

DEVELOPMENT OF A FIELD STUDY EDUCATIONAL PROGRAM  
FOR WASTEWATER TREATMENT PLANT OPERATORS

ABSTRACT

Administrators who wish to improve the operation of wastewater treatment plants under their management can make good use of the instructional materials described in this paper. A manual entitled Operation of Wastewater Treatment Plants was developed for use by individual or group study. Experienced operators wrote the material for operating personnel who have not had the benefit of specialized education in wastewater treatment facility operation. A three phase developmental program is described which defines tasks and routines of daily plant operation, checks these under on-site in-plant conditions and edits and reviews material for instructional purposes by individuals concerned with personnel training and plant operation. The instructional materials are intended to assist training operators in the specialized responsibilities needed in daily treatment plant operations and to encourage them to develop themselves and their capabilities into better plant operators.

# DEVELOPMENT OF A FIELD STUDY EDUCATIONAL PROGRAM FOR WASTEWATER TREATMENT PLANT OPERATORS

## INTRODUCTION

Administrators who wish to improve the operation of wastewater treatment plants under their management can make good use of instructional materials described in this paper. Also important to the administrator is an understanding of how the materials were developed and verified so that he can evaluate their applicability to his particular situation. Included is a history of how a new field study manual entitled Operation of Wastewater Treatment Plants was written, applied, evaluated and rewritten into its current form.

## NEED FOR FIELD STUDY EDUCATIONAL PROGRAM

Proper operation of wastewater treatment facilities is essential to accomplish the intended purpose of the plant. Educational institutions have stressed curriculums preparing students for professional practice in the fields of process research and design of wastewater treatment plants, but frequently the operation of treatment facilities is virtually ignored. Many operators have not received an adequate education to understand the complexities of successful plant operation.

Reasons for inadequate education include the lack of proper educational materials and facilities. Other factors contributing to the problem include public apathy, insufficient qualified training instructors, and the desire of many individuals and agencies to develop their own educational materials. To some extent specialized material is necessary to include unique local problems and regulatory requirements. This program contains the basic information essential for all programs. A group instructor or field study (correspondence course) administrator can use this material plus any specialty information and organizational structures pertinent to his area. A pattern is provided for one area as a model for others.

#### INSTRUCTIONAL OBJECTIVE

Development of capable, trained personnel who can operate wastewater treatment plants efficiently is the objective of this educational program. Efficiency is defined in terms of producing a high quality effluent as intended by the plant designer, meeting established receiving water quality standards, and minimizing costs of operation. Accomplishment of the objective can be greatly assisted by providing operators with the knowledge and procedures they need for efficient operation of wastewater treatment facilities.

## IDENTIFICATION OF ESSENTIAL KNOWLEDGE AND PROCEDURES

Experienced operators were requested to write the information and procedures they felt an operator needed to know to operate his plant. Site visits to various types of wastewater treatment plants were conducted to observe the situations encountered by operators and their daily operational problems. Special attention was given to plant start-up, daily operational schedule, frequently encountered problems, maintenance, sample collection and analysis, and operator response to lab results.

## REVIEW AND SELECTION OF EDUCATIONAL METHODS

A team of experienced operators, consulting engineers, administrators, regulatory personnel, and educators was formed to develop a curriculum capable of accomplishing the objective of this program. How to best convey the desired information and procedures to operators unable to attend conventional classroom programs was the next problem to be solved. For the program to be readily available to as many operators as possible, the cost should be as low as possible without sacrificing the transfer of knowledge. Correspondence schools, home study, and self-study manuals have been used extensively in this type of situation in the past.

Correspondence schools for wastewater treatment plant operators sponsored by International Correspondence School, Clemson University and University of Arizona were examined. Erdos (6) provides considerable insight to all aspects of a correspondence program in a UNESCO source book. U.S. Navy training course manuals for Water and Sewage Plant Operators (20) and the excellent manuals of practice published by the Water Pollution Control Federation (11) were reviewed. Very good textbooks on the operation of wastewater treatment plants that were studied include the "Texas Manual" (10), "New York Manual" (9), and a publication by Bloodgood (3). Techniques used in DuPont (15) and other self-study manuals (2, 18) were carefully studied. Persons actively developing self-study manuals using programmed learning techniques were interviewed (16, 19) and research reported by the Educational Research and Methods Division of the American Society for Engineering Education (5) was thoroughly reviewed. Innovative audio-visual techniques (1, 7, 13) were examined for potential use by operators.

