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Upgraded Diagnostic Operational Modeling Programs for Municipal Wastewater Treatment Plants and Troubleshooting Program for Activated Sludge - IBM Version

User's Manual

REVISED
DIAGNOSTIC OPERATIONAL
MODELING PROGRAMS
FOR
MUNICIPAL WASTEWATER
TREATMENT PLANTS
USER'S MANUAL

IBM VERSION

DISCLAIMER

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FOREWORD

The Diagnostic Operational Programs were first released in 1982. Since that time the programs have been used extensively by professionals throughout the wastewater treatment field to evaluate treatment plant design limitations and operational deficiencies. Comments and suggestions from program users have been actively solicited since 1982 to serve as a basis for further improvements to the original programs. Where possible, the programs have been updated and improved using information obtained from end users of the programs. In addition, further modifications have been made which increase the flexibility of the programs thereby simplifying program use. This User's Manual describes the operation and use of the newly released, updated diagnostic programs. It is important to read the manual through its entirety since many significant changes have been made to the original programs.

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CHAPTER 1

INTRODUCTION

In general, undesirable effluent quality from municipal wastewater treatment plants results from one of two general causes. The first is that treatment plants become overloaded or do not have adequate capacity in one or more unit processes to produce effluent of a desired quality. The second is that plants are not being operated properly. In this manual, the former will be referred to as a "process limitation" and the latter will be referred to as an "operational deficiency." Distinguishing between the two is not always easy. The Diagnostic Operational Modeling Programs are intended to provide a reliable and rapid means of identifying process limitations and operational deficiencies. Programs for the following eleven types of municipal wastewater treatment plants are available:

1. Primary treatment
2. Conventional activated sludge, with or without primary sedimentation
3. Single stage activated sludge for nitrification, with or without primary sedimentation
4. Extended aeration activated sludge with or without primary sedimentation
5. Extended aeration oxidation ditch with or without primary sedimentation
6. Contact stabilization, with or without primary sedimentation
7. Single stage trickling filter with primary sedimentation
8. Two stage trickling filter with primary sedimentation
9. Activated Bio-Filter, with or without primary sedimentation
10. Rotating biological contactors with primary sedimentation
11. Roughing filter followed by activated sludge

Each program allows for the option of selecting either anaerobic or aerobic sludge digestion analysis.

These programs have been prepared for use with the IBM PC/XT Compaq, AT&T or IBM compatible PC microcomputers. The eleven diagnostic programs have been prepared on a set of seven diskettes. Some of the diskettes are used for modeling only one type of wastewater treatment plant while others are used to perform diagnostic runs on various types of wastewater treatment plants. The specific wastewater treatment plant configurations available on each of the program diskettes are listed as follows:

DISKETTE NAME	TREATMENT PLANT TYPE
1. Roughing Filter	A. Activated Sludge with Roughing Filter
2. Activated Sludge without Primary Clarifiers	A. Conventional Activated Sludge
	B. Single-Stage with Nitrification
	C. Extended Aeration
	D. Oxidation Ditch
3. Contact Stabilization	A. Contact Stabilization with Primary Clarifiers
	B. Contact Stabilization without Primary Clarifiers
4. Trickling Filter	A. Single-Stage Trickling Filter
	B. Two-Stage Trickling Filter
5. RBC and Separate Primary Treatment	A. Rotating Biological Contactor
	B. Primary Treatment Only
6. Activated Sludge with Primary Clarifiers	A. Conventional Activated Sludge
	B. Single-Stage with Nitrification
	C. Extended Aeration
	D. Oxidation Ditch
7. Activated Biological Filter (ABF)	A. ABF with Primary Clarifiers
	B. ABF without Primary Clarifiers

The subsequent three chapters of this manual describe how to use the Diagnostic Operational Modeling Programs. Chapter 5 discusses two new programs to analyze activated sludge systems and digestion systems using actual plant data. They are intended to augment the above diagnostic models by providing additional information to troubleshoot problems in the field.

Chapter 2 describes the physical set-up of the computer system and presents several important "do's and don'ts" intended to prevent the user from damaging the computer or the diskettes.

Chapter 3 contains a step-by-step description of how to run the programs and obtain numerical output. This chapter also contains several important recommendations and warnings about storing and using the diskettes.

Chapter 4 presents guidelines for interpreting the program output and a discussion of the limits of accuracy of the programs as well as theory and equations pertaining to algorithm derivation and interpretation.

Before using the Diagnostic Operation Modeling programs for the first time, it is recommended that the user read through the first three chapters of this manual, as well as appendices which are referenced in those chapters.

Note: Before using the PC computer for the first time, it is strongly recommended that the user read the users manuals for the computer, printer, disk drives, and monitor provided by the manufacturers.

Taking the time to read these other manuals will greatly reduce the chance of accidental damage or misuse of this equipment. It will also save a great deal of time in the long run, and make using the computer more enjoyable.

1.1 Limitations

In general, a maximum of ten individual treatment units per type of unit process is allowed (i.e., ten primary clarifiers, ten aeration basins, ten RBC's per RBC train, etc.). If a plant has more than ten of any type of treatment unit, the plant can still be accurately modeled by using, for example, half the flow with half the actual number of units. To do this, all the units would have to be of the same size and configuration. If not, the user must exercise his own judgment in deciding whether or not he can approximate the actual plant configuration in some way which results in less than ten units for each unit process.

The programs may not produce accurate results for small plants such as package plants, due to rounding of numbers by the computer. If erroneous results occur then multiply the appropriate values by a factor of ten. These values are: average flow, peak flow, primary clarifier area, reactor volume, filter volume or RBC surface area and final clarifier surface area, as appropriate. Do not increase the clarifier depths or MLSS concentrations. If the plant being analyzed is a package plant with non-conventional clarifiers with low surface loadings (<250 gpdpsf) then the effluent BOD and TSS predictions may be substantially lower than actual capability because the programs assume conventional clarifiers at 50% plug flow.

1.2 Availability of Programs

Additional copies of the Users Manual and programs are available from I.R.I.S. Also the programs are available on a 3½ inch double sided, quad density disk. For further information write to:

Instruction Resources Information Systems
Ohio State University
1200 Chambers Road
Columbus, Ohio 43212
Attn: Dr. Robert Howe
Telephone: (614) 422-6717

CHAPTER 2

USING THE COMPUTER

This chapter presents a non-technical discussion of how to prepare the IBM compatible computer for use with the Diagnostic Operational Modeling Programs. It is based on the combined experience of the individuals who developed the program formats specifically to be used on this computer system, and is meant to be as simple and foolproof as possible. We recommend that users follow the procedures in this chapter carefully until they are thoroughly familiar with the programs, as well as the capabilities and limitations of the computer itself, before attempting to modify these procedures in any way.

> Note: This chapter is not a substitute for manufacturers' manuals provided with the computer hardware. Those manuals must be read carefully before following any instructions in this manual.

2.1 Computer System Components

The program formats were developed using the following standard components:

1. Computer -- IBM compatible with a minimum 256K random access memory (RAM).

2. Disk Drives -- One or two disk drives with a controller card. Also a hard disk may be used.

3. CRT -- Various manufacturers.

4. Dot Matrix Printer -- Epson or compatible, using a parallel or serial port.

5. Diskettes -- 5¼ inch diameter, various manufacturers, double side double density.

The first step in running the programs is to set up the computer in a suitable work area. A table or desk at least two feet wide and four feet long will be required to hold the computer without crowding. Additional work space, particularly an "L" shaped arrangement, is very helpful. The computer, printer and CRT each require a 110 volt power supply. Power cords should be kept out of the way to avoid accidental unplugging of the equipment. Set the computer in the center of the work space. The CRT can either be placed directly on top of the computer or directly behind it, unless it is built into the computer.

After reading the manufacturers instructions carefully, plug the printer and the CRT into the computer. Make sure that the main power switches on the computer, printer and CRT are turned off, and then plug these units into the power source.

Note: Do not turn on the power to any of these units yet.

2.2 Computer

The computer is the heart of the system. The keyboard provides the user with a means of entering data and commands for the computer to act on. Commands given internally by the computer activate the printer and disk drive(s) while the Diagnostic Operational Modeling Programs are being run.

It is very important that the computer (and all other system components) and the area around them be kept clean and dry. Use a dry or lightly moistened dust cloth for cleaning. Avoid using too much water. Do not use any cleaners whatsoever. Never put open beverage containers, flower vases, etc., on the table where the computer is kept, or on overhead shelves near the computer. Excessive moisture can severely damage or destroy the computer.

Note: The computer, when in operation, will cause electrical interference to some instruments and most radio and television receivers.

2.3 Floppy Disk Drives

A minimum of one disk drive is needed to store and read the diagnostic programs and data. However, two double sided double density disk drives are recommended due to the limited amount of storage space available when only using a single disk drive. Drive A (i.e., the primary drive) is used to read in the Diagnostic Operational Modeling Programs. This drive is also used to permanently store individual treatment plant data files when only using one disk drive. If your system has two drives, individual treatment plant data files can be stored on Drive B. This will be discussed in more detail in Chapter 3.

When in use, each drive holds only one diskette. To insert a diskette into the drive, first open the door on the front of the drive. It will flip up or swivel and allow access to the horizontal slot in the front of the drive. Diskettes are stored in protective paper packets. Remove the diskette from the packet by holding it so the label is on top and in the lower right corner as you look down at it. Put your right thumb over the label, and gently remove the diskette from the packet, and insert it into the drive without turning it so that the label remains on top and in the lower right corner as you look down at the drive. If you have vertically mounted disk drives, then it may be necessary to rotate the disk counterclockwise to enable them to fit properly. Close the drive door by pushing down on the plastic flap or rotate until it flips back down.

Note: Never let anything touch the brown or grey surface of the diskette. Handle the diskette by the plastic cover only. Always keep diskettes in the paper packet when they are not in use.

Note: Never turn the computer on unless there is a diskette in appropriate Drive or unless you have a hard disk. It is not necessary to have one in a Drive.

To remove a diskette, simply open the drive door by pushing in on the top of the flap or swiveling the lever. Carefully pull the diskette out of the drive, and put it back in the paper packet.

Note: Always check the red "in use" light on the drive before removing diskettes. Never remove a diskette while the "in use" light is on. This can destroy the information on the diskette.

Note: Don't leave diskettes in the drives overnight.

Note: The disk drives require cleaning periodically to remove dirt and magnetic particles from the read/write head. Cleaning kits with instructions are available from most computer stores.

2.4 CRT

Many CRT's are available from various manufacturers for use with IBM compatible computers. They vary widely in detail and in orientation of controls, so the user should become familiar with the one provided. Eyestrain is a common symptom of heavy computer use, so take some time to place the CRT where it is easiest to look at for long periods of time. Changing contrast and brightness settings may be helpful if lighting conditions in the room change during the day.

Note: Many users have found that looking at the CRT for long periods of time under fluorescent lights gives them headaches. This is caused by the screen and lights flickering together very quickly. This problem can be minimized by changing to incandescent lighting or taking breaks at regular intervals.

2.5 Printer

The users manual prepared by the manufacturer contains all the information needed to use an Epson (or compatible) dot matrix printer properly. Therefore, normal operating instructions will not be repeated in this manual.

One addition to the normal instructions which previous program users have found handy is to place a standard office-type "in-out" basket behind the printer to receive the output. Paper going into the printer should run underneath the basket. When properly arranged, the output will fold itself neatly in the top part of the basket and prevent output from being fed back into the printer, which jams the machine. This allows the user to devote attention to other matters while a run is being printed.

2.6 Diskettes

Diskettes are very similar to cassette tapes except in physical ways. Therefore, you must use the same precautions to keep them from being damaged. These include the following:

1. Never put a diskette in a hot area such as in the sunlight area of a window or near an oven, heater, electrical panel or lamp.
2. Keep the diskettes away from magnetic fields at all times. This includes: motors, instruments, magnets, metal cabinets, electrical cords, etc.
3. Store the diskettes in a cool dry place. Moisture can cause fatal damage to the surface area of the diskette. Diskettes should be stored vertically in a closed container. Special storage containers are available from most computer stores.

Since the diskettes can be damaged very easily and since it is nearly impossible to "repair" a damaged one, it is strongly recommended that each user station keep two complete sets of diskettes. One set should be a working set available for day-to-day use. The second set should be retained as a backup in case something happens to a working diskette. If a working diskette becomes damaged or is lost, the backup diskette should be used as the working diskette and another copy made to become the new backup diskette. The diskettes can be copied by using most any copy program including the disk copy program.

If you have a hard disk then you may desire to download (or copy) the diskettes onto the hard disk. You must transfer each diskette into its own subdirectory. Warning: The programs will not work properly on a hard disk unless they are copied into separate subdirectories. The procedure to download to the hard disk is:

1. Place one of the program disks in Drive A. Type in: A: <Return>.

2. Type in: MKDIR <Name> <Return>. The <Name> is the name of the subdirectory that the program will be transferred to, e.g., MKDIR RBC, would be a proper way of doing this. The MKDIR is the "make subdirectory" command. You must use only letters and no more than eight for the name.

3. Type in: Copy *.* C:\ <Name> <Return>. Use the same <Name> as Step 2.

4. Repeat steps 1 through 3 for each process you wish to download. Remember to use different <name>s each time.

5. When running, you will need to go into the subdirectory of the process you wish to run. Type in: CD <Name> <Return>. Use the proper subdirectory <Name>.

6. Follow the running instruction in Section 3.1, omitting Step 4.

7. When you have finished you will want to return to the main directory. Type in: CD \ <Return>.

2.7 Quad or High Density Disk Drives

When using an IBM AT compatible with high density drives you can use the exact procedures as for the hard disk, when downloading the programs. It is highly recommended that you download the programs. In Step 3 specify the high density Drive A or B by replacing the C: in the typed in line with A: or B:, whichever is proper. Be sure to format the blank high density disk before downloading.

2.8 Computer Compatibility

The diagnostic programs have been tested on the following computers for compatibility.

1. IBM PC
2. IBM XT
3. IBM AT (recommended to transfer to quad density disks)
4. AT&T
5. Panasonic Portable
6. HP Vectra
7. ITT
8. Toshiba Portable (3½" Format)

CHAPTER 3

RUNNING THE PROGRAMS

This chapter contains instructions on how to run the Diagnostic Operational Modeling Programs. These programs are conversational in nature, which means that the computer will ask the user a series of questions before the computations start. The answers to these questions will guide the computer in its work. The emphasis of this chapter is to explain to the user how each of these questions affects the computations so that users can obtain output best suited to their needs.

The question and answer format of each program is intended to be easy to follow. The majority of the questions asked refer either to the physical configuration of the plant to be modeled or to the wastewater characteristics to be used in the run, and are self-explanatory. For this reason, not all of the questions the user will need to answer are specifically addressed in this manual. The user should understand that incorrect answers will not hurt the programs in any way but will affect the output.

Before proceeding, the user is advised to prepare data sheets with the wastewater characteristics and plant configuration to be used in the run. Forms which indicate the necessary information are contained in Appendices B and C of this manual. In addition, the printer must be used with the LPT1 output port.

