TO: WHOM IT MAY CONCERN

FROM: James M. Stewart
Assistant Director for Research Application

SUBJECT: Institute Report No. 74 — "An Investigation of Curricula, Materials and Methodology for Training Operators of Wastewater Treatment Plants" — by James C. Brown, Department of ESE, University of North Carolina at Chapel Hill

This report describes the current situation with regard to training deficiencies and needs of wastewater treatment plant operators, the need for additional training and certification of wastewater treatment plant personnel. Methods of training, curricula modification, skills to be developed, and courses to be offered are covered in the report.

Recommendations are made for an integrated, long-range program of operator training to be developed under the supervision of the Office of Water and Air Resources of the North Carolina Department of Natural and Economic Resources.

It is suggested as a part of the total training program that appropriate visual aids be developed. One example of this is a slide-tape set with a booklet developed for self-instruction on the subject, "Measurement of Dissolved Oxygen: Azide-Winkler Procedure." Two copies of this are available at the Institute and may be borrowed for a two-week period at no cost.

JMS:p

Attachment
AN INVESTIGATION OF CURRICULA, MATERIALS
AND METHODOLOGY FOR TRAINING OPERATORS
OF WASTEWATER TREATMENT PLANTS

By

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# TABLE OF CONTENTS

ACKNOWLEDGEMENT  
ABSTRACT
SUMMARY AND CONCLUSIONS
RECOMMENDATIONS
INTRODUCTION
The Scope of the Problem
EXISTING TRAINING ACTIVITIES
The Annual Short Course in Chapel Hill
Other Training Activities
Full Time Training
Part Time Training
Special Short Courses
Correspondence Courses
Need for a Unified Training Effort in North Carolina
OPERATING SKILLS AND TRAINING CURRICULUM
The Study Committee
Organization of the Committee
Definitions of Responsibility for the Four Operator Grades
Skill Requirements
General Comment on Training
Suggested Curriculum
PROPOSED INTEGRATED PROGRAM OF OPERATOR TRAINING ACTIVITIES
FOR NORTH CAROLINA
The Annual Short School
Long Term Evening Schools
Special Subject Short Schools
Audio-Visual Instructional Materials
Short Term Plan
Long Term Plan
REVIEW OF AVAILABLE TRAINING MATERIALS
Printed Materials
Audio-Visual Materials
REFERENCES
APPENDICES
A. Minimum Requirements for Education and Experience for Certified Wastewater Treatment Plant Operators
B. Rating Scale for Classification of Wastewater Treatment Works
C. Measurement of Dissolved Oxygen: Azide Winkler Procedure: A Pilot Project in Operator Training
ABSTRACT

The skill and training requirements for four grades of wastewater treatment plant operators recognized under the North Carolina certification law are examined. A detailed list of skills is developed from which a suggested training curricula is proposed. Various methods for training operators are discussed, i.e., short schools, full time training, part time training coordinated with on the job training, correspondence courses, and special subject short courses.

Available types of training materials are reviewed and the role of audio-visual materials is discussed. Recommendations are made for the development of an integrated program of operator training in North Carolina. The program would be developed under the supervision of the Office of Water and Air Resources of the Department of Natural and Economic Resources. The integrated program would require the continued cooperation of the North Carolina Water Pollution Control Association, the University of North Carolina and community colleges and technical institutes in various locations around the State. The integrated program would involve part time training at local institutions, short courses and special subject courses for higher level operators conducted at the University of North Carolina or elsewhere by qualified specialists and the development of appropriate audio-visual materials.
SUMMARY AND CONCLUSIONS

Current EPA estimates based on countrywide requirements indicate that 61,000 new wastewater treatment plant employees will be needed over the next five years. In addition, the number of operators who will need update training is estimated to be 36,000 per year. North Carolina's share of these requirements, on the basis of population, indicates a need to train 300 new operators and provide update training for 890 present operators each year.

To meet these goals training efforts in North Carolina must be expanded. Existing curricula for operator training as followed in the annual short school in Chapel Hill needs some revision in light of the changing technology in wastewater treatment. Training of lower level operators should emphasize mechanical and maintenance skills along with basic process knowledge. Training for these levels of operators could be effectively offered at other convenient locations around the State, e.g. technical institutes and community colleges.

Training for upper level operators should emphasize laboratory skills, management and advanced treatment technology. Training for upper level operators can be continued effectively in the annual short school format. The development of a series of special subject short courses covering various of the more complex or advanced topics of utility to upper level operators also seems appropriate.

In view of the crucial roll played by plant operators in the effective operation of costly wastewater treatment plants and the
extent of the need for new and retrained personnel, it is proposed that an integrated, long range program of operator training for North Carolina be developed under the supervision of the Office of Water and Air Resources of the North Carolina Department of Natural and Economic Resources. The effective development of this program would be enhanced by the cooperation of the University of North Carolina at Chapel Hill, the North Carolina Water Pollution Control Association, various community colleges and technical institutes around the State, and municipal governments with modern wastewater treatment facilities. Such an integrated program could include the following elements:

1. Part time training at local institutions coordinated with on-the-job activities for Grades I and II (lower level) operators. Sufficient local schools should be developed to provide convenient access to trainees.

2. Continuation of the annual short school at Chapel Hill for Grades III and IV (upper level) operators.

3. Development of special subject short courses for presentation at Chapel Hill or elsewhere around the State by qualified personnel.

4. A body of printed instructional material should be adopted from existing sources to provide trainees at local schools with adequate home study material.

5. Audio-visual training materials provide very effective support for training activities. Appropriate materials available from
various sources should be incorporated into local training programs. In addition, new materials, designed to satisfy the training needs of operators should be developed.

RECOMMENDATIONS

It is suggested that this report be reviewed by the Office of Water and Air Resources and other groups concerned with the need for expanded wastewater treatment plant operator training in North Carolina. Following such review, it is recommended that a comprehensive, long range, operator training proposal be developed with attendant budgets. This proposal should be submitted for support to appropriate agencies of the State and federal government.

Spending many millions of tax dollars each year in North Carolina for the construction of treatment facilities while spending only a few thousands of dollars to train the operators who must man these complex facilities is poor economy indeed.
AN INVESTIGATION OF CURRICULA, MATERIALS
AND METHODOLOGY FOR TRAINING OPERATORS
OF WASTEWATER TREATMENT PLANTS

INTRODUCTION

The Scope of the Problem

During the past several years millions of dollars have been spent in North Carolina to upgrade existing wastewater treatment plants and to construct new facilities where none previously existed. The passage of the Clean Water Bond Legislation in the spring of 1972 has provided further impetus to treatment plant construction at the municipal level.

At present the Office of Water and Air Resources of North Carolina Department of Natural and Economic Resources lists a total of 1100 municipal and industrial wastewater treatment plants in North Carolina. Many of these plants are not operating at their expected efficiency and others are overloaded. The public has become aware of these problems, or at least has indicated their desire to improve the quality of our surface waters, and State and federal agencies are responding to these desires. State and federal funds are now available for the construction of new treatment facilities and for upgrading existing plants. Construction activities can be expected to continue...
at a high rate during the next decade. However, construction in itself will not solve the state's water pollution problems.

Municipalities and industries must have properly trained, skilled personnel to operate wastewater treatment plants. The degree of skill required by operators is becoming greater as plants become more complex in response to requirements for improved effluent quality. In many cases treatment works have been designed and constructed with little thought given to operation. In some cases municipal and industrial treatment plants are staffed by personnel who are unable to perform duties in other capacities in the municipal or industrial framework. New and existing wastewater treatment plants must be efficiently operated if we are to reach our water quality objectives. This will require an adequate number of responsible well trained operators.

Little reliable information is available on actual needs for operators either in the country or the state. In 1967 the Federal Water Pollution Control Administration (1) estimated that the needed operators at that time, exclusive of supervisors, laboratory technicians and craftsmen, such as electricians and pipe fitters, was 23,500. The number of operators actually employed at the time was between 16,500 and 19,400, a deficiency of between 4100 and 7000. The FWPCA estimated that the number of operators required by June 1972 would increase to 42,000. The total number of new operators estimated to be required in the five year period was between 22,600 and 25,500 depending on the initial deficiency. Based on population North Carolina's share of the projected increase would have been about 600 new operators in the five year period.
A more recent study by the Environmental Protection Agency (2) of all types of manpower needs in the water pollution control field indicated the most critical need is for additional operators. This study points out that undermanned plants and undertrained manpower are a serious jeopardy to the entire pollution control program and the large capital investment that has been made in plant facilities. EPA estimates that during the five year period, 1972 through 1976, private industry will require 41,000 entry level positions, and public agencies will require 20,000. Furthermore the annual need for update training is estimated about 36,000 per year.

These types of estimates may be questioned; they are sometimes based on unrealistic estimates of future plant construction. Nevertheless, it is safe to state that sizable increases in wastewater personnel are needed. The problem is compounded by the fact that many present operators are inadequately trained.

In recognition of the role played by competent operation and supervision in efficient operation of wastewater treatment plants, the General Assembly of North Carolina enacted a statute (Chapter 90-A, Section 39, General Statutes of North Carolina), which went into force in 1971, requiring that the person in responsible charge of wastewater treatment works be certified as to their competency; requirements for certification to be established by the Department of Water and Air Resources (now the Office of Water and Air Resources). The important role of qualified operators was recognized in the introductory paragraph of the legislation which states as follows:
It is the purpose of this article to protect the public health and to conserve and protect the quality of water resources of the State and maintain the quality of receiving streams as assigned by the North Carolina Board of Water and Air Resources; to protect public investment in wastewater treatment facilities; to provide for classifying wastewater treatment plants; to require the examination of wastewater treatment plant operators and certification of their competency to supervise the operation of such facilities; and to establish procedures for classification and certification.

A voluntary certification program existed for a number of years prior to enactment of the statute. The shortage of qualified operators was clearly pointed out by the returns of a survey conducted in 1971 by the Office of Water and Air Resources. Approximately 1,100 questionnaires were sent out to treatment facilities around the State requesting information as to operator qualifications. Based on analyses of the questionnaires it had been estimated that 75 percent of the operators in the plants were not certified.

To administer the certification law the Office of Water and Air Resources has appointed a seven member Board of Certification whose membership is drawn from municipalities, industries, the Water Pollution Control Association and the Office of Water and Air Resources. The Board has adopted a point rating system for wastewater treatment plants which depends on their size and complexity. The rating schedule determines the grade of certificate (I, II, III or IV - IV is highest) which the person in charge must have. Copies of the point rating system and the experience and education requirements for various operator grades are included in the appendix of this report. Certification in any particular grade is obtained by passing a written examination provided the applicant meets the education and experience requirements. Under the certification law the Office of Water and Air Resources is responsible for providing training.
and the Board of Certification administers the required test and awards certification to those who qualify.

The need for training and then retraining qualified wastewater treatment plant personnel is obvious to those acquainted with the situation. Although this report addresses itself principally to training, it should be emphasized that the shortage of qualified operators could be alleviated if competent personnel could be retained in the wastewater treatment field. This question centers on reducing operator turnover rates and much could be accomplished by improving overall working conditions. Some of the most obvious approaches are as follows: 1. Wages should be at a level such that competent, experienced operators do not sacrifice better pay by continuing to work in the pollution control field. 2. Jobs should be structured so that the operator will have an obvious career ladder before him, one which will provide the incentive to improve his capabilities. 3. Public awareness of the importance of the plant operator to pollution control must be increased.
EXISTING TRAINING ACTIVITIES

The Annual Short Course in Chapel Hill

The oldest ongoing effort to offer formal operator training is the annual short school held each spring at the University of North Carolina in Chapel Hill. The short school is conducted by the Department of Environmental Sciences and Engineering of the School of Public Health in cooperation with the Institute of Government. External administrative responsibility for the short school rests with the North Carolina Water Pollution Control Administration. The program consists of four days of instruction for each of the four operator grade levels. On the fifth day of the program an examination is conducted by the Board of Certification.

The increasing recognition of both operators and employers in training is evidenced by the increasing enrollment trend in the short course during recent years as shown below:

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>75</td>
</tr>
<tr>
<td>1970</td>
<td>130</td>
</tr>
<tr>
<td>1971</td>
<td>149</td>
</tr>
<tr>
<td>1972</td>
<td>233</td>
</tr>
</tbody>
</table>

The passage of the mandatory certification law has stimulated enrollment to some extent.

The program of instruction in the short school follows a syllabus developed some years ago which, in general, has proven satisfactory. Instructors for the course are unpaid volunteers and are drawn from the School of Public Health, State and local government agencies,
consultants and manufacturers. Because of the number of instructors, coordination of the training presents some problems, i.e., not all instructors cover the prescribed materials, and the quality of instruction varies from excellent to poor. Another problem lies in the number of separate subjects that are covered. Group I and II trainees are exposed to a total of 25 lecture hours of which 12 hours are devoted to one-hour presentations of separate subjects. The one-hour period does not allow thorough coverage of the subject and the diversity of the subject matter and quality of presentation tend to confuse the trainee. The program for Group III candidates devotes 20 hours to substantial presentations of two hours or more duration and only 5 one-hour lectures are presented. This is a stronger program as it allows trainees time to concentrate on subjects of significance. The principal training effort in the Grade III program relates to sampling and laboratory procedures. The Grade IV program concentrates in two areas; hydraulics and design, and stream biology. Many of the trainees and instructors have questioned the emphasis given to design type training as most operators, even if they are superintendents, are seldom involved in plant design.

Short term intensive courses have some significant disadvantages by their very nature. A substantial body of material is covered in a short time period and the student has little time to assimilate all the facts and knowledge presented. This problem is compounded when a diversity of subject matter is presented. Furthermore, some of the most important facets of treatment plant operation simply
cannot be adequately taught in a classroom. In many cases some hands-on experience is a must. In fact, a person could obtain from books sufficient knowledge to pass the written test for certification and yet be unable to operate a plant. This last problem is covered by the experience requirements for the various grades of certification.

**Other Training Activities**

Other states, federal agencies and public institutions have used or are developing for use a variety of methods for operator training. A few of these methods are discussed below.

**Full Time Training**

In 1964 Fayetteville Technical Institute began offering a two year program in Water and Wastewater Technology. Along these lines, Fayetteville Tech developed a suggested curriculum (3) for two-year post-high school training. By 1969, 17 schools in 11 states offered full time programs for training environmental technicians.

Recent efforts in the development of full time training programs involve a "behavioral objective" approach as described by Austin (3). This approach was used in the development of two guide manuals which illustrate this training method (4, 5).

**Part Time Training**

A number of part time training programs have been undertaken in various parts of the country, e.g.,

- Charles County Community College, La Plata, Maryland, offers a 32-week, one night per week, three hours per night course for municipal and industrial wastewater treatment plant operators.
- A number of 44-week programs sponsored under the Manpower Development Training Act have been undertaken in a variety of locations. These programs combined on-the-job training with part-time classroom instruction.

- The Georgia Water Quality Control Board in cooperation with the State Department of Vocational Education offers three weeks of classroom training coordinated with 26 weeks of on-the-job training.

**Special Short Courses**

Special short courses oriented to in-depth coverage of particular subjects have been conducted in many locations. A good example of this type of activity are the training programs conducted by the Ontario Water Resources Commission on the subject of chlorination (6,7).

**Correspondence Courses**

Clemson University has prepared correspondence study manuals for four levels of wastewater treatment plant operator training. The General Assembly of South Carolina appropriates funds to support Clemson's administration of the correspondence courses in South Carolina. The course manuals are available outside South Carolina and may be purchased from Clemson.

An extensive manual covering the operation of wastewater treatment plants (8) has been developed at Sacramento State College under a contract with the Environmental Protection Agency. The manual is designed for either correspondence use or self study. This
manual is one of the most comprehensive available on the subject and would also be quite appropriate for use in an evening program.

**Need for a Unified Training Effort in North Carolina**

The need for efficient wastewater treatment plant operator training is obvious. Various methods of presenting training, i.e. short courses, part time training over a longer period of time, self study or correspondence courses, on the job training, etc., might be developed. All of the above methods have advantages in particular situations and for particular individuals. A number of community colleges have participated in past efforts to offer local training on a part-time basis. Others are interested in developing programs to fill the growing need for operators. There is a place for most types of programs, however, a unified set of training objectives and a co-ordinated curricula are needed. Since State law places the general responsibility for the operator training with the Office of Water and Air Resources, the adoption of objectives and a general curricula are administratively possible. The adoption of a set of training objectives and curricula would allow the coordinated development of regional training centers for part-time classroom training co-ordinated with on the job training. The annual short school in Chapel Hill could also fit into the general program and perhaps, as the program developed, the training objectives of the annual school could be modified to fill special requirements.

An overall statewide operator training program if properly conceived might well attract financial support from the federal agencies concerned with manpower training in the wastewater field, e.g., the
Environmental Protection Agency and the Department of Labor. Financial assistance from outside the state would accelerate the development of a comprehensive integrated training program, but, the development of such a program, with or without outside assistance, is in the State's best long term environmental interests and should be implemented. Once the general objectives and plans are adopted they should be adhered to. Radical modifications of such a long-term program simply to take short term advantage of available outside financial assistance, which often lacks continuity, may not be in the best interests of the State. On the other hand, the program adopted should be sufficiently flexible to take advantage of short term funds as they become available.

The study reported here was undertaken to re-examine the training curricula used in the annual short course and in addition, to explore other methods for training wastewater treatment plant operators. To assure that various points of view were taken into account, a study committee was formed. Much of the material contained in this report is due to the efforts of this committee.
OPERATING SKILLS AND TRAINING CURRICULUM

The Study Committee

The Study Committee members were volunteers and were chosen to represent the Office of Water and Air Resources, the University of North Carolina at Chapel Hill, and municipalities of various sizes. Most of the committee members had actual hands-on operating experience at some time in their careers. All of them were aware of the problem of obtaining adequately trained operators for wastewater treatment facilities. The committee did not include anyone with experience operating or managing an industrial wastewater treatment facility. This deficiency was recognized and the problem of providing adequate training is discussed later.

The committee was composed of the following members:

James C. Brown, Chairman, Associate Professor of Environmental Engineering and Director, Wastewater Research Center, University of North Carolina at Chapel Hill.

Darwin L. Coburn, Chairman, Board of Certification, Office of Water and Air Resources, Department of Natural and Economic Resources, State of North Carolina.

Lee Dukes, Assistant Superintendent, Water Department, City of Charlotte, North Carolina.

Donald E. Francisco, Deputy Director, Wastewater Research Center, University of North Carolina at Chapel Hill.

Wilbur E. Long, Chief, Engineering Section, Office of Water and Air...
Resources, Department of Natural and Economic Resources, State of North Carolina.
Ray Shaw, Director, Water and Sewer Division, City of Greensboro, North Carolina.
Joe Stowe, Jr., Department of Public Works, City of Fayetteville, North Carolina.
Morris Tarlton, Superintendent of Waste Treatment Plant, City of Concord, North Carolina.
Virgil Truitt, Public Works Director, Town of Tarboro, North Carolina.
Frank L. Ward, Superintendent, Municipal Treatment Plants, City of High Point, North Carolina.