Programmed instruction techniques were selected as the most appropriate means of conveying the desired knowledge because no additional facilities or material other than the basic manual would be required. Other methods might be more effective, but the limited budgets of small agencies and

income of their operators could preclude the purchase of any special facilities.

A strict programmed instruction lesson is classified as either a linear (12, 17) or a branched type (19). In a linear type, the student covers a portion of the page with a piece of paper as he reads the lesson. Whenever he comes to a blank space or a question, he thinks or writes his answer, uncovers the correct answer, and checks his result. A branched program consists of questions with multiple choice answers. The student reads a short section in the lesson and then encounters a question. He selects what appears to him to be the correct answer. Then he is instructed to turn to a specific page where he is informed whether his answer is correct or not and where to read next, depending on his answer.

Strict adherence to either programmed instruction technique requires considerable time and ingenuity to develop the instructional material. Neither approach is familiar to most operators, although they could adapt to the procedure. Presentation of material on the operation of wastewater treatment plants by either technique limits the value of the material for quick and easy reference when plant operational problems occur. To overcome these shortcomings of strict programmed instruction, the material was arranged in the form of a typical textbook but presented using the techniques of programmed instruction.

Tests by educators and psychologists have indicated that answering questions immediately after reading the material provides immediate reinforcement of knowledge. Research with equivalent groups using programmed instruction indicates that essay and multiple choice questions are equally effective; however, retention is much better one year later in groups using essay questions. The adopted procedure was for the operator to read a short section (1 to 5 pages), write the answer to a few questions (1 to 5), compare his answers with suggested answers at the end of the chapter, and decide whether to reread the short section or continue on to the next section. A major advantage of this approach is that an operator can proceed at his own pace and operators with considerable variations in education and experience all can use the material.

#### PREPARATION OF MATERIAL

Information and procedures needed by operators of wastewater treatment plants was divided into seventeen chapters on the basis of subject matter as shown in Table I. Experienced wastewater treatment plant operators wrote the chapters on treatment plant processes with emphasis on what the operator needed to know to perform his duties effectively. Each treatment process chapter followed the format outlined in Table II.

After the writers of each chapter had prepared their material, it was reviewed, edited, and rewritten in the selected programmed instruction format. Following each short section of a particular topic, several questions were prepared for the operator to answer. These questions were designed to reflect problems an operator could encounter and attempted to obtain a solution from the operator that he could apply to his plant. When the operator checked his answers, he found suggested answers that contain a discussion of possible solutions to the questions posed. Numerous sketches, illustrations, photographs, and useful tables were provided to enhance the appearance of the material and facilitate its usefulness.

The material is written to allow an operator to study only selected lessons which apply to his problems, or to proceed through the entire book, whichever he chooses.



TABLE I. TREATMENT PLANT OPERATION COURSE OUTLINE

CHAPTER	TOPIC
1	Introduction
2	Why Treat Wastes?
3	Wastewater Facilities
4	Racks, Screens, Comminutors, and Grit Removal
5	Sedimentation and Flotation
6	Trickling Filters
7	Activated Sludge
8	Sludge Digestion and Handling
9	Waste Treatment Ponds
10	Disinfection and Chlorination
11	Maintenance
12	Plant Safety and Good Housekeeping
13	Sampling Receiving Waters
14	Laboratory Procedures and Chemistry
15	Basic Mathematics and Treatment Plant Problems
16	Analysis and Presentation of Data
17	Records and Report Writing

TABLE II. TYPICAL TREATMENT PROCESS CHAPTER OUTLINE

SECTION	TOPIC
1	Relationship of process to overall plant
2	Purpose and description
3	Plant start-up
4	Daily operational problems
5	Sampling and analysis (includes performance evaluation)
6	Safety
7	Additional useful information

## FIELD TESTING - PHASE I

Initial testing of the material consisted of recruiting a group of persons willing to test the material and to provide constructive criticism. The initial group was composed of men whose experience ranged from over 20 years down to people interested in becoming operators. Their education level varied from tenth grade to college graduates.

