with either subsequent certification as a Registered Nuclear Medicine Technologist or clinical experience as a nuclear medicine technologist, OR,

4. A Bachelor of Science degree in one of the life sciences with broad experience as a technician in nuclear medicine technology. Both the content of the academic training and of the technician experience in nuclear medicine are subject to review, OR,

5. A diploma or baccalaureate degree as a Registered Nurse with suitable clinical and supervisory experience in nuclear medicine technology. The training and experience in nuclear medicine would be subject to review.

NOTE: Identification of an individual as a technician or as a technologist will be made upon an evaluation of registry or formal training credentials. In general, the title technologist requires registry as a technologist in the specified occupation or a baccalaureate degree in same.

Nuclear Medicine Technologist IV

Nature of Work

A technologist in this classification carries out the supervisory responsibilities of an overall chief technologist. This position carries the responsibility of organizing the technologic staff of the Division of Nuclear Medicine and devising and maintaining an orderly approach to the completion of each day's work load. This work is accomplished with the advice and guidance of the Instructor and in coordination with the clinicians and other faculty members responsible for the clinical service of nuclear medicine.

Illustrative Examples of Work

Supervises and coordinates studies performed in all areas of the laboratory; may conduct, or participate in, any phase of the technologic operation.

Schedules the working hours of the technologic staff to provide optimal service coverage of the laboratory. Assumes personal responsibility to assure technologic coverage of after-hours emergencies.

Supervises preparation of radiopharmaceuticals for patient administration.

Maintains a close liaison with Radiation Safety Office in regard to personnel monitoring and laboratory monitoring of radioactive materials.

Consults and advises with the clinical and technical staff regarding problems of technique or equipment.

Assists the Instructor in teaching nuclear medicine technology students and, with the guidance of the Instructor, is responsible for the training of persons with the classification of Nuclear Medicine Technician I.

Consults with physicians and investigators from other disciplines regarding technical applications of tracer techniques and nuclear medicine equipment applications to specific projects anticipated or ongoing.

Assumes the responsibility for seeing that appropriate laboratory supplies and nursing care needs are available to all areas of the laboratory.

Supervises daily the results of calibrations and malfunction checks in all areas of the nuclear medicine laboratory, and is responsible for performance of such additional tests on the equipment necessary to confirm equipment failure. Takes action to have equipment restored to proper service.

Knowledge, Skills and Abilities

Thorough knowledge in the principle of operation of all instrumentation used in nuclear medicine procedures; thorough understanding of radiopharmaceuticals used in all routine nuclear medicine procedures; considerable knowledge of radiopharmaceuticals used in special procedures.

Considerable knowledge in chemistry, radiation physics and laboratory procedures sufficient to supervise the preparation of all commonly used radiopharmaceuticals. This requires the ability to provide means for, and maintenance of, aseptic technique in pharmaceutical preparations and in the maintenance of clean radioactive conditions.

Ability to participate in the devising of well-defined, technologically oriented research projects.

Ability to promulgate new procedures, instructions and regulations.

Ability to train and supervise the technology staff, evaluate their work, and resolve problems that they encounter.

Ability to train staff technologists in communication of effective instructions and explanations to patients.

NOT ABSOLUTELY REQUIRED IN ALL APPLICANTS, BUT EXTREMELY DESIRABLE:

Considerable knowledge in the use and operation of X-Ray diagnostic equipment, OR,

Considerable knowledge of equipment and procedures used in general medical clinical laboratories.

Some knowledge of data processing methods or orientation in computer methodology.

Acceptable Training and Experience (Order of preference is neither expressed nor implied)

1. Bachelor of Science degree in Nuclear Medicine Technology in an accredited program of nuclear medicine technology training with either subsequent certification as a Registered Nuclear Medicine Technologist or considerable clinical experience as a Nuclear Medicine Technologist, OR,

2. Completion of an accredited program of training with certification as a Registered Radiologic Technologist by the American Registry of Radiologic Technologists and certification as a Registered Nuclear Medicine Technologist plus considerable experience as a supervisor-technician or technologist in the field of clinical nuclear medicine technology, OR,

3. Completion of accredited training and certification by the American Society of Clinical Pathologists as a Registered Medical Technologist with subsequent certification as a Registered Nuclear Medicine Technologist, as well as broad experience at the supervisory level in clinical nuclear medicine technology, OR,

4. A Bachelor of Science degree in one of the life sciences with broad supervisory and clinical experience as a technologist in nuclear medicine. Both the content of the academic training and of

the supervisory technologic experience in nuclear medicine are subject to review, OR,

5. A diploma or baccalaureate degree as a Registered Nurse with suitable clinical and supervisory experience in nuclear medicine technology. The training and experience in nuclear medicine would be subject to review.