Organization of the Committee

The committee met 7 times during the course of the study. The first meeting was devoted to a general discussion of the level of responsibility required for various grades of operators in an attempt to develop general definitions for the four operator grades. The committee was then divided into subcommittees in four defined areas of skill required by operators. The skill areas and subcommittee members are listed below:

Process Knowledge and Operating Skills - Virgil Truitt, Joe Stowe, Jr., Lee Dukes.
Mechanical and Maintenance Skills - Morris Carlton, F. L. Ward.
Laboratory Skills - D. E. Francisco, Ray Shaw.

The subcommittees were responsible for developing and organizing
lists of various skills or abilities in the particular area to which they were assigned. When the subcommittee completed these tasks their work was reviewed by the committee as a whole. The final lists of skills and abilities presented in this report reflect the work of the subcommittees, however, the committee chairman in some instances has changed the format to maintain a unified style of presentation.

Definitions of Responsibility for the Four Operator Grades

Following are the general definitions of responsibility suggested for the four operator grades.

Grade I (Lowest)

A Grade I operator may be required to operate simple types of treatment plants under intermittent supervision. The types of plants involved might be stabilization lagoons, Imhoff tanks, small package aeration plants, or, in fact, any plant which classifies as requiring a Grade I operator. The Grade I operator is responsible for the general operation and maintenance of equipment and facilities under the direction of a supervisor. He must observe variation in operating conditions and interpret meter and guage readings and test results to determine processing requirements. He will operate valves and gates either manually or by remote control. He starts and stops pumps, engines and generators to control and adjust flow and treatment processes as required. He must maintain a shift log and records of meter and guage readings. He collects samples and performs simple laboratory tests and analyses. He performs routine maintenance functions and custodial duties.
Frequently the Grade I operator will be working at a larger complex plant under close supervision. On the other hand, the Grade I operator's most critical level of responsibility is when he is the person in charge of a small plant even though it is relatively simple. In such situations the responsibility for protecting the quality of receiving waters is his.

A Grade I operator's training program should emphasize mechanical and maintenance skills.

Grade II

A Grade II operator may be in charge of a small or medium size secondary treatment plant. In this capacity he is responsible for general operation and maintenance of equipment and facilities found in such plants. He operates the plant in an efficient manner, either alone or under supervision. He recognizes and identifies operational difficulties and makes initial decisions on corrective action to be taken when normal procedures are involved. He notifies his supervisor of any non-routine occurrences. He takes samples and performs basic laboratory work as determined by his supervisor. He records operational data and plant occurrences in a log book. He determines recirculation requirements, sludge withdrawals, functioning of digestors, air requirements in aeration plants, chemical dosages and testing thereof, odor and fly control procedures. He performs routine maintenance on all pumps, motors, starters, equipment and machinery. He establishes plant sampling and stream monitoring programs. He knows the classification of receiving waters and how to maintain such classification. He initiates general good housekeeping and safety practices.
Frequently a Grade II operator will be employed in a plant requiring a higher grade supervisory operator. On the other hand his highest level of responsibility will be when he is the operator in responsible charge of a Grade II plant.

A Grade II operator's training should emphasize mechanical and maintenance skills as well as the fundamentals of wastewater treatment processes.

Grade III

A Grade III operator will either be in charge of or have the knowledge and skill required to be in charge of a fairly large plant with secondary treatment facilities. He is responsible for administrative and supervisory duties; he has a good knowledge of the physical, chemical and bacteriological tests ordinarily performed in a laboratory adequately equipped for wastewater analysis. He assists in the purchase of supplies and equipment. He has a general knowledge of budgeting. He initiates, prepares, and submits operating reports. He establishes plant safety programs and preventive maintenance programs. He trains operators at lower levels and supervises good housekeeping procedures.

A Grade III operator's training should emphasize laboratory skills.

Grade IV (Highest)

A Grade IV operator is responsible to local government (or management in the case of industry) for the effective overall operation of a Grade IV treatment plant. He supervises or or-
ganizes the supervision of all plant operations. He is responsible for communications with state and local officials, development of budgets and control of budget expenditures. He is often responsible for the supervision of sewer ordinances, he maintains effective public relations. He must have a broad knowledge of wastewater treatment processes and recent advances in treatment technology. He understands the effect of wastewater on receiving streams. He participates with other local officials and engineers in planning for future needs.

A Grade IV operator's training covers subjects related to advanced wastewater treatment, administration and water quality as required by his level of responsibility.

One may differ with details of the above definitions. Perhaps the most important concept is the general identification of the training emphasis appropriate for each grade. It might be argued that a Grade I operator may be the man in actual charge of a Grade I plant and that he should, therefore, be trained in the laboratory procedures required to report on plant operation. The argument has some merit but all desirable areas of training cannot be offered at the entrance level. In most plants, large or small, the thing most fundamental to good operation is effective maintenance. The committee is of the opinion that training in these areas should be stressed in the lower grades.

There is a special problem at small treatment plants (including package plants). Operators in these plants frequently work alone
with only occasional assistance during emergencies. The smallest plants, including many package plants, are often staffed by one part-time operator. Ideally, these operators must know everything going on in their facility and should be able to remedy most problems with little supervision. In such situations the operator is supervisor, laborer, laboratory technician, and maintenance mechanic, as required. Yet, as the certification law is presently administered, he need only be a Grade I operator. Special training courses might help in these types of situations, e.g., where a package aeration plant requiring a fair degree of operating skill is involved. Special courses might also be appropriate in industrial waste treatment since most of the general training emphasis is related to municipal waste waters. On the other hand, the real solution to problems such as the above is beyond the scope of this study. It involves the basic institutional structures which permit the development of many small plants each with independent management. Where such a multiplicity of small plants is necessary because of localized development the best solution to the operating problem may be regional management. In this way the many required skills can be provided in an effective manner. The general supervisor of such a system should certainly be required to obtain certification at one of the higher levels.

Skill Requirements

The first step in the development or revision of a training curriculum should be the establishment of goals. The information that should be transmitted to the trainee should help him meet
a certain job objective, i.e., the curriculum should be designed to enhance the development of desired skills. The development or revision of a curriculum should therefore be preceded by a classification and cataloging of the skills and abilities which the trainee requires to perform effectively at a certain level of responsibility.

Therefore, as the first step in developing the recommended new curriculum and training methodology, the subcommittees prepared skill and ability listings and these materials were reviewed and revised by the committee as a whole. The catalogue of desired skills and abilities is as follows:

Administrative and Related Skills

Because of the difficulty in separating Administrative and Related Skills into four categories, only two subdivisions have been developed, i.e., one for Grades I and II and another for Grades III and IV.

A Grade I or II operator may be in responsible charge of a treatment plant and therefore be charged with certain administrative duties. In most cases these duties should be limited. Although the outline below covers a number of items for the Grade I and II operator, it is suggested that most of the classroom training be devoted to the importance of records and record keeping.
Administrative and Related Skills

Grades I and II

I. Administration

A. Records
   1. The value of records as a tool in operating and planning.
   2. Recordkeeping responsibility when in charge of a plant
      a. the plant log book
      b. wastewater flows (maximum, minimum, average)
      c. wastewater temperature
      d. weather conditions
      e. plant units in operation
      f. plant units out of service - why
      g. analytical results (see Laboratory Skills)
      h. work in progress (see Mechanical and Maintenance Skills for Maintenance Records)
      i. work completed
      j. important communications received and sent
      k. breakdowns
      l. personnel absences, accidents
      m. visitors
      n. miscellaneous
   3. Preparation of monthly reports for State and municipal authorities.
   4. Use of records and plant log book data to summarize information needed for an annual report.*

NOTE: A Grade I or II operator in charge of a plant should be able to effectively use a recordkeeping system. In most cases, the original organization of the recordkeeping system would be the responsibility of the operator's supervisor.

B. Public Relations
   1. The need for maintaining and fostering good public relations to insure public support
      a. a well kept plant improves public image and fosters high employee morale
      b. importance of odor control and insect control
      c. information booklets for public and visitors
      d. handling complaints

C. Personnel
   1. Staffing requirements for various types of Class I and II wastewater treatment plants (oxidation ponds, package aeration plants, Imhoff type units with trickling filter plants with separate digesters)
      a. operator-mechanics
      b. laboratory technicians
   2. Personnel Supervision
      a. human relations - problems and remedies
II. Budgeting and Finance

A. Capital and operating costs of various types of wastewater treatment plants.

B. Sources of funds for construction and operation of facilities
   1. Federal government
   2. State government
   3. Local government
   4. Requirements for obtaining State and federal assistance; the parts of a system eligible for State and federal funding

C. Recognition and explanation (to budget control officials) of the needs for various types of capital improvements.

D. Preparation of annual operating budget**
   1. Personnel costs
   2. Utilities and other services
   3. Training
   4. Maintenance and repair of buildings
   5. Maintenance and repair of equipment
   6. Vehicle costs
   7. Chemicals
   8. Miscellaneous materials and supplies

III. Water Law and Miscellaneous

A. Historical development of stream sanitation laws
   1. North Carolina public health laws
   2. North Carolina stream sanitation laws
   3. Federal Laws
   4. The North Carolina Board of Water and Air Resources
   5. The Federal Environmental Protection Agency
   6. Other laws pertaining to wastewater discharge

B. Provisions of State and federal water quality laws
   1. General policy
   2. Classification of receiving waters
   3. Water quality standards - State and federal
   4. Control of new sources of pollution
   5. Control of existing sources of pollution
   6. Procedures, violations, penalties
   7. Voluntary compliance, compulsory compliance

C. Sewer Use Ordinances
   1. Reason for sewer use ordinances
   2. Rules and regulations for wastewater discharge
   3. Industrial waste surcharges; federal requirements
* A Grade II operator when in charge of a plant should be expected to assist his supervisor in the preparation of an annual report.

** A Grade II operator, in charge of a plant, should be able to assist his supervisor in the preparation of the annual budget.
Administrative and Related Skills

Grades III and IV

I. Administration

A. Records, etc.
1. Organization of a system of recordkeeping for plant operation and maintenance
2. Preparation of annual reports summarizing operation and maintenance of system
   a. purpose
   b. organization
   c. distribution for management, for the public
3. Organization and supervision of work safety programs
   (Occupational Safety and Health Act)

B. Public Relations
1. Effective use of public relations media
   a. news releases - why, when, what and who to include
   b. photographs
   c. advertisements - newspapers, radio, T.V.
   d. bulletins and newsletters
   e. activities reports
   f. plant tours
   g. preparation of a plant information booklet

C. Personnel
1. Staffing requirements for various types of plants
2. Procedures for orientation of new employees
   a. objectives of plant operation, function of various plant units, responsibilities of various employees
3. Organization of on-the-job training for new employees and skill development training for existing employees
4. Types of operator training available
   a. home study or correspondence courses
   b. short schools and evening courses
   c. coordination with on-the-job training
5. Preparation of job descriptions and duty schedules for employees
6. Operator certification requirements
7. Applicable labor laws
8. Personnel supervision
   a. selection and placement of new employees
   b. job classifications and recognition of various levels of responsibility
   c. effective communications - employer to employee; employee to employer - oral, written - keep the channels open
   d. recognition of meritorious service - promotions
e. general work rules  
f. discipline  
g. personnel records  

D. Budgeting and Finance  
1. Organization and preparation of annual operating and maintenance budgets  
2. Recognition of capital improvement needs and the preparation of short reports and cost estimates as needed to justify the implementation of the improvements  
3. Forecasting future treatment requirements and estimates of associated costs  
4. Capital Improvement Finance  
a. Municipal revenues  
b. Bonds (general obligation, revenue)  
c. Assessments  
d. Interest rates - repayment schedules  
e. State law regarding municipal finance  
f. Federal assistance (P.L. 660)  
g. State assistance  
h. Local contribution  

II. Water Law and Miscellaneous  

A. A more detailed knowledge of the State and federal law pertaining to effluent discharges and water quality standards  
1. Stream standards as the determinant in effluent quality  
2. Effluent standards  
3. Administrative problems in enforcing requirements  
4. Future trends - removals of nutrients and other deleterious materials  

B. Municipal Sewer Ordinances  
1. Why sewer ordinances are important and where and why they are needed  
2. Sources of information concerning sewer ordinances - city attorney, consulting engineers, State regulatory agency, federal guidelines, other municipalities, UNC Water Resources Research Institute  
3. Prohibition of certain types or quality of wastewater  
4. Surcharges for strong wastes - encourages good housekeeping by discharger - may promote pretreatment  
5. Combined treatment of municipal and industrial wastes is usually more economical than separate treatment - industry must pay its fair share  
6. Items included in most sewer ordinances  
a. introductory statement of purpose, jurisdiction and scope of ordinance  
b. definition of terms  
c. rule requiring use of public sewer  
d. rules covering private disposal systems  
e. rules covering sewer connections and building sewers  

24
f. regulations of waters and wastes admissible to public sewers

g. regulations covering industrial wastes

h. surcharge schedule for strong wastes

i. provisions covering duties of discharger to provide measuring and sampling equipment and the right of the municipality to access

j. service to areas outside the municipality

h. enforcement authority

Process Knowledge and Operating Skills - Grade I

Note: Instruction for Grades I and II may be combined if desirable.

I. Plant Operation

A. Screening and Comminution

1. Types of devices and function (advantages and disadvantages)

2. Quantities of screening and their disposal (grinding, burying, other)

3. Method of controls (float switches, timers, etc.)

B. Grit Removal

1. Reason for grit removal

2. Types of devices

a. Velocity control channel - hand cleaned

b. Velocity control channel - mechanically cleaned (rakes, screw conveyors, bucket chains)

c. Aerated grit removal tanks

d. Detritors

e. Quality (clean - dirty) and quantity of grit, effect of rain

f. Grit disposal

g. Odor, insects, rodents

C. Primary Clarification

1. Primary clarifiers - function, removal of settleable and floating solids

2. Types

a. Rectangular

b. Circular

3. Appurtenances

a. Sludge rake and sludge hopper

b. Skimming devices

c. Rake and skimmer drive arrangement

d. Mechanical - electrical system - starting, stopping overload protection

e. Inlet arrangements

f. Weirs and outlet baffles
4. Sludge and scum removal
   a. Quantities of sludge
   b. Quantities of scum
   c. Removal schedule
   d. Effect of return of secondary sludge
   e. Sludge pumping with displacement and centrifugal type pumps

D. Trickling Filters (See III Design)
   1. Distributors - orifice cleaning and flushing
   2. Insect controls
      a. Hydraulic methods
      b. Chemical methods
   3. Control of ponding

E. Activated Sludge (See III Design)
   A Grade I operator should be expected to have only a general qualitative knowledge of the activated sludge process.

   Note: Some special training will be necessary for the Grade I operator in charge of a "package" activated sludge plant.

F. Secondary Clarification
   1. Secondary clarifiers - function, separation and thickening of secondary sludges from trickling filters or aeration tanks

G. Sludge Digestion
   1. Digestion - function, degradation of fresh organic matter to water, CO$_2$, CH$_4$, and more stable residual organics - reduces volume, odors, improves dewatering characteristics
   2. Types of Digesters
      a. Imhoff tanks - general arrangements
         1. Gas vent cleaning
         2. Flow reversal
         3. Sludge removal
      b. Separate digesters
         1. Single stage
         2. Primary and secondary digestion
   3. Sludge Drying on Sand Belts

H. Chlorination
   1. Pre-chlorination - odor and insect control
      a. Quantities required, points and methods of application
   2. Post chlorination
      a. Mixing and contact chambers
      b. Quantities required
   3. Chlorine handling and feeding equipment
Process Knowledge and Operating Skills - Grade II

Note: If desirable instruction for Grades I and II may be combined.

I. Sewage Collection System

A. Types of sewer systems
   1. Separate
   2. Combined

B. Quantities of wastewater
   1. Average daily flows
   2. Daily variations
   3. Seasonal variations

Note: For material on composition of sewage see section on Laboratory Skills.

II. Operation

   See Grade I outline for Screening, Grit Removal

A. Primary Clarification
   1. Detention times
   2. Overflow rates
   3. Weir loadings
   4. Efficiencies at various loadings
   5. Calculation of sludge volumes

B. Trickling Filters
   1. Basic theory of operation
   2. Types -- standard rate, high rate, roughing, loadings
   3. Recirculation -- recirculation ratios
   4. Advantages and disadvantages as compared to activated sludge

C. Activated Sludge
   1. Basic theory of operation
   2. Types of systems
      a. conventional
      b. complete mix
      c. tapered aeration
      d. step feed (aeration)
   3. Methods of aeration
      a. diffused air
      b. mechanical
   4. Return sludge and waste sludge
   5. Aerobic digestion
   6. Advantages and disadvantages as compared with trickling filters

D. Sludge Digestion
   1. Digester heating
      a. Heat exchange units
         1. fuel -- digester gas, commercial gas, fuel oil
         2. elements of control system
         3. safety features
2. Digester mixing
   a. Heater and recirculation pumps
   b. Mechanical mixing (in tanks)
   c. Gas mixing
3. Gas collection systems
   a. Floating and fixed covers
      1. pressure and vacuum relief
      2. cover position indicators
   b. Gas collection and piping and appurtenances
      1. piping
      2. condensate removal
      3. pressure control and pressure indicators (manometers)
      4. backflow prevention
      5. backflame prevention
      6. gas meters -- orifice and displacement type, gas production (quantity)
      7. Waste gas burner
4. Sludge and supernatant transfer and withdrawal
5. Digester problems and remedies
   a. Normal conditions
      1. pH, alkalinity
      2. volatile acids
      3. gas production
   b. Indicators of problems
   c. Remedies
      1. Reduce quantity of feed sludge
      2. Reverse primary and secondary tanks
      3. Use of lime
E. Plant Instrumentation
   1. Types of instruments and their application
      a. Flow
      b. Pressure
      c. Temperature
      d. Weight (usually weight loss)
      e. Chemical quality (pH, chlorine residual, etc.)
Process Knowledge and Operating Skills - Grade III

Note: Instruction for Grades III and IV may be combined if desirable.