One week was devoted to each chapter, except two weeks were allocated to the chapters on activated sludge and laboratory procedures because of their complexity and length. Each participant was requested to work a pre-test, read the material, answer questions, check his answers, and work a post-test. While the student did his assignment, he marked sections that were not clear or difficult to read and he noted questions whose solutions or answers were not adequately explained in the chapter. The pre-test was used to indicate to the student important topics in the chapter and to evaluate the effectiveness of the teaching techniques and material presented, when compared with the post-test.

Both the pre and post tests contained essay, multiple choice, fill-in, matching, and the true-false types of questions to provide experience in taking various types of tests. Essay questions were used most because they help

reinforce knowledge, aid in developing writing skills, provide the opportunity for the student to indicate what he knows, and allows the designer of the program to identify weaknesses and misconceptions in the prepared material or in the participants experience prior to starting the program.

At each weekly meeting the material was reviewed by the group on a page by page basis. These meetings were recorded on tape and areas needing improvement were noted. The writer of the chapter explained the unclear section to the satisfaction of the participants and these verbal explanations proved very helpful when the material was revised. Potential operators were extremely helpful in identifying words used by professionals that are not understood by the layman. These words are defined at the beginning of each chapter where they are used, footnoted in the chapter where they first appear, and all of these words are listed and defined in one summary glossary at the urging of the participating operators. A special pronunciation key using everyday words and syllables was developed to aid in the understanding of uncommon words. After each meeting the writer of each chapter rewrote his material with the aid of the program consultants and education specialist.

Difficult problems encountered included the sequence of working the chapters, especially the relationship of mathematics

and chemistry with respect to the other chapters, the breadth and depth of the material in each chapter, and the explanation of theory needed to successfully operate a wastewater treatment plant. Logically one would assume that the operator must possess a strong background and understanding of the fundamentals of mathematics and chemistry before he could comprehend the material in the chapters on the operation of wastewater treatment processes. Experienced operators countered that they know little chemistry and were not interested in mathematics and that they felt their plants were being operated at a satisfactory level. Efforts by potential operators revealed that they lacked sufficient familiarity with treatment plants and vocabulary of the profession to comprehend the need and basis for chemistry and mathematics in treatment plant operation. Discussions with operators indicated that they wanted to learn the "nuts and bolts" of plant operation and were not concerned about mathematics or chemistry.

To solve the problem of the appropriate location of the chapters on mathematics and chemistry in the work sequence of the chapters, these chapters were introduced early in the program but the operator has the choice of working the chapters, using them for reference, or waiting until the end to work them. Mathematics are introduced first in Chapter 4 in the operation of grit chambers. The calculations are very

simple and the mathematical operations gradually become more difficult with each chapter as the operator works problems encountered in the daily operation of the various types of treatment processes. The mathematics chapter was provided simultaneously with Chapter 4 to serve as a reference and guide to working mathematical problems in the other chapters.

Chapter 5 on sedimentation and flotation requires the use of laboratory procedures to evaluate the performance of a primary clarifier or sedimentation basin and to determine whether any adjustments in plant operation are necessary. The chapter on laboratory procedures and chemistry was provided with Chapter 5 to serve as a reference and explanation of laboratory procedures to evaluate the performance of treatment processes and overall plant performance. Some experienced operators have completed the chapters on mathematics and laboratory procedures first because they said they wanted to concentrate on the treatment processes when they worked on those chapters and not have to refer to other chapters.

Many operators interviewed before the material was prepared indicated that in their opinion most of the available information on the operation of wastewater treatment plants was too vague, too theoretical, or lacked sufficient instructions on how to do a particular task. This problem was

attacked by asking the question, "What does the operator need to know?" Sketches were provided in the laboratory procedure chapter to illustrate the measurement of water quality on a step-by-step basis (14). Operators were urged to consult manufacturers' literature for details on maintenance procedures.

Operators frequently feel that theory is not pertinent to the operation of their plant. Basic knowledge required to operate plants is contained in sections on the principles of the treatment process and the operation of the process. Originally this material was placed at the end of each chapter at the request of the participating operators, but it was evident that it must be placed at the beginning to provide the necessary background information to comprehend the material in the chapter.

Fourteen operators started Phase I and eight were awarded Certificates of Completion. Most stopped attending before the third week, stating they agreed to help because they wanted to see what the program was like. Mainly these were operators who had attended other operator training courses in conventional classrooms. They appeared to want to listen to lectures, but did not wish to spend the time outside of class going through the material.