As previously mentioned, the programs can be run from either a one or two disk drive system. If you have only one drive, you will be limited to the number of treatment plant files that you can store on the disk unless a hard disk is used. If you have two drives, you will need a formatted disk in drive two in order to save plant data files. To format a data disk, see your disk operating system reference manual under the disk, see your disk operating system reference manual under the section of formatting a disk. You can use as many of these "DRIVE B" disks as you need, thus as they fill up, you can switch to another empty (formatted) disk to add more files.

3.1 Beginning the Run

The last steps the user should perform before the first run are the following:

1. Load paper into the printer. Advance the paper so that a horizontal perforated line is about ½ inch above the top of the print head.

2. Turn on the power to the computer, CRT and printer. <u>You must have a DOS disk or operating system in the boot up Drive A or DOS must be installed on the hard disk</u>. The DOS is not provided because of copyrights and incompatibility problems.

3. Put the desired main program disk in Drive A.

4. Type in: INPUT, and hit the return key.

5. Make sure the "Caps Lock" key is on.

The program will now ask you to enter the drive that you are using to place the data on. If using two drives enter B otherwise enter A. If you are using a hard disk use C.

3.2 Selecting the Desired Treatment Plant Type

You should now see a menu listing the types of treatment plants available for analysis. Enter the number which corresponds to the desired treatment plant type. Note: If you do not see your desired selection, quit the program and start over from the beginning with the correct program disk or correct subdirectory.

3.3 Using the Function Menu

The function menu is displayed after the desired treatment plant type is selected. The function menu has several useful options that will be explained below individually. Each option allows you to perform different operations such as editing, running and entering plant files.

OPTION NO. 1: INPUT A NEW PLANT

This function is the first one that will be used when you initially run your desired program. Before selecting this function be sure you have all the proper information on the plant readily available for entry. The following sections describe in detail how to answer the questions that are asked within the input function:

General Questions

The first questions that must be answered deal specifically with plant influent characteristics.

Entering the wastewater characteristics needed to run the Diagnostic Operational Modeling Programs is quite easy. There are usually only 13 questions that are asked and some of them don't have to be answered. Some of the questions will have default values assigned to them if there is no data available. These variables, and their default values, are as follows:

% Volatile	80%
TKN	30 mg/l
Alkalinity	100 mg/l
pH	7.0 S.U.
PO_4-P	8 mg/l

A realistic value must be assigned to all other wastewater characteristics for the computer to be able to complete the run.

Note: The computer considers a range of flows beginning at 75 percent of the number entered as "AVERAGE DRY WEATHER FLOW," which is the first question asked in this section. This number can therefore be set to achieve a desired minimum flow in the printout. Any deviation from actual conditions will, to a certain degree, affect the accuracy of the model's output at flows less than the actual average flow.

Note: The computer considers a range of flows ending at 130 percent of the number entered as "DESIGN FLOW," which is the third question asked in this section. This number can also be set to achieve a desired maximum flow in the printout. This will also, to a certain degree, cause some deviation from actual expected conditions.

All wastewater values should be entered as accurately as possible to ensure that the mathematical portions of the Diagnostic Operational Modeling Programs have realistic numbers to work with. If they don't, the output will have little value.

The following parameters must be entered after completing influent wastewater characteristics. The format used to describe each required input parameter is as follows:

"Question": (Range of Answer) "Explanation of Question."

Plant title name: (up to 40 characters) this will be the plant name that will appear at the top of each page of output.

State of: (up to 10 characters).

Design average flow (MGD): (greater than zero).

Comments: (up to 70 characters) this will be printed at the bottom of the title page.

Treatment Plant Configuration

This section describes input questions for plant unit processes. Most treatment plant configurations are listed. Therefore, the actual input parameters required will be dependent upon the particular program in use. Note: Questions that require letters for answers need to be inputted with only uppercase letters.

All questions are to be completed with values that are taken from the actual plant configuration. For example, when you are asked for a round clarifier and the plant has only rectangular ones (or vice versa), then type in a zero for the type that you don't have.

CLARIFIER QUESTIONS

Number of round (primary or secondary) clarifiers: (0-10) do not exceed 10.

Diameter (ft) : (greater than 1)
Depth (ft) : (greater than 1)
Weir length (ft): (greater than 1)

REACTOR QUESTIONS

Number of oxidation ditches	:	(less than 10)
Volume (gal)	:	(greater than 1)
Number of round reactors	:	(less than 10)
Diameter (ft)	:	(greater than 1)
Depth (ft)	:	(greater than 1)
Number of rectangular reactors	:	(less than 10)
Length (ft)	:	(greater than 1)
Width (ft)	:	(greater than 1)
Depth (ft)	:	(greater than 1)

REAERATION TANKS

Number of round reaeration tanks	:	(up to 10)
Volume (MG)	:	(greater than zero)
Number of rectangular reaeration tanks	:	(up to 10)
Length (ft)	:	(greater than zero)
Width (ft)	:	(greater than zero)
Depth (ft)	:	(greater than zero)

CONTACT TANKS

Number of round contact tanks	:	(up to 10)
Volume (MG)	:	(greater than zero)
Number of rectangular contact tanks	:	(up to 10)

Length (ft) : (greater than zero)
Width (ft) : (greater than zero)
Depth (ft) : (greater than zero)

TRICKLING FILTERS

Primary or Secondary filter(s) or ABF towers

Media type :

Rock	=	RK	(redwood for ABF towers)
Stacked plastic	=	SP	
Packed plastic	=	PP	

Enter a two letter code : (any of the above 2 letter codes)

Constant flow / Constant recirculation rate / Percent flow (CF/CR/Pf): (any of these 2 letter codes)

Number of filters : (up to 10)

Filter diameter (ft) : (greater than zero)
Filter depth (ft) : (greater than zero)

One of these will appear :

Constant flow (gpm) : (greater than zero)
Recirculation rate (gpm) : (greater than zero)
Percent of influent over filter (%) : (greater than zero)

ABF TOWERS ONLY

Round or Rectangular (RO/RE) : (select a 2 letter code)

Number of towers : (up to 10)
Tower length (ft) : (greater than zero)
Tower width (ft) : (greater than zero)
Tower depth (ft) : (greater than zero)
Flow rate (gpm) : (greater than zero) or recirculation rate (gpm): (greater than zero)

SLUDGE DIGESTION QUESTIONS

Type anaerobic or aerobic : (AN/AE) type in only one of these two letter codes

Sludge thickening : (Y/N)
If you said "Y" for yes, then type : (up to 40 characters)

AEROBIC QUESTIONS

Number of digesters	:	(up to 10)
Volume of each in gallons	:	(greater than zero)

ANAEROBIC QUESTIONS

Number of primary digesters	:	(less than 10)
Volume (gal)	:	(greater than 1)
Digester heated (Y/N)	:	(Y/N)
Digester mixed (Y/N)	:	(Y/N)
Number of secondary digesters	:	(less than 10)
Volume for digester #(x)	:	(greater than 1)

Note: If you have ten units or more, then you can get reasonable results by combining the total volume of all units and entering it as one large unit.

The last question asks you for the name under which you wish to save the plant's data. You can use up to 8 characters but do not use any special characters such as colons, commas or spaces. This will be the data's file name.

After you have finished with these questions then you can proceed to either the RECALL/EDIT option or the RUN MATHEMATICAL MODEL option. You may choose the edit option if you typed in a bad entry or you may wish to change a certain parameter without retyping in the entire plant.

OPTION #2: RECALL/EDIT A NEW PLANT

This section will allow you to change the previously entered data from Option #1 with very little effort.

You will be asked first for the plant name to be used. This would be the name that you typed in when you entered the plant. If you can not remember the name, then hit the return key. The program will list the directory of the disk with the data files.

After you have typed in the proper name, the program will display the EDIT MENU. If the menu isn't on the screen, then either you need to check the disk drive for a possible problem or you typed in a plant name that is not on the disk. If this occurs, and the program halts type in: input <return>, and you can start the program over.

THE EDIT MENU

The edit menu has several options that allows you to edit data within certain sections of the input routine. For example, if you had to change the size of a reactor, you would type the option number that corresponds to the reactors on the menu. Then you would be asked the reactor questions which are exactly as they appeared when you first entered the plant. After you have selected one of the options and reentered the data, you will be returned to the EDIT MENU again. <u>When you finish editing the plant, then choose the option number that says "SAVE."</u> This option will save the new data back onto the disk. The program will ask you for the file name that you want to save these new changes under. If you choose the same name as you typed in to recall the data, then the program will purge (replace) the old data with the new. If you choose a new plant name, then the program will save the changed data in a separate file, but still keep the original data file intact. Use this procedure if you wish to retain the old plant data.

After you have typed in the plant name to save the data, you can choose the option that says "RETURN TO MAIN MENU" which will return you to the function menu. It will make sure that you have stored your changes. If you do not like the changes you have made, you can either change them again or return to the main menu without saving the changes.

OPTION #3: RUN MATHEMATICAL MODEL

This option runs the diagnostic calculations. After you choose number three, the program will load from the disk the routines needed to generate the calculations.

The program will ask you for the drive that the data is stored on (for verification). Then it will ask you for the plant name to be used. This would be the name under which you stored the plant's data. If you do not remember the name, then hit the return key. The program will list the disk's directory so that you can see the names of the files.

The program will ask for a new number. This can be any number you wish, it is only printed on the title page of the output and has no meaning in the calculations. It is only used as a reference to distinguish between different runs.

The program will now load in the plant's data file and run the mathematical model.

OPTION #4: RETURN TO MAIN MENU

This option does exactly what it says...it returns you back to the main menu. <u>Be sure that you save the corrections first, otherwise they will be lost and you will have to retype the corrections</u>.

3.4 Deleting Files

To delete the unwanted files from a disk follow these directions:

1. First, exit from any program you are running.
2. Place the disk from which you want to delete the files in Drive A, or C if using a hard disk. Type in A:<Return> or C:<Return>.
3. Type in: DIR
4. Hit the return key.
5. Find the exact name of the file that you want to delete.
6. Perform the following:
   - Type in: DEL
   - Hit the space bar, and then type in the file name
   - Type in .DAT immediately after the file name
7. Hit the return key.

You can repeat these instructions if you wish for other files.

The directory displays more information on a disk than just the file name. An example of just one file would look like this:

EXAMPLE ␣␣␣ DAT ␣␣␣␣␣ 1265 8-25-61 5:00a

EXAMPLE is the name of the file, DAT is the extension. The number, e.g., 1265 is the number of bytes in the file which is followed by the date and time of its creation.

CHAPTER 4

APPLICATION AND THEORY

INTRODUCTION

This section describes some of the theory utilized in development of the programs. A better understanding of the programs will allow more meaningful application as well as better results through judicial use. The following sections will discuss all of the input and output parameters as to their meaning and derivation. Careful study of this section will help the user when analyzing a treatment system.

INPUTTING WASTEWATER CHARACTERIZATION DATA

First, it is assumed that the wastewater is typical domestic wastes or at least behaves as a domestic waste. It is also assumed that the wastewater is relatively fresh, characterized by a dissolved and un-ionized sulfide concentration of less than 2 mg/l.

If extensive long term data is available then it is recommended that this data is carefully examined for seasonal variation. If seasonal variations are apparent then the system model should be evaluated by season and not annual averages. Examples of significant and common variations are temperature and organic or BOD loading. A real and typical case of this type of variation involved a mountain community with several ski resorts. Annual average data indicated that the plant would produce an acceptable effluent. During the winter months the temperature was less than 10°C and the BOD averaged 310 mg/l, whereas in the summer months the temperature was 20°C and the BOD was only 150 mg/l. The plant would not function during the winter due to low temperatures of the activated sludge and high organic loadings. Further, during the spring, hydraulic flows increased substantially during snow melt. The plant accordingly was modeled for winter conditions, spring break-up and summer conditions. The predicted results closely matched the actual performance and of course the results indicated the need for expansion and modification during the winter and ski season.

The following is an explanation of the wastewater characterization data and sensitivities involved with each parameter.

AVERAGE DRY WEATHER FLOW, MGD

This means the average daily flow for the plant for a specific period. Care should be taken to eliminate abnormal conditions such as storm flows that occur infrequently. The average daily flow is used in calculating organic and solids loadings as well as determining hydraulic residence time, surface loadings and weir loadings. It is an important parameter.

PEAK DAILY DRY WEATHER FLOW, MGD

Peak Dry Weather Flow is the average daily peak flow that occurs for a four to six hour duration during the day. It is used in determining the peak flow factor for all flow regimes on the printout. As an example, if the average dry weather flow was 1.5 mgd and the peak dry weather flow was 3.00 mgd, the peak flow factor would be 2.0. This factor is used when computing the performance of the final clarifiers in all systems. It is a very important parameter.

DESIGN FLOW MGD

Design flow is exactly as stated which is the intended design capacity of the plant. Both the average and design flow can be skewed or adjusted to increase the sensitivity of the diagnostic models. This will be explained in a later section.

INFLUENT BOD, MG/1

This value is the average BOD that the system sees over a given period of time. The model assumes that this value will increase by about ten percent due to recycle flow. For most accurate results the standard deviation should be less than 15% of the mean or inputted value. This is an important parameter.

INFLUENT TSS, MG/1

This is the average value of the total suspended solids (filtered residue). The same concepts and concerns for BOD values mentioned above apply to the TSS values.

INFLUENT VSS, %

This is the average percent volatile solids determined by laboratory analysis. It is a significant parameter when evaluating activated sludge (suspended growth) systems. And a low volatile content or high inorganic content will influence the maximum mixed liquor capacity in a suspended growth system. It is not sensitive in fixed film systems such as with trickling filter and rotating biological contractors. In both cases it does influence sludge production because the non-volatile or inert flux to the system for the most part becomes a part of the sludge production. The volatile content varies geographically. Unfortunately this determination is not always made by operators therefore a default value of 80% is used if data is not available. Volatile content will vary from 65% to 90%. This parameter is not as important as others previously mentioned.

TEMPERATURE °C

This is the average value of the wastewater temperature during the examination period. It is an extremely important value and the standard deviation should be less than 20% of the mean value. Temperature is used in determining the optimum compaction in primary sludge, and for determining kinetic rates in suspended and fixed film systems. This is a very important parameter.

TKN, MG/1

This is the average total Kjeldahl nitrogen in the influent which is the total nitrogen in the trinegative state. It includes organic and ammonia nitrogen. Some treatment plants determine only the ammonical nitrogen. If this is the case for the plant that you are examining, then use that value. Unfortunately many plants do not determine influent nitrogen species at all. If this occurs then a default value is built into the computer system. This is not an important parameter in any of the models. All of the diagnostic models assume that there are adequate quantities of nitrogen to satisfy the nutrient requirement for good biological growth. If the nitrogen values are known in activated sludge systems then the model will predict the species and quantity. A negative value will indicate a nutrient deficiency.

ALKALINITY, MG/1

Alkalinity is not an important input parameter and is no longer used in the diagnostic models. It was originally intended to be utilized in predicting pH depressions but found to be inaccurate.

pH, UNITS

pH is not an important input parameter. It is for reference purposes only.