I. Trickling Filters
   A. Organic and hydraulic loadings
   B. Recirculation arrangements
   C. Stage operation
   D. Efficiency formulae (NRC formula)
   E. Underdrains and ventilation

II. Activated Sludge
   A. Aeration tank loadings
      1. lbs. BOD/day/1000 ft.³ of aeration tank volume
      2. lbs. BOD/day/lb mixed liquor suspended solids under aeration
      3. lbs. BOD/day/lb mixed liquor volatile suspended solids under aeration
      4. lbs. BOD removed/day/lb MLVSS
   B. Air requirements
   C. Efficiency of aeration devices
   D. Return sludge and waste sludge
      1. Estimating quantities of waste sludge
   E. Sludge bulking - cause and remedies
      1. Sludge volume index

III. Chemical Treatment
   A. Justification and methods
      1. For removal of phosphorus
         a. precipitation with aluminum or iron
         b. precipitation with lime
         c. advantages of each process
      2. For general improvement of plant performance
   B. Methods of chemical application
      1. Chemical handling and feeding
      2. Mixing and flocculation
   C. Quantities of sludge produced
      1. Sludge disposal

IV. Sludge Dewatering and Disposal
   A. Sludge thickening - prior to digestion or direct dewatering
   B. Elutriation of digested sludge
   C. Vacuum filters
      1. Principle of operation and performance
      2. Loading rates
      3. Chemical treatment
   D. Centrifuges
      1. Principle of operation and performance
      2. Chemical treatment
   E. Ultimate disposal of sludge
      1. Burning
      2. Burying
      3. Lagooning, without prior dewatering
      4. Values as soil conditioner
V. Sewage and Sludge Pumping

A. Types and application

1. Centrifugal – for sewage
   a. lift stations
   b. plant recirculation
   c. secondary sludge
   d. pump characteristics -- pump curves

2. Centrifugal -- for sludge
   a. type of construction
   b. pump characteristics

3. Positive displacement
   a. For sludges
      1. plunger type -- calculation of flow based on speed and stroke
      2. diaphragm type
   b. For sewage -- diaphragm type
   c. Miscellaneous positive displacement pumps

4. Sewage ejectors

5. Pump drives
   a. Electric
   b. Gasoline or diesel
   c. Stand-by power

6. Pump controls
   a. Bubble tube method
   b. Float switches
   c. Pressure bulbs
   d. Pump alternator

7. Variable speed systems
   a. Multi speed pumps
   b. Wound rotor motors
   c. Liquid reostat
I. Sewer Design

A. Quantities of sewage
1. Domestic
2. Industrial
3. Present and future flows

B. Size and slope of sewer pipes
1. Basic formulae
2. Minimum and maximum velocities
3. Use of charts and graphs

C. Types of piping and joints
1. Vitrified clay -- types of joints
2. Asbestos-cement -- types of joints
3. Concrete cement -- types of joints
4. Cast iron -- types of joints

D. Manholes
1. Spacing and location
2. Bottom construction
3. Prefabricated or built in place
4. Steps, covers, other details

E. Infiltration control
1. Sources of infiltration and illegal connections
2. Joint testing
3. Television inspection

F. Flushing or cleaning

II. Advanced Treatment Systems

A. Definition of advanced treatment -- Treatment beyond normal secondary processes

B. When advanced treatment is necessary

C. Objectives of advanced treatment
1. Removal of organics
2. Removal of suspended solids
3. Removal of nutrients -- nitrogen and phosphorus
4. Removal of dissolved solids

D. Methods to meet objectives
1. Removal of organics
   a. Polishing lagoons
   b. Chemical treatment
   c. Activated carbon adsorption
   d. Filtration
2. Removal of suspended solids
   a. Settling lagoons
   b. Chemical treatment
   c. Filtration
3. Removal of nutrients
   a. Nitrogen
1. two stage activated sludge with an anaerobic phase
2. ammonia stripping at a high pH

b. Phosphorus
1. chemical precipitation with an aluminum or iron salt
   (may be used with filtration)
2. chemical precipitation with lime

4. Removal of dissolved solids
   a. Adsorption
   b. Reverse osmosis
   c. Electro dialysis

III. Hydraulics

A. Fluid statics
1. Pressure on submerged surfaces
2. Units of measurements and conversions
3. Pressure measuring devices

B. Fluid flow
1. Continuity equation: \( Q = AV \)
2. Elevation head
3. Pressure head
4. Velocity head
5. Bernoulli's equation

C. Flow in pipes
1. Kutter formula
2. Manning formula
3. Hazen-Williams formula

D. Use of head loss tables and graphs

E. Flow measuring devices
1. Weirs
2. Flumes
3. Orifices
4. Venturis

F. Development of system head curves for use with pump characteristic curves
1. Pumping system efficiency
2. Power requirements

G. Hydraulic gradients in treatment plants
1. Control points
2. Losses between control points

IV. Plant Design

A. Current design standards for wastewater treatment plants

V. Industrial Wastes

A. Characteristics -- variations in composition to be expected
1. Dissolved materials
2. Suspended materials
3. Floating materials
   All of the above may vary widely and also in amounts of organic, inorganic, toxic, etc., materials
B. Effects of uncontrolled industrial wastes on streams, municipal plants
   1. Resulting problems
C. Some of the methods of control, treatment and combined treatment being used
   1. Control of load, pH, flow, etc.
   2. Byproduct recovery
   3. Volume and load reductions by good housekeeping, water reuse, etc.
   4. Responsibility for treatment and payment for treatment
D. Characteristics and treatment of some specific wastes encountered in this area
   1. Textile
   2. Metal finishing
   3. Laundry
   4. Brewery
   5. Paper
   6. Chicken processing
   7. Rendering
   8. Slaughter house
   9. Others
Mechanical and Maintenance Skills - Grade I

I. Screening

A. Manually Cleaned

B. Mechanically Cleaned
   1. Lubrication
   2. Overload protection
   3. Insect and rodent control
   4. Routine maintenance and adjustment--Tools
   5. Recognition of malfunction
   6. Safety

II. Grit Removal

A. Manually Cleaned

B. Mechanically Cleaned
   1. Lubrication
   2. Overload protection
   3. Recognition of malfunctions
   4. Routine maintenance and adjustment--Tools
   5. Safety

III. Flow Measurement and Sampling

A. Weirs, flumes, venturies, orifices, magnetic meters
   1. Cleaning and purging
   2. Recognition of malfunction

IV. Pumps

A. Types of pumps and their application--centrifugal (for sewage, for sludges), plunger, diaphragm, air lift.
B. Typical problems and remedies for various types of pumps
C. Lubrication
D. Packing and adjustment
E. Pump valves
F. Cleaning
G. Recognition of malfunction

V. Clarifiers

A. Types of clarifiers--circular, rectangular
B. Drive mechanisms--motors, reducers, chains
C. Sludge and scum collection arrangements
D. Overload protection
E. Lubrication
F. Recognition of malfunctions
VI. Chlorination

A. Function and basic components of hypochlorinators and gas feed chlorinators and appurtenances
B. Detection and correction of chlorine leaks
C. Safety in chlorine handling

VII. Sludge Dewatering and Disposal

A. Function and construction of sand drying beds
B. Sludge removal equipment
C. Sand cleaning and resanding
D. Control of vegetation and insects

VIII. General Maintenance and Housekeeping

A. Building maintenance
B. Grounds keeping

IX. Painting

A. Types of paints and their use in various parts of the plant
B. Painting schedules
B. Use of colors

X. Valves

A. Types of valves, their application and maintenance
   1. Gate valves
   2. Sluice gates--shear gates
   3. Butterfly valves
   4. Check valves
   5. Plug valves
   6. Diaphragm valves

XI. Tools

A. Hand tools necessary for proper maintenance
B. Power tools necessary for proper maintenance
C. Safe use of tools

XII. General Safety

A. Isolation of mechanical and electrical equipment during repairs
B. Adequate number of personnel for job
C. Special hazards
   1. Infection
   2. Falling, drowning
   3. Electrocution
   4. Gasses--poisonous, suffocating, explosive
D. Protective clothing
   1. Gloves, safety glasses and masks, hard hats
   2. Clothing and breathing equipment for poisonous gas protection
E. Protective equipment (guards etc.) and warning sign
F. Occupational Health and Safety Act
Mechanical and Maintenance Skills - Grade II

I. Screening and Comminution
   A. Mechanically Cleaned Screens (see Grade I)
      1. Alignment and adjustment of chains and sprockets
      2. Drive mechanism repair
      3. Spare parts inventory
      4. Materials and methods for insect and rodent control
      5. Manufacturers operating manuals and drawings
   B. Comminuters
      1. Lubrication
      2. Overload protection
      3. Replacement of cutting parts

II. Grit Removal (see Grade I)
   A. Mechanically Cleaned
      1. Belt, chain and other adjustments
      2. Materials and methods for insect and rodent control
      3. Spare parts inventory

III. Flow Measurement and Sampling Equipment
   A. Maintenance and adjustment of signal transmission and recording equipment
   B. Checking, adjustment and programming automatic samplers

IV. Pumps (see Grade I)
   A. Principal parts of various types of pumps
   B. Wearing parts requiring periodic replacement
   C. Hydraulic problems—suction and discharge
   D. Mechanical and electrical problems
   E. Use of manufacturer's technical information and drawings
   F. Spare parts inventory

V. Clarifiers (see Grade I)
   A. Sludge and scum removal problems and remedies
   B. Spare parts inventory
   C. Use of manufacturer's manual and drawings

VI. Trickling Filters
   A. Dosing devices—continuous and siphon types
   B. Types of distributors
   C. Central column sealing devices
   D. Bearings and bearing lubrication
   E. Orifice cleaning and adjustment
   F. Guy rod adjustment—leveling and balancing
G. Ponding problems and remedies
H. Insect control

VII. Aerotor Systems

A. Diffused air systems
   1. Blowers, valves, piping, air flow meters
   2. Air filters
   3. Diffusor system--diffusor cleaning
   4. Balancing and adjusting air flows
   5. Lubrication
   6. Spare parts inventory
B. Mechanical Aerators
   1. Fixed platform and floating types
   2. Aerator submergence and efficiency
   3. Speed reducers
   4. Lubrication

VIII. Chlorination (See Grade I)

A. Hypo-chlorinators
   1. Function of component parts
   2. Feed pump maintenance
   3. Feed control system
   4. Spare parts inventory
B. Gas chlorinators
   1. Function and component parts
   2. Detection of malfunction
   3. Adjustment
   4. Feed control systems
   5. Assistance from manufacturers
   6. Spare parts inventory
C. Chlorine evaporators
   1. Function and component parts
   2. Cleaning

IX. Sludge Digestion

A. Function and component parts of single and two stage digestion system
   1. Sludge piping system
   2. Gas collection system maintenance--condensate traps, flame seals, check valves, pressure regulating valves, manometers, tank covers, relief valves
   3. Waste gas flares
   4. Digester heating system maintenance--fire box, heat exchanger tubes, gas system, temperature control
   5. Digester mixing--pump mixing systems, gas mixing systems, compressors, timers, internal mixers
6. Safety hazards and protective devices

X. Sludge Dewatering and Disposal (See Grade I)

A. Centrifuges
1. Sludge feed pumps
2. Chemical feed system
3. Wearing parts in centrifuge
4. Centrate discharge pump
5. Sludge cake conveyor
6. Centrifuge drive--electrical and mechanical
7. Spare parts inventory

B. Vacuum filters
1. Sludge feed pumps
2. Chemical and filtrate pumps
3. Vacuum pumps, separators, receivers, etc.
4. Filter drive--electrical and mechanical
5. Spare parts inventory

XI. Valves

A. Electric and pneumatic operators

B. Lubrication

XII. Painting (See Grade I)

A. Types of paints and their use in various parts of the plant

B. Painting schedules

C. Use of colors

XIII. Equipment for Advanced Treatment

A. Chemical feeders
1. Dry type--volumetric and gravimetric
2. Solution type

B. Granular media filters and appurtenances

Note: Various advanced treatment systems will be required with increasing frequency as water quality standards are upgraded.

XIV. Electrical Systems

A. Electric motors
1. Types, lubrication, bearings

B. Motor starters
1. Function
2. Protective devices
C. Lighting panels
D. Central control panels - local starters and push buttons
E. Ampmeters and voltmeters
   1. Use in detecting equipment or electrical system malfunction
F. Audio and visual warning devices

XV. Maintenance Record and Schedule
A. Scheduling normal maintenance
B. Recording normal maintenance work done
C. Recording unusual maintenance or repair operations

XVI. Manufacturers Information
A. Shop drawings
B. Operating manuals

XVII. Safety (See Grade I)
A Grade II operator will be responsible for seeing that maintenance work under his supervision is conducted in a safe manner.

Mechanical and Maintenance Skills - Grade III

Most of the basic information related to mechanical and maintenance requirements should be covered in Grade I and II training programs. As previously mentioned such training should include both classroom and on-the-job experience.

The additional skills required of a Grade III operator should be in the area of maintenance program supervision and management. In addition he should understand the function of plant instruments and be competent to perform normal adjustments. Major instrument repairs usually require the services of an instrument repair specialist. Such services can sometimes be obtained from instrument manufacturers.

I. Maintenance Supervision
A. Establishment of spare parts inventory
   1. Parts purchasing
   2. Inventory control
B. Establishment of maintenance schedule
   1. Scheduling of routine maintenance
   2. Scheduling of preventive maintenance
   3. Supervision of maintenance record system

C. Preparation of maintenance budget and budget control

D. Supervision of safety program

II. Plant Instrumentation

A. Function
   1. Flow measurement and control
   2. Pressure measurement and control
   3. Level measurement and control
   4. Weight measurement and control
   5. Temperature measurement and control
   6. Chemical measurement and control, i.e. chlorine residual, pH

B. Primary devices

C. Converters and transmitters

D. Indicators, Recorders, Totalizers

E. Control methods

F. Methods of operation, transmission, etc.
   1. Mechanical
   2. Electrical
   3. Pneumatic

Mechanical and Maintenance Skills - Grade IV

The basic mechanical and maintenance skills have been covered in Grades I, II and III. A Grade III operator should be able to supervise a maintenance program. The Grade IV operator should have the ability and initiative required to conceive, organize and supervise an overall maintenance program at a fairly large complex plant as for regional systems involving more than one plant.
Laboratory Skills - Grade I

I. Composition of Sewage

A. Characteristics of sewage
   1. Fresh
   2. Stale
   3. Amounts of various materials in sewage

B. Strength of sewage
   1. Domestic
   2. Industrial

C. Technical terms
   1. Dissolved solids
   2. Suspended solids
   3. Settleable solids
   4. Biochemical oxygen demand - BOD

D. Sewage analysis
   1. Reason for making
   2. What results show
   3. Expression of results

II. Sampling Techniques

A. Purpose of Sampling

B. Types of samples
   1. Grab
   2. Composite
   3. Special

C. Techniques used in collecting samples
Laboratory Skills - Grade II

I. General laboratory knowledge

A. Laboratory safety
   1. Care and handling of acids and bases
   2. Use of aprons, gloves and safety glasses
   3. Poisons
   4. Fire hazards
   5. Don't mix chemicals

B. Use of balances
   1. Automatic
   2. Triple beam - single and double pan
   3. Care of above
      a. Level balance
      b. Solid surface
      c. Clean balance
      d. Keep weights clean

C. Standard solutions
   1. What are they for?
   2. Don't put reagent back into bottle
   3. Importance of proper storage
   4. Importance of proper labeling

D. Care and maintenance of equipment and laboratory
   1. Washing glassware
   2. Thorough knowledge of manufacturers instructions for all equipment in laboratory
   3. Knowledge and use of chemical supply house catalogs

II. Specific Tests

A. Dissolved Oxygen
   1. Selection of method
      a. Azide in NO₂⁻ containing waters
      b. Permanganate in Fe²⁺ waters
      c. Alum flocculation high suspended solids
      d. Electrode methods
   2. Collection of samples
      a. D.O. bottle - importance of design
      b. Adequate overflow
      c. Maintenance of water seal
      d. Sewage sampler
         1. how to build
         2. where to buy
   3. Procedure - consult Standard Methods or Manual of Simplified Methods

B. Biochemical Oxygen Demand
   1. Definition
   2. Importance
3. Procedure
   a. Dilution water - definition and importance
      1. Preparation
      2. Oxygen saturation
      3. Temperature equilibration
      4. Dilution blank
   b. Dilution for determination
      1. Raw sewage 1-5% (3-15 ml sample)
      2. Primary effluent 2-10 % (6-30 ml sample)
      3. Secondary effluent 5-25% (15-75 ml sample)
      4. Receiving stream 25-100% (75-300 ml sample)
   c. Sample preparation
      1. Clean BOD bottles
      2. Sample pretreatment - dechlorination, neutralization, deaeration, and Pasteurization
      3. Dilution technique - description and caution
      4. Incubation - in dark under water at 20°C or with water seal. Importance of temperature
   d. Analysis
      1. Initial oxygen determination after 15 minutes
      2. Final oxygen determination after 5 days
      3. Calculation*
         \[
         \text{Initial D. O.} - \text{Final D.O.} = \text{Decimal fraction of sample}
         \]
         *Choose dilution in which at least 1 mg/l D.O. remains and depletion is at least 2 mg/l.
   4. Interpretation
      a. Range of values
         1. trickling filter effluent, 20-60 mg/l
         2. activated sludge effluent, 10-40 mg/l
         3. extended aeration effluent, 5-20 mg/l
         4. lagoon effluent, 5-20 mg/l
      b. Outside ranges in (a) may be due to a problem in technique, operation of plant, or new type of waste

C. Solids (residue)
   1. Settleable - see Grade I
   2. Suspended (filtrable) - definition and importance
      a. Filter preparation
         1. Asbestos mat or glass fiber
         2. Pre-wash
         3. Dry at 103°C
         4. Cool in desiccator
      b. Weigh filter disk, or disk in Gooch, record weight
      c. Put on vacuum apparatus
      d. Wet filter
      e. Add sample
      f. Filter
      g. Wash with distilled water
      h. Dry at 103°C, cool in desiccator
      i. Weigh
Final weight - Initial weight
mg/l Susp. sol. = \frac{\text{mg/k sample}}{\text{ml sample}} \times 1000

3. Total - definition and importance
   a. Dry evaporating dish or pan at 103°C, cool in desiccator
   b. Weigh dish
   c. Add sample
   d. Evaporate on steam bath, under heat lamp, or in 103°C oven
   e. Cool in desiccator
   f. Weigh dish

   Final weight - initial weight
   mg/l tot. sol. = \frac{\text{mg/k sample}}{\text{ml sample}} \times 1000

4. Volatile suspended solids - definition and importance
   a. Prepare filter as in suspended solids above but ignite at 550°C
   b. Cool in desiccator
   c. Put on vacuum apparatus
   d. Wet filter with distilled water
   e. Add sample and filter
   f. Dry at 103°C
   g. Cool in desiccator
   h. Weigh (this is suspended solids final weight
   i. Ignite at 550°C
   j. Cool in desiccator
   k. Weigh

   Weight loss on last ignition \times 1000
   mg/l vol. susp. sol. = \frac{\text{weight loss on last ignition}}{\text{ml sample}}

5. Total volatile solids - use platinum pan
   a. Ignite pan at 550°C
   b. Cool in desiccator
   c. Add sample
   d. Evaporate to dryness
   e. Cool in desiccator
   f. Weigh
   g. Ignite at 550°C
   h. Cool in desiccator
   i. Weigh

   Weight loss on last ignition \times 1000
   mg/l Tot. Vol. Sol. = \frac{\text{weight loss on last ignition}}{\text{ml sample}}

D. Volatile acids
1. Definition
2. Importance in digester operation
3. Analysis
   a. 100 ml sample and 100 ml distilled water in distillation flask
b. Water cooled condenser
c. Distill 150 mL at slow boil
d. Titrate 100 mL distillate with 0.1N NaOH to phenolphthalein end point red
e. Volatile acids mg/L = 85.7 x mL NaOH

III. Interpretation of Results

A. Interpretation is usually dependent upon knowledge of how previous plant performance has varied with the constituents and concentration of sewage as well as season

B. Analyst should work very closely with supervising operator and alert supervising operator to all changes from normal values

C. Forms, Reports, and Records
   1. Calculation forms - aid in calculation and locating raw data
   2. Log of daily results
   3. Summary reports to State

Laboratory Skills - Grade III

The basic knowledge necessary to evaluate alternative tests, detect interferences, and properly conduct sophisticated analyses is normally covered in a general chemistry course. Such subjects as atomic theory, stoichiometry, normality, molarity, mass action, solubility product, Beer-Lambert law, titration curves, ionization, common ions, organic reactions, pH, etc. are necessary to fully understand the tests expected of Grade III and Grade IV operators. Furthermore, these operators routinely deal with industrial wastes which may present complicated chemical problems. Since this information is so broad and teaching techniques so specialized, we feel that a Grade III operator should have at least one general chemistry course.