Following completion of Phase I and evaluation of the program, the material was rewritten. With all of the material available, format was standardized, topics expanded and added where appropriate, and duplication eliminated.

### FIELD TESTING - PHASE II

Phase II consisted of field testing the program with operators in Northern California and with potential operators enrolled in the Mechanical-Electrical Technology Program at Sacramento City College. This group consisted of men and a woman whose ages ranged from 17 to over 60, experience was from zero to over 20 years and education varied from grammar school to a graduate degree (Figure 1).

Chapters 1 through 3 were mailed immediately. When a chapter was completed by a student, it was mailed to the program director who forwarded it to the author of the chapter. It was corrected, returned to the director for review, and mailed to the operator with another chapter. Mailings were arranged to keep the student working as fast as he desired. Again Chapter 15 on Mathematics was mailed with Chapter 4 on Racks, Screens, Comminutors, and Grit Removal and Chapter 14 on Laboratory Procedures was mailed with Chapter 5 on Sedimentation and Flotation.



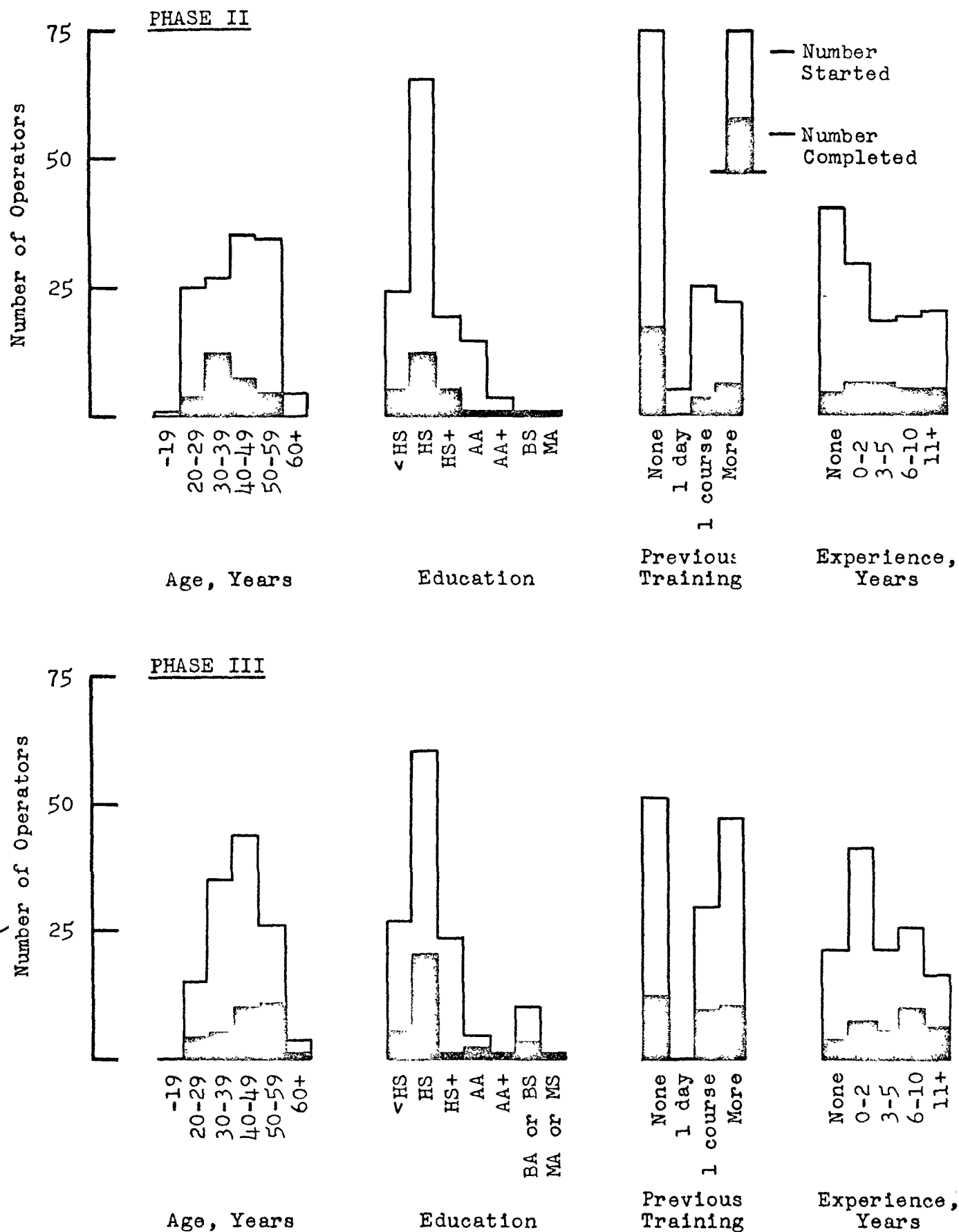


Fig. 1. Vital Statistics of Operator Participating in Testing Program

After the operator had completed Chapter 3, he was visited at his plant by the program director and an experienced operator. The purpose of this visit was to become acquainted with the operator and his plant, explain the purpose of the program to him, urge his cooperation in identifying sections that need improving, and request him to provide the program director with "tricks of the trade" that had been omitted from the material.

When the operator was approximately half through the program he was visited at his plant again. At this time he was asked to identify his plant operational problems and discuss his solutions to insure that solutions to most typical operational problems were contained in the material. Occasionally the visitors were able to help the operator find his problem in the material and also a potential solution. This approach helped the operator realize that the material could serve as a valuable reference source when problems are encountered. Near the end of the program the operator was visited again to provide the opportunity to discuss improvements in the material.

One intended purpose of the plant visits was to evaluate the effectiveness of the material. Originally, a comparison of the quality of the plant effluent when the operator started and completed the program was felt to be an appropriate measure. At the start of the program the local