Appendix K: Task Frequency Data and Statistical Analysis

Task Frequency Data and Statistical Analysis*

Legend:

n = number of respondents per task item

$\bar{x}$ = mean coded value per task item

0 = task not performed in department (value assigned: 0)

a = task performed in department, but not by an average technician in that department (value assigned: 1)

b = 1-3 times per month (value assigned: 2)

c = 4-10 times per month (value assigned: 3)

d = 11 or more times per month (value assigned: 4)

INT

Task	n	$\bar{x}$	0	a
Preparation				
1. Chemically prepare short-life isotopes: a) eluting column	197	2.7	27.9	3.
2. b) chemical preparation	197	1.0	63.4	7.
3. c) sterilize	196	0.6	75.5	8.
4. Calibrate isotopes against a standard	198	3.1	14.1	3.
5. Prepare oral dose: Measure from manufacturer's bottle	198	2.6	25.8	2.
6. Prepare oral dose: mix, dilute to measure	198	2.1	35.3	5.
7. Prepare injections: measure dose	200	3.7	4.5	2.
8. Prepare injections: sterilize dose	198	0.7	74.8	8.
9. Set up instruments for operation: a) in vivo studies	197	3.7	5.6	1.
10. Set up instruments for operation: b) in vitro studies	196	2.9	17.3	7.
11. Administer isotopes to patients: a) orally	199	3.6	2.5	4.
12. Administer isotopes to patients: b) by injection	200	2.4	10.5	34.
13. Receive patients, explain tests to them and allay their fears	200	3.9	0.5	2.
14. Position patient with respect to nuclear medical equipment	200	3.9	1.5	0.
15. Superficial and specialized examination of patients	Respondents varying			inte unif
16. Attend to patient's comfort before and during scan	200	3.9	2.0	0.
17. Understand operating room procedure	Respondents varying			inte unif
Data Handling				
18. Abstract simple data from patient's chart	199	3.0	4.0	20.
19. Make simple dose calculations for a) in vivo examinations	198	3.7	4.0	5
20. Make simple dose calculations for b) in vitro examinations	196	2.9	18.9	9
21. Make simple dose calculations for c) tracer examinations	199	3.5	5.5	4
22. Accumulate and process data for MD's interpretation	200	3.6	3.0	7
23. Examine scan test results for general credibility	200	3.7	2.5	5
24. Perform preliminary interpretations of observations for MD	198	1.9	19.7	39

*In some cases, frequency percentages for a given task will total more than 100%, because of rounding off.

	INTERVIEW DATA				MAILED DATA						
	a	b	c	d	n	$\bar{x}$	0	a	b	c	d
9	3.6	1.5	2.5	64.5	97	2.1	39.2	7.2	1.0	5.2	47.4
4	7.6	8.1	5.1	15.7	88	1.0	64.8	10.2	1.1	4.6	19.3
5	8.7	3.6	2.0	10.2	87	0.4	81.6	10.3	2.3	5.8	
1	3.5	7.1	7.6	67.7	98	2.7	23.5	7.1	3.1	9.2	57.1
8	2.0	7.6	11.1	53.5	97	2.9	13.4	7.2	12.4	14.4	52.6
3	5.6	9.0	11.6	38.4	95	2.1	32.6	11.6	9.5	9.5	36.8
5	2.5	2.0	1.0	90.0	97	3.5	5.2	4.1	3.1	6.2	81.4
8	8.6	2.5	2.0	12.1	86	0.7	72.1	11.6	1.2	2.3	12.8
6	1.5	1.5	4.6	86.8	98	3.5	9.2	2.0	6.1	83.6	
3	7.6	3.1	6.6	65.3	97	3.3	13.4	3.1	3.1	5.2	75.3
5	4.0	5.5	7.0	80.9	98	3.3	4.1	8.2	6.1	18.4	63.3
5	34.5	3.0	3.0	49.0	99	2.5	17.2	22.2	3.0	8.1	49.5
5	2.0	1.5	1.0	95.0	98	3.7	2.0	6.1	1.0	6.1	84.7
5	0.5	1.0	97.0		99	3.8	3.0	9.1	87.9		
ing	interpretations led to non-uniform data				Respondents varying interpretations led to non-uniform data						
0	0.5	0.5	2.0	95.0	99	3.8	3.0	1.0	8.1	87.9	
ing	interpretations led to non-uniform data				Respondents varying interpretations led to non-uniform data						
0	20.1	6.5	8.0	61.3	97	2.9	5.2	17.5	10.3	13.4	53.6
0	5.0	1.0	1.5	88.4	99	3.6	1.0	5.0	2.0	15.2	76.8
9	9.2	3.6	4.6	63.8	97	3.1	12.4	8.2	4.1	12.4	62.9
5	4.0	5.0	6.0	79.4	97	3.2	6.2	10.3	3.1	17.5	62.9
0	7.0	2.0	3.5	84.5	95	3.5	1.0	8.4	3.2	13.7	73.7
5	5.5	1.5	2.0	88.5	97	3.4	3.1	10.3	3.1	7.2	76.3
7	39.4	4.6	5.0	31.3	93	1.7	25.8	36.6	5.4	6.4	25.8