PO_4-P, MG/1

This is an average value of the phosphate concentration expressed as phosphorus. It is not an important input parameter since all the models assume an adequate supply for nutrient requirements. Negative values predicted in activated sludge systems indicate a phosphorus deficiency in the wastewater.

PLANT CONFIGURATION AND DIMENSIONS

The first input values in this section are average design flow and peak wet weather flow. They are for reference purposes only and are for notation purposes when average and design flows in the above section are skewed by the model user.

The remaining input values for various unit processes are of course extremely important. They are the basis for predicting process performance. The one exception to this is the secondary digester volume which is for reference purposes only.

COMPUTER PRINTOUT FORMATS, GENERAL

All of the diagnostic programs print out twenty flow regimes based on values inputted in the wastewater characterization section. The first flow starts with 0.75 times the inputted average dry weather flow value and stops at 1.3 times the inputted design flow value. The program user can input any realistic values desired to increase the sensitivity or expand the flow regimes. As an example, if the user wished to increase the sensitivity of the diagnostic evaluation of a treatment plant that had an average daily flow of 1.00 mgd, the average and design flow could be inputted as 1 mgd and the printout would develop 20 predictions from 0.75 to 1.3 mgd. This is the reason for repeating the design average flow input under the plant configuration section. When examined at a later date and these two values don't match, then the user knows that the first values were probably skewed to develop more data within a desired flow regime. The left hand column of all sheets depict the plant flow as described above and will not be discussed again.

PRIMARY SYSTEM PERFORMANCE AND LOADINGS

Each heading on the printout will be discussed separately excepting the flow data which was previously discussed. Derivation of each value will be explained in detail or conceptually if too complex for the level of this text.

CLARIFIER SURFACE, GPDSF

The primary clarifier surface loading is computed in gallons per day per square foot. The total surface area is computed based on data inputted in the primary clarification section of the data input section. This is merely a calculated value and is used in predicting the BOD and TSS values of the primary clarifier effluent. High, low and normal values for surface loadings are depicted in Appendix E of this manual.

WEIR LOADING, GPD/FT

The primary clarifier weir loading expressed in gallons per day per foot is a calculated value based on the total weir length inputted in the primary clarifier input section. This value is not used in the performance prediction. Experience indicates that weir loading has little or no effect on primary clarifier performance when the surface loadings are adequate. There are of course exceptions to every rule, and the high, low and average values should be examined in Appendix E of this manual.

DETENTION TIME, HRS

This value is the calculated detention time at average flow conditions. This calculated value is not used in the primary clarifier performance prediction. Experience indicates that surface loading with adequate clarifier depth are the factors that significantly affect primary clarifier performance. Primary clarifiers should have an average depth of 8 feet or greater. Appendix E indicates high, low and average values for detention time.

PERCENT REMOVAL BOD, PERCENT REMOVAL TSS

These are predicted values based on surface loading. They are probably the most inaccurate predictions in the entire model system because they are based on correlation factors rather than sound scientific principles. Experience indicates that there are no sound scientific principles that can be strictly applied to gravity treatment of raw sewage. Indeed there are scientific principles that apply to discrete particles of specific densities, drag coefficient, size, density of fluid media, etc. However, in primary clarification of raw sewage one is dealing with a manifold of different particle sizes, density, etc. First attempts to correlate primary clarifier performance did not produce good results. Surface loading appeared to be the most promising. Systems that operated at temperatures of less than 20°C and described as "relatively fresh" seemed to have the best correlation. Examining this concept closer revealed some obvious facts. The more septic a sewage becomes the more putrefaction and liquefaction. The model assumes that a reasonably fresh sewage is being treated. An experienced operator can usually determine a septic sewage by its color. In secondary systems where the primary performance does not match the predicted performance within reasonable limits then the influent BOD and TSS values can be increased so the primary effluent closely matches the actual or measured values. Before this is done be sure that this approach is valid. Often plant staff will report grab samples collected during the day. These reported values will obviously be high compared to composite samples. In the simplest arithmetic terms the percent BOD removal is calculated using the following equation:

$$\% \text{ BOD removal} = \left[1 - \frac{(0.98)(SL)}{350 + SL}\right] X \ 100$$

Where:

SL equals the average surface loading in gallons per square foot per day.

The percent TSS removal is calculated using the following equation:

$$\% \text{ TSS removal} = 1 - \frac{(0.98)(SL)}{748 + SL} \ X \ 100$$

Where:

SL is the average surface loading in gallons per square foot per day.

If the user decides to increase or even decrease the influent values for BOD and TSS to achieve closer values to the verified clarifier performance this will change the predicted sludge production values.

PRIMARY CLARIFIER EFFLUENT BOD AND TSS, MG/1

Both of these values are calculated from the removal efficiency predictions described above. As an example, if the BOD and TSS removal efficiencies were 36% and 46% and the influent BOD and TSS concentrations were 210 mg/1 and 235 mg/1 respectively, the primary clarifier BOD concentration would be as follows:

$$(100 - 36)(210)(0.01) = 134.4 \text{ mg/1}$$

The primary clarifier effluent TSS concentration would be as follows:

$$(100 - 46)(235)(0.01) = 126.9 \text{ mg/1}$$

Note: Appendix G is a sample printout of a primary treatment plant diagnostic. At a flow of 6.05 the predicted removals are 36 and 46 percent for BOD and TSS, respectively. Note that the primary effluent BOD and TSS predictions in the Appendix vary slightly from the above calculations. This is due to different rounding procedures and any errors that occur in rounding are well within the limits of prediction accuracies.

PRIMARY SLUDGE PRODUCTION, LBS. TSS

This is a calculated value based on input and predicted values. Appendix G indicates a total sludge production of 5474 lbs. per day at a flow of 6.05 mgd. The sludge production is calculated as follows:

(MGD)(inf. TSS - Eff. TSS)(8.34) = lbs. of sludge produced per day, substituting the calculated and predicted values.

(6.05)(235-127)(8.34) = 5,450 lbs.

Note the slight difference of 24 lbs. which is not significant.

PRIMARY SLUDGE PRODUCTION, LBS. VSS

This is a calculated value based on input and predicted values. Appendix G denotes an influent TSS of 235 with a volatile content of 83%. It is assumed that volatile content is the same for primary clarifier influent and primary clarifier effluent. Analysis of primary systems indicates that this value does differ slightly, however, the difference is normally not significant. The lbs. VSS is calculated as follows:

(% Volatile)(0.01)(lbs. TSS) = lbs. volatile solids substituting the values in Appendix G.

(83)(0.01)(5474) = 4,543.4 lbs. volatile solids

Again note the slight difference in the total pounds due to rounding. This value is significant when performing a digester analysis.

PRIMARY SLUDGE PRODUCTION, % SOLIDS

This is a predicted maximum value based on temperature. Some treatment facilities have gravity thickeners where primary sludge is thickened prior to pumping to digestion or dewatering. In the above case the predicted value would not apply because the operational intent would be to pump a relatively thin sludge from the primary clarifiers to the thickener. Further, often the piping configuration and the type of sludge pumps will not allow thick sludge to be pumped from the primary clarifier.

This value is the maximum achievable concentration under idealized conditions. It also assumes that the raw sewage is relatively fresh and not septic.

Experience indicates that maximum primary sludge concentrations are affected by temperature. In extremely cold climates the rate of biological activity is substantially reduced therefore sludge can be retained in a primary clarifier for longer periods of time and consequently greater concentrations can be achieved. As the temperature increases the rate of biological activity increases, therefore, putrefaction and subsequent liquefaction occurs more rapidly resulting in lower concentrations of primary sludge. The primary sludge concentration is, therefore, predicted as a function of influent temperature. The equation is as follows:

$$\text{Sludge Concentration \%} = \left[\frac{1}{1.042^{(20-t)}}\right] 6.20$$

Appendix G indicates a temperature of 22°C therefore substituting this value:

$$\text{\% Conc.} = \left[\frac{1}{1.042^{(20-22)}}\right] 6.2 = 5.71\%$$

The program limits the maximum concentration to 8.5% even though higher concentrations at low temperatures have been observed and consistently achieved. This is the exception rather than the rule.

PRIMARY SLUDGE PRODUCTION, GPD

This is a calculated value of gallons of sludge to be pumped from the primary clarifier each day based on predicted and input values. The calculation is as follows:

(lbs. TSS)(0.01)/(%SOL)(8.34) = GPD primary sludge

Substituting calculated and predicted values from Appendix G at a flow of 6.05 mgd

(5474)(100.0)/(5.71)(8.34) = 11,494.8 lbs. or 11,495 lbs. of primary sludge.

MASS BALANCE

In wastewater treatment, matter is neither created or destroyed, therefore, each unit process in a wastewater plant should balance to a reasonable degree. A primary clarification system is not an exception. Using the data in Appendix G the influent TSS is calculated in pounds per day at a flow of 6.05 mgd. This calculation is as follows:

(Flow, mgd)(Inf. TSS)(8.34) = Total lbs/day

Substituting the values

(6.05)(235)(8.34) = 11,857.4 lbs. per day

Using the same equation, the lbs. of TSS in the primary clarifier effluent is calculated by substituting the influent TSS with the predicted primary clarifier effluent TSS.

(6.05)(127)(8.34) = 6,408 lbs. TSS in effluent

Note on Appendix G that the predicted sludge production is 5474 lbs. per day.

The lbs. of sludge produced is added to the lbs. of TSS in the primary clarifier effluent

(5474 lbs. sludge) + (6408 lbs. TSS in eff.) =

11,882 lbs. total which should equal the lbs. TSS in the influent which is 11,857. They match within three significant figures or within 25 lbs. When evaluating actual plant data the same approach should be used. A well operated plant with good data should balance within 20 to 25 percent. It is rare that a system will balance perfectly due to inaccuracies in flow measurement, sampling and analysis. Also when a significant amount of recycle is involved this should be included with the lbs. of TSS in the influent.

The application and theory with respect to primary clarification applies to all models that contain primary clarification. The format and presentation may differ slightly but the theory and application is the same.

ACTIVATED SLUDGE SYSTEMS MODEL AND LOADINGS

ADDITIONAL INPUT VALUES

In addition to the previously mentioned input values, other parameters or limits are required as well as reactor and clarifier dimensions along with the number of units.

The two additional input parameters are the maximum mixed liquor suspended solids (MLSS) in mg/l and the maximum mean cell residence time (MCRT) in days. These are maximum limits and will function as a limit only if the system is capable of achieving the inputted maximum value. Also one of these values will normally predominate. As an example, consider a conventional activated sludge plant at design conditions. Assume the maximum MLSS is set at 1,000 mg/l and the MCRT is at 50 days. The MLSS value will control and a 50 day MCRT will never be approached. More will be explained later.

REACTOR DIMENSIONS

The program asks for both rectangular and circular reactors as well as the dimensions. After these values are inputted, the computer calculates the total volume. Only the volume is used in subsequent calculations. Because the models are designed for domestic wastes, the reactors are assumed to be completely mixed. In domestic wastes there is little difference between plug flow and complete mix because of the high substrate utilization rate.

CLARIFIER DIMENSIONS

The program asks for both rectangular and circular clarifier dimensions as well as weir length. These dimensions are critical since the depth and total surface area are used in the algorithms. The weir length is used to calculate the weir loading and not used to predict performance. Also with clarifiers of different sizes, it is assumed that the flow is proportionally split as a function of surface area.

MAXIMIZING THE REACTORS AND CLARIFIERS

First, it should be noted that the algorithms used in the performance prediction are proprietary and will not be completely revealed in this document. However, enough information will be rendered to foster a functional understanding of the system. This discussion applies to all activated sludge systems.

The activated sludge model starts with either the influent or primary clarifier effluent flow and associated characteristics such as BOD, TSS, VSS, NH_3-N, PO_4, temp., etc.

First the BOD is temperature adjusted by using the factor $1.03^{(20-t)}$ where t is the wastewater temperature in degrees Celsius. As an example if the BOD were 200 mg/l and temperature 24°C then the adjusted BOD would be:

$$(200) \times [1.03^{(20-24)}] = 178 \text{ mg/l}$$

This value is used in the kinetic analysis because the rate of reactivity varies as a function of temperature. The F/M ratio or substrate removal velocity is then determined based on the maximum mixed liquor value inputted by the user. The substrate removal velocity (lbs. of BOD removed per lb of cell mass, MLVSS) is assumed to about equal the food to microorganism ratio (lbs. of BOD applied per lb. of cell mass MLVSS). In a well-operating plant this is true. In a poorly operating plant it is not necessarily true but not a sensitive value compared with high TSS values in the effluent.

For the first iteration it is assumed that the MLSS concentration is equal to the MLVSS concentration. This, of course, is not true. However, it forces a loop that will eventually balance. The substrate removal velocity is determined as follows:

$$\dot{q} = \frac{So}{X_1 \theta}$$

Where:

- q = substrate removal velocity (lbs BOD removed/lb of MLVSS/day)
- So = the temperature adjusted reactor influent BOD
- X_1 = the maximum or adjusted MLVSS in the reactor in mg/l
- θ = the hydraulic residence time in the reactor without recycle flow (days)

As an example if the maximum MLSS was set as 2,500 mg/l the X_1 would be set at 2,500 mg/l knowing that X_1 is MLVSS and not MLSS. The mean cell residence time is then computed with the following formula:

$$\theta_c = \frac{1}{Y_q - Kd}$$

Where:

θ_c = MCRT in days

Y = Net cell growth and assumed as a constant, therefore Y = 0.6 lbs of cell mass produced per lb of BOD destroyed.

q = The substrate removal velocity determined in the preceding equation.

Kd = Is the endogenous respiration rate in days and determined as a function of the substrate removal velocity, where

$$Kd = \frac{0.12q}{.23 + q}$$

After the mean cell residence time is computed then the total MLSS is computed by adding the MLVSS (X_1) with the inert concentration accumulated as a function of the MCRT. The following equation is used:

$$R_i = \frac{F\theta_c (X_o - X_v)}{R_v \times 10^{-6}} = R_i \text{ mg/l}$$

Where:

R_i = Reactor inert solids concentration in mg/l

F = The plant flow in mgd

θ = The mean cell residence time in days

X_o = The reactor influent TSS in mg/l

X_v = The reactor influent VSS in mg/l

R_v = The reactor volume in gallons

The total MLSS is then computed as MLSS = $X_1 + R_i$

Obviously if the inputted maximum mixed liquor was originally set as equal to the MLSS, the computed MLSS will always be greater than the entered or desired MLSS.

The conditional statement determines whether the MLSS computed value is equal to or less than the inputted maximum value. In the first iteration obviously it is not, unless the inert fraction of the influent TSS is zero. If the computed MLSS value is greater than the inputted maximum value, then 100 mg/l is subtracted from the preset X_1 value. If it is not equal to or less than, then 100 mg/l is deducted from the preset X_1 value (i.e., the originally inputted MLSS value). This loop continues until the computed MLSS value is equal to or less than the desired MLSS value.

When the above occurs then the maximum compaction concentration is computed. This is a proprietary computation, and is a function of the mean cell residence time and temperature. If the ultimate compaction is computed to be greater than 10,000 mg/l then the compaction is set at 10,000 mg/l per liter. The reason for this is simply that ultimate compactions of greater than 10,000 mg/l are normally not consistently achievable.