regulatory agency was provided with a list of operators in the program with the request that inspectors offer to help the operators with the lessons and to listen for means to improve the program. The agency responded that all plants being operated by program participants were meeting discharge requirements and that the best operators in the region had enrolled in the program.

At the beginning of the program, supervisors were notified that their employees had volunteered to participate in the program. Following completion of the program, supervisors were polled regarding their impression of the influence of the program on the operator. All supervisors indicated that they detected increased communication skills and a better knowledge of the operation of the treatment plant. Every agency indicated they would be willing to pay from \$10 to \$200 per manual for the material for other operators to participate in the program. None of the operators received a pay raise upon receipt of his Certificate of Completion.

Performance of operators completing the program on California Certification Examinations and civil service examinations is confidential; however, informal discussions with operators and Certification officials has revealed that operators who completed the program achieved a much higher degree of success and higher passing grades than operators who had not participated in the program.

Figure 2 illustrates the percentage of operators who started the program that completed each chapter. Discussions with a large number of operators, or their supervisors, who stopped working the lessons early in the program indicated that the operators were not too interested, but their supervisor thought it would be a good program and enrolled them in the program. Chapter 7, Activated Sludge, was an impossible hurdle for many operators because it was too long and too difficult and, consequently, was extensively revised. Other reasons for quitting included passing of the certification exam and graduation from school. Many operators were unable to complete the program because of lack of time due to the demands of a second job. The large number of operators in remote regions holding second jobs reflects the poor salary structure in these areas.

In an attempt to reduce the number of persons who did not complete the program, an illustrator was retained to improve the presentation of the material (Fig. 3). His sketches were very pertinent and he has received many compliments on the appropriateness of his work. Revision of Chapter 7 on Activated Sludge consisted of completely rewriting the introductory lessons to provide a better insight into the description of the process, how it works, and what is required to keep it working. Details on the start-up,

