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Assessment of Specialized Educational Programs for Licensed Nuclear Reactor Operators

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ABSTRACT

This report assesses the job-relatedness of specialized educational programs for licensed nuclear reactor operators. The approach used involved systematically comparing the curriculum of specialized educational programs for college credit, to academic knowledge identified as necessary for carrying out the jobs of licensed reactor operators. A sample of eight programs, including A.S. degree, B.S. degree, and coursework programs were studied. Subject matter experts in the field of nuclear operations curriculum and training determined the extent to which individual program curricula covered the identified job-related academic knowledge. The major conclusions of the report are:

1. There is a great deal of variation among individual programs, ranging from coverage of 15% to 65% of the job-related academic knowledge. Four schools cover at least half, and four schools cover less than one-third of this knowledge content.

2. There is no systematic difference in the job-relatedness of the different types of specialized educational programs, A.S. degree, B.S. degree, and coursework.

3. Traditional B.S. degree programs in nuclear engineering cover as much job-related knowledge (about one-half of this knowledge content) as most of the specialized educational programs.

EXECUTIVE SUMMARY

OBJECTIVES AND APPROACH

The purposes of this report are to identify the content covered in the curricula of specialized educational programs for licensed nuclear reactor operators and to indicate the extent of job-relevant knowledge taught in these programs. The report examines college credit programs being used by utilities for licensed nuclear reactor operators, i.e. specialized A.S. degree, specialized B.S. degree, and specialized coursework programs (which are comprised of a selected group of courses for which college credit is given).

The approach used to determine the job-relevance of the specialized educational programs is content validation. This approach identifies the extent to which the specific content of a specialized educational program is related to the job of licensed nuclear reactor operator by systematically comparing the knowledge taught in the curriculum of an educational program to the knowledge necessary for carrying out a given job. The basic elements of this approach involve:

1. definition of knowledge needed for the job based on results of job analyses;

2. the identification, selection and description of potentially relevant educational programs; and

3. a systematic comparison of the knowledge content of the job to the knowledge content of the educational programs.

In this study, job content was defined by the academic knowledge list from the Institute of Nuclear Power Operations (INPO) job task analysis of licensed reactor operators (ROs) and senior reactor operators (SROs). The content of each school curriculum in a sample of specialized educational programs, i.e. A.S. degree, B.S. degree and coursework, was defined by detailed course descriptions. In order to carry out the comparison between the content of the specialized educational programs and the job content (academic knowledge list), a group of subject matter experts (SMEs) in the area of nuclear reactor operations curriculum and training rated the extent to which each educational program covered the material on the academic knowledge list.

COVERAGE OF IDENTIFIED JOB-RELATED KNOWLEDGE (KNOWLEDGE LIST)

- There is a great deal of variation among individual specialized educational programs for licensed nuclear operators in their extent of coverage of job-specific academic knowledge.

- The range of variation among individual schools <u>within</u> each type of program--coursework, A.S. degree, and B.S. degree--is similar. No one type of program consistently provides greater coverage of job-related academic knowledge than the other types of programs.

- The schools in this study range from a minimum coverage of less than 15% to a maximum coverage of approximately 65% of the knowledge list content. Four schools cover at least half of this knowledge, and four schools cover less than one-third of this knowledge content.

- The traditional B.S. degree programs in nuclear engineering (B.S.N.E.) reported on in prior work (NUREG/CR-4051) were found to cover approximately 50% of the job-related knowledge identified in the academic knowledge list.

- Coverage of specific subject areas also varies across individual schools, although a few consistent patterns were found:

    - Very little job-relevant Chemistry and Engineering Drawing is covered in any of the programs.

    - The specialized A.S. degree programs focus most on nuclear-related subject areas (such as Atomic and Nuclear Physics, Health Physics, and Reactor Theory). They tend not to cover other basic areas (e.g., Electrical Science, Materials, and Classical Physics).

    - The specialized B.S. degree programs tend to concentrate most on basic generic areas (e.g., Classical Physics, Heat Transfer and Fluid Flow, and Electric Science) as opposed to the more specific applied areas (e.g., Reactor Plant Protection and Health Physics).

    - The coursework programs generally provide moderate coverage of a fuller range of subject areas than do the other two types of programs, rather than focusing on extensive coverage of a limited number of major subjects.

    - The traditional B.S. degree programs in nuclear engineering (B.S.N.E.) provide extensive coverage of both basic fundamentals (e.g., Electrical Science, Materials, and Classical Physics) and nuclear-oriented subjects (e.g., Atomic and Nuclear Physics and Reactor Theory).

- The wide variation among the specialized programs and lack of a standard curriculum appears to be due to the tailored nature of most program development. Generally, the specialized programs are used for specific subject content to complement existing utility training programs.

- A major difference between the content of the specialized educational programs and the content of traditional B.S.N.E. programs, is the latter's extensive coverage of higher level knowledge judged necessary only at the senior operator level, compared to virtually no coverage of this knowledge in the specialized programs.

DEVOTION OF PROGRAM CURRICULUM TO JOB-RELATED KNOWLEDGE AND TO ADDITIONAL KNOWLEDGE CONTENT

- The coursework and A.S. degree programs focus most of their required technical curriculum on job-related knowledge, in contrast to the specialized B.S. degree programs, which devote more attention to additional technical knowledge. Among the specialized coursework and A.S. degree programs, approximately 60% of the technical curriculum is devoted to knowledge list material and an additional 20% to other job-related knowledge. Within the specialized B.S. degree programs, approximately 40% of the required technical material covers content on the knowledge list and an additional 15% covers other job-related knowledge.

- The specialized A.S. degree and B.S. degree programs provide some coverage of non-technical areas (e.g., humanities and social sciences), which are not addressed by the coursework programs.

CONCLUSIONS

- There is no systematic difference in the job-relatedness of the various types of specialized educational programs, A.S. degree, B.S. degree and coursework, when job relevance is defined as the extent of coverage of knowledge content identified as directly necessary for carrying out the jobs of licensed reactor operators.

- Because of the substantial variation among schools within each type of program, it is not feasible to identify a specific program type for particular consideration for a standard educational qualification. No specialized program type sampled in this study--coursework, A.S. degree, or B.S. degree--offers a similar curriculum across individual schools.

- Traditional B.S. degree programs in nuclear engineering are as job-relevant or more job-relevant than most of the specialized educational programs in terms of covering identified job-related academic knowledge.

- The specialized coursework programs can be described as the most "efficient" in terms of job-relevance because of the narrower focus of their curricula. These programs devote the least attention to technical and non-technical content that is not directly job-related. However, as reported above, they do not generally cover more job-related content than the other program types.

- In most cases at least half of the job-specific academic knowledge remains to be covered in plant training programs rather than being taught in the specialized formal educational programs. Thus, there is considerable reliance on plant training for acquisition of job-related academic knowledge within the industry, even when specialized formal educational programs are utilized for licensed operators.

ACKNOWLEDGMENTS

We wish to thank the personnel from the educational institutions participating in this study for their contribution of time and effort in providing the documentation necessary for this work. We also wish to acknowledge the contributions of P. Clare Goodman, NRC technical monitor, to the technical design of the study as well as to the administration of the project. Finally, we want to express our appreciation to Anita Freeze for her excellent work in the preparation of the graphics and manuscript for this report.

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1. INTRODUCTION

1.1 Background and Purpose

The determination of the appropriate educational background relevant for licensed nuclear reactor operators has been a concern of the Nuclear Regulatory Commission (NRC), the nuclear industry, and the public for the past several years (e.g. see INPO-81-001, NUREG-0585, NUREG/CR-1250, SECY-82-162, Melber et al., 1982). The Operator Qualifications Project for the Division of Human Factors Safety of the NRC recently has focused on an examination of the job-relevance of selected educational programs for licensed operator positions. In NUREG/CR-4051 the extent to which traditional baccalaureate degree programs in engineering covered the knowledge necessary for licensed operator positions was analyzed. This report expands the prior work reported in NUREG/CR-4051, by examining a broad range of college credit programs being used by utilities for licensed operators, including A.S. degree, B.S. degree, and coursework programs.

The purposes of this report are to identify the content covered in the curricula of these specialized educational programs for reactor operators and to indicate the extent of job-relevant knowledge taught in these programs. There is an interest in determining if there are consistent patterns in the content areas for which educational institutions are being utilized by the nuclear industry to provide knowledge to reactor operators. In addition, the coverage of material beyond that identified as directly job-relevant is of interest in order to accurately describe the full range of the educational programs serving reactor operators.

1.2 Technical Approach

The approach used to determine the job-relevance of the specialized educational programs is content validation. This approach can be used to identify the extent to which the specific content of an educational program is related to a job by systematically comparing the knowledge taught in the curriculum of an educational program to the knowledge necessary for carrying out the job. The basic elements of this approach involve:

1. definition of knowledge needed for the job based on results of job analyses;

2. the identification, selection, and description of potentially relevant educational programs; and

3. a systematic comparison of the knowledge requirements of the job to the knowledge content of the educational programs.

The specific process used to apply this approach in this study is detailed in the Methodology section (2). Section 3 discusses the results of the study, describing in detail the extent of job-relevance of the sample of specialized educational programs, and Section 4 provides a summary of the major findings and presents the conclusions of the report.

2. METHODOLOGY

2.1 Overview

As stated in the Introduction, the objective of this study is to assess various specialized formal educational programs for licensed nuclear power plant operators. In order to accomplish this objective, a content validation approach was used.

Content validation involves a systematic comparison of the content of a potential qualification (in this case an educational program) with the content of a job. By doing this, a determination can be made regarding the extent to which an educational program is relevant to a job.

While there are variations in conducting a content validation study, the typical steps are as follows:

1. Define job content.
2. Define the content of the educational programs.
3. Systematically compare the content of the educational programs to the job content.

An overview of how the above three steps were conducted for this study is provided below, followed by more detailed explanation in the remainder of this chapter. The following steps and the details of how they were carried out were modeled after an approach developed for and applied in a previous study which focused on formal Bachelor of Science in Nuclear Engineering (BSNE) college programs (NUREG/CR-4051).

Step One: Define Job Content. As in the previous study (NUREG/CR-4051), job content was defined in terms of the academic knowledge list from the Institute of Nuclear Power Operations (INPO) job task analysis of nuclear power plant operators.

Step Two: Define the Content of the Educational Programs. The focus of this study was on specialized educational programs for nuclear power plant operators. Three categories of specialized educational programs were examined: coursework, A.S. degree, and B.S. degree. The content of each program selected for this study was defined by detailed descriptions of the courses taught in each program.

Step Three: Systematically Compare the Content of the Specialized Educational Programs to the Job Content. Four subject matter experts (SMEs) were selected to carry out comparisons between the content of the educational programs and the job content (academic knowledge list). In a workshop setting, the SMEs rated the extent to which an educational program covered the items on the academic knowledge list. They also assessed the job-relevance of any material in the educational curriculum that was not on the knowledge list.

A graphic representation of how content validation was approached in this study is shown below in Figure 2.1.

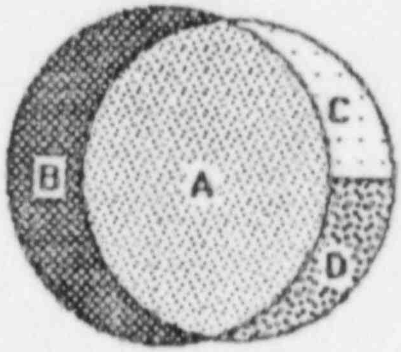


Figure 2.1: Representation of Content Validation

If the knowledge content of the job (defined by the academic knowledge list) is viewed as the circle on the left, and the knowledge content of an educational program (defined by the content of the curriculum) is viewed as the circle on the right, then content validation attempts to identify the amount of overlap between the two. In order to fully understand the relationship between the content of the job and the content of an educational program, several aspects, as indicated on the above figure, must be determined:

A = Overlap of educational program content with job content. This indicates the extent to which what an operator needs to know in terms of academic knowledge is covered in the educational program.

B = Academic knowledge needed by operators not covered in the educational program. This provides information on the extent to which academic knowledge content needed by operators is not covered in the program and thus would have to be covered elsewhere.

C = Additional job-relevant curriculum. This identifies the extent to which there is additional material in the educational program that is not on the academic knowledge list but is still relevant to what an operator needs to know to carry out the job. (An example of this would be material on specific plant systems that might be taught in a particular specialized educational program.)

D = Additional unrelated curriculum. This indicates the extent of additional curriculum in the educational program that is not related directly to what an operator needs to know to carry out the job.

2.2 Step One: Definition of Job Content

The academic knowledge list from the INPO job task analysis was used to define the content of academic knowledge required for the job. The INPO job task analysis provides a detailed list of academic knowledge items necessary for reactor operators (ROs) and senior reactor operators (SROs) to perform normal, abnormal, and emergency job tasks. This academic knowledge list was developed as part of the INPO job task analysis by having technical experts systematically identify the academic knowledge necessary to perform each of the tasks identified in the job task analysis. In addition to the academic knowledge list, the INPO job task analysis has other knowledge lists containing system and component knowledge items. These system and component lists are quite extensive and contain items specific to nuclear reactor design. The system and component knowledge lists were not used in this study nor the previous study (NUREG/CR-4051), because of the plant-specific nature of those knowledge lists.

The academic knowledge list is divided into 12 major subject areas (e.g., Mathematics, Reactor Theory). Each subject area is further organized by various knowledge categories and under the knowledge categories, specific job-related knowledge items are listed. A portion of the first page of the academic knowledge list is shown below as Figure 2.2.

The academic knowledge list contains 232 knowledge categories, with a total of approximately 1,700 specific knowledge items listed under the knowledge categories. A list of the 232 knowledge categories grouped by the 12 subject areas is provided in Appendix A. Knowledge categories that were judged as needed only at the SRO level (i.e., not necessary at the RO level) are indicated with an asterisk (*) (SRO level knowledge categories were identified by NRC operator licensing examiners, as described in NUREG/CR-4051).

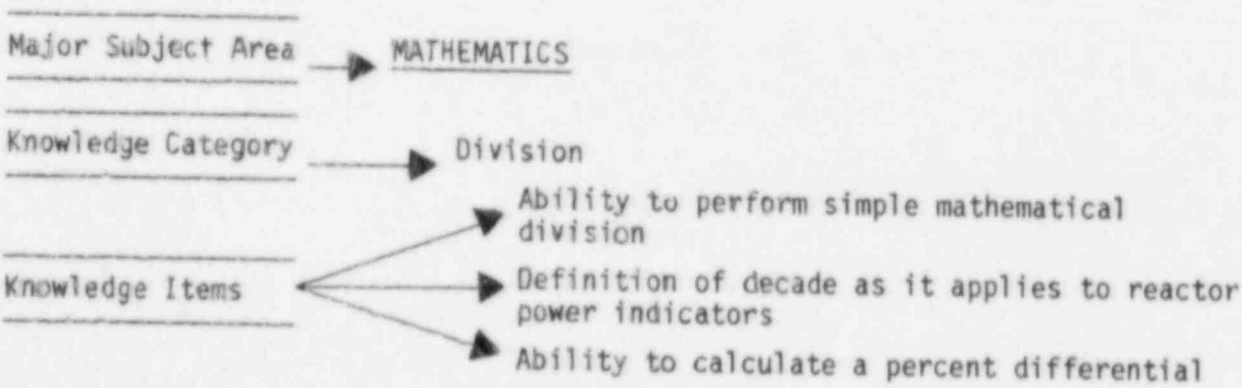


Figure 2.2: Example of Academic Knowledge List Format

2.3 Step Two: Definition of the Content of the Educational Programs

In order to define the content of specialized educational programs, two steps are required. First, potentially relevant educational programs (qualifications) must be identified and selected for the study. Then, the content of each of the selected programs needs to be specifically defined so that it can be compared to the job content (defined by the academic knowledge list).

2.3.1 Identification and Selection of Potentially Relevant Educational Programs

The focus of this study was on three categories of specialized formal educational programs that are currently used by the nuclear industry for the education of nuclear power plant operators. These three categories are:

1. Coursework programs
2. A.S. degree programs
3. B.S. degree programs

A listing of formal educational programs available in the United States in each of the above three categories was generated based on the following sources:

- University Programs and Facilities in Nuclear Science and Engineering (Oak Ridge Associated Universities)
- Career Guide: Education Programs in Nuclear Science (American Nuclear Society)
- New York State Board of Regents External College Degree Programs (New York State Board of Regents)
- Accredited Programs leading to Degrees in Nuclear Engineering Technology (Accreditation Board for Engineering and Technology)
- Information provided by the Nuclear Regulatory Commission
- Discussions with contacts in the nuclear industry

The criteria for a specialized educational program to be included on the list from which schools would be sampled for the study, were:

- The educational program is directed at licensed nuclear operator positions (e.g., nuclear engineering technology programs).
- The program is operating at the time of this study (i.e., courses offered and operators enrolled during the 1984-85 academic year).
- The courses offered through the program are approved for college credit.

Based on the above criteria, a total of 16 coursework programs, 10 A.S. degree programs, and 5 B.S. degree programs were identified. This list may not contain all specialized educational programs for reactor operators, but it is likely to cover most of these programs. A listing of all the schools identified is provided in Appendix B. In general, these programs were developed for nuclear power plant operators and attended by operators. In some cases, it appears that other plant personnel also attend the programs, for example shift technical advisors. A more detailed description of these programs is provided in Section 3.1.

From the listing of specialized educational programs that fulfilled the criteria, a sample of schools under each of the three categories was randomly selected for the study.