I. General Laboratory Knowledge

A. Ability to convert concentrations into a variety of units, N to M, N to mg/L, mg/L to lb/gal to lb/day, lb/gal of alum to lb/gal of Al", etc., understanding of specific gravity and percent solutions, knowledge of common conversion factors

B. Thorough knowledge of suppliers of laboratory and analytical materials or instruments

C. Thorough knowledge of reference books for analytical chemistry of wastewater, i.e., Standard Methods, Simplified Lab Manual, CRC Handbook

D. How to prepare data forms so that all significant parameters are included
E. Turbidity

F. Grease

G. Chlorides

H. Immediate Oxygen Demand
   1. Importance
   2. Standard Methods

I. Radiation Measurements
   1. Units of measurement
   2. Significance of values
   3. Common sources
   4. State Agencies with necessary analytical equipment

J. Bacteriological Quality
   1. Significance of "Indicators"
   2. Coliform Tests
      a. Presumptive
      b. Conformed
   3. Fecal Coliforms
   4. Fecal streptococcus
   5. MPN
   6. Pathogens

K. Alkalinity
   1. Definition
      a. Titration with standard acids
      b. Effects on buffering
   2. Significance
      a. May control pH
      b. Control chemical feed
      c. Digester alkalinity
   3. Analysis - titration

L. Heavy Metals
   1. Sources
   2. Possible effects on treatment process and receiving stream
   3. For analysis send to state lab

Laboratory Skills - Grade IV

Wastewater treatment plants tend to become more complex as the required effluent quality is increased. The proper control of such plants and the maintenance of receiving water quality will often require a high degree of sophistication in the chemical and biological analysis of wastewater and receiving waters. The type of chemical and biological tests listed in the Grade IV Laboratory Skills illustrate the breadth of knowledge and skill required.
The Grade IV operator should be at least familiar with most of these techniques even though he may not be proficient in their use. He should know where to go for assistance.

An adequate training program in all the procedures shown below is not possible in a four or five day short course which must cover a diversity of subjects. Nor is it feasible for extended part time study unless the curricula is devoted entirely to this subject and the required equipment for instrumental analysis is available.

The type of training needed could be presented in a short course conducted in a well equipped instrumental analyzer laboratory. Trainees will necessarily require a fairly strong preparation in basic chemistry.

I. General Laboratory Knowledge

A. Thorough Knowledge of Grade III Information

B. Instrumental Analysis
   1. Spectrophotometric methods
      a. Beer-Lambert Law
      b. Adequate blanking
      c. Preparation of standard curve
      d. Determination of accuracy limits of standard curve
      e. Types and uses of spectrophotometers and colorimeters
   2. Flame photometry
      a. Principles and use in metal analysis
      b. Flame, amplification and balance adjustments
      c. Standard curve
   3. Atomic absorption spectrophotometry
      a. Principles and use in metal analysis
      b. Flame adjustment
      c. Standard curve
   4. Potentiometry
      a. Principles
      b. Care of pH meter
      c. Use in various analyses

II. Wastewater Biology

A. Living Functions
   1. Energy source
      a. Autotrophic (reaction)
         1. photoautotrophs (algae and plants)
         2. chemolithotrophs (nitrifiers)
      b. Heterotrophic (respiration)
         1. definition
         2. examples
   2. Metabolism
      a. Aerobic - requires oxygen
      b. Facultative - with or without oxygen
1. Fermentation in digester
2. Fermentation in treatment plant
c. Anaerobic - requires absence of oxygen
3. Ecological considerations
   a. Competition
   b. Niche

B. Types of living organisms of importance in wastewater
1. Bacteria
   a. Pathogens
   b. Indicators
   c. Beneficial to treatment
2. Algae
   a. Blue green
   b. Green
3. Fungi
4. Protozoa
5. Nematodes
6. Insects

III. Bioassay Tests
   A. Fish toxicity
   B. Waste treatability

IV. Stream Studies
   A. Communities in streams
      1. Suspended
      2. Bottom
      3. Attached

   B. Dependence of community type on:
      1. Water quality
      2. Turbulence
      3. Flow
      4. Stream bed

   C. Impact of sewage on stream
      1. Oxygen sag
         a. Description
            1. Zones at stream
            2. Biological activity and oxygen sag
         b. Temperature effect
            1. Physical
            2. Biological
         c. Light effect
         d. Changes in nitrogen forms
         e. Changes in BOD
         f. Changes in total bacteria
g. Changes in coliforms  
h. Changes in bottom community  
i. Dependence on flow and turbulence  
j. Streeter-Phelps Model  
   1. definition  
   2. sample problem  
2. Stability - diversity  
3. Downstream impact  
   a. Eutrophication  
      1. definition  
      2. lakes  
      3. estuaries  

D. Stream survey  
1. Sample locations  
   a. Above and several below outfall  
   b. Permanent locations  
2. Sampler types  
   a. Open water  
   b. Bottom  
3. Sample Frequency  
   a. Seasonal considerations  
   b. Wastewater and volume considerations  
4. Analyses  
   a. Always include some measure of flow  
   b. Always include some measure of temperature  
   c. State also requires D.O. and coliforms  
   d. Other analyses dictated by waste characteristics and downstream considerations  

V. Industrial Waste Problems  

VI. Discussion of Standard Methods for the Examination of Water and Wastewater  

General Comment on Training  

The listing of a skill requirement should not imply that the particular skill can be acquired solely in the classroom. It does not even imply that the material pertinent to the skill should be presented in the classroom. Certain mechanical skills may require on-the-job-training. Laboratory skills and required laboratory calculations can be presented in a classroom but require hands-on experience for their mastery. Certain types of desirable knowledge can be acquired by individual reading
or study and need only be mentioned in a formal training effort. The depth with which a certain subject is presented or, the selection of subjects to be presented in formal training depends upon the format of the training program. For example, during the presentation of an intensive short course there is little time for individual reading or study and when the group is large, hands-on training is practically ruled out. A training course presented over a period of time such as a night school program would allow time for individual study and for coordinated on-the-job experience. On the other hand, the completion of an extended program requires a reasonable degree of persistence.

Extended full time training with some on the job opportunities would provide an excellent program but, this type of training will be available to only a few individuals, usually younger persons who can afford one or two years for post-high school training. Although full time training is excellent in concept, it appears unlikely that it will significantly contribute to the tremendous needs for quality operators unless the pay scales and long range opportunities in the industry are radically upgraded. With a two year technical school program behind him, a young person will find many opportunities offering both more money and prestige. This report will concern itself mainly with short courses and extended part time training programs.
Suggested Curriculum

The detailed subject matter to be presented during the annual short school in Chapel Hill or in extended evening school programs can be drawn from the lists of skills previously presented. In the table below, suggestions are made as to the number of hours which might be devoted to each subject area. The hours shown on the table apply to the annual short school, but the proportion of time devoted to each subject could be approximately the same in an extended evening school program. In an extended program time would be available for individual study, and more classroom time could be devoted to discussion and problem solution. Many of the subjects are suggested for joint presentation for two operator levels. In such cases the certification examination questions for a particular grade should be drawn from the material covered in the lists of required skills.

Suggested Class Hours to be Devoted to Various Subject Areas

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
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<tbody>
<tr>
<td>Mechanical and Maintenance</td>
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<td>8</td>
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<tr>
<td>Process Knowledge Operation</td>
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<tr>
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<td></td>
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<tr>
<td>Arithmetic</td>
<td>4</td>
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</tbody>
</table>

Total Hours  25  25  25  25

[---] indicates combined presentation
An abbreviated lecture outline covering the subjects in the table is given below.

**Mechanical and Maintenance - Grade IV**

(2 hours)

-- Design and administration of maintenance systems for large complex plants or multi-plant systems

**Process Knowledge and Operation - Grade IV**

(10 hours)

(5 hours, Grade IV alone)

-- Sewer design and maintenance
-- Advanced treatment systems
-- Hydraulics
-- Current design standards (10-State; EPA)
-- Industrial wastes

(5 hours with Grade III)

-- Trickling filters
-- Activated sludge
-- Chemical treatment
-- Sludge dewatering and disposal
-- Sewage and sludge pumping

**Laboratory and Related Subjects - Grade IV**

(4 hours)

-- Instrumental methods of analysis
-- Wastewater biology
-- Industrial waste analysis

**Administrative and Related Skills - Grade IV**

(8 hours)

(4 hours, Grade IV alone)

-- Budgeting and finance
-- Water law
-- Sewer ordinances

(4 hours with Grade III)

-- Records
- Safety programs
- Public relations
- Personnel

Mathematics - Grade IV

- Use of logarithms

Mechanical and Maintenance - Grade III

(4 hours)

- Maintenance supervision
- Plant instrumentation

Process Knowledge and Operation - Grade III

(5 hours with Grade IV)

- Trickling filters
- Activated sludge
- Chemical treatment
- Sludge dewatering and disposal
- Sewage and sludge pumping

Laboratory and Related Subjects - Grade III

(8 hours)

- General laboratory knowledge
- Sampling
- Specific tests

Administration and Related Skills - Grade III

(4 hours with Grade IV)

- Records
- Safety Programs
- Public Relations
- Personnel

Arithmetic - Grade III

(4 hours)

- Calculation involving mathematics through simple algebraic expressions for use in plant control

53
Mechanical and Maintenance - Grades I and II

(8 hours)

-- Use of manufacturers literature and drawings
-- Maintenance record system (card files)
-- Bar racks and comminuters
-- Grit removal devices
-- Flow measurement and sampling devices
-- Pumps
-- Clarifiers
-- Trickling filters
-- Aeration systems
-- Chlorinators
-- Sludge digestion tanks and equipment
-- Sludge dewatering and disposal
-- Equipment for advanced treatment
-- Valves
-- Tools
-- Painting
-- Electrical systems
-- Safety

Process Knowledge and Operation - Grades I and II

(7 hours)

-- Sewage collection system
-- Screening and grit removal
-- Clarification
-- Trickling filters
-- Activated sludge
-- Sludge digestion
-- Sludge dewatering and disposal
-- Sewage and sludge pumping
-- Plant instrumentation

Laboratory and Related Skills - Grades I and II

(4 hours)

-- General laboratory knowledge
-- Sampling techniques
-- Specific tests
-- Interpretation of results
-- Records

Administrative and Related Skills - Grades I and II

(2 hours)

-- Records
-- Public relations

54
-- Water law
-- Budgeting and Finance
-- Personnel

Arithmetic - Grades I and II

(4 hours)

-- Calculations involving addition, subtraction, multiplication and division for use in plant control

The materials outlined above for a 25-hour program of instruction in the annual short school can also be used as a guide for a 25 week program in which classes meet one night per week. A 25 week program would offer a number of advantages; each class session could be extended to two hours, allowing time for questions, discussion, and interchange of ideas; time between classes could be used for guided reading and self-study; in many cases, with the cooperation of the trainees employers, coordination of classroom and individual study with on-the-job training would be possible.
PROPOSED INTEGRATED PROGRAM OF OPERATOR TRAINING ACTIVITIES
FOR NORTH CAROLINA

Of the various training methods those which seem most appropriate for continuation or adoption in North Carolina are the following:

The Annual Short School
This school presently exists; the organizational and institutional supporting structures for the school function well and the school is well attended. Later in this report recommendations will be made for modifications in the objectives of the annual school so that it can be continued as an important part of an integrated operator training program.

Long Term Evening Schools
Evening schools have been successfully sponsored by the North Carolina Water Pollution Control Association and the Office of Water and Air Resources with some aid from the federal government. The number of these schools should be expanded. The length and scope of the training should be normalized and a package of study materials should be adopted for use by the instructors and trainees.

Special Subject Short Schools
This type of short school is particularly useful for the presentation of material by experts specialized in the field. Such subjects usually require instruction in some depth, however, time constraints in the annual short school do not permit such coverage. Instructors at evening schools often do not have
the knowledge required for adequate presentation of such subjects.

Audio-Visual Instructional Materials

Audio-visual materials designed for use by individual trainees or for a general presentation in the classroom would be extremely helpful in the presentation of certain subjects. These instructional materials would be particularly useful in evening school programs or for presentation of certain types of specialized information. Audio-visual methods would also be a valuable tool in effectively presenting instructions in special subject short schools.

The planned coordinated development that the several types of training activities suggested above would, over a period of years, provide a variety of training opportunities suitable for the needs of individual trainees. Sufficient flexibility could be provided to satisfy the diverse needs of operators of various sizes and types of municipal and industrial plants. In addition training in specialized skills and advanced treatment methods could be made available.

The plan outlined below suggests short and long term objectives for the implementation of an integrated program of operator training in North Carolina.

Short Term Plan

I. Annual Short School at UNC Chapel Hill

The annual short school at UNC Chapel Hill would be continued for two to three years for all operator grades. The curricula could either be modified as suggested earlier in this report or the
present curricula could be followed. At present the four grade annual short school fills a training need that is not being met through other means. This is evident from the increasing enrollment in recent years.

II. Development of Evening Schools

Several successful evening study courses have been conducted; some through the voluntary efforts of members of the Water Pollution Control Association and some with financial aid provided by the Environmental Protection Agency through the Office of Water and Air Resources. The courses have been directed principally to Grade I and II operators. This training method should be continued. A plan should be developed to provide Grade I and II training at a number of strategic locations throughout the state. The existing system of community colleges and technical institutes throughout the State provides an excellent base for such training programs. When a community college or a technical institute is located near a well equipped laboratory at a wastewater treatment plant, the opportunity to provide effective training would be enhanced.

Following is a general plan for the development of evening schools:

a) Study centers located at technical institutes, community colleges of other cooperating institutions would be selected. In the short term plan, four or five locations might be selected within convenient driving distance of the trainees' homes.

b) Instructors for the evening schools would be selected.
Curriculum and methodology orientation training would be provided for the instructors. The instructors should be personnel experienced in the operation and management of wastewater collection and treatment facilities. The instructor would function under the general supervision of the Office of Water and Air Resources. The recruitment of competent, dedicated instructors is probably the single most important factor in the ultimate success of an evening school program.

c) Classroom work would consist of 25 two-hour sessions, one each week. Lecture subjects would be developed from the subject areas previously outlined and the time devoted to each subject area would be in the same proportion as in the annual short school. Lectures would be designed to compliment and amplify the home study materials. Two-hour sessions will allow time for discussion fo home study materials and actual on-the-job problems.

Material for home study would be selected from those readily available, e.g., the Sacramento State Manual and some of the Water Pollution Control Federation Manuals of Practice. Uniform reading and problem assignments would be prepared to coordinate with the lecture schedule. The regular reading and home study materials would be made available to every trainee at the lowest possible cost. Other pertinent publications (see Review of Available Training Materials later in this report) would be made available through the library of the training institution or the instructor.
Appropriate audio-visual training materials would be obtained and made available to the instructors and trainees for both classroom and individual use.

When actual hands-on experience is necessary for proper training, e.g., instruction in laboratory procedures, the facilities at a well equipped treatment plant laboratory may be utilized.

The Board of Certification of the Office of Water and Air Resources would arrange to conduct certification examination at the termination of each 25 week evening school program.

III. Development of Audio-visual Materials

The development of audio-visual instructional materials would be initiated as soon as possible. In this regard, a long term plan would be adopted; subjects appropriate for the various media would be selected and production priorities would be established. Some or perhaps all of these materials could be produced at the University of North Carolina in Chapel Hill.

Long Term Plan

I. Evening Schools

The development of evening schools for Grade I and II operators would be continued throughout the state to the point where all training in these grades can be offered through this mechanism. When this goal is achieved, Grade I and II training would be dropped from the annual short school in Chapel Hill.

II. Annual Short School

The annual short school at Chapel Hill would be continued for Grades III
and IV operators. With only two grades and consequently fewer trainees additional time would be available for instruction in the more advanced subjects. The curricula for the short school should be revised along the lines previously suggested.

III. Development of Special Subject Short Schools

Special subject short schools would be developed for presentation at Chapel Hill or elsewhere throughout the state. Short course subjects would be selected by the several cooperating agencies, i.e., the Office of Water and Air Resources, the North Carolina Water Pollution Control Association and the University of North Carolina. Need exists for training in a variety of special subjects which cannot be covered in depth in either the evening schools or the annual short school. Training in such subjects as instrumental analysis, treatment of industrial wastes, package plant operation, chlorination practice, advanced treatment methods, etc., would be appropriate for one or two day short schools. It is probable that such subjects would be well received by operators and managers of municipal and industrial wastewater systems. Some aspects of special subjects such as those mentioned above would lend themselves quite well to audio-visual presentation. Furthermore, the use of audio-visual materials would expedite the presentation of special subject courses throughout the state.

The development of an integrated operator training program such as outlined above will require the commitment of substantial resources, both financial and human. The effort seems well worth undertaking in view of the value of North Carolina's water resources and properly utilizing the huge existing and future investments in water pollution control facilities.
Suggested Roles for Various Agencies in the Development of an Integrated Operator Training Program

At least three agencies have a history of concern or some official responsibility for wastewater treatment plant operator training in North Carolina. These are the following:

The Office of Water and Air Resources of the Department of Natural and Economic Resources

The North Carolina Water Pollution Control Association

The University of North Carolina at Chapel Hill, School of Public Health, Department of Environmental Sciences and Engineering

Each of the above groups, particularly the Office of Water and Air Resources would play a significant part in the development and implementation of an integrated operator training program in the State. Some tentative suggestions related to the participation of each of the three groups in the development of such a program are outlined below. It should be emphasized that the suggested roles are quite tentative and would require considerable discussion prior to adoption.

Office of Water and Air Resources

1. Adopt a general plan for the implementation of an integrated operator training program, including short and long term objectives.

2. Supervise and coordinate the development of the integrated operator training program.
   a) Selection of training institutions
   b) Adoption of standard curricula
   c) Selection of local instructors
   d) Selection and provision of training materials

3. Make appropriate applications for federal funding to expedite program implementation.
4. Assist other agencies in obtaining federal funds to support the activities of these agencies in the development of the integrated training programs.

5. Conduct certification examination at the end of training programs through the agency of the Board of Certification.

North Carolina Water Pollution Control Association

The role of the North Carolina Water Pollution Control Association would be implemented through its training committee. The training committee could undertake to give substantial advice and assistance to the Office of Water and Air Resources as suggested below:

1. Advice in the selection of training institutions.
2. Advice and review in matters related to curriculum.
3. Advice and assistance in the organization and conduct of the annual short schools.
4. Recommendations as to the selection of instructors for evening schools.
5. Assistance in the selection of topics and instructors for special subject short schools.