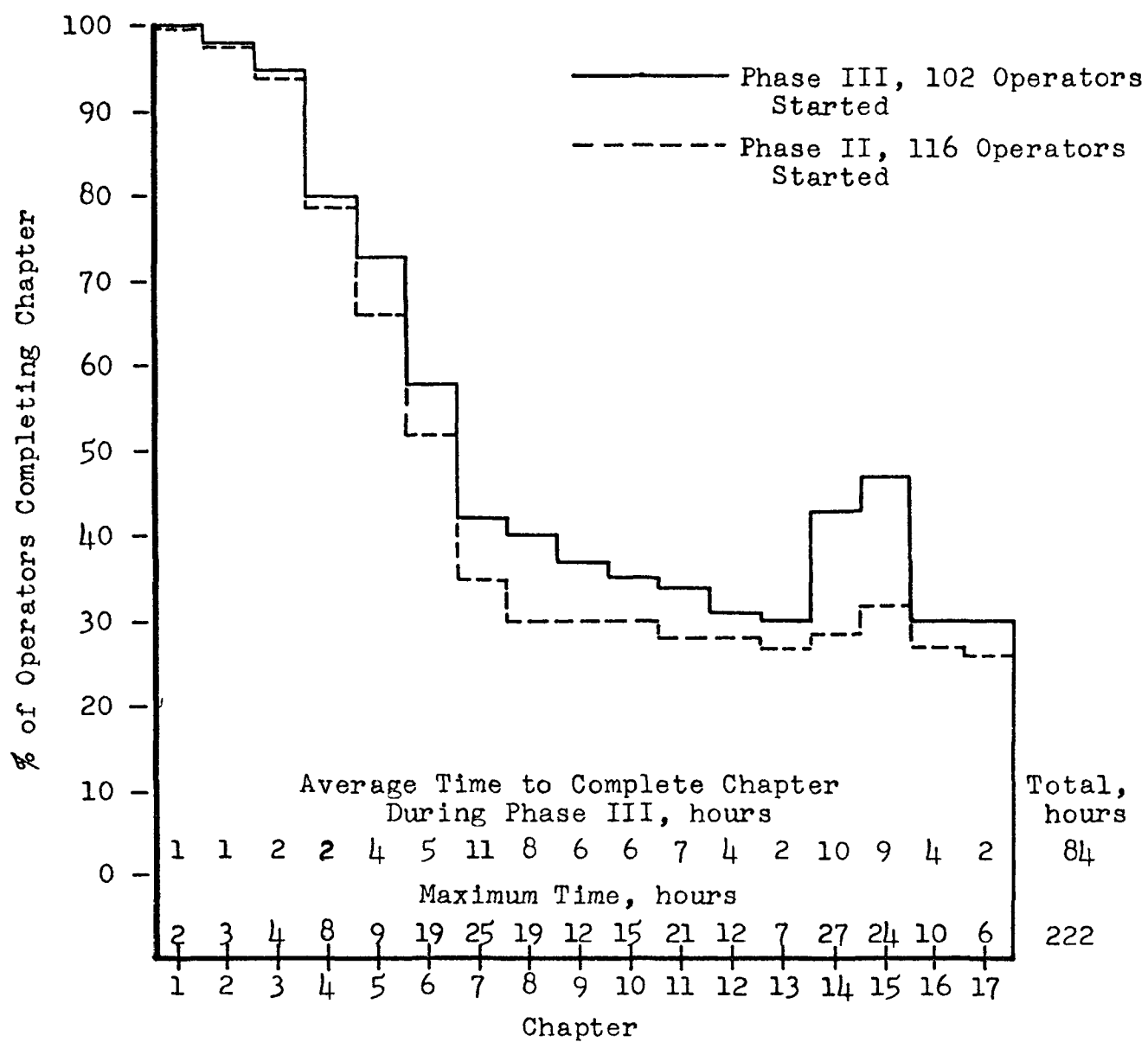