After the ultimate compaction concentration is determined then the depth of blanket (DOB) in feet is determined. The depth of blanket is measured from the surface of the clarifier down to the interface of the settled activated sludge. The algorithm sets the maximum height of the blanket to six feet, therefore, the depth of blanket (DOB) must be equal to or more than six feet. The depth of blanket is computed using the following equation:

$$DOB = d\left(1 - \frac{X_1}{X_r}\right) \text{ where}$$

Where: DOB = depth of blanket, feet

d = average clarifier water depth in feet

X_1 = computed mixed liquor concentration in mg/l

X_r = computed ultimate compaction of the activated sludge in mg/l which will be 10,000 mg/l or less.

If the computed DOB is six feet or greater then the algorithm continues to the next series of computations. If the DOB is less than six feet, a conditional statement directs the procedure to the first part of the program and again reduces the MLVSS by 100 mg/l, then proceeds through all of the previously mentioned computations and recomputes the DOB, and will continue to run in this mode until the DOB is six feet or more. Obviously if the final clarifier depth is inputted as six feet or less the program will not run.

After the depth of blanket is set the algorithm continues to predict the effluent BOD and TSS. This is a proprietary equation. The equation considers the mean cell residence, the average daily flow, the peak flow is assumed to be a six hour duration. Temperature is also considered. The equation predicts the effluent TSS and assumes that the effluent % VSS is about equal to % MLVSS.

After the effluent TSS is determined then the effluent BOD is calculated based on 0.70 times the effluent VSS plus an assumed soluble BOD which is determined as a function of the mean cell residence time.

Each heading on the printouts will be discussed separately excepting the plant flow data which has been previously explained and the derivation of values previously explained in this section. Additional input values are also discussed.

ADDITIONAL INPUT PARAMETERS

In addition to the input values previously discussed, the maximum MLSS and MCRT are required under the wastewater characterization section. The lesser of these values will predominate in the algorithms. As an example if the maximum MLSS value is inputted as 5,000 mg/l and maximum MCRT is inputted as 8 days. In a conventional system rarely will be mixed liquor exceed 2,500 mg/l at design flow. In this case the system will be examined at a mixed liquor equal to or less than 5,000 mg/l. After the system is balanced, then the MCRT is examined and if greater than 8 days, the mixed liquor will be lowered in increments of approximately 100 mg/l until the MCRT is equal to or less than eight days. Conversely, if the mixed liquor is at 1,500 mg/l and the MCRT is set at 35 days in an extended aeration plant the 1,500 mg/l value will probably control since most extended aeration plants are designed to operate at mixed liquor concentration in excess of 3,000 mg/l.

Additional input values include the final clarifier configuration and the reactor or aeration basin configuration. The exact dimensions of the final clarifiers are essential since the performance prediction is based on the clarifier surface loading and the side wall depth. The reactor configuration is not critical but the resultant volume is critical. The algorithm considers only the total volume and assumes a completely mixed system.

BIOLOGICAL PERFORMANCE SHEETS

MAXIMUM MLSS

This is the maximum mixed liquor suspended solids in mg/l as determined or controlled by the blanket depth in the final clarifier, the inputted maximum mixed liquor, or the inputted mean cell residence time. Even though these values are displayed to the nearest mg/l they are only accurate to the nearest 100 mg/l. The nearest mg/l value is displayed in order to show change in MLSS even with the slightest flow change.

MLVSS

The method of computing this value has been explained. It represents the fraction of cell mass in the system and controls the mean cell residence time. Obviously it is a critical value. Other than maximum MLSS and MCRT constraints inputted by the user, the % VSS in the influent is a critical value. The % VSS should be known, if not the 80% default value may be used realizing that this may affect the entire cell mass estimated for the system.

F/M

This is the food to microorganism ratio expressed as lbs of BOD applied per lb of MLVSS (cell mass) per day. In the algorithm the F/M ratio is considered equal to the substrate removal velocity, q, expressed as lbs of BOD removed per lb of MLVSS (cell mass) per day. This is not exactly correct however when examined as total BOD in the reactor versus soluble BOD in the effluent, there is an insignificant difference between F/M and q in a treatment plant that is performing reasonably well.

MCRT DAYS

The method of determining the mean cell residence time in days has been previously discussed in detail. The computer printout is to the nearest day, therefore, at times the MCRT has not changed more than one day. When evaluating a treatment plant it should be noted that the MCRT used in the diagnostic program is based on the reactor only. Many operators will determine and control their system based on MCRT determined by using the reactors, final clarifier and even sludge piping, therefore, MCRT values may differ from the computer printout. The computer printout and associated equations are based on a kinetic analysis. In day to day operations, it makes little difference as to how the MCRT is computed as long as it is consistent.

SVI

SVI is the sludge volume index expressed as grams per 100 mls. It is calculated from the computed ultimate compaction value (X_r) expressed in mg/l. The value is computed as follows:

$$SVI = \frac{10^6}{X_r} = \text{grams/100 ml}$$

Note in the preceding discussion the ultimate compaction has been limited to a maximum concentration of 10,000 mg/l, therefore, the minimum SVI value will always be 100 g/100 ml.

RAS, MGD

This is the average return activated sludge flow in million gallons per day. The return activated sludge flow (F_r) is determined as follows:

$$F_r = \frac{F\,X_1}{X_r - X_1} = \text{mgd}$$

Where:

F = the average daily flow in mgd

X_1 = the MLSS concentration in mg/l

X_r = the ultimate compaction in the final clarifier in mg/l

This equation is based on a simple mass balance around the final clarifier and biological reactor. The pounds of mixed liquor introduced to the final clarifier must equal the pounds discharged in the effluent plus the pounds removed. The total pounds discharged and removed is the sum of the solids leaving with the effluent, the solids being returned to the reactor, and the solids wasted.

The equation was previously mentioned for recycle control, however, the rationale is:

F = the plant flow, mgd

F_r = the return activated sludge rate, mgd

X_1 = the mixed liquor suspended solids, milligrams per liter

X_r = the return activated sludge concentration, milligrams per liter

X_2 = the suspended solids in the final clarifier effluent, milligrams per liter

P_t = total pounds leaving the activated sludge tank (or removed in the clarifier)

Then: $(F+F_r)\ (X_1)\ (8.34) = P_t$ = total pounds introduced to final clarifier

Also: $(F_r)\ (X_r)\ (8.34) + (F)\ (X_2)\ (8.34)$ = totals to be removed from the clarifier or = P_t, therefore

$$(F + F_r)\ (X_1)\ (8.34) = (F_r)\ (X_r)\ (8.34) + (F)\ (X_2)\ (8.34)$$

$$(F + F_r)\ (X_1) - (X_r)\ (F_r) + (F)\ (X_2)$$

$$(F)\ (X_1) + (F_r)\ (X_1) = (X_r)\ (F_r) + (F)\ (X_2)$$

$$(F)\ (X_1) - (F)\ (X_2) = (X_r)\ (F_r) - (F_r)\ (X_1)$$

$$F\ (X_1 - X_2) = F_r\ (X_r - X_1)$$

$$F_r = \frac{F(X_1 - X_2)}{X_r - X_1}$$

To simplify the calculation, the effluent suspended solids concentration has been eliminated from the diagnostic model because it has little sensitivity when the mass of mixed liquor and RAS are considered.

RAS MG/L

This is the idealized return activated sludge concentration computed using the ultimate compaction as previously discussed. It is assumed that this concentration is obtainable. Often the RAS concentration will be considerably different from actual practice. Most commonly, the actual concentration is substantially less than the predicted value. This is often due to excess recycle pumping or poor compaction due to filamentous growths in the system.

WAS, LBS/DAY

This value is the waste activated sludge in pounds per day. This is a calculated value based on the predicted performance parameters. The WAS is computed as follows:

$$WAS = \frac{R_m}{\theta_c}$$

Where:

R_m = Total reactor mass in pounds

θ_c - Mean cell residence time in days

DETENTION TIME, HOURS OR DAYS

This is the reactor detention time determined in hours and days. The detention time does not include the RAS or any recycle flows. It is for reference purposes only and has little significance in most conventional plants. In general the retention time should be greater than 2 hours for substrate uptake and catabolism.

LOAD, LB BOD/1000 FT^3

This is the reactor loading expressed in pounds of BOD applied to the reactor per 1,000 cubic feet of reactor volume. It is a calculated value and not utilized in the prediction algorithms. It is for reference purposes only and a general indicator as to the loading and capacity of the treatment plant. Appendix E indicates loading ranges for high, low and normal loadings.

OUR, MG/L/HOUR

This is the average oxygen uptake rate of the system under the specified flow conditions. It is expressed as mg/l per hour of oxygen consumed by biological metabolism in the biological reactors. It is not respiration rate which is expressed as milligrams of oxygen used per gram of volatile suspended solids (cell mass) in the reactor. Actual in-plant uptake rates can be made and compared with the predicted value. They should be reasonably close if the mixed liquor VSS and reactor influent BOD are close to the model prediction values. The oxygen uptake rate is computed from the total oxygen demand as follows:

$$OUR = \frac{O_d}{200\ V_r} = mg/l/hr$$

Where:

O_d = Total oxygen demand or requirement in lbs per day

V_r = Reactor volume in MG

200 = Constant = (8.34) (24 hrs) = 200

O_2 BOD, LBS/DAY

This is the total oxygen required in the reactors for metabolism expressed in pounds per day. First the ultimate oxygen demand is determined by multiplying the total pounds of BOD per day introduced to the reactor by a factor of 1.42. This approximates the 20 day BOD for carbonaceous and nitrogenous oxidation. Then the lbs of cell mass is subtracted from this value which approximates the BOD of the wasted volatile material. The expression is as follows:

$$O_d = 1.42\left(S_o - W_c\right)$$

Where:

O_d = lbs of O_2 required per day in the reactor

S_o = lbs of BOD per day introduced to the reactor

W_c = lbs of cell mass (VSS) wasted from the system each day

FINAL CLARIFIER PERFORMANCE AND
EFFLUENT CHARACTERISTICS

DETENTION, TIME, HOURS

This is the detention time of the clarification system expressed in hours. It is a calculation based on input values and not used in the process algorithms. It is for reference purposes only. It can be of benefit in diagnosing treatment plant problems, especially for underloaded facilities. As an example, if the detention time in a system was six to eight hours, denitrification and/or septicity could occur and subsequently cause a high solids flux in the effluent.

DOB, FT

This is the depth of the sludge blanket in feet measured from the surface of the final clarifier to the interface of the blanket. It is a predicted value and its derivation is discussed in the previous section. In practice, or when comparing field measured blanket depths with predicted depth from the model, the measured depth should be equal to or greater than the model prediction. If the blanket is higher than predicted (i.e., actual DOB would be a smaller value) then the recycle rate and/or sludge compaction is inadequate.

EFF, BOD, MG/L and EFF, TSS, MG/L

This is the predicted value of the final clarifier effluent expressed in mg/l. The derivation excluding proprietary equations has been previously presented. Any predicted value of BOD or TSS that is less than 5 mg/l is presented as <5 mg/l. The accuracy of these predicted values is greatest between 20 and 40 mg/l. Predicted values of less than 10 mg/l and greater than 60 mg/l are less accurate.

EFF, NH_3, MG/L and EFF, NO_3, PO_4, MG/L

These values are predicted levels of either ammonia nitrogen or nitrate nitrogen expressed as milligrams per liter of nitrogen. The cell mass in an activated sludge system contains about 10% nitrogen and 2% phosphorus. The nitrogen or phosphorus in the wasted sludge is subtracted from the total N or P in the reactor influent and the resultant is expressed as N or P in the effluent in milligrams per liter. For nitrogen concentration the equation is:

$$N_e = \frac{FN - 0.1\ F_w X_v}{F}$$

For phosphorus concentration the equation is:

$$P_e = \frac{FP - 0.02\ F_w X_v}{F}$$

Where:

N_e = the predicted ammonia or nitrate N concentration in the effluent in mg/l

F = Plant flow to the reactor in mgd

F_w = Waste activated sludge flow in mgd

X_v = MLVSS concentration in mg/l

N = Total nitrogen concentration in the reactor influent in mg/l

P_e = The predicted phosphorus concentration in the effluent in mg/l

P = Total phosphorus concentration in the reactor influent in mg/l

If the predicted values for N and P are equal to or less than 5 and 2 mgl respectively, then there is a potential nutrient deficiency. If the values are printed as negative numbers this indicates a definite nutrient deficiency which will cause poor settling and poor performance.

With regard to NH_3 and NO_3 values, the point where nitrification occurs and is indicated on the printout sheet is not accurate. The printout changes from NH_3 to NO_3 at about a ten day MCRT. This is intended to be an indicator showing approximately where nitrification occurs.

SECONDARY SYSTEM PERFORMANCE

CLARIFIER LOAD, SFC, GPSFD

This is the total surface loading on the final clarification system expressed in gallons per square foot per day based on average daily flow. It is a calculated value for reference purposes only. Appendix E shows high and low loading limits as well as normal loadings.

CLARIFIER LOAD, WEIR GPLFD

This is the weir loading expressed in gallons per day per lineal foot and is a calculated value based on the total weir length inputted in the final clarifier input section. This value is not used in the performance prediction. Experience indicates that in most plants weir loading has little or no effect on the final clarifier performance when the surface loadings are adequate. There are exceptions to every rule, and high, low and average values should be examined in Appendix E.

Sludge Production

These values for secondary and primary sludge if applicable are recalculated and tabulated for reference and comparative reasons. Number of lbs printed on the primary sheet and the reactor performance sheet may differ slightly due to rounding errors. The difference is negligible.

Percent Solids

This is the estimated concentration of the combined sludges that is pumped to the digester. The calculation is based on the percentage of primary sludge and waste activated sludge and the mean cell residence time.

GPD - Gallons

This is a calculated value based on the total predicted sludge production and the estimated percent solids of the combined sludges. These flows are subsequently used in the digestion analysis if selected by the user.

VARIATIONS IN ACTIVATED SLUDGE PROGRAMS

Activated Biofilter Systems

The basic process algorithm is the same as described for the activated sludge system excepting the algorithm includes a modified version of the fixed film algorithm that gives credit for BOD removal across the bio-tower.

Contact Stabilization

The algorithms for the contact stabilization programs are the same for the standard activated sludge systems with the exception that the algorithm recognizes a biological contactor where substrate assimilation occurs with minimal metabolism. The contactor is limited to a minimum F/M 0.6 lbs of BOD per lb of MLVSS per day and the reaeration basin is limited to a minimum F/M of 0.1. This is the only significant difference in the program. The kinetic equations are exactly the same. The nitrogen species prediction is also the same except that only a portion of the flow (RAS) is nitrified in the reaeration basin.

FIXED FILM SYSTEMS MODEL AND LOADINGS

Fixed film systems include trickling filters, rotating biological contactors (RBC) roughing filters and activated biofilter towers (ABF). From a biological and kinetic standpoint, they are treated the same and will be explained in a subsequent section.

ADDITIONAL INPUT VALUES

In addition to the previously discussed input, other parameters or limits are required as well as dimensions for trickling filters, ABF biotowers, roughing filters and RBC configurations.