Three schools were selected under the coursework category. The coursework programs were evenly distributed across a wide range of credit hours (from 19-87 credit hours); therefore, the coursework programs were stratified into three subgroups: low, moderate, and high number of credit hours offered, with one program randomly selected from each subgroup. Three schools were randomly selected under the A.S. degree category and two schools were randomly selected under the B.S. degree category.

One back-up school was randomly selected for each category, in case of difficulties in obtaining participation from any of the schools. For the B.S. degree category only, it was necessary to use the back-up school as a replacement due to the late arrival of curriculum materials from one of the B.S. degree programs in the original sample.

2.3.2 Documentation of the Content of the Educational Programs

In order to define the content of the eight specialized educational programs randomly selected for the study, detailed documentation was obtained for the courses in each program. School officials, usually the director of the program or the dean responsible for the nuclear-related program, were asked via telephone to participate in the project. All agreed to participate and a follow-up letter was sent to them describing the study. They were requested to provide detailed course descriptions of all courses in the program. A sample of the type of course descriptions required for the content comparison process was included with the letter. This sample showed the level of detail requested for the course descriptions.

The documentation obtained from each school was placed in a consistent format so that it could be used easily by the subject matter experts for the comparison process. The detailed course descriptions for each school were organized with tabs under the 12 academic knowledge list subject headings (plus an "Other" category for required courses that did not appropriately fall under one of the 12 major subject areas). Two individuals with nuclear expertise reviewed each curriculum and arranged the course descriptions under the 13 headings.

The documentation for each school was placed in a notebook for use by the subject matter experts. The schools were identified by type of program (A.S., B.S., coursework) and code number only (e.g., A-1). At the front of each curriculum description was a listing of required technical courses and number of credits arranged under the subject headings. Also listed were required non-technical courses and required credit hours of electives.

In order to determine the adequacy of the curriculum descriptions received from each school, quality of documentation ratings (ranging from 0 to 10) were obtained from an NRC licensing examiner thoroughly familiar with the academic knowledge list and with the rating procedure used in this project. None of these ratings indicated documentation that would be inadequate for comparison purposes (no ratings less than 5). The subject matter experts also evaluated the quality of the school documentation at the workshop. While schools varied in the evaluations received, the documentation was adequate for carrying out the comparison process for all schools.

2.4 Step Three: Systematic Comparison of the Content of the Educational Programs to the Job Content

Following the approach used in NUREG/CR-4051, the process used for systematically comparing the content of the specialized educational programs to the job content (the academic knowledge list) involved the following steps:

1. Selection of subject matter experts (SMEs)
2. Development of the instructions for the SMEs for comparing the educational program content to job content
3. Collection of the data from the comparison process

2.4.1 Selection of Subject Matter Experts

The comparisons of the content of each of eight specialized educational programs with job content were made by four SMEs. The four SMEs were selected from a group of ten curriculum experts who were identified based on the following criteria:

- Technical expertise--knowledge of the subjects covered in specialized educational programs for nuclear power plant operations and the content areas of the academic knowledge list.
- Nuclear reactor operations knowledge--familiarity with reactor operations and the jobs of licensed nuclear reactor operators.
- Professional experience as educators in either training programs or academic institutions.

The four SMEs chosen were selected based on discussions with and approval from the Nuclear Regulatory Commission. Selection was based on a desired balance between SMEs from training organizations and those in academic institutions.

The backgrounds of the SMEs selected included: U.S. nuclear navy background; operations experience as a licensed operator on commercial and research nuclear reactors; development and delivery of operator training courses including simulator training; and teaching of formal educational courses in college nuclear engineering programs. The length of nuclear experience of the SMEs ranged from 8 to 18 years. A list of the four individuals who served as SMEs for this study is provided in Appendix C.

2.4.2 Development of Instructions for the SMEs

Instructions for the subject matter experts to carry out the comparison of the educational programs to job content were prepared. A subject matter expert from the previous study assisted by evaluating the instructions in terms of clarity and completeness. The instructions, described below, are shown in their entirety in Appendix D.

The instructions outline a preparatory task (I) followed by two rating tasks (II and III) for each SME to complete independently for each school assigned to that SME.

> I: Review of School Curriculum. Before rating curriculum coverage of the knowledge list content on a school, the SMEs were asked to thoroughly review the content of the school curriculum, which was provided in a notebook. These instructions are shown on page D-2 of Appendix D.
>
> II: Academic Knowledge List Ratings. The SMEs were then instructed to rate the extent to which each of the 232 knowledge categories on the academic knowledge list was covered by the curriculum being reviewed. The following rating scale was used:
>
> - 0 = Prerequisite - knowledge not taught in curriculum, but necessary for content that is covered in curriculum
> - 1 = No Coverage - essentially no coverage of the category in curriculum
> - 2 = Minor Coverage - a small part of the category is covered, but many gaps
> - 3 = Moderate Coverage - some of the category covered, some not covered
> - 4 = Substantial Coverage - most of the category is covered with a few minor gaps
> - 5 = Total Coverage - essentially all of the category is covered
>
> The instructions indicated that a 4 or 5 rating would be counted as a knowledge category that is covered in the curriculum being reviewed.
>
> The specific instructions for this task, the Academic Knowledge List Ratings, are provided on pages D-3 to D-5 of Appendix D. The results of the Academic Knowledge List ratings are provided in Sections 3.3 and 3.4 of the Results chapter.

III. Additional Curriculum Estimates. The Academic Knowledge List Ratings identify the academic knowledge content necessary for nuclear power plant operators that is covered in a particular curriculum, and the content needed by operators that is not covered in the curriculum. However, to fully assess the relationship between academic knowledge needed by operators and the knowledge content of a particular school's curriculum, it needs to be determined whether there is "additional" curriculum content in the program and the nature of this "additional" curriculum. Therefore, "Additional Curriculum Estimates" were completed by the SMEs as a separate rating task. These estimates were for the purpose of identifying two types of potential "additional" curriculum:

- Additional curriculum (not on academic knowledge list), but still related to the job of operator.
- Additional curriculum (not on academic knowledge list), and not related to the job of operator.

In other words, for this task the SMEs made estimates concerning the amount of additional job-related (necessary) and non-job-related (not necessary) curriculum in the program being reviewed (if any). The instructions for this task are detailed on pages D-6 and D-7 of Appendix D. The results of the Additional Curriculum Estimates are provided in Section 3.6.

The instructions, the academic knowledge list, and part of one school's curriculum (Math and Chemistry coursework for School AS-1) were sent to each of the SMEs before coming to the workshop. The SMEs familiarized themselves with the academic knowledge list and completed the "Academic Knowledge List Ratings," on the partial curriculum. They then sent this back and the pilot data was analyzed to assess that there was adequate agreement on completing the tasks.

2.4.3 Collection of Data from the SMEs

The data was collected at a 3-day workshop held in Seattle, Washington during June, 1985. The workshop agenda consisted of an initial discussion of the workshop tasks, followed by individual working sessions on each school, and group discussions of each school. In general, the individual working sessions went from 1 1/2 to 3 hours in length, after which the schools completed during that time period were discussed in a group format. These group meetings included discussions on the quality of the documentation on each school.

Three SMEs reviewed each school curriculum. The assignment of schools to the SMEs is listed on the following page.

	School Rated							
SME	AS-1	BS-1	C-1	AS-2	C-2	BS-2	C-3	AS-3
1		X	X	X	X		X	X
2	X	X	X		X	X		X
3	X		X	X	X	X	X	
4	X	X		X		X	X	X

AS-1, AS-2, AS-3 = A.S. Nuclear Technology Degree Programs
BS-1, BS-2 = B.S. Degree Programs
C-1, C-2, C-3 = Coursework Programs

Figure 2.3: Study Design

Following the workshop, the data was analyzed as discussed in the next chapter, Results.

3. RESULTS: CURRICULUM COVERAGE OF JOB-RELATED KNOWLEDGE

3.1 Overview of Sample of Specialized Educational Programs

The sample of eight programs studied cover the spectrum of the types of specialized educational programs being used by the nuclear industry for licensed reactor operators. All of the programs in the sample serve workers at nuclear power plants who are currently licensed or in training for licensing at the RO and/or SRO level(s); two of the programs are directed at Shift Technical Advisors. In addition, some of the programs serve a general student population in preparation for entry into reactor operator positions in the nuclear industry. In most cases, the continuing education section of the educational institution coordinates the development of programs, which generally involves combining courses from engineering or engineering technology departments, science and mathematics departments, and at times junior college courses and plant training courses which have been evaluated for granting of college credits.

The three coursework programs are all associated with degree programs, so that students may apply credits earned toward a degree. Two of the coursework programs serve Shift Technical Advisors as well as Senior Operators. The three associate degree programs are all in nuclear technology, in contrast to the two bachelor degree programs in the sample which are not in nuclear technology nor in nuclear engineering.

As described in Section 2.3.1, the three coursework programs (Schools C-1, C-2, and C-3) are drawn from the wide range of these type of programs. As shown in Table 3.1, School C-3 encompasses 36 credit hours, compared to 66 hours for School C-1 and 122 hours for School C-2 (converted to quarter credit hours). All of the coursework programs are comprised of a set of required technical courses; they do not have elective or non-technical courses as part of the program.

The A.S. degree programs (Schools AS-1, AS-2, and AS-3) also vary in terms of total credit hours, (from 65 to 120 credit hours). All the A.S. degree programs also require some credits in non-technical areas such as humanities and social sciences.

The B.S. degree programs (Schools BS-1 and BS-2) are the most extensive in terms of total credit hours (203 and 192 hours, respectively). Their number of required technical credits are similar to the more extensive coursework and A.S. degree programs, but they have the greatest non-technical credit requirements. They also include technical electives as part of the program, which generally is not part of the coursework and A.S. degree programs.

3.2 Rating Agreement Among Subject Matter Experts

Three SMEs made ratings on each of the 8 schools in terms of coverage of the Academic Knowledge List and Additional Curriculum Estimates. Therefore, in order to carry out analyses on each school, one summary rating based on the three SME ratings had to be generated. The mean of the three ratings was used as this summary rating. A justification for

TABLE 3.1

OVERVIEW OF PROGRAM CREDIT HOURS

Course Credits (in quarter hour equivalents)	Coursework			Associate			Bachelor	
	C-1	C-2	C-3	AS-1	AS-2	AS-3	BS-1	BS-2
Required Technical Credits	66	122	36	102	68	75	144	85
Non-Technical Credits	0	0	0	18	22	23	36	52
Technical Elective Credits	0	0	0	0	*	0	23	0
Technical or Non-Technical Elective Credits	0	0	0	0	0	0	0	55
TOTAL CREDITS	66	122	36	120	90	98	203	192

*At least one technical elective, number of credits unspecified, is required.

using the mean score of ratings is that there is sufficient agreement among them to warrant a summary score for all three.

The amount of agreement among the raters was assessed using the Chi^2 statistic. The average Chi^2 value for the knowledge category ratings for each school ranged from 4.0 to 5.2, and for the additional curriculum estimates ranged from 5.9 to 7.2, for a random sample of half the schools. The probability that interrater agreement occurred by chance (i.e. the level of statistical significance) ranged from 8% to 15% for the ratings of coverage of the knowledge list content and from less than 2% to 5% for the estimates of additional curriculum content. These Chi^2 values indicate adequate agreement among the SMEs to justify using the mean ratings.

In rating the 232 knowledge categories across the eight schools, the ratings of the three subject matter experts for each school differed by only one point on the 5 point scale in approximately half of the cases (46%). In another quarter of the cases, the three raters differed by two points on the rating scale.

In terms of estimating the extent of the curriculum covering material not on the knowledge list there was close agreement among the subject matter experts on the extent of additional job-related material taught by each school. In estimating the percentage of the total required technical curriculum which was additional to the content of the academic knowledge list, but job-relevant in their judgment, the raters' judgments were within 5 points for four of the schools, within 10 points for two of the schools, and within 25 points for the remaining two schools (out of a possible range of 100 percentage points). There was greater variation concerning the extent of additional material that was not directly related to the jobs of licensed reactor operators. The subject matter experts were within 10 points for three of the schools, within 30 points for two of the schools, and within 45 points for the remaining three schools. The mean percentage score was used as the best estimate of the portion of the required technical curriculum that was additional to the knowledge list content.

3.3 Extent of Coverage of the Academic Knowledge List

3.3.1 Individual School Profiles

The extent of coverage of the complete list of job-related academic knowledge by specialized educational programs was determined by computing the percentage of all 232 knowledge categories from the academic knowledge list receiving a mean rating of "substantial coverage" (mean score greater than 3.5 on a 5 point rating scale, see Section 2.4.2 and Appendix D, Task II). When at least two of the three raters for an individual program indicated the content of a knowledge category was not directly taught in a school curriculum but would be prerequisite to other content in the curriculum, the category was designated as prerequisite (see Appendix D, p. D-4). Where this prerequisite knowledge would be covered was not addressed; presumably it would be covered either in high school level coursework or in plant training courses taken prior to entry into the specialized educational programs.

The results for each school are presented in Figures 3.1 to 3.3. For example, as shown in Fig. 3.1, for School C-1, 5% of the 232 knowledge categories are prerequisites for material covered in the curriculum, 44% of the categories are covered in the program, and the remaining 51% of the categories are not covered.

The results indicate that there is very little knowledge list content that is prerequisite to the content taught in the specialized educational programs. On average, only 4% of the knowledge categories were identified as prerequisites; the individual programs ranged from 2% to 8% of the knowledge list content as prerequisite material.

A review of the overall coverage of identified job-related knowledge by individual programs indicates that the curriculum of School C-2 provides the greatest coverage of the knowledge list content; 63% of all the knowledge categories are taught in this coursework program. School AS-1, School BS-2, and School C-1 all cover approximately half of the total knowledge list content. The remaining programs, Schools AS-2 and AS-3, School BS-1, and School C-3 cover less than one third of the knowledge categories.

The most striking feature of the school profiles is the variation across the individual programs. The schools differ substantially in the extent of job-related content being taught.

3.3.2 Coverage of the Total Knowledge List by Program Type

Combining the results of the individual schools by program type, as shown in Figure 3.4, indicates no differences among the types of programs in terms of extent of overall coverage. On the average, each type of program covers approximately 35%-40% of the knowledge categories. This is due to the variation across individual programs within each type, described above. Two of the three coursework programs, one of the three A.S. degree programs, and one of the two B.S. degree programs cover half or more of the total knowledge list, while one coursework program, two A.S. degree programs, and one B.S. degree program covers less than a third of the knowledge list content.

These findings demonstrate that there is no particular type of specialized educational program that consistently provides more substantial coverage of the job-related knowledge than other program types.

3.3.3 Comparison to B.S. in Nuclear Engineering

The results from the specialized educational programs were compared to findings from a similar study of coverage of job-related knowledge by B.S. degree programs in nuclear engineering (B.S.N.E.) (see NUREG/CR-4051). As shown in Figure 3.5, the nuclear engineering degree programs on the average cover 53% of the knowledge list content. More of the knowledge list content is prerequisite in these programs, 9% relative to an average of 4% in the specialized programs. (The prerequisite material in the