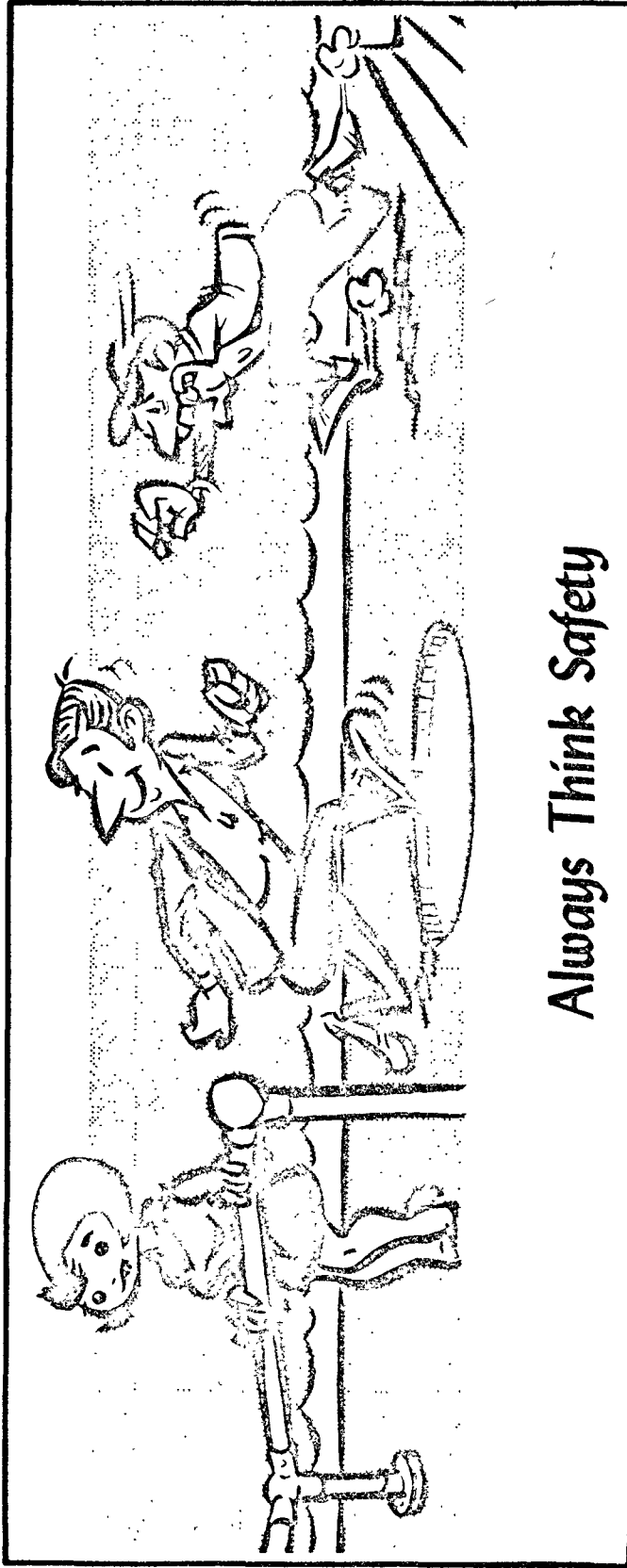