For trickling filters, diameter and depth are required. In addition, the type of media must be known. There are three general categories for the media. These are rock, stacked plastic and packed plastic. The prediction algorithm is based on the effective surface area of the fixed film system. The effective surface area for these types of media are assumed to be 17, 28, and 32 square feet per cubic foot of media, respectively.

In addition, there are three types of recycle mode options. These are:

1. Constant recycle. This means in addition to the plant flow, a constant amount of water is recirculated around the filter. The constant recycle flow is expressed in gallons per minute.
2. Constant flow. This means that the filter sees a constant flow regardless of the plant flow. When inputting this value be sure that it is at least equal to or greater than the last flow iteration. The input value is expressed in gallons per minute. As an example, if design flow value is inputted as 1.5 mgd then the last flow iteration will be 1.3 x 1.5 = 1.95 mgd. The constant flow input must be

greater than 1.95 x 694.4 = 1354 gpm for all the flow to pass through the filter. If the inputted constant flow value is less than the plant flow iterations then the computer will print "the recirculation rate is negative beyond this point." The computer will then go to the next page of the printout and continue to calculate or predict values to the point of negative flow.

3. Percent of flow. This assumes a certain percent of the plant flow is recycled around the filter. The input value is expressed in percent. The percent of flow is then calculated for each flow iteration. There is a recycle flow option for each filter including secondary filters for two stage systems.

For RBC systems other inputs are required. First the manufacturer and type of drive unit is requested. These two inputs are not used in the process algorithms at this time. They are for reference purposes only. At the time of the model development the only RBC systems available were mechanically driven units. At the present time there is not sufficient data available to distinguish between the present variations. Present data indicates that the performance predictions are accurate for both systems.

The program then asks for the number of process trains and the number of shafts per train. It then asks for the surface area of each individual shaft in the process train. These parameters are critical (trains and surface area) as they are used in the process prediction algorithm.

For the ABF system, the size of the ABF biotower and type of media is required. There are only two options available, redwood slats or plastic media.

PROCESS ALGORITHMS

The process algorithms are based on a modification of the National Research Council (NRC) equation for trickling filters. Recirculation is assumed to be directly around the filter elements. Systems that recirculate round a clarifier and filter will not work with these programs.

The reason is that in this type of plant the clarifiers are designed to accommodate the recycle flow and, therefore, are substantially larger than conventional clarification systems. For ABF systems, all the return activated sludge is assumed to be recycled over the ABF tower.

The NRC equation does not address temperature of sewage or the final clarifier size. The basic NRC equation is as follows:

$$E_1 = \frac{1}{1 + 0.0085 \sqrt{\frac{So}{VF}}}$$

Where:

E_1 = the fraction efficiency of BOD removal for the system including recirculation. Thirty minute settling is assumed

S_o = BOD loading to the filter in lbs per day

V = the volume of the filter in acre feet

F = the recirculation factor expressed as:

$$F = \frac{1 + \frac{Q_r}{Q}}{\left[\left(1 + \frac{\frac{Q_r}{Q}}{10}\right)\right]^2}$$

Where:

Q_r = the recirculation flow

Q = the plant flow

The basic equation has been modified as follows:

S_o has been changed to $S_o\ (1.03^{(20-t)})$ to compensate for temperature of the wastewater

V has been adjusted for type of media and its effective surface area.

For rock media,	V = V
For stacked media,	V = 1.6 V
For packed media,	V = 1.8 V and,
For redwood slats,	V = 0.7 V

These adjustments reflect the relative difference in effective surface area.

For two stage systems the basic equation is:

$$E_2 = \frac{1}{1 + \frac{0.0085}{1 - E_1} \sqrt{\frac{S_o \; (1.03^{(20-t)})}{CVF}}}$$

Where:

E_2 = the fraction efficiency of the second stage filter

C = correction factor as explained above.

The same basic equations are used for RBC systems and ABF. The RBC surface is adjusted to compensate for effective surface area. In the ABF system adjustments are made to compensate for the substrate (BOD) assimilation by the activated sludge. After the efficiency of removal for BOD is determined then this value is adjusted as a function of the final clarifier surface area. The clarifier depth is assumed to be a minimum of seven feet. The BOD is then calculated as a function of the filter influent BOD and the efficiency of removal factor. The effluent TSS is back calculated from the effluent BOD value as a function of observed results from several trickling filter or RBC systems. In the ABF system, the BOD removal across the ABF biotower is calculated and then that value is deducted from the total substrate flux to the system. The substrate flux less the removal through the ABF biotower is used to determine the BOD loading to the activated sludge portion of the ABF system. In the case of roughing filters, the same equations are used excepting the final clarifier algorithm is not utilized.

The above equations are proprietary, however, they could be determined by back calculating these values from the basic equations presented in this section.

SECONDARY SYSTEM LOADING AND PERFORMANCE SHEETS

Filter, Surface Loading

This is surface loading on the filter expressed as gallons per day per square foot based on the plant flow to the filter. It is a calculated value for reference purposes only and is not used in the prediction model.

Filter Loading, Pounds of BOD, 1000 Ft^3

This is the organic loading on the filter expressed as pounds of BOD applied per one thousand cubic feet of media. It is a calculated value and not used in the process prediction model. It is, however, an indicator as to potential performance.

Filter Loading for Two Stage Filters

The surface loading in gallons per day per square foot and the recirculation values are calculated and not directly used for predicted performance. The BOD loading in pounds per thousand cubic feet is a predicted value based on the previously discussed modified NRC equations.

Clarifier Loadings, Surface GPDSF, Weir, GPD/Ft

These two values are the total clarifier surface loading in gallons per day per square foot and the weir loading in gallons per lineal foot per day. The weir loading is a calculated value that is an indicator only. Representative values for weir loading are indicated in Appendix E of this manual. The clarifier surface loading is a calculated value and used to determine the effluent BOD concentration.

Clarifier Detention Time, Hours

This is the theoretical detention time of the final clarifiers. It is a calculated value and used for reference purposes only. It is significant to note that excessive detention times (greater than 4 hours) may cause septicity to the extent where resolublization of BOD will occur along with an increase in TSS concentration.

Effluent BOD and TSS Concentration

These are predicted values based on the modified NRC equation and final clarifier surface loadings. The BOD is first predicted and the total suspended solids (TSS) is estimated from the BOD values.

Secondary Sludge Production

The total and volatile solids production in pounds per day is a predicted value based on the conversion of BOD to cell mass and inert solids flux from the primary clarifier. This determination is proprietary in nature and, therefore, not discussed in this manual.

Total Sludge Production

These values are based on the sum of the primary and secondary sludge productions. The percent solids is an estimated concentration of the combined sludges based on temperature and percent of mixture of primary and secondary sludges. The predicted values are estimates based on idealized conditions. The actual sludge concentration may vary significantly. Accordingly the gallons per day (GPD) of sludge pumped may also vary since the determination is based on the predicted total pounds produced per day and the predicted concentration. The total sludge production data is stored in a file within the computer and used in the digester performance section of the diagnostic model.

ROTATING BIOLOGICAL CONTACTORS (RBC)

As previously explained, the RBC algorithm is identical to the trickling filter algorithms except that the computer printout presents the organic loadings in pounds of BOD per thousand square feet of RBC surface area. Further it prints out the loading to the first shaft or stage and then the total load which includes the first shaft. Representative loadings for the first stage and total area are indicated in Appendix E. Note that Appendix E indicates a high loading on the first stage as 3.5 pounds of BOD per thousand square feet. Present information indicates that loadings in excess of five pounds of BOD per thousand square feet on the first stage may cause process failure and produce effluent BOD and TSS concentrations in excess of the predicted values. One of the reasons for this is that the effluent BOD and TSS predictions are based on the total surface area. The first shaft or stage loading is calculated for reference purposes only.

DIGESTER PERFORMANCE SHEETS

All of the diagnostic programs have a digester option for performance prediction of either anaerobic digestion, aerobic digestion or both. As previously mentioned, the data from the secondary performance sheet is used for the digester performance output. Because of the variability in actual sludge concentration and the fact the sludge production values are predicted quantities based on other predicted elements, the data on this printout may not be functional for on line plant evaluations. It is, however, the only practical method for evaluating systems that have not yet been built or on line systems that have no data. In order to assess on line systems more accurately, a new program titled Digester Analysis has been provided and will be in a subsequent Chapter. Further, the theory and rationale for the digester predictions will be included in the subsequent chapter.

Total Sludge Flow, Gallons Per Day

This value is a transferred value from the secondary performance sheet. During the process of transfer and rounding of numbers, the flow in gallons per day may differ by one gallon, however, this should have no impact on the calculated or predicted values.

Volatile Solids Loading in $Lbs/Ft^3/Day$

This is a calculated value based on the digester volume and the pounds of volatile sludge introduced to the digester each day. It is not used when predicting reduction of volatile solids but is an indicator of loading. Representative loadings for the digester is indicated in Appendix E.

Mean Cell Residence Time, Days

Since the digester is assumed to be completely mixed and overflow is equal to inflow, then the hydraulic detention time is equal to the mean cell residence time. The value is calculated as hydraulic residence time and expressed on the printout as mean cell residence time. This value is used to predict the percent reduction of volatile solids.

Percent Reduction of Volatile Solids

This is a predicted value based on the mean cell residence time. The algorithm will be discussed in a subsequent chapter for the digester analysis program. The diagnostic program limits the maximum percent reduction of volatile matter to 75%.

Alkalinity, mg/l

This is a predicted value based on the concentration of raw sludge fed to the digester. It is a derivation of a simple yet accurate formula first published in 1968 in the WPCF Manual of Practice No. 16, page 17. This value is not calculated for aerobic digestion.

Gas Production, Ft^3 Per Day

The total gas production per day in cubic feet is for anaerobic digestion only. It is calculated from the predicted percent reduction of volatile matter. It is assumed that the gas quality is approximately 35% carbon dioxide and 65% methane which equates to about 15 cubic feet per lb of gas under standard conditions.

Percent Solids of Digested Sludge

This is a calculated value based on the percent reduction of volatile solids, the percent solids of the raw sludge, and the daily raw sludge flow. It assumes that the digester is completely mixed. The equation is presented in the subsequent chapter.

CHAPTER 5

DIGESTER AND ACTIVATED SLUDGE ANALYTICAL AND TROUBLESHOOTING PROGRAMS

INTRODUCTION

These programs are new to the diagnostic series. They are intended to augment the general diagnostic program by providing additional information to troubleshoot problems in the field. The digester program includes both aerobic and anaerobic digestion. The activated sludge system analytical program is applicable for all types of activated sludge.

RUNNING THE DIGESTER PROGRAM

To run the program type: HELLO <Return>, the computer reads the first message and displays it on the screen. Make sure the "Cap Locks" key is on. The first message gives the user three options, the digester analysis, activated sludge, or an activated sludge example. If Digester Analysis is selected the computer will then ask what type, Anaerobic or Aerobic? The user must select one option. For explanatory reasons, anaerobic digestion will be used because it includes all the possible parameters. Whereas in aerobic digestion alkalinity and gas production is not considered, therefore, an N/A (not applicable) is printed for these parameters.

The next question asks if the raw sludge contains waste activated sludge. The user must respond Y (yes) or N (no). If the user answers yes then the computer asks for the mean cell residence time (MCRT) days. Even if the sludges are pumped separately to the digester the mean cell residence time should be inputted.

The computer will continue to ask questions and if there are no changes desired (edit routine) then the program will print out the calculated values and predicted values. All of the questions are simple and should be available for input, however, there will be times when the information is not available. You must enter some number. Do not enter zero (Ø) because it may cause a division by zero and subsequently the computer will stop and display this message. It is suggested that if you do not know the actual required input values either guess them or enter the value one (1) which will render unrealistic results but still allow the program to run. The following parameters must be inputted into the computer:

1. Mean Cell Residence Time, Days (if an activated sludge system)

   This value should be entered to the nearest integer. It is necessary to know the value or be close to it.

2. Digester Volume, Gallons x 1000

   Enter this value to the nearest thousand gallons. As an example, if the digester volume were 835,421 gallons the operator should enter 835.000.

3. Raw Sludge Flow, Gallons Per Day

   This value should be entered to the nearest integer. It is necessary to know this value or be close to it to produce meaningful results.

4. Raw Sludge Solids, Percent

   This value should be entered to the nearest tenth. It is necessary to know this value or be close to it to produce meaningful results.

5. Raw Sludge Volatiles, Percent

   This value should be entered to the nearest integer. The value should be known or close to it in order to produce meaningful results.

6. Digester Temperature, Degrees Celsius

   This value should be entered to the nearest integer. The values should be known or accurately estimated to produce meaningful results.

7. Digester Liquor Solids, Percent

This value, if known should be entered to the nearest tenth. If it is not known, either estimate it or enter one. It will affect the calculated values only.

8. Digester Volatile Solids, Percent

This value should be entered to the nearest integer. If it is not known either estimate the value or enter one. It will affect the calculated values.

9. Gas Production, X 1000 ft^3

This value should be entered to the nearest 1000 cubic feet. If it is not known then either estimate the value or enter one. This input will affect the calculated values only.

10. Alkalinity, mg/l, as Calcium Carbonate

Enter this value to the nearest integer. If the actual value is not known then you may estimate it or enter the value one. It is used in the calculated values only.

11. Volatile Acids, mg/l, as Acetic Acid

Enter this value to the nearest integer. If the actual value is not known then either estimate the value or enter one. This value only affects the calculated values.

CALCULATED VALUES

Detention Time, Days

This value is printed to the nearest day or integer. It is calculated as follows:

$$\theta = \frac{V}{F_s}$$

Where:

θ = the hydraulic retention time in days

V = the digester volume in gallons

F_s = the raw sludge flow in gallons per day

Organic Loading, Pounds of Volatile Solids Per Cubic Foot Per Day

This value is printed to the nearest one hundreth of a pound and is calculated as follows:

$$L_o = \frac{0.00834\ F_s\ R_c\ R_v}{0.1337V}$$

Where:

L_o = Organic loading in pounds of volatile solids per cubic foot of digester volume per day.

F_s = Raw sludge flow in gpd

R_c = Raw sludge concentration in percent

R_v = Raw sludge volatile content in percent

V = Volume of the digester in gallons.

Reduction of Volatile Solids in Percent

This value is printed to the nearest integer and is calculated as follows:

$$V_r = \frac{0.01\ (R_v - D_r)}{0.01\ R_v - \left[0.0001\ R_v D_r\right]} \times 100$$

Where:

V_r = Volatile solids reduction in percent

R_v = The raw sludge percent volatile solids

D_r = The digested sludge percent volatile solids

Reduction of Volatile Solids in Pounds per Day

The value is indicated to the nearest integer and is determined as follows:

$$V_p = 0.0000834\ F_s\ R_c\ R_v\ V_r$$

Where: V_p = lbs of volatile solids reduced per day.

Note: Other variables have been previously identified.

Gas Yield in Cubic Feet of Gas Produced per Pound of Volatile Matter Destroyed

This value is calculated and printed to the nearest tenth of a cubic foot of gas and is determined as follows:

$$Y_g = \frac{F_g}{V_p}$$

Where:

Y_g = Gas yield in cubic feet of gas per lb of volatile matter destroyed.