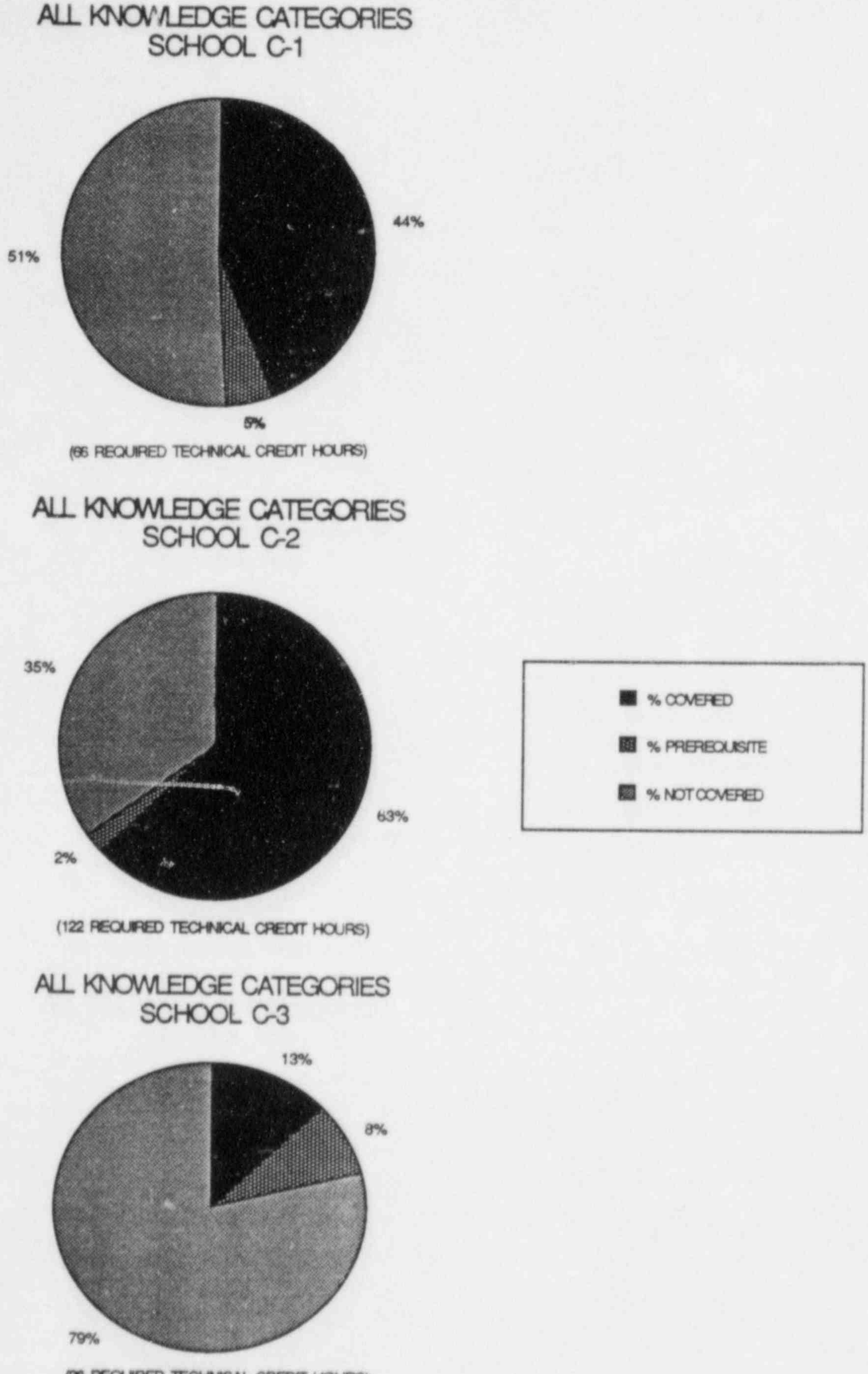


Figure 3.1: Coverage of Academic Knowledge List by Coursework Programs

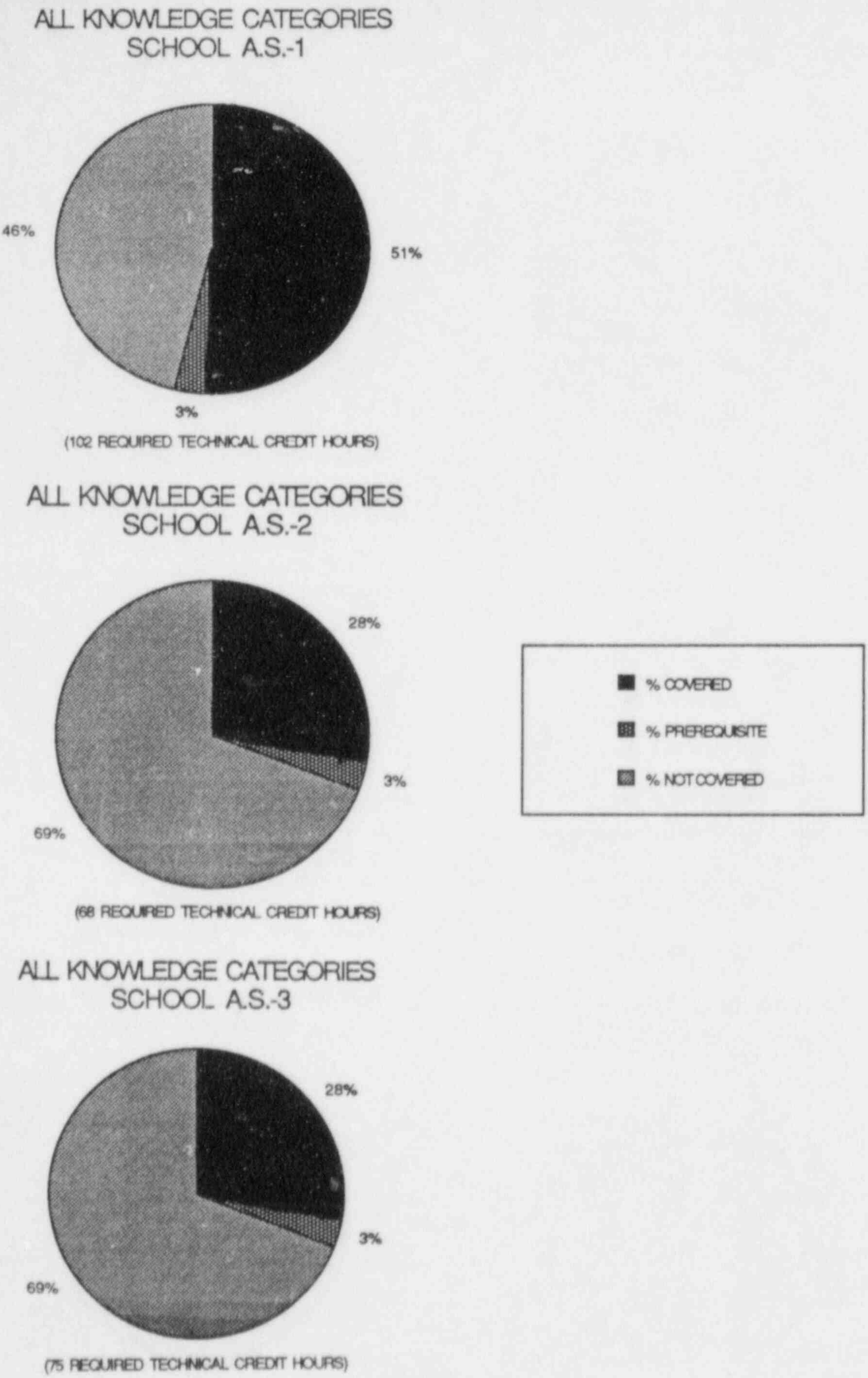


Figure 3.2: Coverage of Academic Knowledge List by A.S. Degree Programs

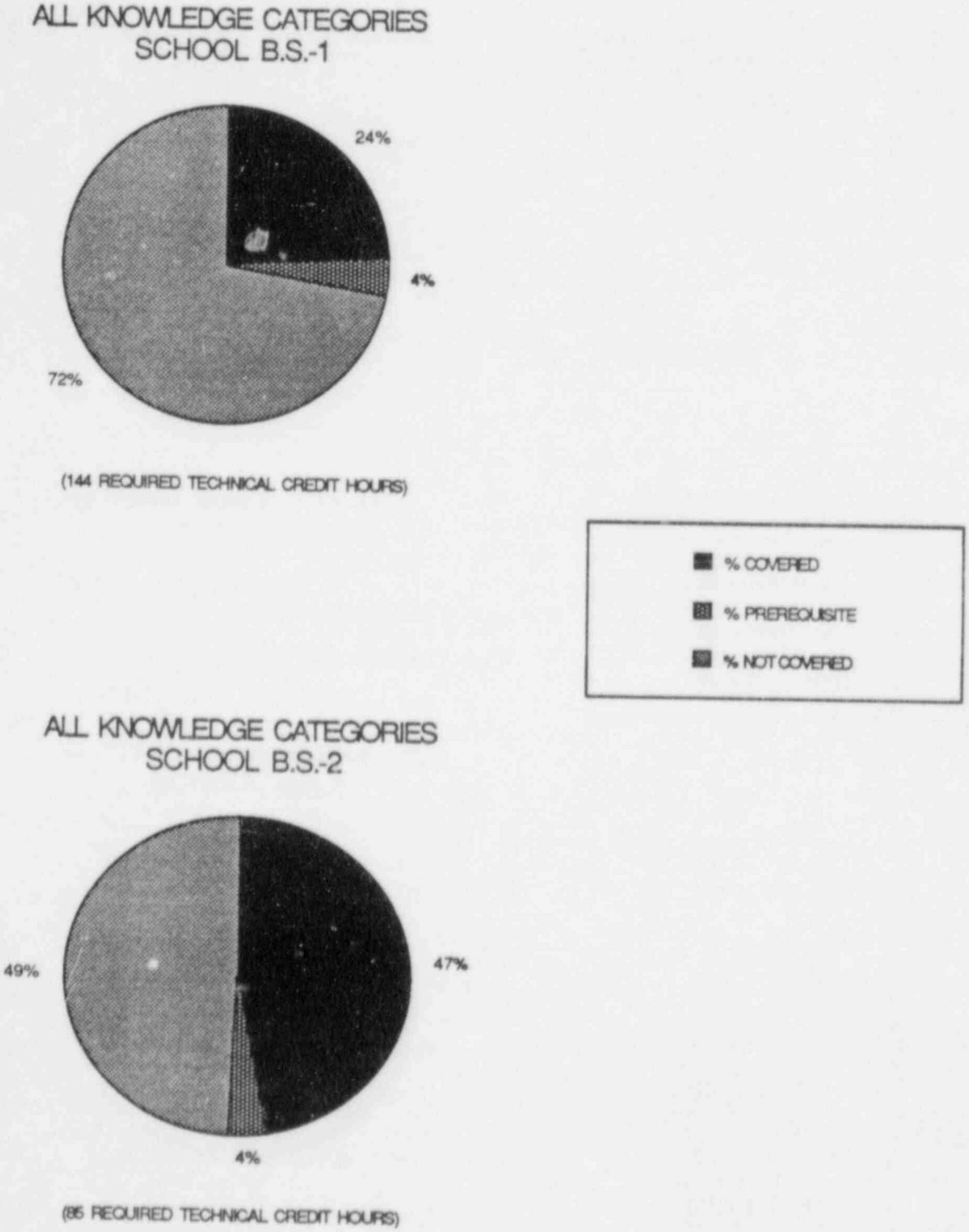


Figure 3.3: Coverage of Academic Knowledge List by B.S. Degree Programs

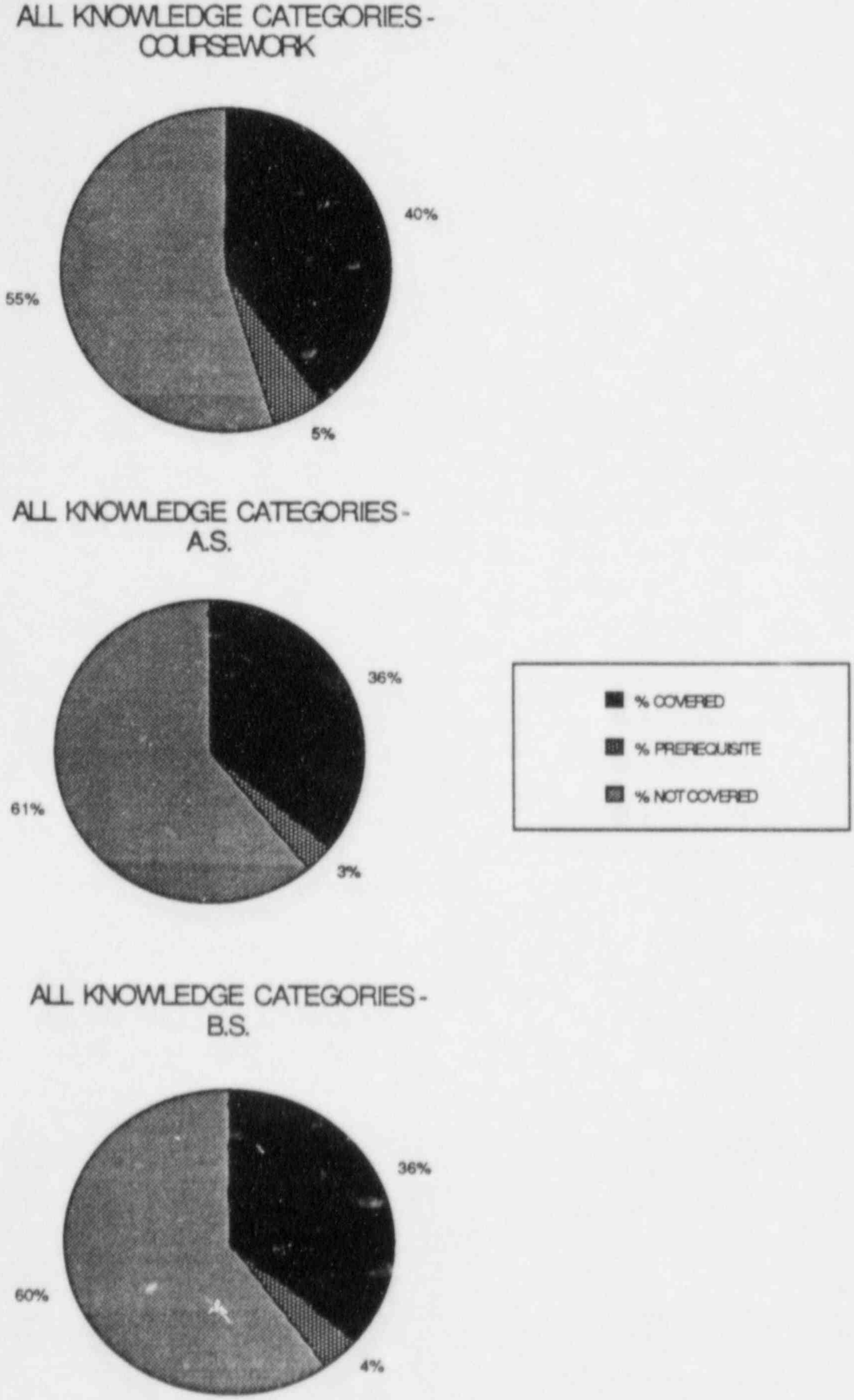


Figure 3.4: Comparison of Coverage of Academic Knowledge List by Type of Program

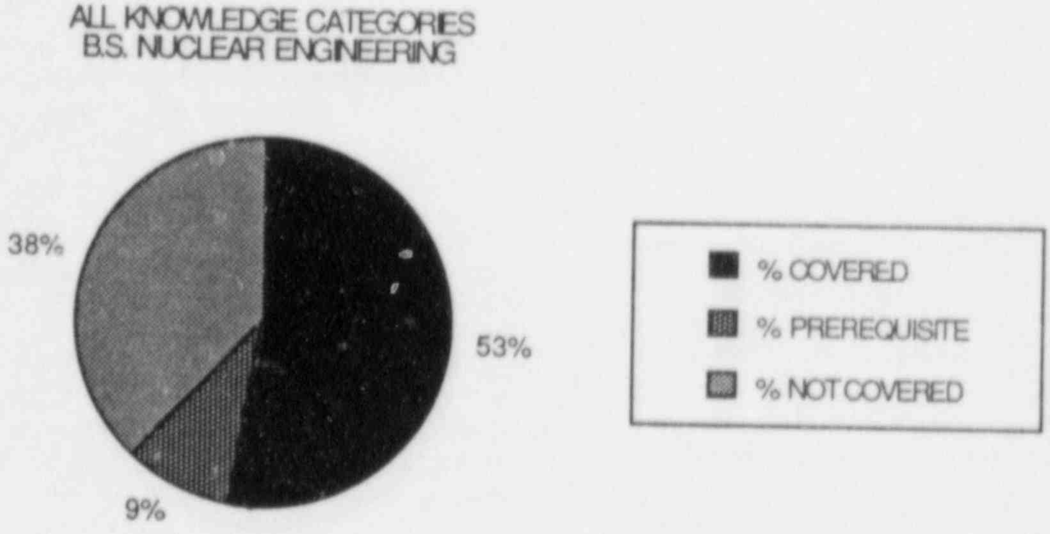


Figure 3.5: Coverage of Academic Knowledge List by B.S.N.E. Programs

B.S.N.E. programs refers specifically to content covered in high school courses required for entry into B.S. engineering degree programs.) While the B.S.N.E. programs provide more than the average coverage of the specialized coursework, A.S. degree, and B.S. degree programs, (which ranges from 35%-40%), they provide the same extent of coverage as three of the individual programs (Schools AS-1, C-1, and BS-2), and less than one of the programs (School C-2) which covers 63% of the total knowledge list. Thus, the B.S.N.E. programs are similar to several of the individual specialized educational programs in terms of the extent of their overall coverage of identified job-related knowledge.

3.4 Coverage of Major Subject Areas

3.4.1 Individual School Profiles

In order to characterize the content of coverage of identified job-related knowledge by specialized educational programs, the extent of coverage within each major subject area was examined for each of the eight programs. A knowledge category was considered covered by a given curriculum when the average rating of the category was "substantially covered" (mean score greater than 3.5 on a 5 point scale as described in Section 2.4.2 and Appendix D, Task II).

The extent to which each school curriculum provided coverage of the knowledge categories comprising each major subject area is presented in Figures 3.6 to 3.9. The percentage of knowledge categories within a subject area specifically documented as taught in a curriculum is indicated as the "percent covered." In addition, the percentage of knowledge categories comprising each subject area that were prerequisites to the material taught in a program is indicated as "percent prerequisites." For example, in Figure 3.6, School C-1 Profile, 55% of the 20 knowledge categories under Mathematics are necessary prerequisites for the Mathematics covered in the curriculum, and 20% of the categories are taught directly in the program.

As discussed above (in Section 3.3.1), the variation across the individual schools is substantial. There are only a few subject areas where there is consistency in the extent of coverage across schools.

Mathematics was the only subject area where a considerable portion of the job-relevant knowledge was a prerequisite to the math courses in each program. For most of the programs, between 1/3 and 1/2 of the mathematics knowledge categories were prerequisites to the mathematics taught in a curriculum. Combining prerequisites and direct coverage in the curriculum, Mathematics also was the subject most completely covered across all schools. At completion of the programs, students would have covered at least 2/3 of the Mathematics knowledge on the knowledge list in seven of the eight schools.

Atomic and Nuclear Physics is substantially covered by six of the schools, ranging from almost 60% to over 90% coverage of knowledge categories in that subject area. In addition, five of the schools cover the majority of the knowledge categories in the areas of Reactor Theory and Health Physics.