The University of North Carolina at Chapel Hill

1. Organization and conduct of annual short schools held at Chapel Hill.
2. Organization and conduct of some special subject short schools.
3. Conduct of curriculum and methodology orientation programs for evening school instructors.
REVIEW OF AVAILABLE TRAINING MATERIALS

Printed Materials

A fair amount of printed material is available and would be useful in the conduct of any extended program of operators training where time was available for reading between classroom sessions. A sampling of available materials is listed below:

WATER POLLUTION CONTROL FEDERATION
OPERATION OF WASTEWATER TREATMENT PLANTS - MOP No. 11
Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C. 20016
This book covers all phases of wastewater treatment plant operation. It is a practical and well organized book.
Price: $2.00 to members of WPCF, from WPCF

WATER POLLUTION CONTROL FEDERATION
WASTEWATER TREATMENT PLANT OPERATOR TRAINING COURSE ONE (with Visual Aids)
WPCF Pub. No. 13, Address - See item No. 1
A series of lecture outlines for use with visual aids available from WPCF covering all phases of wastewater treatment. This publication and the visual aids should be very useful to instructors of Grade I and II operators. The use of the visual aids with brief comments could form a good introduction to a long term course.
Price: $1.50 to members; $25.00 with visual aids, from WPCF

WATER POLLUTION CONTROL FEDERATION
WASTEWATER TREATMENT PLANT OPERATOR TRAINING COURSE TWO (with Visual Aids)
WPCF Pub. No. 14, Address - See item No. 1
See course one, WPCF Pub. No. 13. This is a more advanced series of lecture outline with supporting visual aids.
Price: $2.00 to members of WPCF; $40.00 with visual aids; from WPCF

ENVIRONMENTAL PROTECTION AGENCY (Kerri, Kenneth D.)
OPERATION OF WASTEWATER TREATMENT PLANTS (A Field Study Program)
A good manual designed for individual study but could be used for home study in connection with a classroom program. This manual appears to be better than many others in regard to maintenance operations. The manual is one of the most complete available. Many example problems are provided. This manual compares favorably with the Texas manual.
Price: $12.00 from EPA

CLEMSON UNIVERSITY (Austin, John)
CRITERIA FOR THE ESTABLISHMENT AND MAINTENANCE OF TWO YEAR POST HIGH SCHOOL WASTEWATER TECHNOLOGY TRAINING PROGRAMS (Vol. I and II)
Outlines training methods and objectives.
CHANIN, GERSON
OPERATOR SHORT COURSE - Water and Wastewater Workbook Series/1 Water and Wastes Engineering
Magazine Publishing Division, The Reuben H. Donnelley Corporation
466 Lexington Avenue, New York N. Y.
An excellent introduction to mathematics and general chemistry for water and wastewater plant operators. This short text could be used for instruction and study in combination with a laboratory manual such as methods for chemical analysis of water and wastes.
Price: $3.00 from publisher

CHANIN, GERSON
OPERATOR SHORT COURSE - Water and Wastewater Workbook Series/2 Water and Wastes Engineering
Address: See Series/1
A general discussion of water chemistry and biology. A well written short text suitable for supplementary reading.
Price: $2.00 from publisher

CLEMSON UNIVERSITY (Austin, John H.)
CORRESPONDENCE COURSE MANUAL FOR WASTEWATER PLANT OPERATORS CLASS D
South Carolina Water and Pollution Control Association (1969)
This manual includes a separate home workbook for the use of correspondence students. The manual would be excellent for supplemental reading or as a principal text for a Grade I and II evening school. About 70 percent of the manual is concerned with basic mathematics and laboratory procedures. A good introduction to treatment processes is also included.
Price: $12.00 from publisher

CLEMSON UNIVERSITY (Miller, William G.)
CORRESPONDENCE COURSE MANUAL FOR SEWAGE PLANT OPERATORS CLASS C
South Carolina Water and Pollution Control Association (1962)
More advanced mathematics are introduced (algebra). General biology is discussed. About 70 percent of the manual is directed to these subjects. The style of presentation is perhaps too academic for treatment plant operators. The manual also contains an introduction to sewage treatment processes. This manual includes a separate home workbook for the use of correspondence students. This manual is being revised.

CLEMSON UNIVERSITY
CORRESPONDENCE COURSE MANUAL FOR SEWAGE PLANT OPERATORS CLASS B
South Carolina Water and Pollution Control Association (1963)
This manual includes a home workbook for use of correspondence students. The material in the manual resembles a review of high school mathematics, chemistry and physics. It may be useful as background reading material but does not appear appropriate for use as a principal text for upper level operators.
TEXAS A AND M UNIVERSITY (Ronhorde, I. N.)
SEWAGE WORKS OPERATION - UNIT I
Engineering Extension Service, Texas A and M University System, College Station, Texas 77843
A brief treatment of sewage treatment plant operation. Material is concentrated on primary treatment and digestion.
Price: $1.66 from publisher

TEXAS A AND M UNIVERSITY (Ronhorde, I. N.)
SEWAGE TREATMENT - UNIT II
Engineering Extension Service, Texas A and M University System, College Station, Texas 77843
This manual concentrates on secondary treatment of wastewater. This manual would be suitable as supplementary reading for an evening school.
Price: $1.66 from publisher

TEXAS A AND M UNIVERSITY
THE SEWERAGE SYSTEM - UNIT III
Engineering Extension Service, Texas A and M University System, College Station, Texas 77843
This manual covers general ideas on sewage collection system construction and maintenance. Material on sewage pumping stations is also included.
Price: $1.66 from publisher

TEXAS WATER UTILITIES ASSOCIATION
MANUAL OF WASTEWATER OPERATIONS
Texas State Department of Health, Austin, Texas (1971)
A 755 page hard cover book covering all phases of wastewater collection and treatment from the operations point of view. This book is the best of its type available. If it is not used as a principal text for training programs it should be available to trainees for reference and supplemental reading.
Price: $14.00 from publisher

NEW YORK STATE DEPARTMENT OF HEALTH
MANUAL OF INSTRUCTION FOR SEWAGE TREATMENT PLANT OPERATORS
Health Education Service, P. O. Box 7283, Albany, New York
An excellent short book (243 pages) covering wastewater treatment. This book has been used for a number of years in operator training and contains much useful and practical information. It is fairly low in cost and would be suitable for a principal text for evening courses in cases where funds were limited.
Price: $1.50 from publisher

Note: There are a few other New York publications to be added.

ENVIRONMENTAL PROTECTION AGENCY
METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES (1971)
A good manual with more background material than is available in standard methods for the examination of water and wastewater. It would be better suited for operator training.
Price: $3.00 Stock No. 5501-0067, U. S. Government Printing Office
WATER POLLUTION CONTROL FEDERATION
SIMPLIFIED LABORATORY PROCEDURES FOR WASTEWATER EXAMINATION
WPCF Pub. No. 18 (1971) Address - see item No. 1
Discussion of sampling, laboratory equipment, laboratory procedures and analytical procedures in a readable style. Each description of analytical procedures includes a short discussion of the meaning of the results and possible interferences.
Price: $2.00 to members from WPCF

NEW YORK STATE DEPARTMENT OF HEALTH (Gilereas, F. Wellington)
LABORATORY PROCEDURES FOR WASTEWATER TREATMENT PLANT OPERATORS
Health Education Service, P. O. Box 7283, Albany, New York
This is an excellent short text covering most of the laboratory procedures used in wastewater analysis. The book is particularly strong in the discussion of the reasons for conducting various analysis and the interpretation of results.
Price: $1.50 from publisher

NAGANO, JOE
LABORATORY PROCEDURES
California Water Pollution Control Association
P. O. Box 61, Lemon Grove, California 92045
This manual covers most of the laboratory skills and procedures necessary in wastewater treatment.
Price: $3.50 from publisher

COURSE IN BASIC CHEMISTRY FOR WATER AND WASTEWATER PERSONNEL (1970)
A good review of some elements of basic chemistry. The material covered could serve as an introduction to the study of specific laboratory procedures
Right to reproduce can be obtained from State of Michigan, Department of Public Health, 3500 North Logan, Lansing, Michigan 48914 (Donald M. Pierce)

BURNS AND MC DONEL
APPLIED HYDRAULICS FOR WATER AND SEWAGE PLANT OPERATORS
Burns and McDonnell Engineering Co. Kansas City, Missouri
An excellent short treatment of practical and applied hydraulics. Would be a fine reference for supplemental reading.
Availability questionable.

COURSE IN APPLIED HYDRAULICS (1971)
A general treatment of basic hydraulics with many example problems. This manual would be quite useful in training the higher grades of operators.
Right to reproduce can be obtained from State of Michigan, Department of Public Health, 3500 North Logan, Lansing, Michigan 48914 (Donald M. Pierce)

BURTMAN, LEONARD AND LADIN H. DELANEY
MATHEMATICS FOR WASTEWATER TREATMENT PLANT OPERATORS (1970)
California Water Pollution Control Association, P. O. Box 61, Lemon Grove, California 92045
An excellent mathematics instruction workbook with many drill exercises and examples drawn from the wastewater field. This would be an excellent self study book for a trainee who was deficient in this subject.
Price: $3.50. from publisher

67
COURSE IN APPLIED MATHEMATICS (1971)
A short manual covering basic arithmetic with applications drawn from the fields of water and wastewater treatment.
Right to reproduce can be obtained from State of Michigan, Department of Public Health, 3500 North Logan Street, Lansing, Michigan 48914
(Donald M. Pierce)

WATER POLLUTION CONTROL FEDERATION
SLUDGE DEWATERING - MOP No. 20 (1969)
Address - see item No. 1
An excellent text on sludge dewatering including chemical conditioning, land dewatering, vacuum filtration and centrifugation. This manual as well as all other WPCF publications listed here should be available to plant operators.
Price: $3.00 to members of WPCF, from WPCF

WATER POLLUTION CONTROL FEDERATION
AERATION IN WASTEWATER TREATMENT - MOP No. 5 (1971)
A discussion of aeration theory and practice as applied in wastewater treatment. Includes material on various types of diffused air and mechanical aeration devices and their proper application. Aerator maintenance is covered. This publication is a must for operators of activated sludge plants.
Price: $3.00 to WPCF members, from WPCF

WATER POLLUTION CONTROL FEDERATION
ANAEROBIC SLUDGE DIGESTION - MOP No. 16 (1968)
Theory and practical operation of anaerobic digesters are discussed. Attention is given to digester feeding and loadings and to digester problems and their remedies. Considering the many operating problems resulting from the process of anaerobic digestion, this book is well worth study by treatment plant operators.
Price: $1.50 to WPCF members, from WPCF

BRADY, JOHN
ACTIVATED SLUDGE (1971)
California Water Pollution Control Association, P. O. Box 61, Lemon Grove, California 92045
A practical short manual on the operation and control of activated sludge processes. This manual is essentially the same as Chapter 7 in the Sacramento State manual.
Price: $2.50 from publisher

BRADY, JOHN
SLUDGE DIGESTION AND HANDLING (1971)
California Water Pollution Control Association, P. O. Box 61, Lemon Grove, California 92045.
This manual covers, in a practical way, the operation and control of anaerobic sludge digesters and sludge disposal. It is essentially the same as Chapter 8 in the Sacramento State manual.
Price: $2.50 from publisher
WATER POLLUTION CONTROL FEDERATION
CHLORINATION OF SEWAGE AND INDUSTRIAL WASTES - MOP No. 4 (1965)
Address - See item No. 1
A complete discussion of the various uses and points of application in domestic and industrial wastewaters. Text includes use of chlorine compounds and chlorine safety practice. Presently out of print.

ONTARIO WATER RESOURCES
BASIC GAS CHLORINATION WORKSHOP MANUAL
Ontario Water Resources Commission, Training and Licensing Branch, 135 St. Clair Avenue, West, Toronto 7, Ontario.
A manual devoted entirely to chlorine handling and feeding; covering safety, gas feeding equipment, chlorine residual analysis. This manual should available to evening school trainees for supplemental reading.

ONTARIO WATER RESOURCES
BACKGROUND NOTES FOR CHLORINATION WORKSHOP
Ontario Water Resources Commission, Training and Licensing Branch, 135 St. Clair Avenue, West, Toronto 7, Ontario

WATER POLLUTION CONTROL FEDERATION
PAINTS AND PROTECTIVE COATINGS FOR WASTEWATER TREATMENT FACILITIES - MOP 17 (1969)
Address - see item No. 1
This publication discusses the use of protective coatings for the various types of corrosion which occurs in treatment plants. Various types of coatings and surfaces to be protected are described. The preparation of surfaces and coatings application are described. This publication should be available in every treatment plant.
Price: $1.50 to WPCF members, from WPCF

WASTES ENGINEERING
ENGINEERING SOLUTIONS TO SEWAGE TREATMENT PLANT DESIGN PROBLEMS
The Ruben H. Donnelley Corporation, 466 Lexington Avenue, New York, N.Y.
A short case study book which would be useful for supplemental reading.
Price: $1.00 from publisher

WATER POLLUTION CONTROL FEDERATION
SAFETY IN WASTEWATER WORKS - MOP No. 1 (1967)
Address - see item No. 1
A thorough treatment of hazards and recommended safety practices for workers involved with sewer maintenance and wastewater treatment plant operation. This manual as well as all other WPCF publications listed here should be available to plant operators.
Price: $.75 to members of WPCF, from WPCF

WATER POLLUTION CONTROL FEDERATION
REGULATION OF SEWER USE - MOP No. 3 (1963)
A definitive text on regulation of sewer use including suggested sewer ordinances, industrial waste regulations, monitoring of wastewater flows, etc.
Price: $1.00 to members of WPCF from WPCF
A short text on sewer maintenance including material on maintenance records and organization, cleaning and testing equipment, pumping station maintenance, safety practices, public relations and design considerations.
Price: $1.50 to members of WPCF from WPCF

A packet of materials concerned with the development of effective safety programs in wastewater treatment works. Material includes lecture guides for use with slides.
Price: $2.25 from publisher

A 375 page book on the design of modern sewage treatment plants. This publication would be quite useful in providing background information for Grades III and IV operators.
Price: $3.50 from WPCF

Discusses an accounting system which will serve well for wastewater collection and treatment utilities.
Price: $2.00 to members of WPCF, from WPCF

A well written manual on public relations covering employee public relations, handling of complaints, developing public support and other significant subjects.
Price: $2.00 to WPCF members, from WPCF

The manuals recommended for use in the development of an extended training program are the following:

- Manual of Wastewater Operations (Texas)
- Operation of Wastewater Treatment Plants (E.P.A.-Kerri)
- Correspondence Course Manuals for Wastewater Plant Operators - Class D (Clemson)
- Manual of Instruction for Sewage Treatment Plant Operators (New York State)
- Operation of Wastewater Treatment Plants (MOP No. 11 - WPCF)
For instruction in laboratory procedures and chemistry the following are suggested:

- Methods for Chemical Analysis of Water and Wastes (EPA)
- Simplified Procedures for Wastewater Examination (WPCF)

All of the Water Pollution Control Federation Manuals of Practice are excellent. If they can not be made available for each individual trainee they should be available in the library of the training institution for supplemental reading.
Audio-visual training materials related to wastewater treatment and analyses are available from several sources. A listing of materials and sources is given below.

**35 mm Slides with Keyed Magnetic Tape Cassettes**

The slides and tapes listed below are available from the Environmental Protection Agency in Cincinnati* or Region IV in Atlanta**.

<table>
<thead>
<tr>
<th>Title</th>
<th>Code</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Oxygen Demand Procedures</td>
<td>(XT-27)</td>
<td>17 minutes</td>
</tr>
<tr>
<td>Dissolved Oxygen Determination</td>
<td>(XT-29)</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Operational Control Tests for Activated Sludge, Part I</td>
<td>(XT-40)</td>
<td>16 minutes</td>
</tr>
<tr>
<td>Operational Control Tests for Activated Sludge, Part II</td>
<td>(XT-41)</td>
<td>17 minutes</td>
</tr>
<tr>
<td>Operational Control Tests for Activated Sludge, Part III</td>
<td>(XT-42)</td>
<td>22 minutes</td>
</tr>
<tr>
<td>Dissolved Oxygen Analysis -- Activated Sludge</td>
<td>(XT-43)</td>
<td>34 minutes</td>
</tr>
<tr>
<td>Upgrading Biological Treatment</td>
<td>(XT-25)</td>
<td>28 minutes</td>
</tr>
<tr>
<td>Control Testing</td>
<td>(XT-43)</td>
<td>34 minutes</td>
</tr>
<tr>
<td>Margin for Safety</td>
<td>(XT-38)</td>
<td>18 minutes</td>
</tr>
<tr>
<td>The Safe Way</td>
<td>(XT-32)</td>
<td>14 minutes</td>
</tr>
<tr>
<td>Why a Safety Program in Every Pollution Control Works</td>
<td>(XT-39)</td>
<td>12 minutes</td>
</tr>
<tr>
<td>Safety Program Guide</td>
<td>(XT-38)</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Inventory Your Chlorine Handling Practices</td>
<td>(XT-35)</td>
<td>32 minutes</td>
</tr>
<tr>
<td>Ultimate Disposal to the Environment</td>
<td>(XT-30)</td>
<td>42 minutes</td>
</tr>
<tr>
<td>The Determination of Phosphorus</td>
<td>(XT-44)</td>
<td>15 minutes</td>
</tr>
<tr>
<td>The Determination of Phenolics</td>
<td>(XT-28)</td>
<td>17 minutes</td>
</tr>
<tr>
<td>Atomic Adsorption</td>
<td>(XT-20)</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Basic Infrared Spectroscopy--Liquid Sampling Techniques</td>
<td>(#1002)</td>
<td>26 minutes</td>
</tr>
<tr>
<td>Basic Infrared Analysis--Quantitative Analysis--Performing the Analysis</td>
<td>(#1006)</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Basic Gas Chromatography--Basic Relationships and Instrumentation</td>
<td>(#2001)</td>
<td>23 minutes</td>
</tr>
<tr>
<td>Basic Gas Chromatography--The Column</td>
<td>(#2002)</td>
<td>26 minutes</td>
</tr>
<tr>
<td>Basic Gas Chromatography--Detectors</td>
<td>(#2003)</td>
<td>29 minutes</td>
</tr>
<tr>
<td>Basic Gas Chromatography--Sample Preparation</td>
<td>(32004)</td>
<td>29 minutes</td>
</tr>
<tr>
<td>Basic Gas Chromatography--Column Temperature</td>
<td>(#2005)</td>
<td>21 minutes</td>
</tr>
<tr>
<td>Basic Gas Chromatography--Qualitative and Quantitative Analysis</td>
<td>(#2006)</td>
<td>29 minutes</td>
</tr>
</tbody>
</table>
The material listed above concerning analytical procedures is very appropriate for the training of experienced laboratory personnel in new analytical techniques. A set of audio-visual materials covering basic wastewater laboratory techniques developed on the assumption that the user has had little or no previous training or laboratory experience would be more suitable for implementing the development of basic wastewater laboratory skills.

35 mm Film Strips with Cassette Narration

Film strips and accompanying cassettes are available on loan from the Environmental Protection Agency, Region IV**.

- Activated Sludge Process and Vacuum Filtration (S-160) 8 minutes
- The Trickling Filter Plants (S-159) 8 minutes
- The Primary Treatment Plant (S-138) 7 minutes
- The Membrane Filter (S-386) 12 minutes

35 mm Slides without Audio Material

The slides listed below are available on loan from the Environmental Protection Agency, Region IV**, and are on sale for $120.00 by the Health Education Service, P. O. Box 7283, Albany, New York 12224.