F_g = Gas flow in cubic feet per day

V_p = The pounds of volatile solids destroyed per day.

Alkalinity/Volatile Acid Ratio

This is a non-dimensional number and is merely the ratio between the alkalinity and the volatile acids. It is used by some operators and engineers as an indicator as to the condition of the digester.

Actually it is not the condition of the digester but rather the buffering capacity. If Alk/VA ratio was 2.5 this would mean that the buffering capacity is approximately 2.5 times the volatile acid concentration. It is strictly a simple stochiometric relationship as follows:

When alkalinity is determined as calcium carbonate ($CaCO_3$), it indicates the buffering capacity in the digester against volatile acids. Assuming the buffer is calcium carbonate and the volatile acid is acetic, the reaction is:

$$2CH_3COOH + CaCO_3 \rightarrow Ca(CH_3COO_2) + H_2CO_3$$

The reaction product is an organic salt, calcium acetate and carbonic acid. The carbonic acid (H_2CO_3) further breaks down into carbon dioxide (CO_2) and water (H_2O). It is now obvious that if a large increase in volatile acids occurred there also would be an increase in carbon dioxide in the digester gas. The carbon dioxide increase will be indicated in the gas analysis. It is also significant to note that the pH will remain the same until most of the alkalinity is used up by increased volatile acid production. The higher the alkalinity, the better the buffering capacity and the less chance for digester upset caused by sharp volatile acid increases. Also, if the alkalinity concentration is known, then the operator can predict when the pH will drop, and add chemicals such as lime or ammonia to maintain the proper pH for the methane formers. Since it takes one mole of $CaCO_3$ to neutralize two moles of CH_3COOH and the molecular weight of the calcium carbonate is 100 and acetic acid is 48, the reaction is in direct proportion. As an example, if the volatile acid concentration increased by 1,000 mg/l as CH_3COOH, the required alkalinity would be computed as follows:

$$\frac{\text{mg/l } CaCO_3 \text{ required}}{\text{mole wt. of } CaCO_3} = \frac{\text{volatile acid increase in mg/l}}{\text{2 mole wts of } CH_3COOH}$$

substituting,

$$\frac{x}{100} = \frac{1,000}{98}$$

$$x = \frac{(1000)(100)}{98} = 1,020 \text{ mg/l } CaCO_3 \text{ required}$$

As a rule of thumb, one milligram of calcium carbonate neutralizes one milligram of acetic acid. This assumes a strict stoichiometric reaction with the above mentioned compounds. There are many other volatile acids that have higher and lower molecular weights such as valeric acid ($CH_3(CH_2)_3COOH$), butyric (CH_3CH_2COOH) and formic acid (HCOOH). Also, in the carbonate group, magnesium, potassium, and sodium carbonate exist. Being cognizant of this, it is good policy to keep at least 1,000 mg/l of alkalinity ahead of any volatile acid concentration.

As for determining gas production, this is important with respect to determining process efficiency and materials balance as is volatile solids determinations. Considering the laws of mass conservation and energy and a digester gas containing 35 percent carbon dioxide and 65 percent methane only 13.9 cubic feet of gas can be produced per pound of volatile matter destroyed. This can be easily proved by applying Avagadro's law which deduces that one gram mole of any gas will produce a volume of 22.4 liters under standard conditions. It is determined as follows:

Compute molecular weights of $CO_2 + CH_4$

CO_2

$$C = 12 \times 1 = 12$$
$$O = 16 \times 2 = 32$$
44 grams

CH_4

$$C = 12 \times 1 = 12$$
$$H = 1 \times 4 - 4$$
16 grams

At 0.35 CO_2 and 0.65 CH_4 compute weight of 22.4 liters of gas at standard temperature and pressure.

$$0.35 \times 44 = 15.4$$
$$0.65 \times 16 = 10.4$$
25.8 grams per 22.4 liters

$$1\ ft^3 = 28.3 \text{ liters, } 1 \text{ pound} = 454 \text{ grams}$$

Compute volume of gas weighing one pound

$$\frac{25.8}{22.4} = \frac{454}{X}; \quad X = \frac{(454)(22.40)}{25.8} = 396 \text{ liters}$$

or $$\frac{396}{28.3} = 13.9 \text{ cubic feet of gas from one pound}$$

Checking digester loadings and retention times aids in determining process problems with respect to proper operation within the design parameters. Mass balance calculations assure proper analysis and flow measurement for good process control. Every operator knows it is necessary to balance his check book in order to prevent trouble. The same principle applies to operating a digester or, for that matter, any unit process.

PREDICTED VALUES

The predicted values are based at least in part on theoretical equations and input values such as raw sludge flow, digester volume and temperatures. These values can be compared to the calculated values and if they differ significantly there is something definitely wrong. The predicted values assume a well mixed digester. They are more accurate than the diagnostic models not only because of the input accuracy but also they better correct for temperature and waste activated sludge loads. The predicted values are as follows:

Reduction of Volatile Solids, Percent

This value is expressed to the nearest integer and is determined by the following equation:

$$V_r = 1 - \frac{100}{1 + 0.05\,\theta\,(1.015^{8-\theta_c})(1.03^{t_r - t_s})}$$

Where:

V_r = the reduction of volatile matter in percent

θ = the digester hydraulic residence time in days which is also equal to the mean cell residence time for a completely mixed reactor.

θ_c = the mean cell residence time of the activated sludge system if any.

t_r = Temperature of the reactor in degrees Celsius.

t_s = 20°C for aerobic digestion and 37°C for anaerobic digestion.

If V_r is computed to be greater than 80% then V_r is set at 80%.

Reduction of Volatile Solids, Pounds per Day

This value is expressed to nearest integer and is calculated as follows:

$$V_p = 0.0000834\ F_s\ R_c\ R_v\ V_r$$

Where:

V_p lbs of volatile solids destroyed per day

Note: The other variables have been previously identified. The V_v is the theoretical and not the calculated value.

Digester Liquor Solids, Percent

This value is expressed to the nearest tenth, and is calculated as follows:

$$S_t = \frac{S_1 + (V_i - V_p)}{8.34\ F_r} \times 100$$

Where:

S_t = Total digester liquor solids expressed in percent.

S_i = lbs. of inert solids introduced to the digester each day.

V_i = lbs. of volatile solids introduced to the digester each day.

V_p = lbs. of volatile solids reduced each day.

F_r = Raw sewage flow in gallons per day.

Digester Volatile Solids in Percent

This value is expressed to the nearest integer and is calculated as follows:

$$V_s = \frac{V_i - V_p}{S_i + (V_i - V_p)} \times 100$$

Where:

V_s = the percent volatile solids in the digester liquor

Gas Production in Cubic Feet x 1,000

This value is expressed as cubic feet x 1,000 and is calculated as follows:

$$G_t = \frac{14.5\ V_p}{1,000}$$

Where:

G_t = the gas production in cubic feet per day x 1000

V_p = lbs. of volatile matter theoretically destroyed per day

Note: 14.5 is assumed to be the maximum gas produced per lb of cubic feet destroyed per day.

Alkalinity as $CaCO_3$ in mg/l

$$A_t = R_c \left[1000 - (20\ \theta_c)\right]$$

Where:

A_t = the alkalinity in the digester expressed as mg/l of $CaCO_3$

R_c = the raw sludge concentration in percent

θ = the mean cell residence time of the activated sludge in days.

Comparison of Theoretical Data with Calculated Data

Even when the most precise data is available, the theoretical and calculated data will not match exactly, but they should be reasonably close.

When the calculated data shows a substantially better reduction of volatile solids than the theoretical, this may be due to incorrect analytical data. A typical example of this is the raw sludge flow and concentration. Often the raw sludge concentration is higher than actual or the flow is higher than actual. If the pounds of volatile solids introduced to the digester is actually less than reported then the gas yield or production will be lower than the theoretical. It is suggested that a mass balance be performed around each unit process to verify the data. In order to demonstrate the value of this, consider the following example:

Raw sludge is pumped into a well-operated, heated and mixed digester. The digester liquid is transferred to a holding tank by displacement of a uniformly fed raw sludge and subsequently dewatered by a vacuum filter.

Design Parameters

1. Digester capacity = 2 million gallons.

2. Digester loading should be less than 0.2 pounds of volatile matter per ft^3 per day (3 kg per m^3).

3. Digester detention time should be greater than 20 days.

Operating and Analytical Data

1. Raw Sludge

    a. 73,200 gallons per day

    b. Average concentration = 5.2 percent total matter

    c. Volatile content = 79.6 percent

    d. Gas production = 225,000 ft^3/day at 35 percent CO_2 and 65 percent CH_4.

    e. Digested sludge = 2.5 percent total matter

    f. Digested volatile content = 57.7 percent

Check Digester Loading

(73,200 gal)(0.052)(0.796)(8.34) = lbs of volatile matter

= 25,300 lbs of volatile matter

Digester volume = 2,000,000 gallons or $\frac{2,000,000}{7.48}$ = 267,380 ft^3

Therefore the loading in pounds of volatile matter per cubic foot per day is:

$$\frac{25,300}{267,380} = 0.095 \text{ lbs of VM/ft}^3\text{/day}$$

Note: Loading is less than half of design parameter.

Check Digester Detention Time

73,200 gallons per day input

Digester volume = 2,000,000 gallons

Therefore:

$$\frac{2,000,000}{73,200} = 27.3 \text{ days detention time}$$

Note: Detention time falls within design parameters.

Check Materials Balance

1. Compute solids into reactor

   Known: 73,200 gallons input per day at 5.2 percent matter and 79.6 percent volatile

   Therefore:

   (73,200)(0.052)(8.34) = 31,800 lbs solids/day

   (31,800)(0.796) = 25,300 lbs volatile solids/day

2. Compute percent reduction of volatile matter

   Known: 79.6 percent volatile in

   57.7 percent volatile out

   Since percent reduction of volatile matter is relative, assume 100 lbs dry weight is to be digested.

   Therefore:

   100 lbs of sludge would contain 79.6 lbs of volatile matter (79.6 percent) and 20.4 lbs of fixed or non-volatile solids (20.4 percent).

The fixed or non-volatile solids will remain the same after digestion since they are non-biodegradable. Therefore, the remaining sludge will contain 20.4 lbs of fixed material. The remaining sludge is 57.7 percent volatile and 42.3 percent fixed.

Therefore:

42.3 percent of total remaining sludge equals 20.4 lbs. Changing the statement to an algebraic expression:

$$0.423\ T = 20.4$$

Where:

$$T = \frac{20.4}{0.423} = 48.2 \text{ lbs total after digestion}$$

Then, 48.2 lbs total after digestion

Less	20.4	lbs of fixed solids
	27.8	lbs volatile solids after digestion
	79.6	lbs volatile matter before digestion
Less	27.8	lbs volatile matter remaining
	51.8	lbs volatile matter removed during digestion

Therefore:

$$\frac{\text{lbs volatile matter removed}}{\text{lbs volatile matter before digestion}} \times 100$$

= percent reduction of volatile matter

or, $\frac{51.8}{79.6} \times 100 = 65$ percent reduction of volatile matter

3. Compute solids discharged from digester

Known: 31,800 lbs total to digester
-25,300 lbs volatile solids to digester
6,500 lbs fixed solids to digester

65 percent of the volatile matter is reduced or converted to gas

or, (0.65)(25,300) = 16,450 lbs of volatile matter converted to gas

25,300 lbs volatile solids to digester
-16,450 lbs volatile solids converted to gas
8,850 lbs volatile solids discharged from digester

4. Draw a simple digester diagram and indicate all computed input and output data. See Figure 1.

5. Check mass balance based on computation and analysis.

   a. Solids Input. As indicated on Figure 1 and computed by analysis and flow measurement.

   b. Solids Ouput.

      1) Computed by percent reduction of volatile matter and assuming input gallons equals output gallons. See Figure 1 and previous calculations.

      2) Compute by analytical and operating data
      73,200 gallons out
      2.5 percent matter

Therefore:

(0.025)(73,200)(8.34) = 15,260 lbs out

Compute volatile matter out:

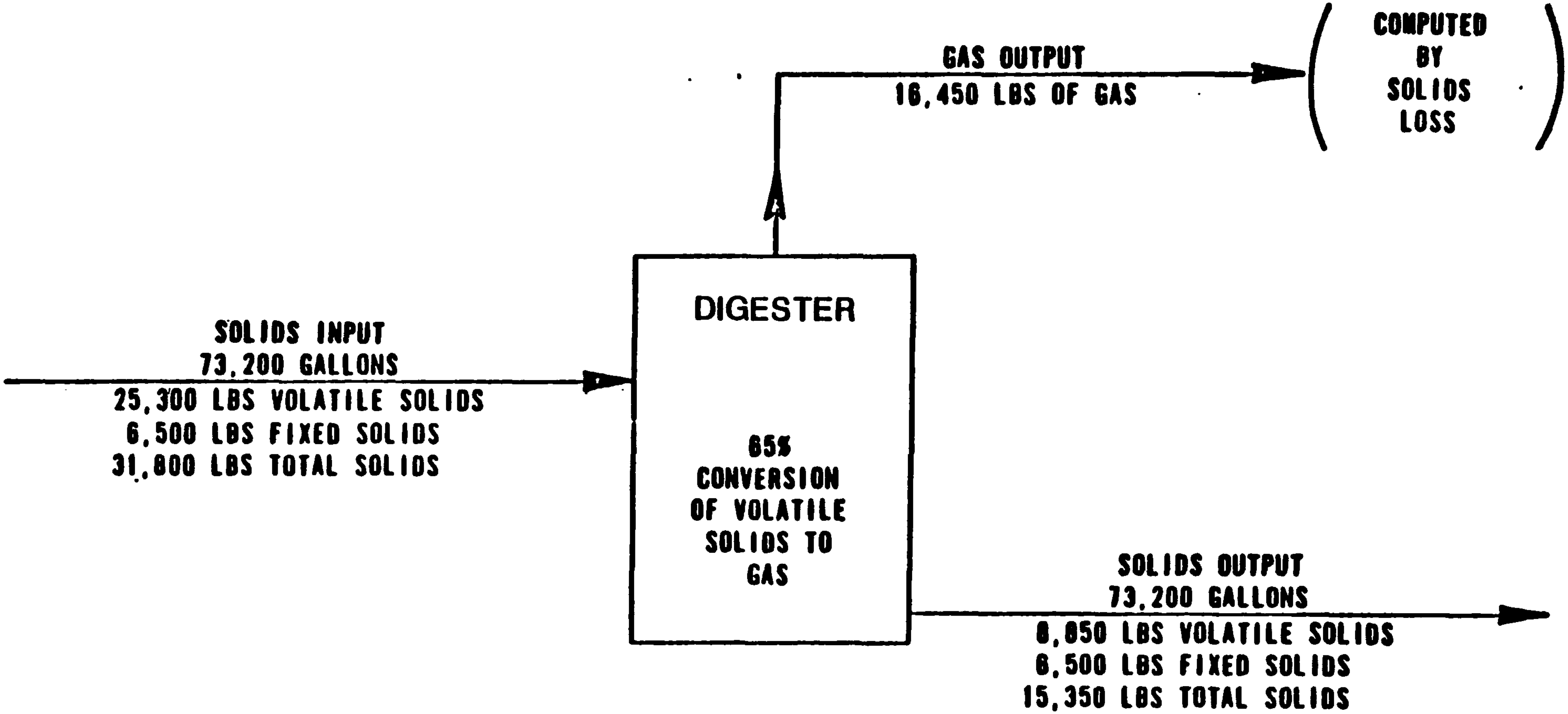
(0.577)(15,260) = 8,800 lbs volatile

15,260 - 8,800 = 6,460 lbs fixed

   c. Compare by computed and analyzed output in pounds.