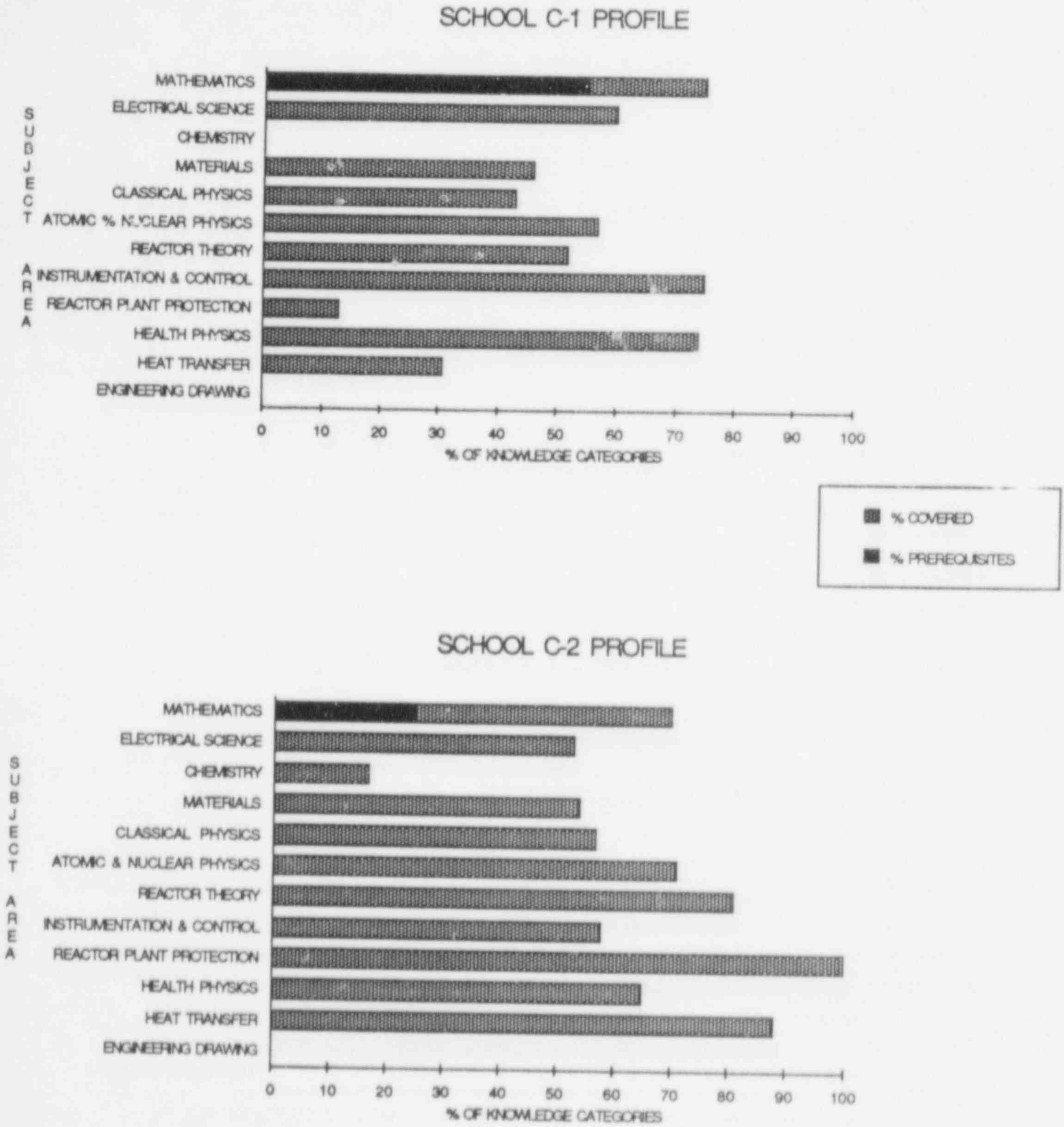


Figure 3.6: Coverage of Academic Knowledge List by Subject Area - Schools C-1 and C-2

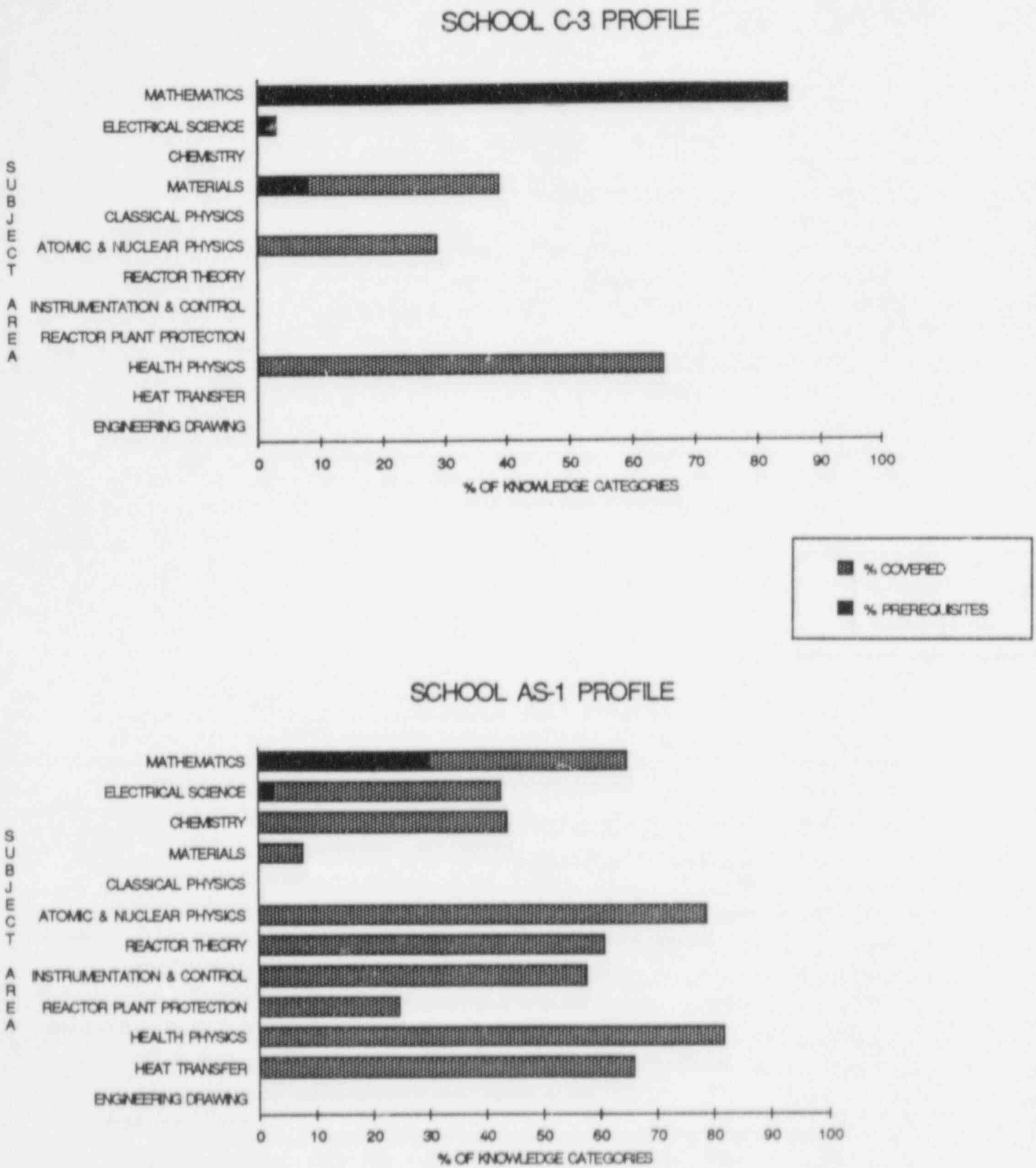


Figure 3.7: Coverage of Academic Knowledge List by Subject Area - Schools C-3 and AS-1

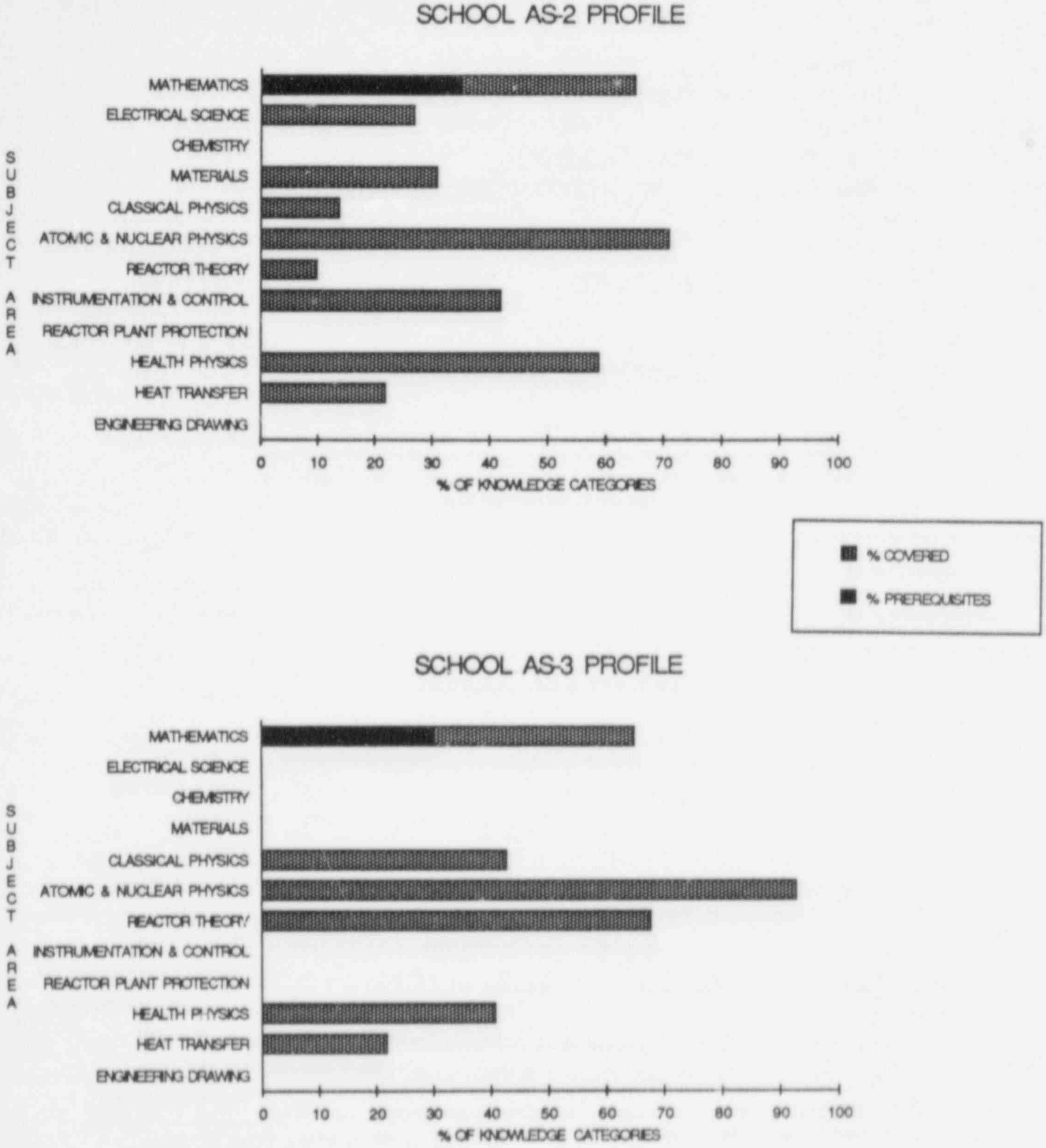


Figure 3.8: Coverage of Academic Knowledge List by Subject Area - Schools AS-2 and AS-3

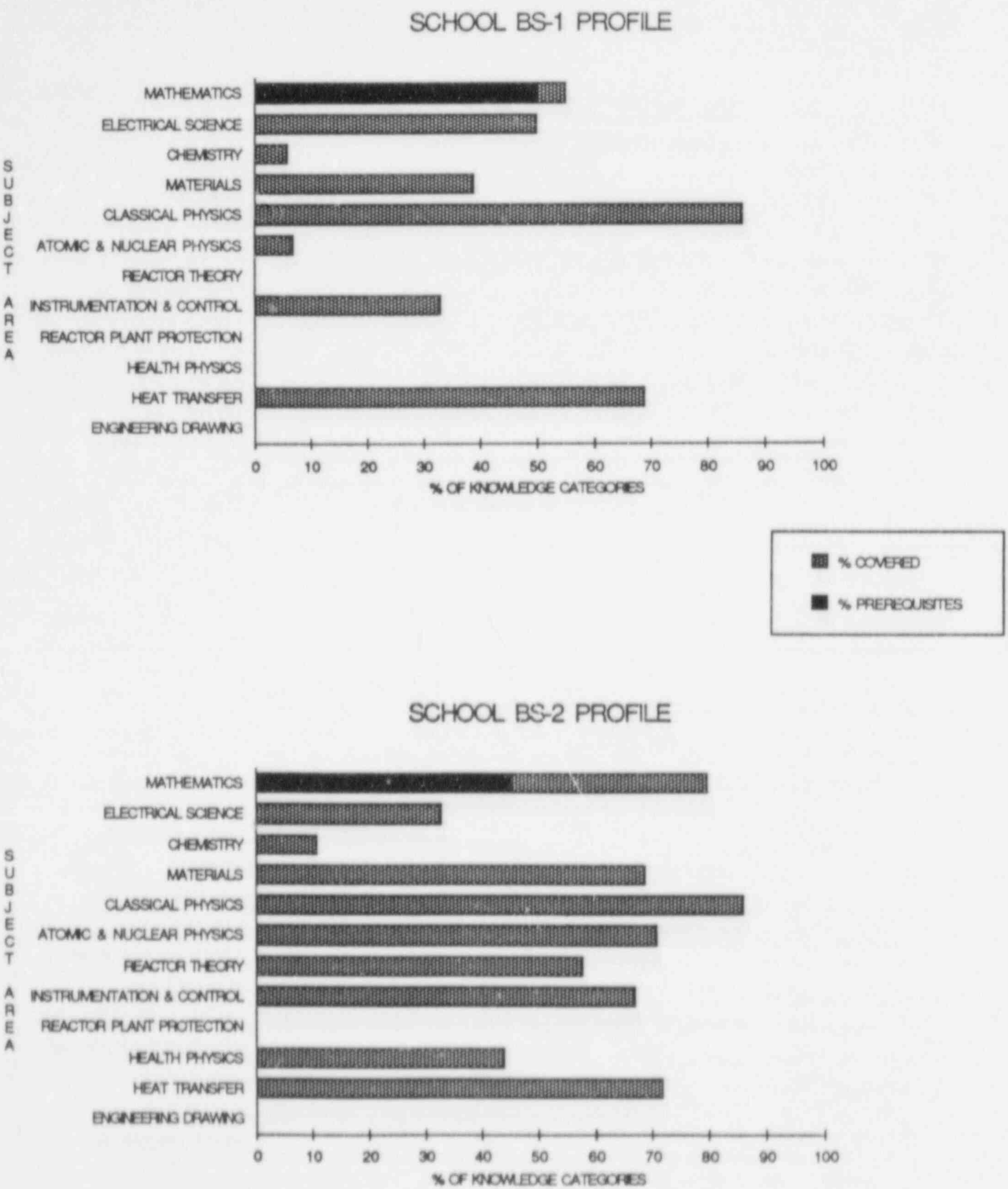


Figure 3.9: Coverage of Academic Knowledge List by Subject Area - Schools BS-1 and BS-2

Reactor Plant Protection is not covered at all by five schools and is taught minimally by two schools (with less than 25% coverage of this area).

Chemistry and Engineering Drawing are the subject areas least covered in the specialized educational programs. Engineering Drawing is not covered by any of the programs. Seven of the eight schools cover little or none of the job-related chemistry identified on the knowledge list. Four teach none; three teach less than 20%. This is likely to be due to the narrow focus of chemistry that is directly relevant to nuclear reactor operators, which is limited primarily to water chemistry. This specialized area of chemistry is only one small area covered in basic college-level chemistry courses.

The individual schools vary with respect to coverage of the remaining subject areas. For example, half of the schools cover most of Heat Transfer (from 66% to 88%), while half cover little or none. The curricula of the individual schools in the areas of Electrical Science, Materials, Classical Physics, and Instrumentation and Control, similarly, are spread across the range from minimal to substantial coverage of the knowledge categories within these subjects.

Turning to the individual programs, School C-2 provides substantial coverage of most of the subject areas with the exception of Chemistry and Engineering Drawing. Schools AS-1, C-1 and BS-2 also cover a broad range of the subject areas. School AS-3 appears to be focused primarily in the areas related to physics, covering some job-related knowledge in Mathematics, Classical Physics, Atomic and Nuclear Physics, Reactor Theory, Health Physics, and Heat Transfer, and not covering knowledge identified in the other subject areas. School C-3 teaches courses primarily in the areas of Materials, Atomic and Nuclear Physics and Health Physics. Schools BS-1 and AS-2 cover some material across a broader range of subject areas, but only two to three of the subject areas show substantial coverage.

The variation across the schools most likely reflects the tailored nature of these specialized educational programs. These A.S. degree, B.S. degree and coursework programs are, for the most part, used to teach specific areas in conjunction with particular plant training programs.

3.4.2 Patterns by Type of Program

The findings for individual schools were aggregated by type of program--coursework, A.S. degree and B.S. degree--in order to determine if distinctive patterns existed for specific types of educational programs. The coverage of subject areas by type of program is presented in Figure 3.10. For example, the B.S. degree programs cover 68% of the knowledge categories in Mathematics (including prerequisites), the A.S. degree programs cover 62%, and the coursework programs cover 77% of the knowledge identified under Mathematics.