<table>
<thead>
<tr>
<th>Test</th>
<th>Slides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene Blue Test</td>
<td>27 slides</td>
</tr>
<tr>
<td>Residual Chlorine Test</td>
<td>3 slides</td>
</tr>
<tr>
<td>pH Hydrogen Ion Concentration Test</td>
<td>19 slides</td>
</tr>
<tr>
<td>pH Test Procedure Using Meter</td>
<td>8 slides</td>
</tr>
<tr>
<td>Settleable Solids Test</td>
<td>17 slides</td>
</tr>
<tr>
<td>Sludge Solids Test</td>
<td>21 slides</td>
</tr>
<tr>
<td>Total Solids Test</td>
<td>18 slides</td>
</tr>
<tr>
<td>Suspended Solids Test</td>
<td>20 slides</td>
</tr>
<tr>
<td>Dissolved Solids Test</td>
<td>2 slides</td>
</tr>
<tr>
<td>Sludge Volume Index</td>
<td>4 slides</td>
</tr>
<tr>
<td>Dissolved Oxygen Test</td>
<td>28 slides</td>
</tr>
<tr>
<td>Dissolved Oxygen Test for Activated Sludge Mixed Liquor</td>
<td>8 slides</td>
</tr>
<tr>
<td>BOD Test</td>
<td>20 slides</td>
</tr>
<tr>
<td>BOD Test-Alternate Dilution Procedure</td>
<td>9 slides</td>
</tr>
<tr>
<td>Coliform Group Bacteria Test</td>
<td>49 slides</td>
</tr>
<tr>
<td>Chlorine Demand Test</td>
<td>28 slides</td>
</tr>
<tr>
<td>Sludge Conditioning for Vacuum Filtration</td>
<td>20 slides</td>
</tr>
<tr>
<td>Volatile Acids in Sludge Test</td>
<td>31 slides</td>
</tr>
</tbody>
</table>
16 mm Color Films with Magnetic Sound

The color films listed below are available on loan from the Environmental Protection Agency, Cincinnati, Ohio*.

Arsenic Analysis (color film) (M-1) 6 minutes
Boron Analysis (color film) (M-2) 6 minutes
Flame Photometer Operation (color film) (M-3) 5 minutes
Atomic Adsorption Instrumentation (color film) (M-4) 7 minutes

Overhead Projector Transparencies

These transparencies are available from the Environmental Protection Agency, Region IV**.

Geology 8 slides
Chemistry 19 slides
Oceans 19 slides
Ecology-Biology 11 slides
BOD Test 23 slides

1/2 " Video Tapes

These video tapes are available from the Environmental Protection Agency, Region IV**.

Coagulation and Flocculation 28 minutes
Activated Sludge 20 minutes
Atomic Absorption - Hg 10 minutes
Oil Analysis (2 tapes) 35 minutes
Robot Monitors 7 minutes

* Mrs. Eileen Hopewell, Environmental Protection Agency, 4676 Columbia Parkway, Cincinnati, Ohio 45226

** Environmental Protection Agency, Southeast Water Laboratory, College Station Road, Athens, Georgia 30601

35 mm Slides with Accompanying Lecture Guides

These materials are available from the Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D. C. 20016.

Wastewater Treatment Plant Operator Training Course 1 (107 slides)
Wastewater Treatment Plant Operator Training Courses 2 (164 slides)
The lecture guides provided with the slides provide a complete outline of a general course in wastewater treatment. The lecture guides are quite complete and the slides help illustrate some of the important points.

One of the subjects which lends itself well to audio-visual instruction is that of laboratory procedures for wastewater analysis. This is evident from the number of titles concerned with analytical procedures in the previous listing. The materials in the media of 35mm slides with keyed cassettes, available from EPA are excellent. Some of these materials are directed to beginning laboratory personnel; others are designed for those with more advanced professional background. Although some presentations are designed for beginners, a fair level of general laboratory knowledge and a good foundation in chemistry is required for full understanding. In general these presentations are not sufficiently detailed to instruct an inexperienced technician in the performance of particular tests.

In committee discussions during this study it was concluded that audio-visual materials would be an extremely effective method of instruction in evening schools and that the area of laboratory skills was particularly well suited to the media. With this in mind, Dr. James C. Lamb undertook the development of audio-visual material for a particular test procedure; the test selected was that for dissolved oxygen. The objective was to provide a set of slides with coordinated audio material with sufficient instructional content so that a laboratory technician with little experience could actually use the step by step instruction in performance of the test. The instruction was developed for individual use; it is, however, also suitable for class presentation. The individual use feature allows
a trainee to receive instruction at any time and at his own pace repeat-
ing any sequence until the material is mastered. The text of the audio
material developed for this instruction is included in the appendix of
this report. The accompanying slides may be borrowed from the Water
Resources Institute of the University of North Carolina.

A complete set of audio-visual instruction covering all the
laboratory skills required for Grades I and II operators in sufficient
detail for individual use, would be a significant aid in the development of
evening school training programs. If such instruction were available,
one of more sets, along with accessory equipment might be made available
for each evening school.

Other subjects which seem appropriate for the type of presentation
outlined above would be laboratory skills for Grades III and IV operators,
certain unit operations of wastewater treatment not covered by materials
available from other sources and some specialized maintenance operations.

It is suggested that a program of audio-visual aid development
be initiated as soon as funding can be obtained. These materials would
be designed for individual or classroom use as described above. It is
believed that audio-visual instruction, developed in the detail evident
in the pilot instruction (the dissolved oxygen test) would not duplicate
anything presently available. Such materials would be a very significant
aid in operator training programs.
REFERENCES


APPENDIX A

MINIMUM REQUIREMENTS OF EDUCATION AND EXPERIENCE FOR CERTIFIED WASTEWATER TREATMENT PLANT OPERATORS

In accordance with Chapter 90A, Section 39 of the General Statutes of North Carolina, the following minimum requirements of education, experience and knowledge are established for the various grades of wastewater treatment plant operators as shown:

GRADE I

A candidate for a Grade I Certificate (lowest) shall be expected to have a general knowledge of the operation of small treatment plants. He shall have knowledge of equipment usually employed in such plants, and be able to describe the general maintenance requirements for such plant units.

The applicant must submit an application showing that one of the following prerequisite combinations of training and experience has been met in order to take the Grade I examination:

1. Three years of acceptable experience in wastewater treatment plant operation.

2. Finished Junior High School (Eighth Grade) and two years of acceptable experience in wastewater treatment plant operation.

3. One approved training school for wastewater treatment plant operators and one year of acceptable experience in wastewater treatment plant operation.

4. Graduate of a High School or higher educational institution and no experience in wastewater treatment plant operation.

If a satisfactory grade is made on the examination, the applicant will become a duly certified Grade I Wastewater Treatment Plant Operator.
GRADE II

A candidate for a Grade II Certificate shall be expected to have: a general knowledge of the various types of wastewater treatment plants and the processes involved; a general knowledge of the composition of wastewater and the proper sampling thereof; a general knowledge of the procedure involved in making basic physical and chemical tests and their application to treatment plant control; the ability to make simple calculations; general knowledge of the proper maintenance of the various treatment plant units and the mechanical equipment involved; to keep and interpret records; practice safety and maintain good public relations; and such other information as may be deemed pertinent by the Wastewater Treatment Plant Operators Board of Certification.

The applicant must submit an application showing that one of the following prerequisite combinations of training and experience has been met in order to take the Grade II examination:

1. One approved training school for wastewater treatment plant operators and two years of acceptable experience in a Grade I wastewater treatment plant or higher.

2. A Grade I Certificate and one year of acceptable operator experience in a Grade I wastewater treatment plant or higher.

3. Graduate of high school or its equivalent in special training and six months of acceptable experience in a Grade I wastewater treatment plant or higher.

4. Graduate of a recognized college, university, or approved technical course and no operator experience.

If a satisfactory grade is made on the examination, the applicant will become a duly certified Grade II Wastewater Treatment Plant Operator.
GRADE III

A candidate for a Grade III Certificate shall be expected to know more, and to answer more highly specialized questions relative to wastewater treatment and plant operation than is required for a Grade II Certificate. In addition to the requirements mentioned for a Grade II Certificate, a candidate for a Grade III Certificate should have a greater knowledge of the physical, chemical and bacteriological tests ordinarily performed in an adequately equipped laboratory for the determination of the nature, type and concentration of various wastewaters. He should be able to perform more advanced calculations including velocity of flow and pressures in pipes, etc., and should have a detailed knowledge of the principles of treatment plant operation, efficiencies, corrosion and its prevention, and the proper maintenance of all items of equipment in a wastewater treatment plant. He should be familiar with various types of pumps commonly used in wastewater treatment plants, their advantages and disadvantages, and be able to calculate pump efficiencies. He should know of the problems created by industrial wastes, their effect on the sewers, treatment plant, and receiving stream. He should be able to measure, by various means, the flow of wastewaters, to properly make composite samples, and to run the necessary physical, chemical and bacteriological tests necessary to provide the required degree of treatment prior to discharge into the receiving water.

The applicant must submit an application showing that one of the following prerequisite combinations of training and experience has been met in order to take the Grade III examination:

1. A Grade II Certificate and four years of acceptable experience in a Grade II wastewater treatment plant or higher.
2. Graduate of high school or its equivalent in special training and three years of acceptable experience in a Grade II wastewater treatment plant or higher.

3. Two years of college with training in chemistry and biology or public health and two years of acceptable experience in a Grade II wastewater treatment plant or higher.

4. Graduate of a recognized college or university with a major in science or engineering and one year of acceptable experience in a Grade II wastewater treatment plant or higher.

If a satisfactory grade is made on the examination, the applicant will become a duly certified Grade III Wastewater Treatment Plant Operator.

GRADE IV

A candidate for a Grade IV Certificate (highest) shall be expected to have more specific knowledge covering the entire field of wastewater treatment than the candidate for a Grade III Certificate. He should have more advanced knowledge of the design and construction of wastewater treatment facilities as well as more advanced knowledge of the chemistry and biology involved in the various processes of wastewater treatment. He should be familiar with various industrial wastes and know how to measure, sample and run the common physical, chemical and bacteriological tests necessary to provide the proper pretreatment or treatment thereof. He should have a good knowledge of the proper operation and maintenance of the various units in a modern wastewater treatment plant including pumps, motors and electrical equipment. He should be familiar with new developments in the field of wastewater treatment, and should have a good knowledge of the laws and regulations relating to stream sanitation. He should be able to develop necessary records and prepare required reports, etc. He should be able to properly supervise other employees and place into practice good public relations and safety programs, etc.
The applicant must submit an application showing that one of the following prerequisite combinations of training and experience has been met in order to take the Grade IV examination:

1. A Grade III Certificate and five years of acceptable experience in a Grade III wastewater treatment plant or higher.

2. Graduate of high school or its equivalent in special training and four years of acceptable experience in a Grade III wastewater treatment plant or higher.

3. Two years of college with training in chemistry, bacteriology or public health and three years of acceptable experience in a Grade III wastewater treatment plant or higher.

4. Graduate of a recognized college or university in sanitary or chemical engineering and two years of acceptable experience in a Grade III wastewater treatment plant or higher.

If a satisfactory grade is made on the examination, the applicant will become a duly certified Grade IV Wastewater Treatment Plant Operator.
# APPENDIX B

NORTH CAROLINA DEPARTMENT OF WATER AND AIR RESOURCES
WASTEWATER TREATMENT PLANT OPERATORS
BOARD OF CERTIFICATION

## RATING SCALE FOR CLASSIFICATION OF WASTEWATER TREATMENT WORKS

<table>
<thead>
<tr>
<th>NAME OF PLANT:</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UNITs</strong></td>
<td><strong>POINTS</strong></td>
</tr>
<tr>
<td>Influent Pumps</td>
<td>3</td>
</tr>
<tr>
<td>Bar Screens</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical Screens or Comminuting Devices</td>
<td>2</td>
</tr>
<tr>
<td>Grit Removal</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical Grit Removal</td>
<td>2</td>
</tr>
<tr>
<td>Flow Measuring Device</td>
<td>1</td>
</tr>
<tr>
<td>Instrumented Flow Measurement</td>
<td>2</td>
</tr>
<tr>
<td>Preaeration or Equalization</td>
<td>1</td>
</tr>
<tr>
<td>Grease or Oil Separators — Gravity</td>
<td>2</td>
</tr>
<tr>
<td>Mechanical</td>
<td>5</td>
</tr>
<tr>
<td>Air</td>
<td>10</td>
</tr>
<tr>
<td>Chemical Precipitation</td>
<td>3</td>
</tr>
<tr>
<td>Septic Tanks</td>
<td>2</td>
</tr>
<tr>
<td>Imhoff Tanks</td>
<td>3</td>
</tr>
<tr>
<td>Sand Filters</td>
<td>2</td>
</tr>
<tr>
<td>Primary Tanks, Mechanical Sludge Removal</td>
<td>5</td>
</tr>
<tr>
<td>Manual Sludge Removal</td>
<td>3</td>
</tr>
<tr>
<td>Trickling Filters, High Rate</td>
<td>7</td>
</tr>
<tr>
<td>Standard Rate</td>
<td>5</td>
</tr>
<tr>
<td>Aeration, Diffused Air</td>
<td>10</td>
</tr>
<tr>
<td>Mechanical</td>
<td>8</td>
</tr>
<tr>
<td>Separate Sludge Reaeration</td>
<td>3</td>
</tr>
<tr>
<td>Secondary Tanks, Mechanical Sludge Removal</td>
<td>5</td>
</tr>
<tr>
<td>Manual Sludge Removal</td>
<td>3</td>
</tr>
<tr>
<td>Chlorination, Pre.</td>
<td>1</td>
</tr>
<tr>
<td>Post</td>
<td>3</td>
</tr>
<tr>
<td>Sludge Digestion, Heated</td>
<td>10</td>
</tr>
<tr>
<td>Aerobic</td>
<td>5</td>
</tr>
<tr>
<td>Unheated</td>
<td>3</td>
</tr>
<tr>
<td>Sludge Drying Beds</td>
<td>2</td>
</tr>
<tr>
<td>Sludge Thickeners</td>
<td>2</td>
</tr>
<tr>
<td>Vacuum Filters or Centrifuges</td>
<td>10</td>
</tr>
<tr>
<td>Sludge Elutriation</td>
<td>7</td>
</tr>
<tr>
<td>Sludge Incinerators</td>
<td>10</td>
</tr>
<tr>
<td>Sludge Gas Utilization</td>
<td>2</td>
</tr>
<tr>
<td>Stabilization Lagoons with Outlet to Stream</td>
<td>5</td>
</tr>
<tr>
<td>Settling Ponds for Inorganic Non-toxic Materials</td>
<td>10</td>
</tr>
<tr>
<td>(Sand, gravel, scone, and other mining operations)</td>
<td></td>
</tr>
<tr>
<td>Holding Pond with no Outlet to Stream</td>
<td>2</td>
</tr>
<tr>
<td>Holding Ponds for Effluent Flow Equalization and Stage Discharge</td>
<td>5</td>
</tr>
<tr>
<td>Spray Irrigation</td>
<td>5</td>
</tr>
<tr>
<td>Laboratory Facilities</td>
<td>1-3</td>
</tr>
<tr>
<td>Population Equivalent (1 point per 2000 P.E.)</td>
<td>1-30 Maximum</td>
</tr>
<tr>
<td>100 gpd/person (Based on Design Flow)</td>
<td></td>
</tr>
<tr>
<td>Tertiary Treatment</td>
<td>3</td>
</tr>
<tr>
<td>Nutrient Removal</td>
<td>5</td>
</tr>
<tr>
<td>All Treatment Facilities Designed for Metals Removal, Cyanide Destruction and Similar Processes</td>
<td>30</td>
</tr>
</tbody>
</table>
### APPENDIX B

### CLASSIFICATION

<table>
<thead>
<tr>
<th>Class</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>5-25 Points</td>
</tr>
<tr>
<td>Class II</td>
<td>26-50 Points</td>
</tr>
<tr>
<td>Class III</td>
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Facilities having a rating of 1 through 4 points, inclusive, do not require certified operators. Classification of all other facilities requires a comparable grade operator in responsible charge.
APPENDIX C

MEASUREMENT OF DISSOLVED OXYGEN:

AZIDE-WINKLER PROCEDURE:

A PILOT PROJECT IN OPERATOR TRAINING

by

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September 1972

85
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>OBJECTIVE</td>
<td>1</td>
</tr>
<tr>
<td>COMPONENTS OF THE MODULE</td>
<td>1</td>
</tr>
<tr>
<td>INSTRUCTIONS FOR THE USE OF THE MODULE</td>
<td>2</td>
</tr>
<tr>
<td>MODULE OUTLINE AND SUPPLEMENTARY INFORMATION</td>
<td></td>
</tr>
<tr>
<td>Topic No. 1 - Equipment and Supplies</td>
<td>4</td>
</tr>
<tr>
<td>Topic No. 2 - Preparation of Reagents</td>
<td>5</td>
</tr>
<tr>
<td>Topic No. 3 - Laboratory Procedure</td>
<td>7</td>
</tr>
<tr>
<td>Temperature Conversion Table</td>
<td>8</td>
</tr>
<tr>
<td>APPROXIMATE SCRIPT OF TAPES</td>
<td></td>
</tr>
<tr>
<td>Introductory Comments</td>
<td>9</td>
</tr>
<tr>
<td>Topic No. 1 - Equipment and Supplies</td>
<td>11</td>
</tr>
<tr>
<td>Topic No. 2 - Preparation of Reagents</td>
<td>16</td>
</tr>
<tr>
<td>Topic No. 3 - Laboratory Procedure</td>
<td>20</td>
</tr>
</tbody>
</table>
INTRODUCTION

As a wastewater treatment plant operator, you often may want to measure dissolved oxygen (D.O.) concentration in water. This could be necessary in connection with several of your activities, including the following:

1. Periodic measurement of D.O. in the receiving stream above and below your plant outfall to supply data for reports to pollution control agencies.
3. Measurements at various points in your plant to insure adequate D.O. for efficient performance and to regulate operation of aerators for economical process control.

OBJECTIVE

The overall objective of this instructional module is to assist you in learning how to use the Azide modification of the Winkler test. If the module is successful, upon its completion you should be able to measure the D.O. in a water sample with accuracy considered to be reasonable practice in wastewater treatment plant operation (within 0.2 mg/l, or better).

COMPONENTS OF THE MODULE

The basic key to using this module is the booklet which you are now reading. This provides limited written information about the test and instructions for use of other materials in the module.

Actually, most of the detailed instructional material is supplied on magnetic tape, supplemented by color slides. The written and recorded materials and slides are designed to compliment each other and should be used simultaneously, following directions to be given on the tape. Accordingly, you should be sure before starting that all necessary equipment and supplies are available and functioning properly. A list of the items follows:

1. **Written materials**
   
   a). This booklet
   
   b). An approximate transcript of material on the tape (located in back of this booklet). You really should not need this, but it might be helpful if you have trouble understanding any of the tape.
c). Evaluation form

d). The "standard" procedure for determining dissolved oxygen by the Azide modification. Pages 474-481 in the 13th Edition of "Standard Methods for the Examination of Water and Waste-water" describe the background and procedure for conducting this analysis. This book can be obtained from the Water Pollution Control Federation, 3900 Wisconsin Avenue, N.W., Washington, D. C. 20016 (Phone 202-362-4100) and should be in every wastewater treatment laboratory.