Fig. 2. Success of Operators Who Started Program in Completing Chapters



## Always Think Safety

Fig. 1.7 Special care and safety must be practiced when visitors are taken through your treatment plant. An accident could spoil all of your public relation efforts (8).

Fig. 3 Typical Illustration

operation, and maintenance of the process were condensed where possible.

Again the material was reviewed by the project consultants and educators and rewritten on the basis of the evaluation of the Phase II testing program.

### FIELD TESTING - PHASE III

Phase III was a national testing program with operators from 25 states located all over the United States. These operators were requested--and many did--to suggest improvements in the lessons where local operational problems had been overlooked or not included in the material. Vital statistics of these operators are contained in Figure 1. Each state and Environmental Protection Agency Regional Director of Manpower and Training received a copy of the material and several agencies contributed helpful comments.

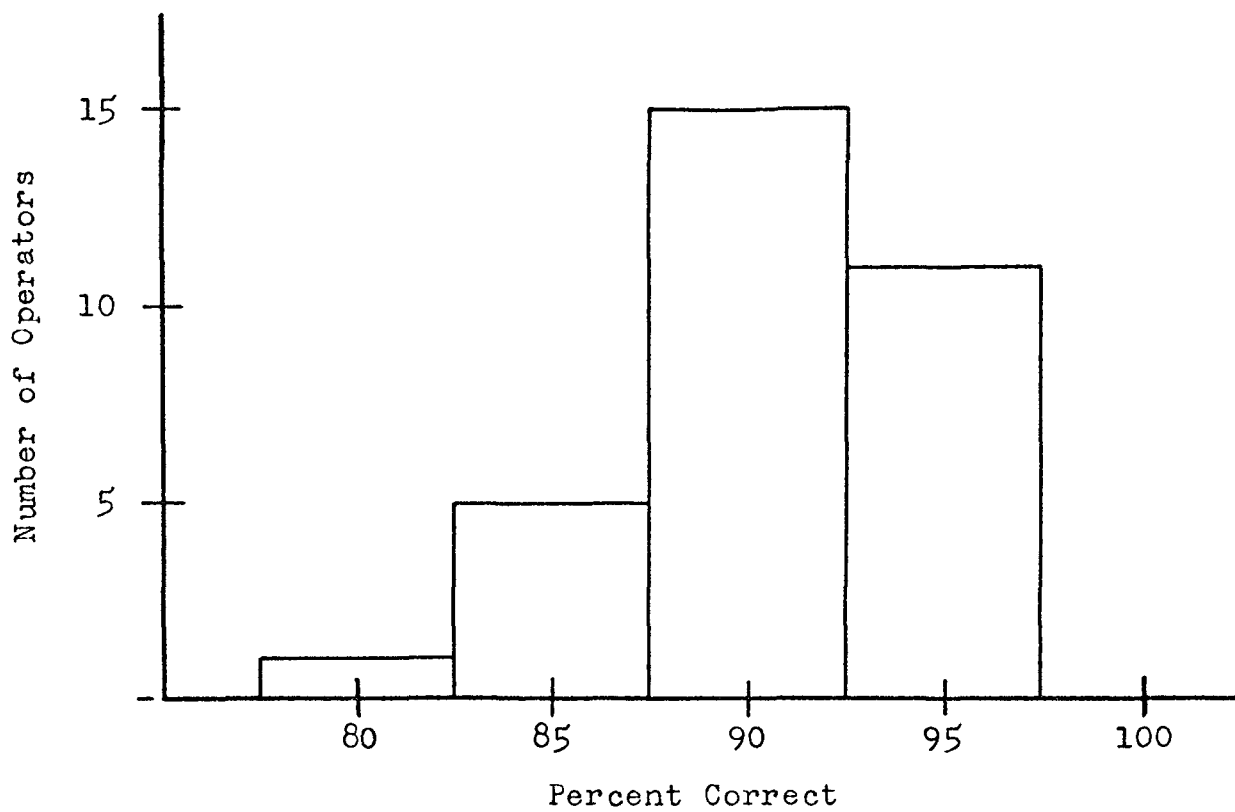
Procedures for working the lessons were similar to Phase II except approximately 20 operators were assigned to an individual who corrected all of their material. This plan was instigated to allow the person correcting the material to become familiar with a group of operators and encourage them to stick with the program. If an operator made the same mathematical error in several chapters, he

could receive comments on how to correct this error. Field visits, unfortunately, had to be eliminated because of the dispersed locations of the operators. Contact was maintained with local operators to encourage suggestions for improvement.

Evaluation of Phase III consisted of comparing the improvement of scores between the pre and post-tests. Added to the post-tests in Chapters 9 through 13 and 16 and 17 were review questions. Several of the operators worked the review questions on the answer sheet they labeled pre-test, confirming a suspicion that they worked the chapter and then answered both the pre and post-tests. Figure 4 summarizes the grades received on the post-tests by the operators completing the program. The results reveal a high degree of success by these operators on the questions the authors deemed pertinent to the operation of wastewater treatment plants. An advocate (19) of programmed instruction claims that everyone should obtain an A grade because the operator is not supposed to continue until he understands the material in each short section.

Following the completion of Phase III the material was reviewed by consultants and educators and revised where necessary on the basis of the evaluation of this phase. All of the material was edited and all words were checked for reading-skill level (4). Colloquialisms were eliminated to





Out of 1233 Possible Multiple Choice Answers

Fig. 4. Summary of Average Score of Successful Operators on All Post-Tests, Phase III

facilitate translation to other languages. Virtually all of the words remaining in the completed Manual, Operation of Wastewater Treatment Plants (8), are twelfth-year level or lower, with the exception of those words essential for the operator to communicate with his colleagues in the wastewater treatment profession.

### SUMMARY AND CONCLUSIONS

Procedures followed in the development and use of operator educational material are outlined in this paper. In summary, the procedure involved:

1. Defining educational objectives
2. Identifying knowledge and procedures essential to achieve objectives
3. Reviewing educational techniques, materials, and media
4. Developing curriculum
5. Selecting qualified instructors and/or writers
6. Administering the program
7. Evaluating the program
8. Repeating administration and evaluation until material and method of presentation were satisfactory
9. Providing procedures to revise program when necessary

A field study manual on the operation of wastewater treatment plants was developed and tested by experienced operators which is capable of providing operators with the information they need to know to operate their plants and solve operational problems. Operators studying alone or enrolled in regular courses who use this manual are provided helpful learning material and a useful reference.

#### ACKNOWLEDGEMENTS

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