	Computed	Analyzed	Δ
Total Solids	15,350	15,260	+90
Volatile Solids	8,850	8,800	+50
Fixed Solids	6,500	6,460	+40

Note: Accuracy is approximately 0.6 percent, 15 percent accuracy is considered good.


GAS OUTPUT
16,450 LBS OF GAS
COMPUTED BY SOLIDS LOSS
SOLIDS INPUT
73,200 GALLONS
25,300 LBS VOLATILE SOLIDS
6,500 LBS FIXED SOLIDS
31,800 LBS TOTAL SOLIDS
DIGESTER
65% CONVERSION OF VOLATILE SOLIDS TO GAS
SOLIDS OUTPUT
73,200 GALLONS
8,850 LBS VOLATILE SOLIDS
6,500 LBS FIXED SOLIDS
15,350 LBS TOTAL SOLIDS

d. Compare actual or measured gas production with calculated production.

   1) Measured gas production is 225,000 ft^3 per day.

   2) Based on 65 percent CH_4 and 35 percent CO_2 and 100 percent conversion of volatile solids to gas. See previous calculation where one pound is converted to 13.9 cubic feet. Therefore, the theoretical gas production should be:

(16,450 lbs destroyed)(13.9) = 228,600 ft^3 gas

Note: Accuracy is within limits.

6. Conclusion

Mass balance checks out, therefore analytical data and flow measurement are correct. The computer program is based on a mass balance except the weight of gas is not calculated, but is assumed to be 14 to 15 cubic feet of gas per lb of volatile matter destroyed.

ACTIVATED SLUDGE ANALYSIS

The activated sludge analysis program is intended to analyze and troubleshoot all conventional activated sludge systems including extended aeration and oxidation ditch systems. The program does not address contact stabilization or activated biofilter (ABF) systems. Even though the program appears to be simple with regard to data input and output, it is actually complex with many variables and combinations that is beyond the scope of this manual. For this reason there has been included an example program to familiarize the user with some of these variables.

Inputting Data

Note: The program is structured for ease of editing input data because it is recognized that in many plants all the required data is not available and therefore must be estimated. The values or parameters that are estimated may require revision several times or until the plant is in reasonable balance.

When the activated sludge analysis program is selected (not the example program) it first asks for your name. Input your name using less than 20 characters. It then asks for the date and gives an example on how to input the date. If the date is inputted incorrectly the computer will tell you to use the correct format. As an example, if the value of 13 is inputted as the month it will tell you that the month number is out of range and asks you to input the date again.

After proper input of the date the computer then asks for the plant name. The computer will accept up to 20 characters.

The program then asks if you wish to change any of the information. If you enter yes then you must input all of the data. If no (N) is pushed then the programs proceeds to the next step. You are then asked to input the treatment plant data as follows:

1. Total Reactor Volume in gallons.

2. Total Final Clarifier surface area in square feet.

3. Average clarifier sidewater depth in feet.

The above information must be accurate. If this data is not known, it can be measured in the field. After inputting the data the computer will then display the information inputted with an Edit (E) or Quit (Q) option. If E is pressed then it will allow you to edit any one of the entries. It will ask you for the line number. Enter the line number and hit return, and after the value is inputted it will again give the edit or quit routine. If Q is pressed then it will go to the next section for entry of wastewater characteristics.

There are 18 parameters in the wastewater characterization section. Again some of these parameters may not be known but can be estimated and some of them may be redundant, such as the return activated sludge and waste activated sludge concentrations which are usually the same. The following is a list of parameters with a brief discussion:

1. <u>Influent flow in gpm</u>. If this data is not available then the flow must be estimated. If possible measure the flow using basic hydraulic formulas at an existing flume or channel.

2. Daily peak influent flow in gpm. This means the daily peak flow for the normal 4 to 6 hour duration. Again, it can be measured. For most facilities, the peak flow is about 1.5 times the average daily flow.

3. Influent BOD in mg/l. If this average value is not available it can be estimated and adjusted later to balance the system. An experienced individual can make a good guess as to strength. If this is not possible a good starting point would be 200 mg/l.

4. Influent total suspended solids in mg/l. If this value is not known, several grab samples should be analyzed. The average of these values should be utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT.

5. Influent volatile suspended solids in percent of total. If the value is not known, several grab samples should be analyzed and the average value utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT.

6. Mixed liquor suspended solids in mg/l. If this value is not known, several grab samples should be analyzed and the average value utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT.

7. Mixed liquor volatile suspended solids in mg/l. If this value is not known, several grab samples should be analyzed and the average value utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT.

8. Reactor dissolved oxygen concentration in mg/l. If records are not available, the dissolved oxygen concentration should be measured. Obviously it is a significant parameter since lack of adequate oxygen will cause system failure.

9. Return activated sludge concentration in mg/l. If this value is not known, several grab samples should be analyzed and the average value utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT.

10. Return activated sludge flow in gpd. If this value can not be measured or estimated then the user should guess the value. It can be determined later provided the RAS concentration is known.

11. Waste activated sludge concentration in mg/l. If this value is not known, several grab samples should be analyzed and the average value utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT. If wasting is performed via the return activated sludge line then these values should be the same.

12. Waste activated sludge flow in gpd. If this value is not known and can not be measured or estimated then the user should guess the value. It can be determined later provided the WAS concentration is known.

13. Average clarifier blanket depth in feet. This is the sludge blanket depth measured from the clarifier surface down to the blanket. THIS VALUE MUST BE KNOWN and if information is not available, the user should measure the blanket depth with a blanket finder or similar device.

14. Sludge volume index in grams/ml. If this value is not known, several grab samples should be analyzed and the average value utilized. A GUESS IS NOT ADEQUATE FOR A STARTING POINT.

15. Zone settling velocity in feet per hour. THIS TEST MUST BE DONE. It is recognized that it is not normally done in wastewater treatment plants, therefore Appendix H includes a discussion on zone settling velocity (ZSV), methodology and associated forms.

16. Effluent total suspended solids in mg/l. It is assumed that this value is known since it, along with effluent BOD is the basis for determining the need to analyze the treatment plant.

17. Effluent BOD in mg/l. It is assumed that this value is known since it, along with effluent TSS is the basis for determining the need to analyze the treatment plant.

18. <u>Water temperature in degrees Celsius</u>. This should be the temperature of the mixed liquor in degrees Celsius. If it is not known through recorded data it should be measured.

After the above data is entered, all the data is displayed by line item. With an Edit (E) or Quit (Q) option. If E is pressed the computer will ask for the line number. Enter the line number and press return. It will then display the parameter selected. Enter the new parameter and press return. It will again display all the entered values with the Edit or Quit option. All of the parameters may be changed as many times as required.

When Quit (Q) is pressed the program proceeds to the next step. This step examines the solids balance around the final clarifier. It computes the mixed liquor flow in pounds and the clarifier underflow in pounds. If the balance is not within reasonable limits, the computer will indicate that it is not, and gives you the option to change the RAS flow or concentration. If the user enters yes (Y) then the return sludge flow is requested. Then you also have the option to change the RAS concentration. If the user decides not to make any changes and presses N when the computer first asks, then the computer will automatically change the RAS concentration to balance the system. There are several other options and routines that will be explained in the example program discussion.

After the solids balance is within reasonable limits the computer then determines the mean cell residence time (MCRT) in three different ways using the data as it stands at this point. If the MCRT values are not reasonably consistent, then the computer will so indicate and give the option to go back and input new values. After new values are inputted then it will again look at the solids balance around the final clarifiers and if within acceptable limits then proceed to the MCRT balance. If the MCRT values are within reasonable limits the user must set the MCRT. The user may enter a new MCRT based on his best judgment or one of the calculated MCRT values.

After the MCRT is set then the user may enter Quit (Q) where the user will be given the option to print the data and diagnostics on the screen or the printer.

The computer, after the screen or printer printout, then asks if you wish another run. If you desire to run the program again and keep the existing or previously inputted values, then press yes (Y), if not press no (N).

PROGRAM THEORY

After the user inputs the data a solids balance is performed around the final clarifier. Effluent TSS is neglected because normally it is not sensitive to the analysis. The balance is based on reasonable limits and not precise pounds. The solids flow (flux) to the clarifier is computed as follows:

$$P_i = 8.34\ (X_1)(F+F_r)$$

Where:

P_i = lbs per day to the final clarifier

X_1 = the mixed liquor suspended solids concentration in mg/1

F = average daily plant flow in mgd

F_r = the daily return activated sludge in mgd

The underflow flux is computed as follows:

$$P_o = 8.34\ (X_r)(F_r)$$

Where:

P_o = lbs per day of solids removed from the final clarifier

X_r = the inputted RAS suspended solids concentration in mg/1

F_r = the RAS flow in mgd.

After the above is balanced as previously discussed then the computer determines the MCRT three ways. These are:

1. By wasting method
2. By inert solids method
3. By the kinetic method.

All of the above methods use the reactor volume only in the computation.

The wasting method is calculated as follows:

$$\theta_{cw} = \frac{V_r X_i}{F_w X_r}$$

Where:

θ_{cw} = Mean Cell residence time based on wasting

V_r = Reactor volume in millions of gallons

X_i = Mixed liquor solids concentration in mg/l

F_w = Waste flow in mgd

X_r = Concentration of TSS in waste flow expressed in mg/l

The inert method is calculated as follows:

$$\theta_{ci} = \frac{V_r X_i}{F I_i}$$

Where:

θ_{ci} = the mean cell residence time based on inert solids

V_r = Reactor Volume in millions of gallons

X_i = The concentration of inert solids (non volatile) in the mixed liquor expressed as mg/l

F = Average daily plant flow in mgd

I_i = The concentration of inert solids (non volatile) in the reactor influent expressed as mg/l.

The kinetic method is computed as follows:

$$\theta_c = \frac{1}{Yq - K_d}$$

Where:

θ_c = Mean cell residence time

Y = 0.6 lbs of cell mass produce per lb of BOD catabolized per day

q = Substrate removal velocity in lbs of BOD removed per lb of cell mass per day

K_d = Endogenous respiration rate to the minus one days.

After these values are calculated and the MCRT is set then the computer performs an analysis on the system and prints out all of the data and performs a diagnostic of the inputted and calculated data. Statements are printed out as to the possible cause of poor performance. These statements are manifold and not discussed in this text.

As previously stated there are so many variables and conditions involved, it would be impossible to cover all the conditions. It is recommended that the user spend a few hours running the Example program in order to become familiar with the program and its flexibility.

RUNNING THE EXAMPLE PROGRAM

Select the example program on the main menu by entering the appropriate number. It will boot or start automatically.

Next the screen will display the date, a persons name, and the plant name. When using the regular program the computer will ask these questions. In the example all the data is inputted for you. Press N for NO to indicate that you do not wish a change and to continue on in the program.

The computer then displays the unit process data. Press Q to continue.

The computer then displays the wastewater characteristics data. Note the data, then press Q to continue.

The computer also displays MCRT values calculated three ways. Note that these values are nearly perfectly matched.

Now press G to go back. The computer will now display the wastewater characteristics previously displayed. Press E for Edit. The computer will then ask for the line number. Enter 9 and press return. Line item No. 9 is the RAS concentration in mg/l. Enter 5,000 for the RAS concentration

APPENDIX A

ALGORITHM SOURCES

APPENDIX A

ALGORITHM SOURCES

The algorithms used in the Diagnostic Operational Modeling Programs were prepared solely by:

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Assistance with development of the program formats and preparation of this manual was provided solely by:

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Mr. Charles E. Corley, R.S.
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Ms. Veronica Fitz
Boise State University, Idaho

Mr. James Kohl
State of Wisconsin Dept. of Natural Resources

Mr. Bill Mixer
Casper College, Wyoming

Mr. D. Wayne Staples
State Water Control Board
Common Wealth of Virginia

APPENDIX B

INFLUENT AND EFFLUENT WASTEWATER DATA SHEETS

APPENDIX B

INFLUENT AND EFFLUENT WASTEWATER
DATA SHEETS

Treatment Plant Name: ______________________

Location (in what state): ______________________

Wastewater Characteristics Input Data:

Average dry weather flow ______________________ (MGD)

Average wet weather flow ______________________ (MGD)

Peak dry weather flow ______________________ (MGD)

Peak wet weather flow ______________________ (MGD)

Design dry weather flow ______________________ (MGD)

Design peak wet weather flow ______________________ (MGD)

Influent BOD ______________________ (mg/1)

Influent TSS (total suspended solid) ______________________ (mg/1)

Influent VSS[1,2] (volatile suspended solids) ______________________ (%)

Temperature (maximum/minimum __________/__________ (°C)

TKN (total Kjeldahl nitrogen)[2] ______________________ (mg/1)

Alkalinity[2] ______________________ (mg/1)

pH[2] ______________________

PO_4-P (Orthophosphates)[2] ______________________ (mg/1)

Maximum MLSS[3] ______________________ (mg/1)

Maximum MCRT[3] ______________________ (days)

Footnotes:

1. Be sure that this value is expressed as a percentage of total suspended solids, rather than a concentration in mg/1.

2. If you are not sure about these values, just leave them blank; default values will be assigned by the computer programs.