No. 1: Equipment and Supplies
No. 2: Preparation of Reagents
No. 3: Laboratory Procedure

3. A group of color slides numbered "D.O. Azide-1" through "D.O. Azide-43".

4. A magnetic tape cassette playback unit, either monaural or stereo.

5. A 35 mm slide viewer, preferably a large desktop unit.


INSTRUCTIONS FOR THE USE OF THE MODULE

You may wish to review some of the material in this module before going into your laboratory to run the D.O. test. This is entirely up to you, but we would like to point out that the module describes a laboratory procedure and it is highly important that the test be conducted strictly in accordance with instructions. Accordingly, eventually you will find it desirable actually to set up the slide viewer and tape playback unit in the laboratory in which you will be working. They should be located in a safe, dry place which is as convenient as possible to the bench on which you will conduct the test but well protected from splashing water, spilled chemicals, and other hazards.
To operate the tape playback, first push the "eject" button and insert the tape cassette with side No. 1 facing up. All of the tape should be rewound on the left spindle. If it is not, merely push the rewind button until the tape stops moving to the left. You are now ready to play the tape.

Set up the slide viewer, insert the first (title) slide and check its operation. If you have the correct slides, the title should be "Measurement of Dissolved Oxygen: Azide-Winkler Procedure."

All of the rest of the instruction in this module is on or guided by the tape. Accordingly, you now should start the playback unit and take all further directions for use of tape, slides, written materials and other equipment and supplies from the tape recorder. If you have problems in understanding parts of the tape, you can refer to the approximate transcript for clarification. When you start the tape, the first words which you hear should be:

"Measurement of Dissolved Oxygen: Azide-Winkler Procedure"

START THE TAPE PLAYBACK UNIT
MODULE OUTLINE AND SUPPLEMENTARY INFORMATION

TOPIC NO. 1 - EQUIPMENT AND SUPPLIES

A. Objective
Upon completion of this topic, you will have assembled all of the equipment and supplies necessary to run D.O. by this procedure.

B. Audiovisual Materials
1. Tape No. 1
2. Slides "D.O. Azide-1" through "D.O. Azide-16"

C. Checklist of Glassware, etc.
1. Two 300 ml BOD bottles
2. Three 2 ml automatic, Mohr or volumetric pipets
3. Three pipet fillers (if Mohr or volumetric units are used)
4. One 25 ml Pyrex buret
5. One buret stand
6. One buret clamp
7. One 250 ml Erlenmeyer flask
8. One 250 ml graduated cylinder
9. (Optional) One magnetic mixer, with at least one Teflon-coated magnet.
10. (Optional) One 200 ml volumetric flask, cut at 203 ml level and fitted with rubber stopper.

D. Checklist of Reagents (Slide 8 and pgs. 477-479, "Standard Methods").
1. Manganese Sulfate solution (MnSO₄)
2. Alkali-iodide-azide reagent (Alk.-KI)
3. Concentrated Sulfuric Acid (H₂SO₄)
4. Starch Solution (Starch)
5. 0.025 N Thiosulfate (Na₂S₂O₃)
TOPIC NO. 2 - PREPARATION OF REAGENTS

A. Objective

To prepare, safely, all of the reagents required to run D.O. by the Azide modification of the Winkler Procedure.

B. Audiovisual Materials

1. Tape No. 2

C. Chemicals Required to Prepare Reagents

1. To prepare Manganese Sulfate Solution (MnSO₄), one of the following:
   a) MnSO₄ · H₂O
   b) MnSO₄ · 2 H₂O
   c) MnSO₄ · 4 H₂O
2. To prepare Alkali-Iodide-Azide Reagent (Alk.-KI):
   a) Sodium Hydroxide Pellets (NaOH)
   b) Either: Potassium Iodide (KI), or Sodium Iodide (NaI)
   c) Sodium Azide (NaN₃)
3. Concentrated Sulfuric Acid (H₂SO₄)
4. To prepare Starch Solution (Starch), you will need arrowroot or soluble starch. Buy already mixed, if available.
5. To obtain 0.025N (N/40) Thiosulfate (Na₂S₂O₃), purchase it already mixed and standardized, if possible. As a second choice, buy a stronger and standardized prepared solution. To mix the powdered chemical and standardize it yourself, you will need access to an analytical balance and must follow the procedure on pages 478-479 of "Standard Methods."

D. Summary of Procedures for Mixing Chemical Reagents

1. Manganese sulfate
a) Weigh out manganese sulfate in a liter beaker.
   If you have MnSO\textsubscript{4} \cdot H\textsubscript{2}O, weigh out 364 grams.
   If you have MnSO\textsubscript{4} \cdot 2H\textsubscript{2}O, weigh out 400 grams.
   If you have MnSO\textsubscript{4} \cdot 4H\textsubscript{2}O, weigh out 480 grams.

b) Dissolve this in distilled water
c) Dilute to a liter

2. Alkali-iodide-azide Reagent
   a) Weigh out 500 grams of sodium hydroxide in a liter beaker.
   b) Weigh out 150 grams potassium iodide (or 135 g. sodium iodide) in a 250 ml beaker and add this to the sodium hydroxide.
   c) Dissolve the sodium hydroxide and potassium iodide in about 800 ml of distilled water.
   d) Weigh out 10 grams of sodium azide in a 250 ml beaker and dissolve in about 50 ml of distilled water.
   e) Add the sodium azide to the sodium hydroxide-iodide.
   f) Dilute to one liter.

3. Sodium thiosulfate, 0.025N (N/40)
   If you have a sodium thiosulfate solution of a strength other than 0.025N (N/40), you can mix the proper solution as follows. Calculate the required volume by this equation:

   \[ V_1 \times N_1 = V_2 \times N_2 \]

   where \( V_1 \) and \( N_1 \) are the volume and normality of the original solution and \( V_2 \) and \( N_2 \) are the volume and normality of the final solution.

   For example, if you wish to find the volume \( V_1 \) of 0.1N (N/10) solution \( (N_1) \) required to make 1000 ml \( (V_2) \) of 0.025N (N/40) thiosulfate \( (N_2) \),

   \[ V_1 \times 0.1 = 1000 \times 0.025 \]
   \[ 0.1 \times V_1 = 25 \]
   \[ V_1 = 250 \text{ ml} \]
Thus, you will need to dilute 250 ml of 0.1N solution to 1000 ml to obtain a 0.025N solution. Measure out exactly 250 ml of the 0.1N (N/10) solution in a volumetric flask. Pour it into a one liter (1000 ml) flask, and dilute to the mark.

TOPIC NO. 3 - LABORATORY PROCEDURE

A. Objective
To measure D.O. in two samples of air-saturated water and to check results within 0.2 mg/l of the correct value.

B. Audiovisual Materials
1. Tape No. 3
2. Slides "D.O., Azide-17" through D.O., Azide-43"

C. Summary of Test Procedure
1. Add 2 ml MnSO₄ Reagent
2. Add 2 ml Alk.-KI Reagent
3. Mix (invert 15 times) and settle
4. Mix (invert 15 times) and settle
5. Add 2 ml conc. H₂SO₄ and mix
6. Measure 203 ml of sample
7. Titrate with 0.025 N Na₂S₂O₃
8. D.O. = ml of Na₂S₂O₃ added.
### D. Temperature Conversion Table

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This tape accompanies a booklet and slides concerned with measurement of dissolved oxygen concentration in water using the Azide modification of the Winkler test, described on pages 474-481 of the 13th Edition of "Standard Methods for the Examination of Water and Wastewater.

This may be the first time in which you have used tape and slides for this type of learning process. After you have gotten used to it, you will find the technique to be very convenient in several ways. In the first place, you can pick your own time and place for the lesson and, often, you can listen even while you are doing other things. You can set your own pace and if you don't follow something the first time, just stop the tape recorder, reverse it for a few seconds and play it through again. Of course you can do this as many times as you like. Also, you can stop the machine if it is necessary to do something else, such as getting a piece of equipment or even going to answer the telephone. Then you can start again whenever you are ready. Of course, if you were a student in a classroom, you could not expect to find life that convenient, or the professor that tolerant!

The same thing applies to the slides. On the tape we will indicate to you when you should start using the slides, and when it's time to change one we will let you know. If you find that you are rushed when you change them, just stop the tape when we tell you to change the slide and then start the tape again at your leisure. Once in a while you will want to stop the tape when you have to carry out some steps in the laboratory procedure or to look for a piece of equipment. After you have found it, or after finishing whatever you wanted to do, just start up the tape again whenever it's convenient.

Incidentally, we will appreciate it greatly if you would make a special effort to avoid getting fingerprints or spots on the slides. Handle them by the cardboard without touching the transparent center part. Otherwise, after a few people use them, they will be ruined from accumulations of oils, chemicals and other dirt on the film.

In improving the content of this module and insuring maximum value to you from future ones, it is essential that we obtain your reaction to the various materials and techniques which are employed. Without knowing which parts of the module were good and which were not so good, from your point of view, we have little basis for changing to make it more effective in the future.

Accordingly, we have supplied you with an evaluation form to help in organizing your comments about the module. In completing this, please remember that we are interested only in your own personal reaction and that you can be of greatest help in our future activities by giving it to us "straight from the shoulder." In addition to indicating your reaction by checking the appropriate boxes, we would welcome
any additional written comments which you might have. These could be written at the end of the evaluation form or on additional sheets of paper.

Upon completing the module and the evaluation form, we would appreciate your returning the form promptly to the address given at the end of the form. We, and others who may benefit in the future from your comments, thank you very much for your cooperation!

You now should have your tape playback unit and the slide viewer set up in your laboratory in a position which is convenient to the bench on which you are going to do the determination. They also should be safe from splashing of chemicals or water on either the tape recorder or the viewer.

The first topic which we will cover deals with equipment and supplies which you will need to have on your laboratory bench to carry out this measurement. For your convenience, we also have summarized these items under "Topic No. 1", page 4 in the booklet, as a checklist.

The materials should be collected and placed in a convenient spot on your laboratory bench. It is usually a good idea to do the wet part of the analysis on a drainboard of the bench, or even in sink itself, to avoid spilling chemicals on your benchtops, floor, clothes or other equipment. After all, several of the chemicals are quite concentrated and could be harmful. It's always better to avoid spreading them around the laboratory any more than is necessary!

Now, place the first slide in the viewer and turn it on.

SLIDE 1

This should show the title of the module:

MEASUREMENT OF DISSOLVED OXYGEN:

AZIDE-WINKLER PROCEDURE

by

J. C. Lamb, U.N.C. at Chapel Hill

P. A. Vesilind, Duke University

96
This module is divided into three separate topics. Topic 1 involves the collection of equipment and supplies, Topic 2 is on the preparation of reagents, and Topic 3 is a description of the test procedure itself. Topic 1 is on the tape you are presently listening to, and Topics 2 and 3 are on separate cassettes. The lists of slides which go with each cassette are given on pages 4 and 7 of the booklet.

**TOPIC NO. 1: EQUIPMENT AND SUPPLIES**

**Objective:** Upon completion of this topic, you will have assembled all of the equipment and supplies necessary to run D.O. by this procedure.

**SLIDE 2**

This slide shows two 300 ml BOD bottles, the type which you will use in this exercise. Although not really necessary, we usually use BOD bottles for measuring D.O. because they always are available in wastewater laboratories and are convenient in size and shape for the D.O. test.

It is rather important that this type of bottle be used for running BOD tests because they are made of a special highly inert glass and because of their design. You will note that the stopper is pointed on the bottom. This avoids entrapping air in the top of the bottle, which might cause changes in dissolved oxygen content of the liquid. Also, the neck of the bottle is shaped to provide a "water seal", which is very important in BOD determinations when the bottles usually are stored in a dry incubator for several days. Unless water is kept in the seal, expansion and contraction sometimes can cause air to be drawn into the bottle and the bubble could change dissolved oxygen concentration in the liquid.

Incidentally, notice that the bottles are numbered. Those which you buy will be numbered and, if you so specify, you usually can obtain them numbered in any sequence which you might desire. Obviously, it would be helpful to avoid having duplicate numbers in your laboratory because sometimes they may cause confusion. Also, notice that the stoppers are numbered. Generally, they are ground to fit each bottle and you should try to keep a bottle and its stopper together because the right combination usually will assure a good seal.

For this exercise you should have at least two clean bottles available on your bench.
This slide shows two types of 2 ml pipets which you might use. They can be ordinary Mohr pipets, as shown at the right of the slide, or volumetric pipets, as shown at the left. In either event, the pipets should have moderately large openings in the tips to allow rapid passage of the relatively concentrated and viscous chemicals.

You will need at least three of these, unless you can use the automatic pipets to be described shortly.

With either type, we recommend strongly that you avoid drawing the reagents into the pipet by mouth. This can be very dangerous with the concentrated chemicals used in the D.O. test.

Instead, pipet fillers should be used to avoid any mouth contact. Many types are sold by laboratory supply houses, some of which are shown on pipets in this slide. They work by using a rubber bulb to provide the vacuum necessary to draw liquid into the pipet.

A most convenient type of pipet is shown here. This automatic unit is operated by compressing the rubber bulb by pushing down the plunger on top and inserting the tip below surface of the reagent. When the plunger is released, liquid is drawn into the pipet. The amount of liquid can be adjusted very accurately by moving a set screw on the shaft.

It is convenient to mount this type of pipet through a rubber stopper, as shown in the middle of the slide. Then the unit can be left in the reagent bottle to serve as stopper as well as pipet, as shown at the right. When it is desired to add the reagent, the pipet is withdrawn, its plunger depressed to force out all of the liquid, and then released with tip under the surface to allow the pipet to fill with the proper amount of liquid.

These units are called "Automatic pipets" and may be obtained in different sizes from laboratory supply houses. You will need units in the size range between 2 and 5 ml for accurate measurement of 2 ml portions during the D.O. test.
SLIDE 6

This shows a buret, clamp and stand. We suggest that you select a good grade of pyrex 25 ml buret. The stopcock should be greased lightly with silicone stopcock grease to prevent leakage of the solution. You should be careful to avoid putting on enough grease to obstruct the hole through which the solution must pass during titration.

Virtually any type of buret stand would be satisfactory, although the one shown is very convenient because it has a white base, which makes it easier to see the endpoints of titrations. The quick release clamp makes it easy to attach and remove the buret.

SLIDE 7

Slide 7 shows two additional items of glassware which will be needed to conduct the D.O. test. The Erlenmeyer flask, on the left, (250 ml) will be necessary in titrating the solution after addition of reagents. The 250 ml graduated cylinder will be needed to measure solution to be removed from the BOD bottle for titration.

SLIDE 8

In addition to the supplies and equipment which we already have listed and discussed, you obviously are going to need reagents to run the D.O. test. These are listed on pages 477, 478 and 479 in the 13th edition of "Standard Methods." This slide shows the specific chemicals which will be needed and we also have included a checklist at the bottom of page 4 in the booklet to help you assemble them.

If you already have the solutions on hand, and are certain that they have been accurately prepared, then you may wish to skip the tape on preparation of reagents and proceed directly to measurement of dissolved oxygen. If so, just continue with this tape.

If you do not already have the reagents prepared and are not familiar with how to do so, you will find that covered under Topic No. 2 in the booklet and on Tape No. 2. If you would like to follow-through on that material, you now should turn off the tape recorder, remove this cassette from the machine without rewinding it, and substitute Tape No. 2, describing preparation of reagents, which will give you all necessary directions. After completing it, you can return to this cassette and continue from here.
SLIDE 9

This slide shows a piece of equipment which is not absolutely necessary to run the test, but is great for convenience and usually helps improve accuracy. That is a magnetic stirrer with magnet.

The plastic coated magnet bar can be inserted in the Erlenmeyer flask during titration and the flask placed on the magnetic mixer. This provides thorough and rapid mixing of the reagent with contents of the flask throughout the entire titration. This is very convenient and reduces tendency for "overshooting" the endpoint.

This type of unit may be obtained from any laboratory supply house and will have many applications in your laboratory besides D.O. determinations.

SLIDE 10

This shows an "automatic buret." Many units accomplishing about the same thing are on the market. They are convenient because the buret can be filled quickly and accurately just by pumping the rubber bulb to force liquid from the bottle up into the buret. Extra liquid overflows, leaving the buret automatically filled to the "zero" line at the top. Some units, such as this one, divert the overflow back into the reservoir so that it is not lost. This should be considered by anyone who has to run several determinations daily.

SLIDE 11

This piece of glassware also is not necessary but often is convenient if many D.O. determinations must be run.

At one point in the procedure to be described, it will be necessary to transfer 203 ml of sample from BOD bottle to Erlenmeyer flask. Because this is a rather awkward amount to measure, many laboratory personnel cut the top off a volumetric flask so that when full, it holds exactly 203 ml.

That can be accomplished by taking a 200 ml volumetric flask, shown at the left of the slide, pouring into it 203 ml of water, and cutting the neck of the cylinder carefully at the 203 ml level. The flask after being cut is shown next in the slide, proceeding from left to right. The third flask has been fitted with a No. 6 1/2 stopper to fit over the neck of the flask and into the top of a BOD bottle.

The next 5 slides show the sequence of events in using this 203 ml container.
SLIDE 12

The flask is positioned on top of the BOD bottle, as shown here, and held securely in place.

This operation should be carried out over or in the sink, by the way, in case of minor spills because the BOD bottle will contain an acid solution at this point. Until learning the procedure, it would be reasonable to practice with clean water.

SLIDE 13

Inverting the bottle and flask pair causes the flask to fill, as shown here.

SLIDE 14

Over the sink, remove the BOD bottle, leaving the flask full (with exactly 203 ml) of solution.

SLIDE 15

Place the Erlenmeyer firmly over the stopper on the neck of the flask.

SLIDE 16

Invert the pair, allowing the liquid to pass into the Erlenmeyer. Remove the 203 ml flask and the operation now is complete.

As indicated, this item is not really necessary because you can merely measure 203 ml in a graduated cylinder and pour this into the Erlenmeyer. However, if many D.O. determinations must be made, the technique can save a lot of time and effort.

This concludes the portion of this module devoted to Equipment and Supplies. You may now turn off the slide viewer and, in a minute, the tape playback unit.

If you wish to review details of preparing your reagents, you should now proceed to Tape No. 2 (Topic No. 2).

If you wish to move directly to the laboratory procedure for determining D.O., using reagents already on hand, then proceed directly to Tape No. 3 (Topic No. 3).

THIS ENDS TAPE NO. 1. PLEASE REWIND THE TAPE.
TOPIC NO. 2 PREPARATION OF REAGENTS

Objective To prepare, safely, all of the reagents required to run D.O. by the Winkler Azide procedure.

Introduction

The instructions for preparing the reagents are on this tape and on the approximate transcript. In addition, we have included brief outlines of the procedures on pages 5-7 of the instruction booklet, and we recommend that you follow along with these procedures as you listen to the tape.

The chemical reagents which must be mixed for the D.O. test are:

1. Manganese sulfate reagent
2. Alkali-iodide-azide reagent, which is made with sodium hydroxide, potassium iodide and sodium azide. In addition, you will need the following chemicals which need not be mixed.
3. Starch solution
4. Sulfuric acid
5. Sodium thiosulfate, which does not have to be mixed if you can buy 0.025N (N/40) solution.

The chemicals which you must have are listed under Topic 2C on Page 5 in the instructional booklet. Take the time now to find the right chemicals and collect them in a convenient place.

We will now outline the procedure for mixing the manganese sulfate and the alkali-iodide-azide reagents.

Preparation of Manganese sulfate

Look over the procedure on pages 5 and 6 in the instruction booklet for mixing the manganese sulfate reagent. (Topic 2, paragraph D-1). This gives you a summary of what you will be doing.

The weighing can be done on any balance which is accurate to within one gram. We recommend a triple beam balance as being fairly inexpensive and easy to use. It is not necessary to use an analytical balance since such accuracy is not needed.