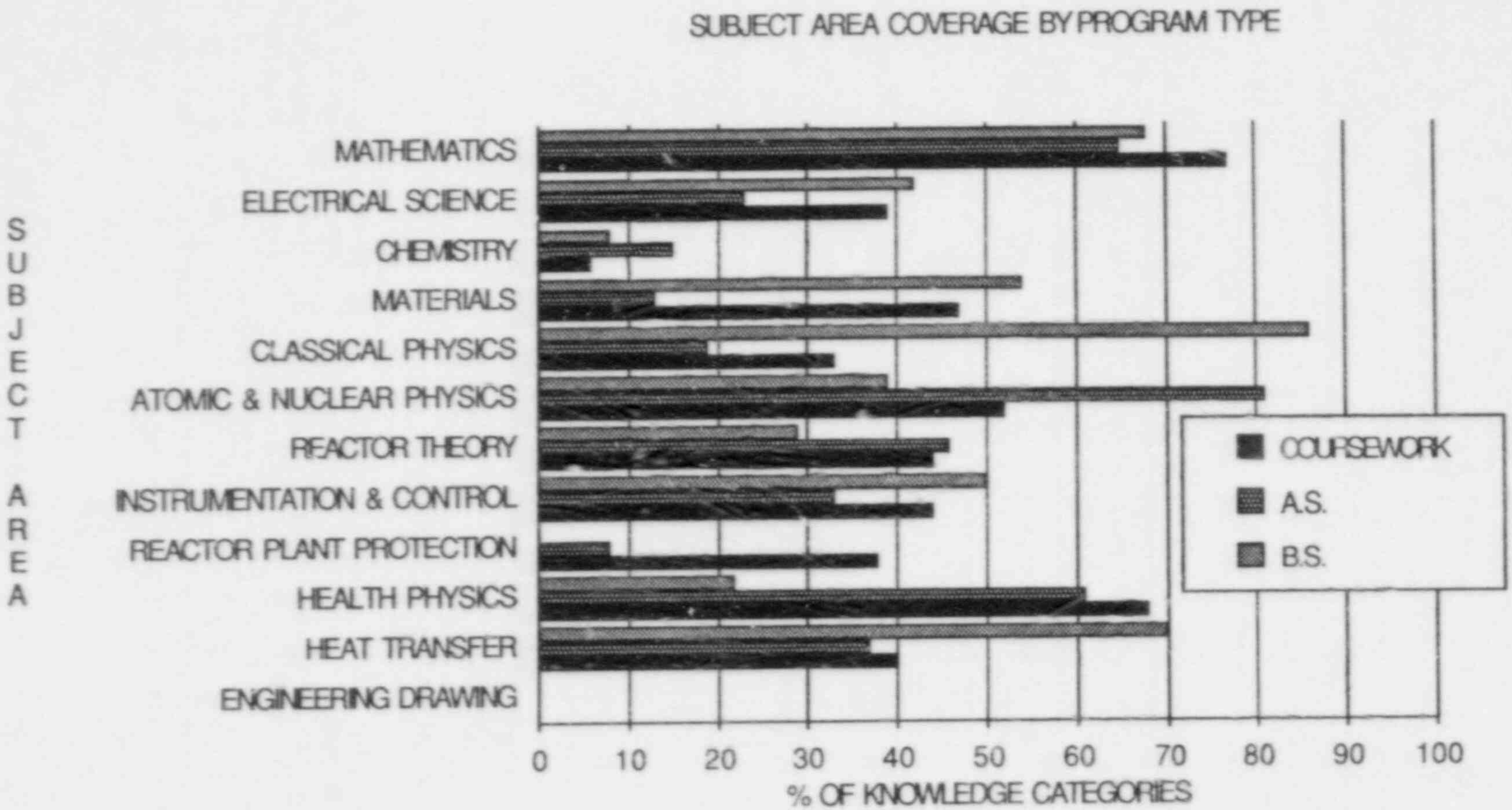


Figure 3.10: Comparison of Subject Area Coverage of Academic Knowledge List by Type of Program

The specialized B.S. degree programs cover most of the knowledge categories comprising Classical Physics and Heat Transfer, and cover these areas much more extensively than the A.S. degree and the coursework programs. These programs also cover a moderate amount (40% or more) of the job-related knowledge in the areas of Electrical Science, Materials, Atomic and Nuclear Physics and Instrumentation and Control. The areas least covered in the B.S. degree programs are Chemistry, Reactor Plant Protection, Health Physics and Engineering Drawing. It appears, then, that the specialized B.S. degree programs tend to focus on basic fundamentals more than on the specific applied areas.

The specialized A.S. degree programs cover Atomic and Nuclear Physics and Health Physics to a considerable extent and teach a moderate amount of the topics within Reactor Theory, Heat Transfer and Fluid Flow, and Instrumentation and Control. They cover little of the basic areas of Electrical Science, Materials, and Classical Physics, and provide virtually no coverage of the areas of Chemistry, Reactor Plant Protection, and Engineering Drawing. These programs tend to emphasize coverage of the nuclear-related topics. They, generally, are not being used to teach fundamentals in other areas.

The specialized coursework programs cover a moderate amount of all the subject areas, excluding Chemistry and Engineering Drawing (which are not covered by any of the programs). The subjects most extensively covered are Health Physics (68%) and Atomic and Nuclear Physics (52%). The coursework programs tend to cover a broad range of subject areas rather than focusing on extensive coverage of a more limited selection of subject areas.

3.4.3 Comparison of Specialized Programs to a B.S. Degree in Nuclear Engineering

The extent of subject area coverage of specialized educational programs was compared to that of traditional B.S. degree programs in Nuclear Engineering, based on results from the earlier study (NUREG/CR-4051). The coverage of knowledge categories by subject area for B.S.N.E. programs is presented in Figure 3.11.

The nuclear engineering B.S. degree programs cover both basic fundamentals (Mathematics, Electrical Science, Materials, Classical Physics, Heat Transfer and Fluid Flow) and nuclear-oriented subjects (Atomic and Nuclear Physics, Reactor Theory, and Health Physics) quite extensively. Coverage of these subject areas (including prerequisites) ranges from 60% (Electrical Science and Heat Transfer) to 100% (Classical Physics and Atomic and Nuclear Physics).

The B.S.N.E. programs are similar to the specialized programs in the very limited coverage of job-related chemistry and engineering drawing. They differ from the specialized programs in their lack of coverage in Instrumentation and Control.

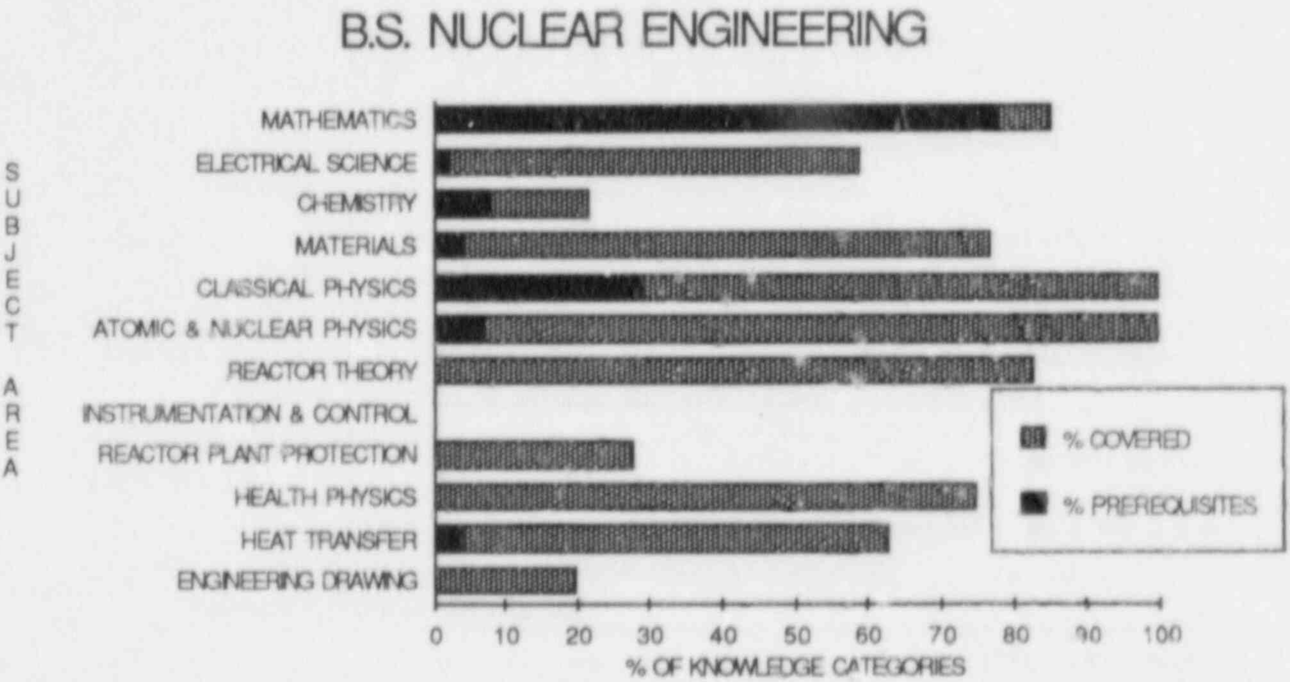


Figure 3.11: Coverage of Academic Knowledge List by Subject Area - B.S.N.E. Degree Programs

Note: Percentages computed from NUREG/CR-4051 (Appendix A).

The B.S.N.E. programs, in general, appear to be as job-relevant as the specialized educational programs in terms of the range of subject matter covered and the extent of coverage within subject areas on the knowledge list.

3.5 Coverage of SRO Level Knowledge Categories

A small subset of knowledge categories have been identified as necessary for the SRO job position but not for the RO position in NUREG/CR-4051. These categories are listed in Table 3.2.

The coverage of these areas in the specialized programs was examined. Six of the schools did not cover any of the material within these knowledge categories, and the remaining two--B.S.-1 and A.S.-3--covered 8% and 21%, respectively, of the categories.

These findings are in marked contrast to the coverage of SRO level knowledge categories by the B.S.N.E. curriculum (NUREG/CR-4051). These nuclear engineering programs covered 85% of the knowledge categories necessary for the SRO position but not for the RO level position, and an additional 9% were covered in prerequisites to entry into the engineering program.

The SRO level knowledge content was identified as covered primarily in upper division courses as opposed to being taught during the first two years of engineering degree programs. It appears that some of the job-specific academic knowledge that is higher level remains to be covered in plant training since it is not taught in the specialized educational programs.

3.6 Devotion of Curriculum to Job-Related Knowledge

The focus of the results presented thus far has been on the extent to which the identified job-related academic knowledge is covered in various types of educational programs. However, it is important to determine what portion of each school's program is devoted to the job-related knowledge identified in the academic knowledge list and what portion is devoted to additional knowledge in order to estimate the job-relevance of the total program.

Figure 3.12 illustrates a hypothetical relationship between the content of technical coursework in a given curriculum and the knowledge list content. The area designated A shows the portion of the knowledge list content taught in a school curriculum; the area designated B indicates the portion of the knowledge list not taught in a school curriculum.

Sections 3.3 through 3.5 describe in detail the coverage of the job-related academic knowledge content by the sample of specialized educational programs. In this section, the technical curriculum content of specialized educational programs that is <u>not</u> on the knowledge list, referred to as "additional curriculum" is addressed. As discussed in Section 2.1, there are two major reasons for focusing on this additional

TABLE 3.2

KNOWLEDGE CATEGORIES NEEDED AT SRO LEVEL ONLY

MATHEMATICS

- Trigonometry
- Geometry

ELECTRICAL SCIENCE

- Electron Theory

MATERIALS

- Pellet - Clad Interaction
- Fuel/Clad Embrittlement
- Fatigue Failure/Work Hardening
- Effects on Fuel Due to Inclusions and Core Burnup
- Compressive Strength
- Tensile Strength

CLASSICAL PHYSICS

- Kinetic Energy

BASIC ATOMIC AND NUCLEAR PHYSICS

- Atomic Mass Unit
- Mass Defect and Binding Energy
- Energy Release
- Ionization
- Equilibrium Concept
- Radioactive Decay Process

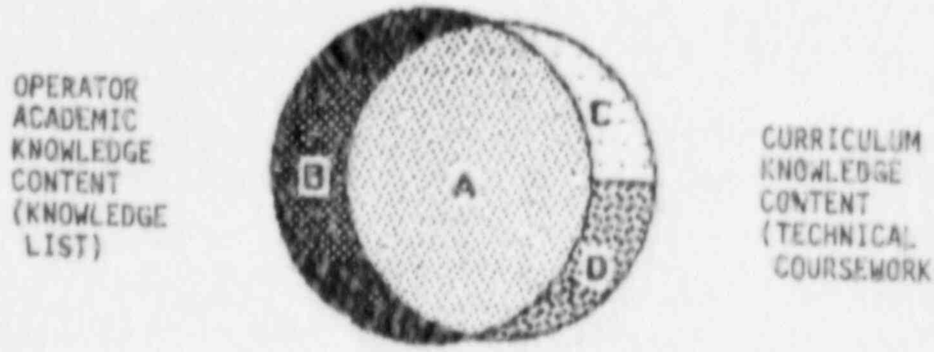
REACTOR THEORY

- Fast Neutrons
- Absorption Cross Section
- Neutron Life-Cycle
- Buckling
- Neutron Leakage

HEALTH PHYSICS

- Theory of Operation of Basic Radiation Detector (GM Tube Type)
- Roentgen
- Curie

curriculum. First, if a major portion of a given curriculum is devoted to content that is not job-relevant, the use of the program as a minimum qualification requirement would be questionable even if the program also provided substantial coverage of job-relevant material. While the program would be relevant and one avenue for obtaining necessary job knowledge, the unrelated content would make it inappropriate as a minimum standard. Second, there may be curriculum content that is not specified on the academic knowledge list, that is still job-related. The academic knowledge list represents one thorough and systematic effort to identify knowledge content necessary for the job of licensed reactor operators, but it is possible that some specific elements may not be included. In this situation, the job-relevance of the specialized educational programs could be underestimated.



A - Content on knowledge list and taught in curriculum.

B - Content on knowledge list not taught in curriculum.

C - Content taught in curriculum but not on knowledge list that is judged as job-relevant.

D - Content taught in curriculum but not on knowledge list that is judged as unrelated to the job.

Figure 3.12: Hypothetical Distribution of Knowledge List and Curriculum Knowledge Content

There are two ways in which the total curriculum was examined: (1) focusing on the total set of required technical courses and identifying the portion of this required technical curriculum that is devoted to items on the knowledge list and (2) identifying the proportion of the total curriculum devoted to electives and non-technical courses.

In estimating the percentage of the required technical curriculum that covered material that was not on the knowledge list (i.e. the percentage of additional knowledge) the subject matter experts indicated which portions of this additional material, in their judgment, were job-relevant and which were not job-related (described in Section 2.4.2 and in Appendix D, Task III). While the definition of job-related knowledge we have used thus far has been limited to the specific items on the academic knowledge list (which was based on a systematic job analysis), the assessment by the subject matter experts of the relevance of the additional knowledge being taught in these programs provides further information on the scope and focus of the curricula of specialized programs.

3.6.1 Curriculum Coverage by Individual School Programs

The percentage of the material within the required technical courses that provides direct coverage of knowledge categories is presented for each school in Figures 3.13-3.16. In five of the eight schools (C-1, C-2, C-3, AS-1, and AS-2) approximately two thirds of the technical coursework covers items from the knowledge list; in the remaining three schools (AS-3, BS-1, BS-2) a little less than half of the required material is devoted to the knowledge list items.

For five of the schools (C-1, C-3, AS-1, BS-1, and BS-2) approximately 15% of the required technical curriculum covers material not on the knowledge list but considered relevant by the subject matter experts to the jobs of licensed reactor operators; for the remaining three schools (C-2, AS-2, and AS-3) approximately 25% of the curriculum was considered additional relevant material. The content of the additional related material varied across schools and touched on most of the subject areas. It is in the areas of Chemistry, Materials, and Instrumentation and Control where additional related knowledge content is most commonly taught (see Appendix Table E-3).

Some examples of specific content that were not on the knowledge list, but were considered job-related by the subject matter experts are presented in Table 3.3.

The amount of additional material provided by a curriculum that was judged as not job-related for nuclear reactor operators varied widely across the individual programs: 10% -15 % at Schools C-2, AS-1, and AS-2; 20% - 25% for Schools C-1, C-3, and AS-3; and 40% - 45% for Schools BS-1 and BS-2.

The subject areas where more than 20% of the content of an area was additional unrelated knowledge were Mathematics (at 7 schools), Classical Physics (at 6 schools), Instrumentation and Control (at 4 schools), and Chemistry, Materials, and Heat Transfer and Fluid Flow (at 3 schools) (see Appendix Table E-3). Table 3.3 presents some examples of items in these areas that were judged as unrelated to nuclear reactor operator positions.

3.6.2 Curriculum Coverage by Program Type

By aggregating the programs by type--coursework, A.S., and B.S.--a clearer pattern of differences in the required technical curriculum can be seen. The percentage of the curriculum which covers knowledge list material, which covers additional related material and which covers unrelated knowledge content is shown in Fig. 3.15.

A greater portion of the coursework and A.S. degree programs are devoted to coverage of material on the knowledge list compared to the specialized B.S.