	n	$\bar{x}$	0	a
Equipment				
25. Operate a rectilinear scanner for conventional scanning	200	3.7	5.0	1
26. Operate a autofluoroscope for static studies	196	0.1	94.4	4
27. Operate a scintillation camera for static studies	199	1.7	54.8	4
28. Operate an autofluoroscope for fast dynamic studies (under one minute scan)	195	0.1	93.3	4
29. Operate a scintillation camera for fast dynamic studies	199	1.3	57.3	7
30. Operate a scanner for slow dynamic studies (over one minute scan)	195	1.9	41.5	5
31. Operate an autofluoroscope for slow dynamic studies	195	0.1	92.8	4
32. Operate a scintillation camera for slow dynamic studies	196	1.5	54.6	5
33. Calibrate nuclear medical instruments	196	3.0	8.7	9
34. Check performance of existing and new nuclear medical instruments against manufacturer's specifications	196	1.9	12.8	35
35. Determine if a nuclear medical instrument is in need of major repair	196	2.6	1.5	24
36. Perform minor maintenance on nuclear medical instrument	193	1.9	14.0	26
37. Evaluate nuclear medical instruments from manufacutrer's literature and specify and rank those instruments that satisfy doctors' requirements	195	1.2	16.9	56
38. Advise doctors on the technicalities and procedures involved in operating a nuclear medical instrument	196	2.2	9.7	26
Safety				
39. Check monitoring instruments	199	2.5	5.5	21
40. Monitor personnel in compliance with hospital regulations	198	2.2	9.6	26
41. Monitor space in compliance with hospital regulations	198	2.5	3.5	19
42. Handle and store radioisotopes safely	200	3.8	1.0	2
43. Assay wet chemical solutions for activity and contaminants	196	2.3	28.1	9
44. Safely dispose of radioactive wastes	200	3.4	5.5	15
Clerical				
45. Handle secretarial work: appointments, type reports	198	2.8	3.5	28
46. Routinely check incoming equipment	196	2.2	4.6	30
47. Inventory and order radiopharmaceuticals and materials	199	3.3	0.5	10
48. Keep accounts of hospital licensing and isotope procurement	195	2.6	5.6	32

INTERVIEW DATA | MAILED DATA

a	b	c	d	n	$\bar{x}$	0	a	b	c	d
1.0	1.0	1.0	92.0	100	3.7	6.0	1.0	7.0	86.0	
4.1	0.5	0.5	0.5	94	0.2	92.6	4.3	3.2		
4.0	2.0	39.2		95	0.9	74.7	2.1	1.0	22.1	
4.1	0.5	0.5	1.5	94	0.2	93.6	2.1	1.1	3.2	
7.0	7.0	4.0	24.6	96	0.8	74.0	3.1	2.1	6.2	14.6
5.6	10.8	5.6	36.4	96	1.9	39.6	7.3	9.4	8.3	35.4
4.1	1.5	1.5		91	0.1	93.4	3.3	1.1	2.2	
5.1	6.1	7.6	26.5	94	0.9	70.2	3.2	7.4	4.3	14.9
9.2	11.7	10.2	60.2	97	2.4	18.6	12.4	16.5	15.5	37.1
35.2	21.9	8.7	21.4	95	1.7	28.4	22.1	22.1	9.5	17.9
24.0	26.0	8.7	39.8	97	2.2	10.3	23.7	29.9	9.3	26.8
26.9	33.7	10.4	15.0	93	1.6	21.5	31.2	30.1	2.2	15.0
56.9	20.0	1.5	4.6	93	1.0	40.9	32.3	18.3	1.1	7.5
26.2	24.1	17.4	22.6	96	1.5	27.1	29.2	19.8	11.5	12.5
21.1	26.1	16.1	31.2	98	2.3	9.2	21.4	27.6	17.4	24.5
26.3	23.7	11.6	28.8	97	2.3	10.3	20.6	24.7	18.6	25.8
19.2	30.3	22.2	24.8	96	2.4	5.2	17.7	32.3	19.8	25.0
2.0	2.5	5.5	88.5	100	3.6	2.0	8.0	13.0	77.0	
9.2	11.7	10.7	40.3	94	2.2	22.3	18.1	12.8	13.8	33.0
15.5	13.5	65.5		99	3.2	1.0	9.1	16.2	12.1	61.6
28.8	6.6	3.0	58.1	95	2.5	10.5	31.6	4.2	7.4	46.3
30.6	28.6	9.7	26.5	95	1.8	17.9	33.7	21.0	7.4	20.0
10.6	7.0	18.1	63.8	99	1.0	12.1	9.1	18.2	59.6	
32.3	8.7	7.2	46.2	96	2.6	5.2	30.2	10.4	8.3	45.8