The simplest method of weighing out the manganese sulfate reagent is to first weigh a liter beaker and then spoon the chemical into the beaker.

(a) Place a clean and dry liter beaker on the balance and record the weight.

(b) Now look at the chemical formula on the bottle of manganese sulfate and note the number of waters attached to
the MnSO₄. You will find either 1, 2 or 4 H₂O with the MnSO₄. The amount of chemical you place in the beaker depends on the number of water molecules on the MnSO₄.

If there is one water, place 364 g. in the beaker. If there are two waters, place 400 g. in the beaker. If there are four waters, place 480 g. in the beaker.

For example, if your chemical is MnSO₄ · 2H₂O (two water molecules), you must add 400 g. into the beaker. Suppose your beaker weighs 116 grams, you must set the scale to read 516 g (400 + 116) and pour in enough chemical to bring the pointer to zero.

Proceed now to weigh out your manganese sulfate.

Pour enough distilled water into another clean beaker to make it about 3/4 full, slide a magnet in, and place the beaker on a magnetic stirrer. With the stirrer running fast enough to give good mixing without splashing, add the manganese sulfate to the distilled water. Rinse the remaining manganese sulfate (powder) out of the first beaker into the one on the mixer. When the solution becomes a clear pink, the manganese sulfate is dissolved.

Pour the solution into a one liter volumetric flask and fill to the mark with distilled water.

Mark a one liter glass stoppered bottle as "MnSO₄ for D.O." and pour contents of the volumetric flask into the bottle.

You now have a liter of manganese sulfate ready to be used for the D.O. measurement.

Preparation of Alkali-iodide-azide reagent

Look over the written procedure for mixing the alkali-iodide-azide reagent. (Topic 2, paragraph D-2 on page 6).

Weigh a clean, dry liter beaker on the balance.

Weigh out 500 grams of sodium hydroxide in this beaker. Be very careful with the pellets. They will adsorb water from the air and burn whatever they happen to be touching. If you touch a pellet with your clothes or skin, wash immediately with plenty of water.

Place a magnetic stirrer on the drain board of a sink and put on it a clean one liter beaker with about 800 ml of distilled water. Drop a magnet into the beaker, start it up, and slowly pour in the sodium hydroxide.
Do this very carefully and slowly, since the beaker will get very hot. If you go too fast, there might even be enough heat generated to crack the beaker; that's why you have it on the drainboard.

After the sodium hydroxide is dissolved, weigh out 150 g of potassium iodide in a 250 ml beaker.

Pour this powder into the sodium hydroxide solution.

In a small beaker, weigh out 10 g of sodium azide. Pour about 50 ml distilled water into the beaker and swirl it around until it dissolves. Add this azide solution to the liter beaker with the hydroxide and iodide.

Pour the entire contents of the liter beaker into a one liter volumetric flask and dilute with distilled water to the mark.

Pour the contents of the volumetric flask into a one liter glass stoppered bottle and mark it as "ALK.KI for D.O."
Also identify the bottle as having a dangerous chemical in it by labeling it as "CAUTION! Strong base."

You now have one liter of alkali-iodide-azide reagent ready to use.

Other Reagents

The starch solution and sodium thiosulfate need no mixing if they can be purchased from laboratory chemical firms. If you cannot get the starch, mix your own following the procedure in "Standard Methods," page 478.

Sodium thiosulfate solution can be purchased already standardized at 0.025N (sometimes labeled N/40 or 1/40N).

If you can get a solution but not 0.025N you can mix it from a solution of any other known normality. See the instruction booklet for a review of this procedure, under Topic 2, paragraph D-3, pages 6 and 7.

The concentrated sulfuric acid (H₂SO₄) is used as purchased, with no mixing or dilution.

Storage of Reagents

It is convenient and safe to keep only small volumes of all of these chemicals on the laboratory bench and store the bulk in a safe cabinet. We recommend that you get three BOD bottles (or other glass-stoppered bottles) and mark them as follows:
"MnSO₄ for D.O."
"ALK-KI for D.O."
"H₂SO₄ CONC."
Fill them about 3/4 full from the proper bottles, using due caution with...
the alkali-iodide-azide, and of course the sulfuric acid. It is recom-
mended that you do this on a sink drainboard.

It is also convenient to put the starch into a small eye dropper
bottle since you can add the starch readily with the eye dropper.

You now should have all of the chemical reagents ready to use. You
are ready to resume where you left off on Tape 1.

THIS CONCLUDES TOPIC 2.

PLEASE REWIND THE TAPE.

THEN RETURN TO TAPE 1.
TOPIC NO. 3: LABORATORY PROCEDURE

Objective: To measure D.O. in two samples of air-saturated water and to check results within 0.2 mg/l of the correct value.

Introduction: You should be set up with tape playback and slide viewer in your laboratory. Also, you should have the reagents, properly mixed and standardized, to measure D.O. in a sample of water.

For our purposes in this module, the sample could come from any source, including the water tap in your laboratory, or your plant effluent, or the receiving stream, for example. However, it would be nice if we could pick a sample whose dissolved oxygen concentration we already know so that when you have finished the test you can check to see whether your answer is reasonably close to the correct one.

One of the easiest methods for obtaining a "known" sample is to aerate distilled water, or tap water, long enough to insure that it is saturated with oxygen. If you look on pages 480 and 481 in the 13th edition of "Standard Methods" you will see a table showing the solubility of oxygen in water exposed to water-saturated air. Because of using distilled water or tap water you will have a very low chloride concentration and the only columns in this table which will be of interest are the left two on page 480 and left two in page 481. Of course the higher chloride concentrations encountered in estuaries or oceans would require use of other columns in the table, which correct for that factor.

The extreme left column on each page lists temperatures of water in degrees Centigrade from 0 to 50°C. The next column lists the dissolved oxygen concentrations in water, at saturation, corresponding to temperatures in the left column.

Thus, if we take a sample of water containing little or no chloride, aerate it for a long time by bubbling air through it or by shaking, and measure its temperature, we should find an oxygen concentration corresponding to the one in the Table for that temperature.

SLIDE 17

This slide shows page 480 in "Standard Methods." With a red pencil we have indicated the two left columns in which we are interested. Opposite 10°C in the left column we find a dissolved oxygen concentration in air saturated water of 11.3 mg/l, as indicated by the red mark around those figures in the slide. Opposite 20°C, the saturation value is shown to be 9.2 mg/l D.O., as shown by the darker mark.

Now just to check yourself, you might determine what the dissolved oxygen concentration would be in air saturated water at 25°C. Turn off the tape recorder long enough to obtain that value from the table and then turn the machine back on to see whether you were correct.
Of course, you should have obtained a concentration of 8.4 mg/l opposite 25° C, right at the bottom of the Table on page 480.

**SLIDE 18**

Slide 18 shows page 481 in the 13th Edition of "Standard Methods," which is a continuation of the Table on page 480.

As another check, you can determine what the dissolved oxygen concentration would be in air saturated water at 35° C. Turn off the tape recorder until you obtain this value and then turn it back on for the correct answer.

I am sure that you found the correct value of 7.1 mg/l directly opposite 35° C in Slide 18.

Turn off the slide viewer.

Of course, we don't usually aerate samples on which we plan to measure D.O. - in fact, we are always very careful to avoid aeration, because that would change the sample D.O.

However, in this practice exercise we need a sample of "known" D.O. to help you check your answer when you have finished. Therefore, we are going to suggest that you run your D.O. test on distilled water or tap water which you have aerated enough to reach saturation and to measure the temperature of that water. Then you should be able to check the D.O. which you find in your measurement against that in the Table within 0.2 mg/l, or less.

First collect enough distilled or tap water to more than fill two BOD bottles. This means that you will need about 700 ml of water in a clean one liter beaker. The simplest way to aerate would be to use laboratory compressed air, if you have it, or a small air pump to bubble air through the water for 10-15 minutes at a brisk rate. If you have a diffuser stone, similar to those used in aquariums, it could help improve the efficiency of aeration. Remember that you cannot over-aerate the water. The more you aerate it the closer you will approach true saturation - so, if in doubt, aerate longer.

If you do not have laboratory compressed air or a small air pump, you should be able to saturate the water by pouring it back and forth between two one liter beakers or, perhaps, shaking it in a jar for several minutes. If you shake it enough, you will approach saturation reasonably close. Later you will be able to check this by measuring the D.O. after different periods of shaking. When you have shaken long enough to reach saturation, the D.O. will no longer change with further agitation.
In either event, you now have about 700 ml of water saturated with air. The next step is to measure its temperature accurately. This should be done with a laboratory grade thermometer, most of which are graduated in degrees Centigrade (°C). If you happen to have an accurate thermometer graduated in Fahrenheit (°F) this should be satisfactory and you will find a table in the booklet under Topic No. 3, on page 8, which allows you to convert °F to °C. Of course, after that you can enter the Table on pages 480 and 481 to find the saturation D.O.

Please turn on the slide viewer and move to Slide No. 19.

SLIDE 19

Fill both 300 ml BOD bottles with the aerated water. Allow a few minutes for all of the bubbles to escape from the bottle.

SLIDE 20

If the bubbles tend to stick to the inside near the neck, then tap the bottle lightly near its neck with the stopper. Most of the bubbles then will move upward and escape through the surface of the liquid. When you place the stopper into the bottle there should be no air bubbles visible anywhere in the liquid.

Stopper both bottles.

You now have two stoppered BOD bottles containing water whose dissolved oxygen concentration you can determine. Entering the Table on pages 480 and 481 with temperature of the water, which you have measured already, you should be able to determine the D.O. in the two bottles.

Incidentally, you should keep the seal on the two bottles full of water to insure that no air escapes or enters through the stopper while you are getting ready to run the D.O.

SLIDE 21

This shows the chemical reagents, the magnetic mixer and buret. It might be handy to arrange the chemicals in the order in which they will be used and to locate them where any dripping which might occur will do no harm in your laboratory.

Of course, you should recognize that any drips which occur on laboratory benches later might be picked up by you if you lean against the benches. This can have a pretty bad effect on your wardrobe, especially when dealing with chemicals as strong as concentrated sulfuric acid. So, a word to the wise is sufficient – good organization and reasonable care in handling chemicals can prevent creating a pretty objectionable laboratory situation.
Incidentally, note that the reagent bottles are clearly labeled. Also, there is a separate pipet with each bottle. You should not use the same pipet for the three reagents because that could cause cross contamination by transferring a little of the reagent clinging to the pipet from one bottle to the next.

As we have indicated earlier, we strongly urge that you use some type of pipet filler or automatic pipet. Because we feel that the automatic units are most practical and well worth the cost, we have used them in the slides. Obviously, from a chemical point of view these units are not necessary and the transfers of reagents can be made using any acceptable type of laboratory equipment.

SLIDE 22

Holding a finger over the stopper, to avoid its dropping from the bottle, pour water out of the seal on top to avoid contaminating liquid in the bottle when the stopper is removed.

SLIDE 23

Place the BOD bottle on the drainboard near the reagent bottles. Incidentally a wet towel under the BOD bottle might be helpful in case an occasional drop of reagent misses during transfer. Of course, the bottle could be placed directly in the sink, but this usually is not very convenient because of height.

SLIDE 24

Empty the pipet, insert its tip below surface of the manganese sulfate solution and draw 2 ml of the reagent into the pipet.

SLIDE 25

Remove stopper of the BOD bottle and promptly insert the pipet containing manganese sulfate about one inch below surface of the water. Discharge the 2 ml of manganese sulfate solution into the BOD bottle. Replace the pipet in the manganese sulfate reagent bottle.

SLIDE 26

Moving immediately to the next reagent bottle, and using the second pipet, withdraw 2 ml of alkali-iodide-azide reagent and add to the BOD bottle.
SLIDE 27

Replace the pipet in the alkali-iodide-azide reagent bottle and replace the stopper in the BOD bottle.

You will note that a small amount of liquid has accumulated in the seal of the BOD bottle because you added 4 ml of reagent. This water may contain some of the reagents and it is desirable to avoid splashing it around the laboratory if possible.

SLIDE 28

Accordingly, it would be wise to dump this liquid into the sink, as shown here. Be sure to keep your finger firmly on the stopper of the bottle to avoid having it drop out into the sink.

SLIDE 29

Because some of the reagents may adhere to the bottle and drop off while it is being shaken, it also is a good idea to rinse the top of the bottle lightly with tap water, as shown in this slide.

SLIDE 30

Placing your finger firmly over the stopper of the bottle, shake it by turning it upside down and then right side up at least 15 times. You will note that a precipitate now has formed inside the bottle. In order for the determination to be conducted accurately, it is necessary to shake the bottle enough to insure that this precipitate actually comes into contact with all of the dissolved oxygen in the bottle. This is necessary because the oxygen reacts with the precipitate and if you do not shake the bottle thoroughly enough, the reactions will be incomplete and you will obtain the wrong value for D.O.

SLIDE 31

Place the bottle on the drainboard of the sink and allow it to settle until the precipitate has moved well below the middle of the bottle, as shown in this slide. Then shake it at least another 15 times to redistribute the precipitate and let it settle again.

The reason for this step is to provide further insurance that the precipitate actually contacts all of the dissolved oxygen in the bottle before proceeding with the determination. The reason for allowing the precipitate to settle below the middle of the bottle is that we want to insure that none of the precipitate escapes when we add the acid later.
We should point out that color of the precipitate is significant. If it is pure white, this indicates that little or no D.O. is present in the sample. With dissolved oxygen present, the sample takes on a yellow-brown tint and with higher D.O. you will observe a progressively darker color in the precipitate.

This is illustrated in this slide. The left bottle contains no D.O. and, moving to the right, the others have progressively higher D.O. After you have gained some experience, you will be able to tell by appearance that some of the samples may be discarded immediately because they contain too little dissolved oxygen to make it really worthwhile to proceed with the rest of the procedure.

After the precipitate has settled, using the third pipet withdraw 2 ml of concentrated sulfuric acid from the third reagent bottle and carefully add it to the BOD bottle. Replace the stopper in the BOD bottle, carefully dump the water seal into the sink and rinse briefly to remove traces of reagents. Then shake the bottle until the precipitate disappears. Again, it is important to mix thoroughly to insure that the reagents are uniformly distributed throughout the bottle.

If dissolved oxygen was present, the liquid should have a yellow-brown tint due to presence of iodine released from the chemical reagents. The amount of iodine released is proportional to the amount of oxygen which was present initially in the sample and darker colors indicate higher D.O. concentrations. The rest of the determination is based on measuring the amount of iodine present in the bottle.

More details about the chemistry of this determination can be found in pages 386-388 of the book by Sawyer and McCarty and in some of the references listed on page 488 of "Standard Methods."

Pour 203 ml of the solution from the BOD bottle into a graduated cylinder. Incidentally, the water level in this piece of glassware should be read in the center of the cylinder (the low point of the water surface).

As pointed out earlier, if many D.O. determinations are to be made you may want to prepare the special flask to speed up the process of measuring this 203 ml sample. The yellow plastic ring around the graduate is there to reduce the probability of breakage if it is turned over on the bench.
SLIDE 35

Pour the 203 ml of solution into a 250 ml Erlenmeyer flask for titration.

SLIDE 36

Close the stopcock at the bottom of the buret and carefully pour in 0.025 N sodium thiosulfate solution. The amount really is not important, but it's a good idea to put at least 10-15 ml into the buret.

Thoroughly flush any trapped air out of the stopcock and point of the buret by running several ml into a beaker. Discard this.

Refill the buret. It is not necessary to fill the unit to the "zero" mark, although sometimes this may be convenient.

SLIDE 37

Read and record the level of thiosulfate in the buret. The liquid level in the center of the buret tube is the one which should be recorded. As shown in Slide No. 37, the water surface tends to curve downward from the wall toward the center of the buret so you will be reading the lowest point on the water surface.

Some burets are designed to produce a different shape of image at the water surface to facilitate reading and to make it less likely that you might make an error.

SLIDE 38

After recording initial level of thiosulfate in the buret, start mixing the flask, using the magnetic unit or by hand, and open the stopcock gradually to add thiosulfate to the flask. This addition should be slow and cautious because it's very easy to overshoot the endpoint of the titration, which would mean that you would have to start over again with a new water sample.

As thiosulfate is added, the color in the flask will become lighter and lighter. Actually the endpoint of the titration would be reached when the sample becomes clear, but this is very difficult to judge because of the very pale color near the endpoint. For this reason, the titration is done in two steps.

The first step includes addition of thiosulfate until a pale yellow color has been reached, as shown in this slide.
During titration it will be necessary to mix the sample thoroughly to distribute the reagent throughout the water. As indicated earlier, the most convenient way to accomplish this is to insert a magnet into the flask and place it on a magnetic stirrer turning at medium speed.

If a magnetic stirrer is not available, it will be necessary to mix the flask contents by swirling, while holding it under the buret. This is a little more tedious and requires some practice because it is necessary to learn how to operate the buret stopcock with one hand while swirling the flask with the other. Using the manual procedure, it may be more convenient to use a slightly larger Erlenmeyer flask to facilitate the mixing.

After reaching a pale yellow color, starch is added to the flask to react with the small amount of iodine remaining in solution and produce a blue color. The amount of starch added is not critical and usually is about 1-2 ml.

The rest of the titration should be made drop by drop, insuring that each drop is thoroughly mixed before adding the next.

Just before the endpoint is reached the color of the solution will change rather quickly from dark blue to pale blue. The flask in the slide shows the color as it would appear one or two drops from the endpoint.

Addition of the last drop upon reaching the endpoint will produce a perfectly clear solution. Titration should stop precisely at this point.

The buret should be read to obtain the final level of thiosulfate.

The calculation of D.O. is very simple because the strength of the sodium thiosulfate solution was deliberately planned to make each milliliter of thiosulfate equivalent to 1.0 mg/l of D.O. in the original sample.

Accordingly, the D.O. is found by merely subtracting the initial buret reading from the final reading, to give the number of ml added to the flask. This difference is equal to the D.O. of the original sample in mg/l.
If you have executed the procedure correctly, you should have obtained a D.O. for your samples within 0.2 mg/l of the value in the Table corresponding to the temperature at which you aerated the sample. If the values for both of your bottles agree within that tolerance, then congratulations on a job well done!

SLIDE 43

If the values of D.O. which you obtained for the two bottles agree very closely with each other, this suggests that your laboratory measurement "technique" (reproducibility) may be reasonably good.

Agreement of the two (with each other) but failure to check with the value from the Table in "Standard Methods" might be attributed to one or more of the following reasons and you should investigate to find out which and correct the situation:

1. failure to aerate the sample long enough to reach saturation
2. incorrect measurement of temperature or inaccurate thermometer
3. incorrect strength of thiosulfate solution
4. failure to titrate to exact endpoint.

Now you may turn off the slide viewer.

If the two D.O. values which you obtained for your samples do not agree with each other within 0.2 mg/l it indicates faulty technique -- probably in the titration step. The most common errors include overshooting of the endpoint (addition of too much thiosulfate) and failure to have adequate mixing during addition of thiosulfate. The solution to these types of problems is practice to improve the precision with which you can titrate to the exact endpoint.

If you are not able to work out problems which you may be having with this procedure, we suggest that you contact the chemist at a nearby treatment plant for a fairly large city. Usually, you will find that they will be very glad to help a fellow worker!

THIS ENDS TAPE NO. 3.

PLEASE REWIND THE TAPE.