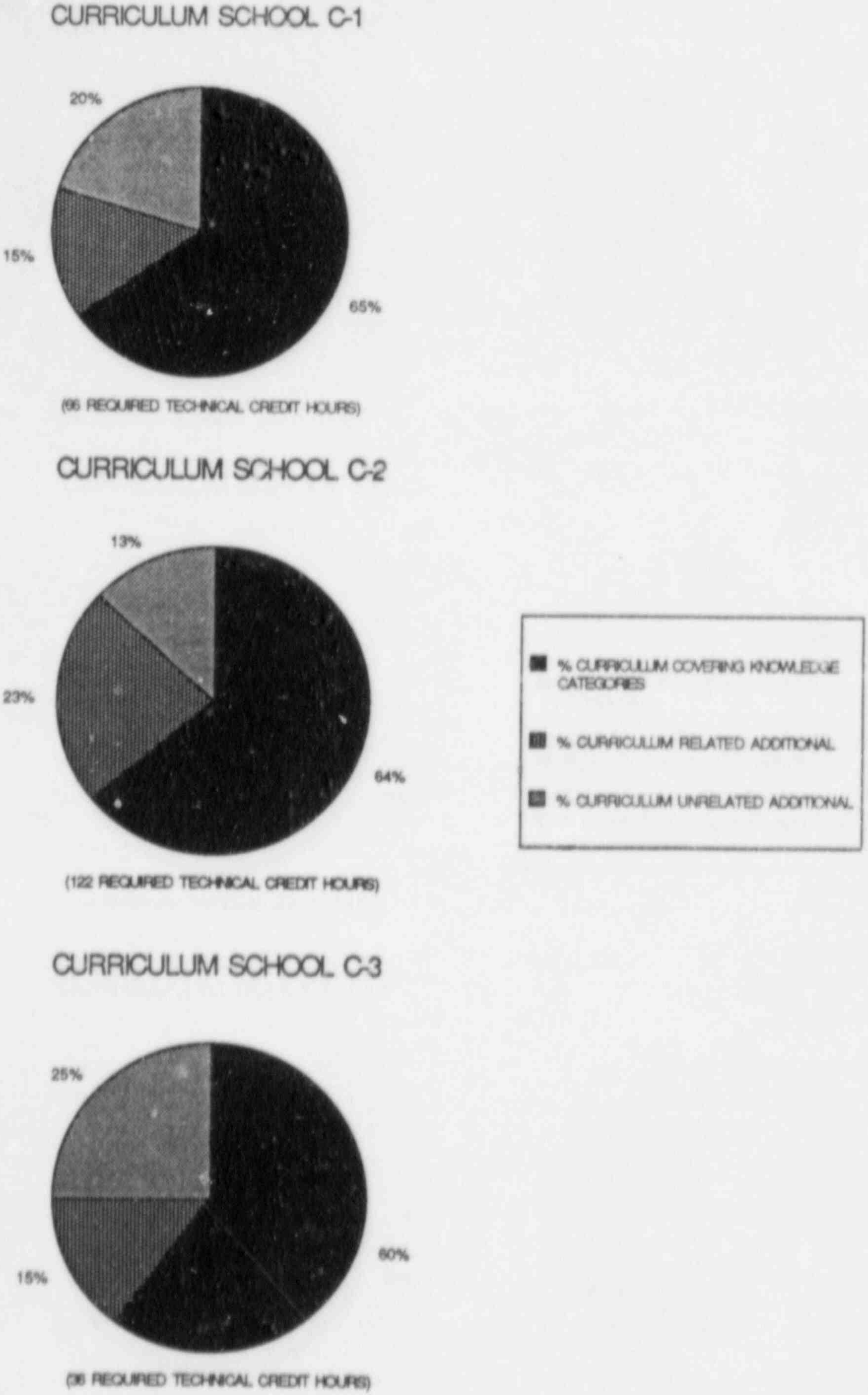


Figure 3.13: Extent of Job-Related Curriculum of Coursework Programs

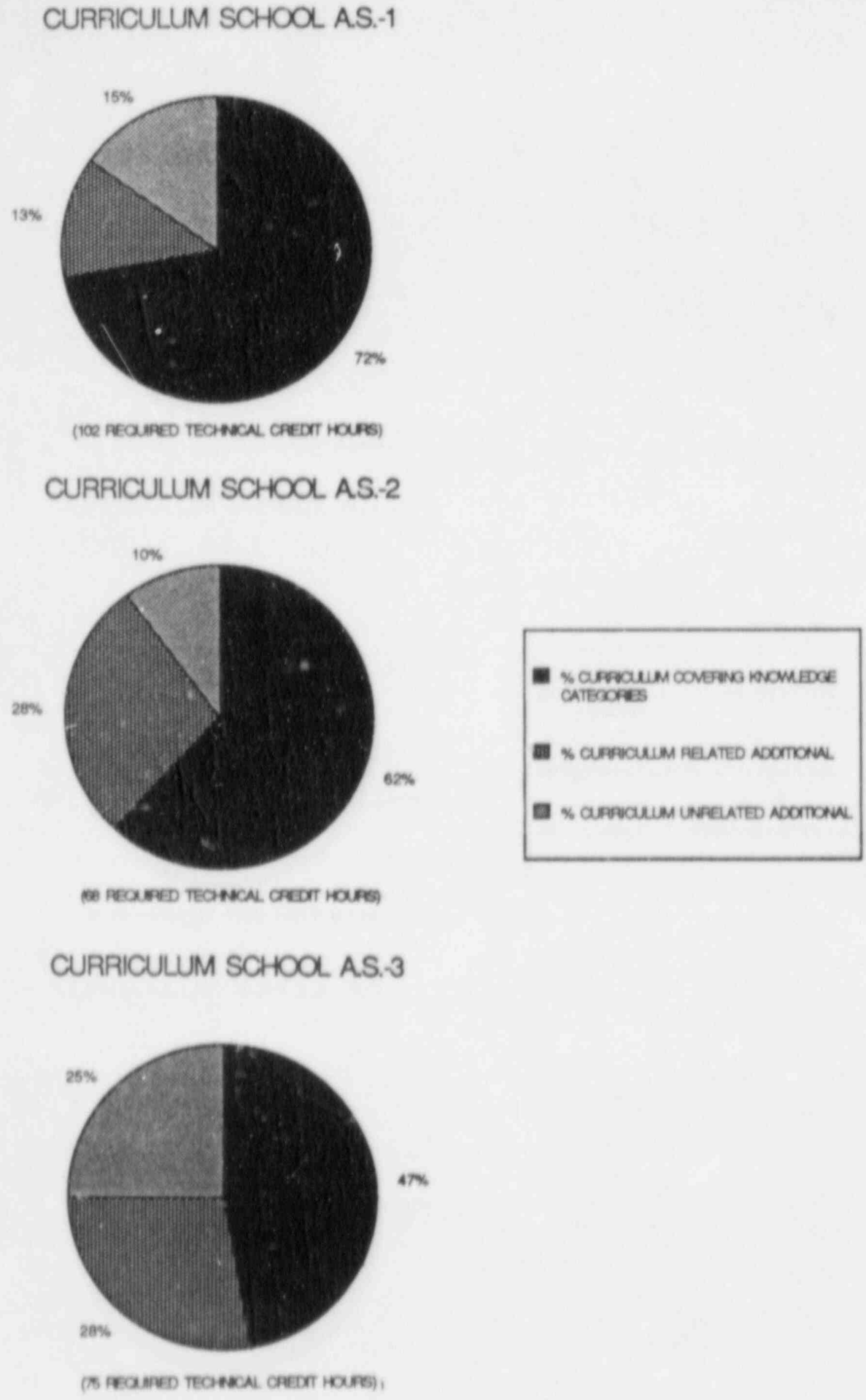


Figure 3.14: Extent of Job-Related Curriculum of A.S. Degree Programs

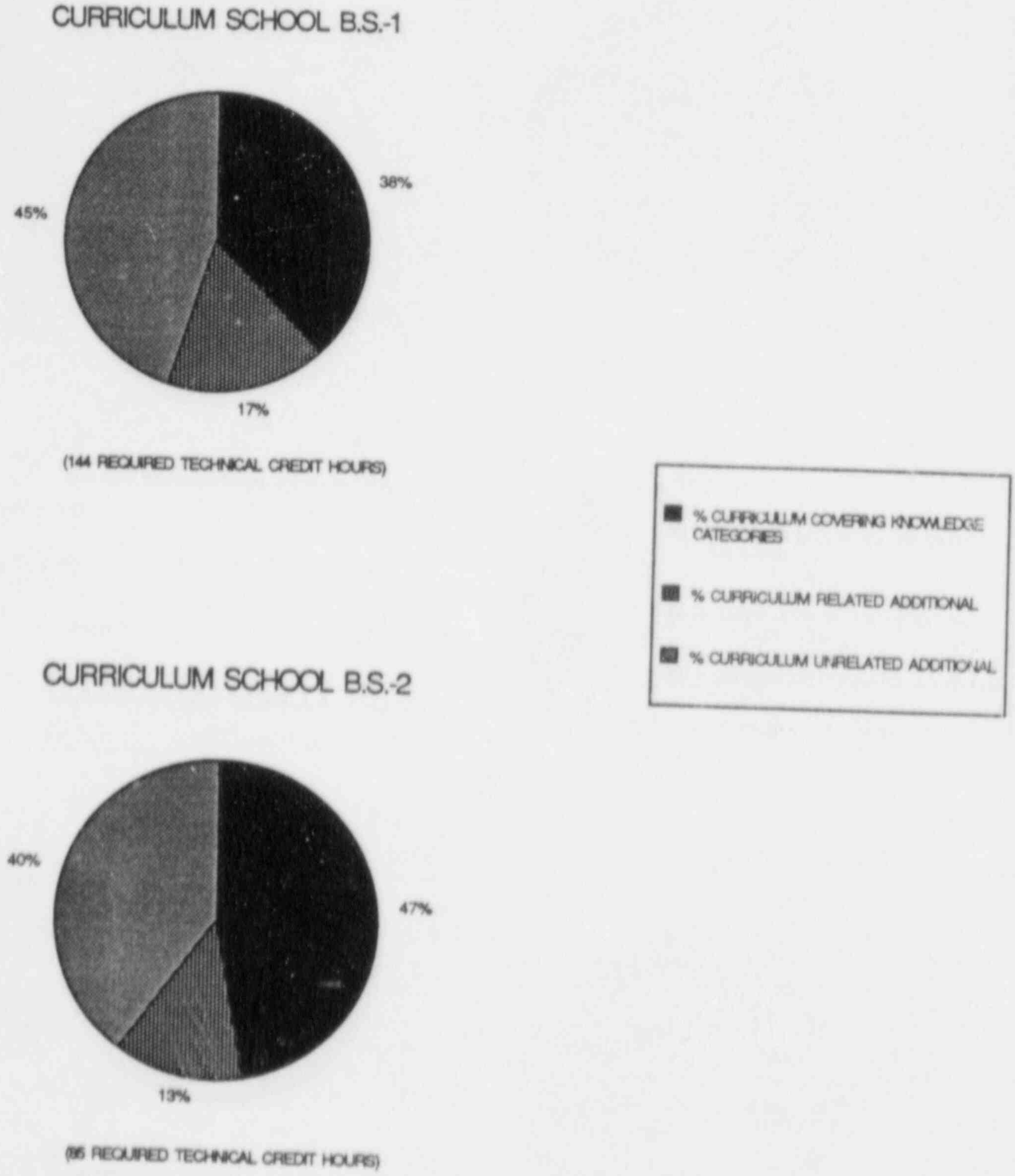


Figure 3.15: Extent of Job-Related Curriculum of B.S. Degree Programs

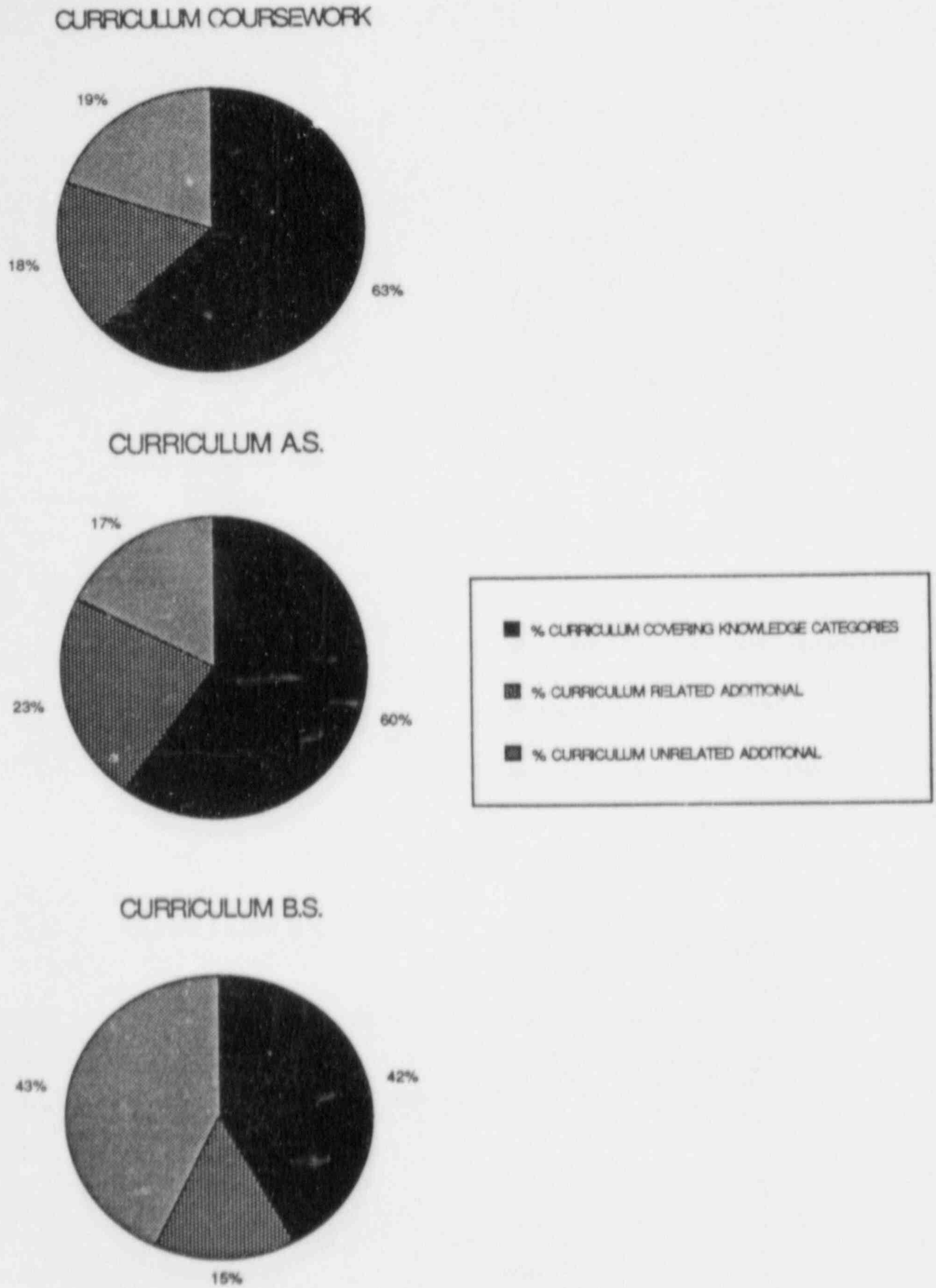


Figure 3.16: Extent of Job-Related Curriculum by Type of Program

TABLE 3.3

EXAMPLES OF ADDITIONAL CURRICULUM BY SUBJECT AREA

Subject Area	Type of Additional Curriculum: Job-Related	Type of Additional Curriculum: Not Job-Related
Mathematics	-----*	Conic sections Antidifferentiation and the definite integral Polar coordinates
Electrical Science	-----	-----
Chemistry	Atomic structure Nature of chemical bonding Chemical equilibrium Oxidation and reduction (relating to corrosion) Chemistry of hydrogen, oxygen, nitrogen, and sulfur	Qualitative analysis Gravimetric analysis Spectroscopy Refractometry Polarimetry Chromatography
Materials	Stress, strain and elastic properties Steel, super alloys, cast iron, ductile iron, malleable iron Analysis and prevention of failure Hydrogen embrittlement Wear, fretting and erosion	Deflections for flexural loading Intermediate beams and columns Structure of crystalline solids
Physics	Dynamics of systems of particles Friction Laws of motion	Moments of inertia Center of mass Dry friction Shear and moment diagrams Kinematics in moving frame of reference Wave motion and sound Optics and light
Atomic and Nuclear Physics	-----	-----
Reactor Theory	Reactor plant systems and components ECP/SDM procedures	-----
Instrumentation and Control	Principles of operation of the source range, intermediate range and power range nuclear instruments	Radiation counting statistics Data reduction techniques
Reactor Plant Protection	NRC licensing procedures Environmental interactions	-----
Health Physics	Basis for exposure guidelines Radioactive waste control Chart of the nuclides	-----
Heat Transfer and Fluid Flow	Turbine cycle Energy conversion Super heat and reheat cycles Turbine precautions Evaporative cooling towers Nozzles	Internal combustion engine cycles Heat transfer from fins Lift and drag Mach numbers Jet and propeller propulsion Rotation of open and closed vessels Darcy's law

*-----indicates minimal additional curriculum in this category

degree programs. Approximately 60% for the former programs as opposed to about 40% for the B.S. degree programs cover content on the knowledge list.

When the definition of job-related knowledge is broadened to include both the content of the academic knowledge list and the additional content judged as job-related by the subject matter experts, approximately 80% of the curriculum of the coursework and A.S. degree programs are devoted to knowledge content that is job-related compared to approximately 60% of the B.S. degree programs.

The specialized B.S. degree programs focus approximately 40% of the technical curriculum on knowledge that is not directly job-related compared to less than 20% of the coursework and A.S. degree program curricula.

The traditional B.S.N.E. programs are most similar to the specialized B.S. degree programs in that the nuclear engineering degree programs also devote at least half of the required technical curriculum to material not on the knowledge list (NUREG/CR-4051). (In the study of B.S.N.E. programs separate judgments concerning the job-relevance of the total additional content of the curriculum were not made.)

3.6.3 Devotion of Curriculum to Electives and Non-Technical Courses

There are also differences by type of program in the extent to which technical electives and non-technical courses are included in the curricula (see Table 3.1). The specialized coursework programs are entirely defined by the required technical curriculum, while the specialized A.S. degree programs include approximately five non-technical courses. The specialized B.S. degree programs are most extensive in both technical electives and non-technical course requirements. Thus, both types of specialized degree programs require further additional material that is generally not directly job-related in terms of specific knowledge content.

4. SUMMARY AND CONCLUSIONS

4.1 Coverage of Identified Job-Related Knowledge (Knowledge List)

- There is a great deal of variation among individual specialized educational programs for licensed nuclear operators in their extent of coverage of job-specific academic knowledge.

- The range of variation among individual schools within each type of program--coursework, A.S. degree, and B.S. degree--is similar. No one type of program consistently provides greater coverage of job-related academic knowledge than the other types of programs.

- The schools in this study range from a minimum coverage of less than 15% to a maximum coverage of approximately 65% of the knowledge list content. Four schools cover at least half of this knowledge, and four schools cover less than one-third of this knowledge content.

- The traditional B.S. degree programs in nuclear engineering (B.S.N.E.) reported on in prior work (NUREG/CR-4051) were found to cover approximately 50% of the job-related knowledge identified in the academic knowledge list.

- Coverage of specific subject areas also varies across individual schools, although a few consistent patterns were found:

  - Very little job-relevant Chemistry and Engineering Drawing is covered in any of the programs.

  - The specialized A.S. degree programs focus most on nuclear-related subject areas (such as Atomic and Nuclear Physics, Health Physics, and Reactor Theory). They tend not to cover other basic areas (e.g., Electrical Science, Materials, and Classical Physics).

  - The specialized B.S. degree programs tend to concentrate most on basic generic areas (e.g., Classical Physics, Heat Transfer and Fluid Flow, and Electric Science) as opposed to the more specific applied areas (e.g., Reactor Plant Protection and Health Physics).

  - The coursework programs generally provide moderate coverage of a fuller range of subject areas than do the other two types of programs, rather than focusing on extensive coverage of a limited number of major subjects.

  - The traditional B.S. degree programs in nuclear engineering (B.S.N.E.) provide extensive coverage of both basic fundamentals (e.g., Electrical Science, Materials, and Classical Physics) and nuclear-oriented subjects (e.g., Atomic and Nuclear Physics and Reactor Theory).

- The wide variation among the specialized programs and lack of a standard curriculum appears to be due to the tailored nature of most program development. Generally, the specialized programs are used for specific subject content to complement existing utility training programs.

- A major difference between the content of the specialized educational programs and the content of traditional B.S.N.E. programs, is the latter's extensive coverage of higher level knowledge judged necessary only at the senior operator level, compared to virtually no coverage of this knowledge in the specialized programs.

4.2 Devotion of Program Curriculum to Job-Related Knowledge and to Additional Knowledge Content

- The coursework and A.S. degree programs focus most of their required technical curriculum on job-related knowledge, in contrast to the specialized B.S. degree programs, which devote more attention to additional technical knowledge. Among the specialized coursework and A.S. degree programs, approximately 60% of the technical curriculum is devoted to knowledge list material and an additional 20% to other job-related knowledge. Within the specialized B.S. degree programs, approximately 40% of the required technical material covers content on the knowledge list and an additional 15% covers other job-related knowledge.

- The specialized A.S. degree and B.S. degree programs provide some coverage of non-technical areas (e.g., humanities and social sciences), which are not addressed by the coursework programs.

4.3 Conclusions

- There is no systematic difference in the job-relatedness of the various types of specialized educational programs, A.S. degree, B.S. degree and coursework, when job relevance is defined as the extent of coverage of knowledge content identified as directly necessary for carrying out the jobs of licensed reactor operators.

- Because of the substantial variation among schools within each type of program, it is not feasible to identify a specific program type for particular consideration for a standard educational qualification. No specialized program type sampled in this study--coursework, A.S. degree, or B.S. degree--offers a similar curriculum across individual schools.

- Traditional B.S. degree programs in nuclear engineering are as job-relevant or more job-relevant than most of the specialized educational programs in terms of covering identified job-related academic knowledge.

- The specialized coursework programs can be described as the most "efficient" in terms of job-relevance because of the narrower focus of their curricula. These programs devote the least attention to technical and non-technical content that is not directly job-related. However, as reported above, they do not generally cover more job-related content than the other program types.

- In most cases at least half of the job-specific academic knowledge remains to be covered in plant training programs rather than being taught in the specialized formal educational programs. Thus, there is considerable reliance on plant training for acquisition of job-related academic knowledge within the industry, even when specialized formal educational programs are utilized for licensed operators.

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APPENDIX A

ACADEMIC KNOWLEDGE LIST: MAJOR SUBJECT AREAS AND KNOWLEDGE CATEGORIES

APPENDIX A

ACADEMIC KNOWLEDGE LIST: MAJOR SUBJECT AREAS AND KNOWLEDGE CATEGORIES

MATHEMATICS

1. Division
2. Multiplication
3. Addition
4. Subtraction
5. Conversion of Numbers
6. Application of Scientific Notation
7. Unit Conversions
8. Unit Modifiers
9. Algebra
10. Algebraic Laws

*11. Trigonometry

12. Rate of Change
13. Analysis of Graphs
14. Calculators (handheld/desktop)

*15. Geometry

16. Logarithmic Coordinate System
17. Nomographs
18. Obtaining Information from Nomographs
19. Exponents
20. Logarithms

ELECTRICAL SCIENCE

*21. Electron Theory

22. Static Electricity

*Knowledge category judged necessary for SRO position but not RO position.

ACADEMIC KNOWLEDGE LIST (continued)

23. Relationship Between Units of Electrical Measurement
24. Units of Electrical Measurement
25. Electrical Hazards and Safety
26. Electrical Grounds
27. Electrical Basic Circuits
28. Bi-Stables
29. Relays
30. Analog Channels
31. Digital Channels
32. Circuit Modules
33. Direct Current (DC)
34. Alternating Current (AC)
35. Simple Circuits
36. AC Waveforms
37. Inductance
38. Basic Alternating Current Theory
39. Impedance
40. Capacitance and Capacitive Reactance
41. Sources of Electrical Power
42. Switchgear Components
43. Distribution
44. AC Motor
45. AC Generator
46. DC Generator
47. Transformer
48. Synchroscopes

ACADEMIC KNOWLEDGE LIST (continued)

49. Ground Detection
50. Voltage Regulators

CHEMISTRY

51. Mixtures, Solutions, Compounds
52. Conductivity
53. Acids and Bases
54. Corrosion
55. Sampling
56. S/G Chemistry
57. Secondary Chemistry Control
58. Water Chemistry Control Methods
59. Types of Impurities
60. Sources of Impurities
61. Effects of Impurities
62. Radiochemistry
63. Sampling
64. Hydrogen Gas in Reactor Water
65. Boron Concentration Calculation
66. Water Treatment Processes
67. Water Quality/Purity
68. Grades of Water

MATERIALS

69. Expansion
70. Brittle Fracture
71. Heatup/Cooldown Limit
72. Irradiation

ACADEMIC KNOWLEDGE LIST (continued)

*73. Pellet - Clad Interaction

*74. Fuel/Clad Embrittlement

75. S/G Tube Denting

*76. Fatigue Failure/Work Hardening

*77. Effects on Fuel Due to Inclusions and Core Burnup

78. Definition of Thermal Shock and Thermal Stress

79. Causes and Effects of Thermal Shock and Thermal Stress

*80. Compressive Strength

*81. Tensile Strength

CLASSICAL PHYSICS

82. Units of Pressure (Vacuum)/Differential Pressure Measure

83. Units of Temperature Measurement

84. Units of Periodic Motion Measurement

85. Units of Flow

86. Units of Distance Measurement

87. Pressure

*88. Kinetic Energy

BASIC ATOMIC AND NUCLEAR PHYSICS

*89. Atomic Mass Unit

90. Nuclear Isotopes

91. Definition of Isotopes

*92. Mass Defect and Binding Energy

*93. Energy Release

*94. Ionization

*95. Equilibrium Concept

96. Radiation Interactions

ACADEMIC KNOWLEDGE LIST (continued)

*97. Radioactive Decay Process

98. Neutrons Associated with Fission

99. Precursors

100. Theory of Fission Process

101. Neutron Flux Effects

102. Residual Heat/Decay Heat

REACTOR THEORY

103. Delayed Neutrons

104. Prompt Neutrons

105. Slow Neutrons

*106. Fast Neutrons

107. Source Neutrons

*108. Absorption Cross Section

109. Neutron Interactions with Matter

110. Fission Neutrons

*111. Neutron Life-Cycle

112. Source Neutrons

113. Poison Effects

114. Neutron Flux

*115. Buckling

*116. Neutron Leakage

117. Coefficients and Reactor Control

118. Reactivity

119. Reactor Period/Startup Rate (SUR)

120. Transient Reactor Behavior

121. Fission Product Poisons

ACADEMIC KNOWLEDGE LIST (continued)

122. Shutdown Margin

123. Subcritical Multiplication

124. Delayed Neutron Fractions

125. Reactor Parameters

126. Effects of Flow Changes

127. Axial Flux

128. Core Imbalance

129. Core Quadrant Power Tilt

130. Estimated Critical Position (ECP)

131. Dropped Rod

132. Reactor Startup and Shutdown

133. Reactor Response to Control Rods

INSTRUMENTATION AND CONTROL

134. Temperature Sensors

135. Pressure Sensors

136. Level Sensors

137. Humidity Sensors

138. Sensors - General

139. Flow Sensors

140. Basic Control Loop Diagrams

141. Logic and Flow Diagrams

142. Basic Control Circuits

143. Pneumatic Devices

144. Failure Symptoms

145. Control Loop Functions

ACADEMIC KNOWLEDGE LIST (continued)

REACTOR PLANT PROTECTION

146. Thermal-Hydraulic Operating Envelope
147. Safety Limits
148. Limiting Conditions for Operation
149. Administrative Controls and Procedural Concepts
150. Automatic Reactor Plant Protection Concepts
151. Design Basis Accident
152. Integrated Plant Transient Response
153. Core Cooling Mechanisms
154. Potentially Damaging Operating Conditions
155. Gas/Steam Binding Affecting Core Cooling
156. Recognizing Core Damage
157. Core Recriticality
158. Hydrogen Hazards During Accidents
159. Monitoring Critical Parameters During Accident Conditions
160. Radiation Hazards and Radiation Monitor Response
161. Criteria for Operation and Cooling Mode Selection

HEALTH PHYSICS

162. Geiger-Mueller (G-M) Detectors
163. Scintillation Detectors
164. Proportional Detectors
165. Ion Chamber Detectors
166. Thermo-Luminescent Dosimeter Detector
167. Count Rate Survey Meters
168. Personnel Dosimetry
169. Portable Radiation Detectors

ACADEMIC KNOWLEDGE LIST (continued)

170. Process Radiation Monitor

171. Area Radiation Monitor

*172. Theory of Operation of Basic Radiation Detector (GM Tube Type)

*173. Roentgen

174. Rad

175. Rem

176. Dose

177. Dose Rate

*178. Curie

179. Biological Effects of Radiation

180. Methods of Limiting Radiation Exposure

181. Radiation Measurement Units

182. Plant Materials

183. Humans

184. Time

185. Shielding

186. Distance

187. Radiation Source Calculations

188. Controlled Areas

189. Contamination Protective (anti-c) Clothing

190. Respirators

191. Decontamination

192. Site Controls and Limits

193. Contaminated Tool Use

ACADEMIC KNOWLEDGE LIST (continued)

194. Potentially Contaminated Systems

195. Atmospheric Dispersion of Radioactive Materials

HEAT TRANSFER AND FLUID FLOW

196. Temperature

197. Thermal Driving Force

198. Sensible Heat

199. Latent Heat - Fusion, Vaporization, Condensation

200. Properties of Water and Steam

201. Pressure-Temperature Relationship

202. Steam Tables

203. Basic Steam-Water Cycle

204. Specific Heat

205. Properties of Gases, Gas-Liquid Interfaces

206. Steam Water Cycle

207. Heat Transfer

208. Heat Cycles

209. Heat Exchangers

210. Flow Rate

211. Fluid Statics

212. Buoyancy

213. Density

214. Laminar Flow

215. Turbulent Flow

216. Two-Phase Flow

217. Pump Theory

218. Flow Indications

ACADEMIC KNOWLEDGE LIST (continued)

219. Fluid Flow in a Closed System
220. Forced Convection Coolant Flow
221. Natural Convection Coolant Flow
222. Heat Production When Shutdown
223. Critical Heat Flux/Departure from Nucleate Boiling
224. Core Flow Oscillations and Instability
225. Core Flow Distribution
226. Reactor Power Limits
227. Heat Generation During Operation

ENGINEERING DRAWING

228. Engineering Drawing
229. Interpretation/Use of System/Component Diagrams/Prints
230. Indications
231. Interpretation/Use of Piping/Flow Diagrams/Prints
232. Interpretation/Use of Electrical Schematics/Prints

APPENDIX B

<u>IDENTIFIED UNIVERSE OF SPECIALIZED EDUCATIONAL PROGRAMS FOR NUCLEAR REACTOR OPERATORS</u>

APPENDIX B

IDENTIFIED UNIVERSE OF SPECIALIZED EDUCATIONAL PROGRAMS FOR NUCLEAR REACTOR OPERATORS

I. Currently Operating Programs

B.S. Degree Programs

1. Kansas State University (KS)
   Bachelor of Science, Nuclear Reactor Engineering Technology

2. Regents External Degree (NY)
   Bachelor of Science, Nuclear Engineering Technology

3. Rochester Institute of Technology (NY)
   Bachelor of Science, Electromechanical Technology, Nuclear Option

4. University of Portland (OR)
   Bachelor of Science, Mechanical or Electrical Engineering

5. Winona State University (MN)
   Bachelor of Science, Physics, Applied Nuclear Science Option

A.S. Degree Programs

1. Aiken Technical College (SC)
   Associate, Nuclear Engineering Technology

2. Chattanooga State Technical Community College (TN)
   Associate, Mechanical Engineering Technology, Power Plant Operator Option

3. Columbia Basin Community College (WA)
   Associate, Nuclear Technology

4. Community College of Allegheny County, Allegheny Campus (PA)
   Associate, Nuclear Power Technology

5. Joliet Junior College (IL)
   Associate, Applied Science

6. Lakeshore Technical College (WI)
   Associate, Electrical Power Engineering Technician

7. Regents External Degree (NY)
   Associate, Nuclear Engineering Technology

8. Shoreline Community College (WA)
   Associate, Mechanics or Electrical Engineering Technology, Nuclear Option

9. Terra Technical College (OH)
   Associate, Nuclear Power

10. Thames Valley State Technical College (CT)
   Associate, Nuclear Engineering Technology

Coursework Programs

Organization Teaching Courses/
Educational Institution Granting
College Credit (if different)

1. Baltimore Gas & Electric (MD)/Regents External Degree (NY)

2. Consolidated Edison of New York (NY)/Regents External Degree (NY)

3. Consumer Power Co. (MI)/Regents External Degree (NY)

4. Energy Consultants/Regents External Degree (NY)

5. General Electric Company (NY)/Regents External Degree (NY)

6. General Physics (MD)/Regents External Degree (NY)

7. Joliet Junior College (IL)

8. Kansas State University, Emporia State University, Kansas Gas and Electric Company/Kansas State University (KS)

9. New York Power Authority (NY)/Regents External Degree (NY)

10. Niagara Mohawk Power Corp. (NY)/Regents External Degree (NY)

11. Pennsylvania Power & Light (PA)/Regents External Degree (NY)

12. Public Power & Light (NJ)/Regents External Degree (NY)

13. Rochester Institute of Technology (NY)

14. University of Idaho (ID)

15. University of Missouri (MO)

16. Westinghouse Electric Corporation (PA)/Regents External Degree (NY)

II. Discontinued Programs in Nuclear Technology

B.S. Degree Programs

1. Oregon State University (OR)
2. Oklahoma State University, Stillwater (OK)
3. Memphis State University (TN)

A.S. Degree Programs

1. Mississippi Gulf Coast Junior College (MS)
2. Hartford State Technical College (CT)
3. Pennsylvania State University (PA)
4. Hudson Valley Community College (NY)
5. Denmark Technical College (SC)
6. Community College of Allegheny Co., Boyce Campus
7. Southern Technical Institute
8. Texas State Technical Institute

III. Proposed Programs in Nuclear Technology

A.S. Degree Programs

1. Salem County Community College (NJ)
2. University of New Haven (CT)

APPENDIX C

CURRICULUM EXPERTS PARTICIPATING IN STUDY

APPENDIX C

CURRICULUM EXPERTS PARTICIPATING IN STUDY

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APPENDIX D

WORKSHOP INSTRUCTIONS

APPENDIX D

WORKSHOP INSTRUCTIONS

INTRODUCTION TO WORKSHOP TASKS

There are three major tasks to complete for each of the six specialized educational programs you will be reviewing during the workshop. Before beginning these tasks for each school, you should ensure that you are very familiar with the content of the Academic Knowledge List.

TASK I. REVIEW OF SCHOOL CURRICULUM. Before beginning the other tasks, it is important that you thoroughly review the curriculum content of the school program you will be rating.

Task II. ACADEMIC KNOWLEDGE LIST RATINGS. You will then make ratings (0-5) on the extent to which each knowledge category on the knowledge list is covered in the curriculum you are reviewing.

Task III. ADDITIONAL CURRICULUM ESTIMATES. Following the knowledge list ratings, you will make estimates (0-100%) concerning the amount of additional curriculum content in a school program, if any, that is not contained in the knowledge list.

We will discuss each of these tasks in detail before you begin your review of any of the school curricula. Detailed written instructions for each of these tasks is provided in the following pages for your reference when carrying out the rating tasks.

TASK I. REVIEW OF SCHOOL CURRICULUM

Task I, before beginning other workshop tasks, is to thoroughly read through the curriculum content of the school you are reviewing. Each school is identified with a letter code instead of the school's name to ensure an objective assessment of program content.

The coursework description for each school is categorized by major subject areas, which correspond to the 12 major subject areas of the Academic Knowledge List:

1. MATHEMATICS
2. ELECTRICAL SCIENCE
3. CHEMISTRY
4. MATERIALS
5. CLASSICAL PHYSICS
6. ATOMIC & NUCLEAR PHYSICS
7. REACTOR THEORY
8. INSTRUMENTATION & CONTROL
9. REACTOR PLANT PROTECTION
10. HEALTH PHYSICS
11. HEAT TRANSFER & FLUID FLOW
12. ENGINEERING DRAWING

Course descriptions in a school's curriculum that do not fall in one of these 12 subject areas are contained in a thirteenth category, titled OTHER. Course descriptions that cover content in more than one major subject area have been duplicated under all relevant major subject areas (and clearly marked as repeat descriptions).

Allow yourself at least 20-30 minutes to systematically review a school's curriculum before beginning the other tasks. Once you are thoroughly familiar with the curriculum content of the school, proceed with Tasks II and III.

TASK II. ACADEMIC KNOWLEDGE LIST RATINGS

After you have thoroughly familiarized yourself with the curriculum content of the school you are reviewing (Task I), you will then make academic knowledge list ratings to assess the coverage of job-related academic knowledge in the curriculum. This task will consist of rating each of the 232 knowledge categories in the Academic Knowledge List in terms of the extent to which it is covered in the curriculum you are reviewing. Now, turn to page 1 of the Academic Knowledge List Rating Form, located in front of each school curriculum notebook, and repeated in part below.

MATHEMATICS	Prerequisite	No Coverage	Minor Coverage	Moderate Coverage	Substantial Coverage	Total Coverage
(1)* 1. Division	0	1	2	3	4	5
(1) 2. Multiplication	0	1	2	3	4	5
(1) 3. Addition	0	1	2	3	4	5
(1) 4. Subtraction	0	1	2	3	4	5
(1) 5. Conversion of Numbers	0	1	2	3	4	5
(1) 6. Application of Scientific Notation	0	1	2	3	4	5

For each knowledge category you will make a rating by circling the appropriate number (0, 1, 2, 3, 4, or 5). The scale points are defined as follows:

0 = Prerequisite - knowledge not taught in curriculum, but assumed covered prior to entry into program
1 = No Coverage - essentially no coverage of the category in curriculum
2 = Minor Coverage - a small part of the category is covered, but many gaps
3 = Moderate Coverage - some of the category covered, some not covered
4 = Substantial Coverage - most of the category is covered with a few minor gaps
5 = Total Coverage - essentially all of the category is covered

A 4 or 5 rating will be counted as a knowledge category that is covered in the curriculum. If you are unsure of a rating, make the best rating you can and place a ? next to the number you circle. It is not assumed that all the knowledge categories on the Academic Knowledge List are (or should be) taught in a particular curriculum.

TASK II. ACADEMIC KNOWLEDGE LIST RATINGS (continued)

When making your ratings, you need to consider the following three issues (explained in detail below):

(1) generic vs. specific application knowledge items

(2) prerequisite knowledge coverage

(3) differences between a school curriculum and the knowledge list in major subject categorization of knowledge content.

(1) Your rating of a knowledge category should indicate the extent to which the category, as defined by the knowledge items listed under it, is covered in the school curriculum you are reviewing. The specific items under a given knowledge category differ in the extent to which they are generic in nature. Some items are essentially subsumed by others. An item may be a specific application of a general concept within the context of nuclear power plant operation or simply a definition that is one aspect of a concept listed as another knowledge item. For example, within the subject area of ELECTRICAL SCIENCE, a "generic" knowledge item and a "specific application" item on page 7 and 8 of the Academic Knowledge List are shown below:

41. Sources of Electrical Power

Theory of paralleling AC power sources ← generic knowledge item

Reasons and methods for synchronizing AC power supplies to the same electrical bus (transfer electrical load from one power supply to another)

Purpose of having synch scope moving slowly in the clockwise (fast) direction prior to paralleling two AC machines

Purpose for having two AC machines in phase when paralleling

Consequences of paralleling two power sources out of phase

Relationship of incoming to running voltages when paralleling ← application knowledge item

In order to rate the extent to which a knowledge category is covered in a given curriculum, it is important to review the list of specific knowledge items that comprise the category and make a judgment based on the coverage of the category as a whole, with coverage of generic items having a greater influence than specific application items in the assessment of coverage. In a few cases, a knowledge category is defined simply by the knowledge category title, as there are no separate knowledge items listed under it.

TASK II. ACADEMIC KNOWLEDGE LIST RATINGS (continued)

(2) Some knowledge categories may not be covered directly in a given curriculum, but it is clear that the knowledge would have been acquired as a prerequisite to learning other knowledge content that is covered in the curriculum. For example, | 3. Addition | defined by the item "Ability to perform basic addition," may not be taught in a given school curriculum, but is a basic prerequisite to other, higher order, mathematical knowledge that is covered in the curriculum. In these cases, rate the knowledge category "0" for prerequisite.

(3) In most cases, the knowledge categories listed under a subject area in the Academic Knowledge List will correspond to course content within that same subject area in a school's curriculum. However, a particular knowledge category may be covered in the curriculum under a subject area that is different than where it is categorized on the knowledge list. For example, some of the knowledge categories under the subject area MATHEMATICS in the Academic Knowledge List (e.g., Units) may actually be covered in a school's PHYSICS curriculum. Similarly, a knowledge category under PHYSICS may be covered in coursework in the HEAT TRANSFER AND FLUID FLOW curriculum at a particular school. Please keep this in mind when making your knowledge category ratings. You may need to check several subject areas (and especially the area designated OTHER) in a school's curriculum to determine whether a knowledge category from the Academic Knowledge List is covered in the curriculum.

As a preliminary step for carrying out Task III (Additional Curriculum Estimates), place a check mark directly on the curriculum description next to topic(s) that cover at least some part of a knowledge category (as defined by the items under it, in the Academic Knowledge List. This should be done as you make your knowledge list ratings.

Now, please use the Knowledge List Rating Form located in the front of the curriculum notebook of the school you are assessing and rate the curriculum for that school in terms of coverage of each knowledge category. As you rate the knowledge categories, be sure to "check-off" on the school's curriculum description all topics that cover items on the knowledge list.

TASK III. ADDITIONAL CURRICULUM ESTIMATES

Task II, your academic knowledge list ratings, will help us identify the academic knowledge content necessary for licensed nuclear power plant operators that is covered in a curriculum, and the knowledge content needed by operators that is not covered in the curriculum (areas A and B in Figure 1, below). However, to fully assess the relationship between academic knowledge needed by operators and the knowledge content of a particular school's curriculum, and to identify whether there is additional curriculum content (related and not related to the job), you will need to make "Additional Curriculum Estimates." These estimates will help us identify areas C (additional curriculum, but still related to the job of operator) and D (additional curriculum, not related to the job of operator).

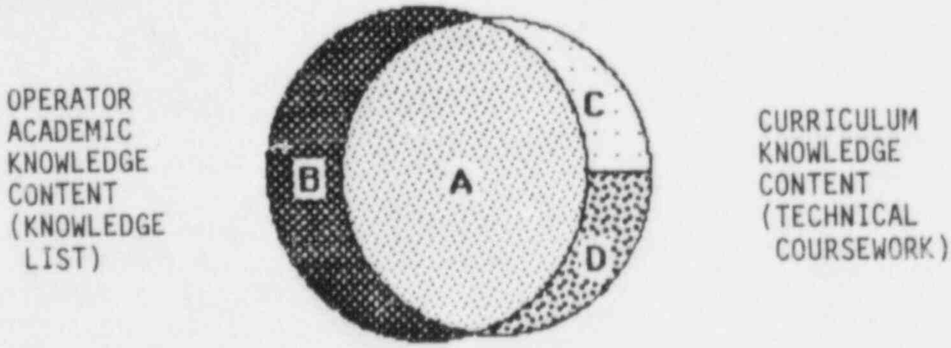

Figure 1. Hypothetical Distribution of Knowledge List and Curriculum Knowledge Content

To make the "Additional Curriculum Estimates," requires three steps in addition to the check marks on the curriculum you made when completing Task II.

1. After you complete Task II for a particular school, read through the entire curriculum for that school and determine whether each curriculum area not checked off is, in fact, curriculum content specifically related to the job of operator or not related to the job of operator (RO or SRO).

    - If a topic is not checked, but in your judgment it is still relevant to what an operator needs to know (e.g. a vendor-specific reactor systems course), place a C next to that curriculum topic.

    - If a topic is not checked, and in your judgment it is not relevant to what an operator needs to know, place a D next to that curriculum topic.

TASK III. ADDITIONAL CURRICULUM ESTIMATES (continued)

2. Then for each of the 12 major subject areas and the OTHER category, estimate the percentage (0-100%) of the total curriculum content for each subject area that the C items comprise. Then estimate the percentage of the total curriculum content for each subject area that the D items comprise. This is a global estimate, since you will need to weigh in your mind higher level or more complex content more than lower level content.

   Place your C and D percentage estimates for each subject area on the Additional Curriculum Estimates Form, the form located immediately after the Academic Knowledge List Rating Form.

3. Once you have estimated C and D percentages for each subject area, then take all those into account to arrive at a percentage of additional curriculum in the total curriculum that is job related (C) and non-job related (D). Also place these percentage estimates on the Additional Curriculum Estimates form.

   Total curriculum is defined as all technical courses, and does not include humanities or other non-technical courses listed in the overview of a school's curriculum. Again, you will need to weigh and balance the complexity of various subject areas to make this overall estimate. This is a difficult and global judgment, but please do your best. If necessary, indicate a general estimate, e.g., less than 10%, about 50%.

APPENDIX E

DETAILED TABLES OF JOB RELEVANCE OF CURRICULA

APPENDIX E

DETAILED TABLES OF JOB RELEVANCE OF CURRICULA

TABLE E-1

PERCENTAGES OF COVERED[1] AND PREREQUISITE KNOWLEDGE CATEGORIES BY SUBJECT AREA FOR EACH SCHOOL

SUBJECT AREA	PROGRAM TYPE/INDIVIDUAL SCHOOL															
	Coursework						Associate Degree						Bachelor Degree			
	C-1		C-2		C-3		AS-1		AS-2		AS-3		BS-1		BS-2	
	C[2]	P[3]	C	P	C	P	C	P	C	P	C	P	C	P	C	P
Mathematics	20	55	45	25	0	85	35	30	30	35	35	30	5	50	35	45
Electrical Science	60	0	53	0	0	3	40	3	27	0	0	0	50	0	33	0
Chemistry	0	0	17	0	0	0	44	0	0	0	0	0	6	0	11	0
Materials	46	0	54	0	31	8	8	0	31	0	0	0	39	0	69	0
Classical Physics	43	0	57	0	0	0	0	0	14	0	43	0	86	0	86	0
Atomic & Nuclear Physics	57	0	71	0	29	0	79	0	71	0	93	0	7	0	71	0
Reactor Theory	52	0	81	0	0	0	61	0	10	0	68	0	0	0	58	0
Instrumentation & Control	75	0	58	0	0	0	58	0	42	0	0	0	33	0	67	0
Reactor Plant Protection	13	0	100	0	0	0	25	0	0	0	0	0	0	0	0	0
Health Physics	74	0	65	0	65	0	82	0	59	0	41	0	0	0	44	0
Heat Transfer & Fluid Flow	31	0	88	0	0	0	66	0	22	0	22	0	69	0	72	0
Engineering Drawing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Knowledge Categories[4]	44	5	63	2	13	8	51	3	28	3	28	3	24	4	47	4

[1]Category is counted as covered if rating is greater than 3.5.
[2]C = Covered.
[3]P = Prerequisite.
[4]This is the percentage of all 232 knowledge categories on the academic knowledge list, not an average across the subject areas.

TABLE E-2

PERCENTAGE OF COVERED[1] AND PREREQUISITE KNOWLEDGE CATEGORIES OF EACH SUBJECT AREA BY TYPE OF PROGRAM

SUBJECT AREA	PROGRAM TYPE					
	Coursework		Associate Degree		Bachelor Degree	
	Covered	Prerequisite	Covered	Prerequisite	Covered	Prerequisite
Mathematics	22	55	33	32	20	48
Electrical Science	38	1	22	1	42	0
Chemistry	6	0	15	0	8	0
Materials	44	3	13	0	54	0
Classical Physics	33	0	19	0	86	0
Atomic & Nuclear Physics	52	0	81	0	39	0
Reactor Theory	44	0	46	0	29	0
Instrumentation & Control	44	0	33	0	50	0
Reactor Plant Protection	38	0	8	0	0	0
Health Physics	68	0	61	0	22	0
Heat Transfer & Fluid Flow	40	0	37	0	70	0
Engineering Drawing	0	0	0	0	0	0
All Knowledge Categories[2]	40	5	36	3	36	4

[1]Category is counted as covered if rating is greater than 3.5.
[2]This is the percentage of all 232 knowledge categories on the academic knowledge list, not an average across the subject areas.

TABLE E-3

PERCENTAGE OF CURRICULUM CONTENT OF EACH SCHOOL COVERING MATERIAL ADDITIONAL TO THE ACADEMIC KNOWLEDGE LIST[1]

SUBJECT AREA	PROGRAM TYPE/INDIVIDUAL SCHOOL															
	Coursework						Associate Degree						Bachelor Degree			
	C-1		C-2		C-3		AS-1		AS-2		AS-3		BS-1		BS-2	
	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U
Mathematics	10	80	18	30	0	100	8	25	30	18	23	33	7	80	7	75
Electrical Science	3	0	13	22	0	0	13	5	3	2	0	0	13	17	23	32
Chemistry	10	3	37	13	0	0	20	50	35	5	43	17	30	43	17	28
Materials	7	17	38	12	23	27	0	0	27	5	0	0	10	38	25	48
Classical Physics	3	28	15	25	0	0	27	40	25	22	0	0	23	48	18	50
Atomic & Nuclear Physics	35	20	10	0	8	17	3	0	7	0	25	12	0	0	13	8
Reactor Theory	7	2	18	8	30	35	10	0	3	0	33	8	0	0	23	27
Instrumentation & Control	27	3	57	20	13	32	22	40	10	0	0	0	23	22	15	15
Reactor Plant Protection	22	3	28	0	0	0	18	0	93	0	23	1	0	0	0	0
Health Physics	18	0	9	0	24	39	12	0	32	0	25	18	0	0	10	0
Heat Transfer & Fluid Flow	23	10	8	15	0	0	17	0	28	0	23	20	17	23	17	28
Engineering Drawing	0	0	0	0	0	0	0	13	0	0	0	60	3	87	0	0
Other	10	87	37	0	0	0	50	23	13	87	30	67	15	82	0	0
Total Estimate	15	20	23	13	15	25	13	15	28	10	28	25	17	45	13	40

[1]Percentage of total required technical curriculum devoted to content not on knowledge list that is judged as job-related (R) and unrelated (U) to the job.

TABLE E-4

PERCENTAGE OF CURRICULUM CONTENT COVERING MATERIAL ADDITIONAL TO THE ACADEMIC KNOWLEDGE LIST BY PROGRAM TYPE[1]

SUBJECT AREA	TYPE OF PROGRAM					
	Coursework		Associate Degree		Bachelor Degree	
	Related	Unrelated	Related	Unrelated	Related	Unrelated
Mathematics	9	70	21	26	7	76
Electrical Science	6	7	6	2	18	24
Chemistry	16	6	33	24	23	36
Materials	23	18	9	2	18	43
Classical Physics	6	18	26	21	21	49
Atomic & Nuclear Physics	18	12	5	4	7	4
Reactor Theory	18	15	7	0	12	13
Instrumentation & Control	32	18	18	20	19	18
Reactor Plant Protection	17	1	56	0	0	0
Health Physics	17	13	22	0	5	0
Heat Transfer & Fluid Flow	11	8	16	0	17	26
Engineering Drawing	0	0	0	7	2	43
Other	16	87	31	59	8	82
Total Estimate	18	19	23	17	15	43

[1]Percentage of total required technical curriculum devoted to content not on knowledge list that is judged as job-related (R) and unrelated (U) to the job.

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This report assesses the job-relatedness of specialized educational programs for licensed nuclear reactor operators. The approach used involved systematically comparing the curriculum of specialized educational programs for college credit, to academic knowledge identified as necessary for carrying out the jobs of licensed reactor operators. A sample of eight programs, including A.S. degree, B.S. degree, and coursework programs were studied. Subject matter experts in the field of nuclear operations curriculum and training determined the extent to which individual program curricula covered the identified job-related academic knowledge. The major conclusions of the report are: (1) there is a great deal of variation among individual programs, ranging from coverage of 15% to 65% of the job-related academic knowledge. Four schools cover at least half, and four schools cover less than one-third of this knowledge content; (2) there is no systematic difference in the job-relatedness of the different types of specialized educational programs, A.S. degree, B.S. degree, and coursework; (3) traditional B.S. degree programs in nuclear engineering cover as much job-related knowledge (about one-half of this knowledge content) as most of the specialized educational programs.

17. KEY WORDS AND DOCUMENT ANALYSIS

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