3. For activated sludge only.

Effluent Characteristics (existing)

	Avg. wet weather flow	Avg. dry weather flow
BOD	__________	__________
TSS	__________	__________
VSS	__________	__________
pH	__________	__________
TKN	__________	__________
NO_3	__________	__________

Plant Superintendent

Name ____________________

Phone No. (   ) __________

APPENDIX C

TREATMENT PLANT CONFIGURATION DATA SHEETS

APPENDIX C

TREATMENT PLANT CONFIGURATION
DATA SHEETS

Treatment Plant Name ______________________________

State of ______________________________

Type of Treatment Plant (check appropriate box)

( ) 1. Primary treatment

( ) 2. Conventional activated sludge, with or without primary sediemntation

( ) 3. Single stage activated sludge for nitrification, with or without primary sedimentation

( ) 4. Extended aeration with or without primary sedimentation

( ) 5. Extended aeration oxidation ditch with or without primary sedimentation

( ) 6. Contact stabilization, with or without primary sedimentation

( ) 7. Single stage trickling filter with primary sedimentation

( ) 8. Two stage trickling filter with primary sedimentation

( ) 9. Activated Bio-Filter Process, with or without primary sedimentation

( ) 10. Rotating biological contactors with or without primary sedimentation

( ) 11. Roughing Filter followed by activated sludge

( ) 12. Digester Analysis

1. Primary Clarification Input Data:

Circular Clarifiers

Clarifier Number	#1	#2	#3	#4	#5
Diameter of ea. clarifier (ft)					
Avg. depth of ea. clarifier (ft)					
Weir length of ea. clarifier (ft)					

Rectangular Clarifiers

Clarifier Number	#1	#2	#3	#4	#5
Length of ea. clarifier (ft)					
Width of ea. clarifier (ft)					
Avg. depth of ea. clarifier (ft)					
Weir length of ea. clarifier (ft)					

Fine Screen

Are fine screens being used (yes or no): ___________

If yes, answer the following questions:

Type of screen: ______________________________

Number of screens: ___________________________

Width (ft): ___________________________

Height (ft): ___________________________

Screening opening: (in): ____________________

Capacity ea. (MGD): ____________________

2. Secondary Clarification Input Data:

Circular Clarifiers

Clarifier Number	#1	#2	#3	#4	#5
Diameter of each clarifier (ft)					
Avg. depth of ea. clarifier (ft)					
Weir length of ea. clarifier (ft)					

Rectangular Clarifiers

Clarifier Number	#1	#2	#3	#4	#5
Length of ea. clarifier (ft)					
Width of ea. clarifier (ft)					
Avg. depth of ea. clarifier (ft)					
Weir length of ea. clarifier (ft)					

3. Reactor(s) Input Data:

Type of Reactor: Circle the type of process shown below and indicate the dimensions for each of the reactors

Activated Sludge/Extended Aeration

Circular Reactors (Aeration Basins)

Reactor Number	#1	#2	#3	#4	#5
Diameter (ft)					
Water depth (ft)					

Rectangular Reactors (Aeration Basins)

Reactor Number	#1	#2	#3	#4	#5
Length of ea. basin (ft)					
Width of ea. basin (ft)					
Avg. depth of ea. basin (ft)					

Extended Aeration Oxidation Ditch

Ditch Number	#1	#2	#3	#4	#5
Volume of ea. ditch (gal)					

Contact Stabilization

Round Reaeration Tanks

Tank Number	#1	#2	#3	#4	#5
Volume of ea. tank (MG)					

Rectangular Reaeration Tanks

Tank Number	#1	#2	#3	#4	#5
Length of ea. tank (ft)					
Width of ea. tank (ft)					
Avg. depth of ea. tank (ft)					

Round Contact Tanks

Tank Number	#1	#2	#3	#4	#5
Volume of ea. tank (MG)					

Rectangular Contact Tanks

Tank Number	#1	#2	#3	#4	#5
Length of ea. tank (ft)					
Width of ea. tank (ft)					
Avg. depth of ea. tank (ft)					

Activated Bio-Filter (ABF)

Bio-tower media (circle one): Redwood, stacked plastic, packed plastic

Are bio-towers constant flow or constant recirculation:

Circular Bio-Filters	#1	#2	#3	#4	#5
Diameter of ea. bio-filter (ft)					
Depth of ea. bio-filter (ft)					
Flow rate (GPM)					

Rectangular Bio-Filters	#1	#2	#3	#4	#5
Length of ea. bio-filter (ft)					
Width of ea. bio-filter (ft)					
Depth of ea. bio-filter (ft)					
Flow rate (GPM)					

Circular Aeration Basins

Reactor Number	#1	#2	#3	#4	#5
Diameter (ft)					
Avg. depth (ft)					

Rectangular Aeration Basins

Reactor Number	#1	#2	#3	#4	#5
Length of ea. basin (ft)					
Width of ea. basin (ft)					
Avg. depth of ea. basin (ft)					

Activated Sludge/Extended Aeration/Contact Stabilization/ABF

Type of aeration (circle one): diffused air, mechanical aeration

Tank Number	#1	#2	#3	#4	#5
diffused: scfm/reactor mechanical: hp/reactor					

Single Stage Trickling Filter

Filter media (circle one): rock, stacked plastic, packed plastic

Are filters constant flow, constant recirculation, or percent recirculation

Filter number	#1	#2	#3	#4	#5
Diameter of ea. filter (ft)					
Depth of ea. filter (ft)					
Flow rate (GPM)					

Two Stage Trickling Filter

Primary Filter media (circle one): rock, stacked plastic, packed plastic

Are filters constant flow, constant recirculation, or percent recirculation

Primary Filter Number	#1	#2	#3	#4	#5
Diameter of ea. filter (ft)					
Depth of ea. filter (ft)					
Flow rate (GPM)					

Secondary Filter Media (circle one): rock, stacked plastic, packed plastic

Are filters constant flow, constant recirculation, or percent recirculation

Secondary Filter Number	#1	#2	#3	#4	#5
Diameter of ea. filter (ft)					
Depth of ea. filter (ft)					
Flow rate (GPM)					

Rotating Biological Contactor (RBC)

Manufacturer of RBC units ______________________________

Type of drive unit (air or mechanical) ____________________

No. of process trains ____________

No. of stages per train ___________

Stage No. 1 surface area/per stage ________ ft^2

Stage No. 2 " " " " ________ ft^2

Stage No. 3 " " " " ________ ft^2

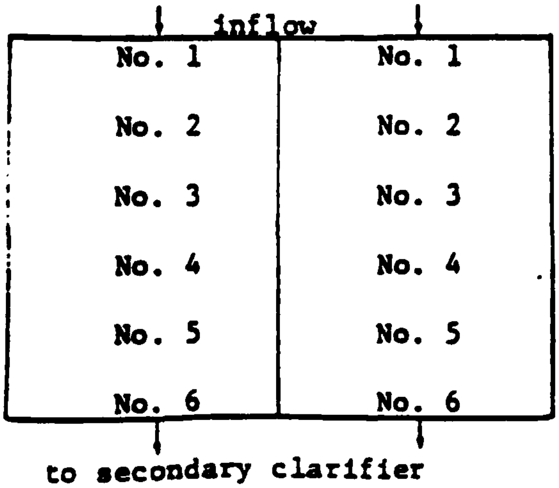
Stage No. 4 " " " " ________ ft^2

Stage No. 4 " " " " ________ ft^2

Stage No. 5 " " " " ________ ft^2

Stage No. 6 " " " " ________ ft^2

Example:



In example there are two trains with six stages in series. Stage Nos. 1,2,3 in each train have 100,000 ft^2 of surface area each or a total of 600,000 square feet. Stages Nos. 4,5,6 have a surface area of 150,000 ft^2 each or a total of 900,000 ft^2.

4. Sludge Digestion Input Data:

<u>Anaerobic Digestion</u>

Primary Digesters ____________________

Tank Number ____________ #1 #2 #3 #4

Volume of each primary digester ____________ gallons

Are the digesters heated ____________(yes or no)

Are the digesters mixed ____________(yes or no)

Is there any type of thickening prior to digestion? If so what kind

____

Secondary Digesters ____________________

Tank Number ____________ #1 #2 #3 #4

Volume of each digester____________ gallons

Can the digesters be heated ____________(yes or no)

Can the digesters be mixed ____________(yes or no)

<u>Aerobic Digestion</u>

Tank Number ____________ #1 #2 #3 #4

Volume of each digester ____________ gallons

Is there any type thickening prior to digestion? If so what type

____

<u>Additional Data for Digester Diagnostic</u>

MCRT if Applicable	Days
Raw Sludge flow	GPD
Raw Sludge Solids	%
Raw Sludge Volatiles	%
Digester Temperature	°C
Digester Liquor Solids	%
Digester Volatile Solids	%
Gas Production X1000	ft^3*
Alkalinity as $CaCO_3$	MG/L*
Volatile Acids	MG/L*

*For anaerobic digestion only.

APPENDIX D

DEFINITION OF OUTPUT PARAMETERS

PRIMARY CLARIFIER

FLOW	=	Hydraulic flow rate of the wastewater treatment plant; expressed in million gallons per day (MGD).
PCE BOD	=	Concentration of BOD_5 of primary clarifier effluent (mg/l).
PCE TSS	=	Concentration of total suspended solids of primary clarifier effluent (mg/l).
PS	=	Primary sludge; production rate (lbs/day), solids content expressed in lbs. of dry solids per lb. of sludge in terms of percentage (%) and flow rate (gallons/day).
SL	=	Surface loading or overflow rate of the primary clarifier (gal/ft^2/day).

BIOLOGICAL PROCESS PARAMETERS

MAX MLSS	=	Maximum value of the mixed liquor suspended solids concentration (mg/l).
MLVSS	=	Mixed liquor volatile suspended solids (%).
F/M	=	Food to microorganism ratio (dimensionless).
MCRT	=	Mean cell residence time of biological reactors (days).
SVI	=	Sludge volume index; defined as the volume in ml occupied by one gram of mixed liquor solids after 30 minutes settling.
RAS	=	Return activated sludge; flow rate (MGD) and concentration (mg/l).
WAS	=	Wasted activated sludge; mass flow rate (lbs/day).
DET TIME	=	Hydraulic detention time, (hrs) and (days).
LOAD	=	Activated Sludge, Extended Aeration and Contact Stabilization Systems - expressed in lbs BOD_5 per 1000 ft^3 of reactor volume (lbs BOD_5/1000 ft^3).
	-	All Trickling Filter and ABF Systems - expressed in lbs BOD per 1000 ft^3 of media volume (lbs BOD_5/1000 ft^3).
	-	RBC systems - expressed in lbs BOD per 1000 ft^2 of media surface (lbs BOD_5/1000 ft^2).
OUR	=	Oxygen uptake rate (mg/l/hr).
O_2RQD	=	Oxygen requirement (lbs/day).

SECONDARY CLARIFIER

DOB	=	Depth of blanket (ft). (Measured from surface)
EFF BOD	=	Effluent concentration of BOD_5 (mg/l).
EFF TSS	=	Effluent concentration of total suspended solids (mg/l).
EFF NO_3	=	Effluent concentration of nitrate nitrogen (mg/l).
EFF PO_4-P	=	Effluent concentration of orthophosphates (mg/l).
CLARIFIER LOAD	=	Hydraulic loading of the secondary clarifier; surface loading (gal/ft^2/day) and weir loading (gal/ft of weir length/day).
SEC. SLUDGE PROD	=	Sludge production from secondary clarifier per day; expressed in lbs. of total suspended solids (lbs/day) and in lbs. of volatile suspended solids (lbs/day).
TOTAL SLUDGE PROD	=	Total sludge production from both primary and secondary systems per day; in terms of lbs. of TSS (lbs/day), lbs of VSS, (lbs/day) and in terms of flow rate (gal/day); it is characterized by its solids content in terms of percent solids (% SOL).

DIGESTER

TOTAL SLUDGE FLOW	= Total sludge flow rate into the primary digester (gal/day); or as previously defined under the title "Total Sludge Prod."
VSS LOADING	= Volatile suspended solids loading to the primary digesters expressed in lbs of VSS loaded per ft^3 of digester per day ($lbs/ft^3/day$).
MCRT	= Mean cell residence time in the primary digesters (days).
% VSS RED.	= Volatile suspended solids reduction (%); in the primary digesters.
RAW SLUDGE FLOW, GPD	= Gallons of raw sludge pumped to the digester each day.
% SOLIDS RAW SLUDGE	= Concentration of raw sludge being pumped to the digester.
% VOLATILE SOLIDS, RAW SLUDGE	= The volatile content of the raw sludge solids in percent.
DIGESTER TEMP. °C	= The temperature of the digester liquor in degrees centigrade.
% SOLIDS, DIGESTER LIQUOR	= Concentration of digester solids in percent.
% VOLATILE SOLIDS, DIGESTER LIQUOR	= The volatile content of the digester sludge in percent.
GAS PRODUCTION, FT^3 X 1000	= The actual gas production in cubic feet divided by one thousand. For anaerobic digesters only.
ALKALINITY AS $CaCO_3$, MG/L	= The total alkalinity of the digester liquor assumed to be calcium carbonate. For anaerobic digesters only.
VOLATILE ACIDS, MG/L	= The volatile acid concentration in milligrams per liter assumed to be acetic acid (CH_3COOH).

APPENDIX E

REPRESENTATIVE VALUES FOR OUTPUT PARAMETERS

PRIMARY TREATMENT SYSTEM

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
Surface Loading (GPDSF)	400	800	1500
Weir Loading (GPD/FT)	8000	20,000	40,000
Detention Time (Hrs.)	4.0	2.0	1.0
BOD_5 Percent Removal	40	25	15
TSS Percent Removal	70	50	30

SECONDARY TREATMENT SYSTEM

Conventional Activated Sludge

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
MAX MLSS (MG/L)	2500	2500	<2500
MLVSS (%)	60	75	85
F/M	0.10	0.30	0.40
MCRT (DAYS)	20	7	3
SVI	100	100	>150
DET. TIME (HRS)	8	6	3
LB BOD/1000 FT^3	20	50	75
OUR (MG/L/HR)	10	20	40
CLARIFIER LOAD			
- SFC (GPSFD)	200	400	600
-WEIR (GPLFD)	8000	12,000	16,000

SECONDARY TREATMENT SYSTEM

Single Stage Activated Sludge for Nitrification

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
MAX MLSS (MG/L)	2500	2500	<2500
MLVSS (%)	60	75	85
F/M	0.10	0.30	0.40
MCRT (DAYS)	25	10	7
SVI	100	100	>150
DET. TIME (HRS)	10	8	4
LB BOD/1000 FT^3	20	50	75
OUR (MG/L/HR)	10	20	40
CLARIFIER LOAD			
- SFC (GPSFD)	200	400	600
-WEIR (GPLFD)	8000	12,000	16,000

SECONDARY TREATMENT SYSTEM

Activated Bio-Filter (Biological Reactor Performance page)

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
MAX MLSS (MG/L)	2500	2500	<2500
MLVSS (%)	60	75	85
F/M	0.10	0.30	0.40
MCRT (DAYS)	15	6	3
SVI	100	100	>150
DET. TIME (HRS)	8	6	3
LB BOD/1000 FT^3	20	50	75
OUR (MG/L/HR)	10	20	40
CLARIFIER LOAD			
- SFC (GPSFD)	200	400	600
-WEIR (GPLFD)	8000	12,000	16,000

SECONDARY TREATMENT SYSTEM

Extended Aeration
Extended Aeration Oxidation Ditch

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
MAX MLSS (MG/L)	3000	3000	<3000
MLVSS (%)	60	65	75
F/M	0.10	0.15	0.2
MCRT (DAYS)	40	30	20
SVI	100	100	150
DET. TIME (HRS)	36	24	12
LB BOD/1000 FT^3	5	15	25
OUR (MG/L/HR)	5	10	25
CLARIFIER LOAD			
- SFC (GPSFD)	200	400	600
- WEIR (GPLFD)	8,000	12,000	16,000

SECONDARY TREATMENT SYSTEM

Contact Stabilization

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
Contactor			
MAX MLSS (MG/L)	2500	2500	<2500
MLVSS (%)	55	70	85
F/M	0.60	0.90	1.20
MCRT (DAYS)*	20	7	3
SVI	100	100	150
DET. TIME (HRS)	6.0	3.0	1.0
OUR (MG/L/HR)	15	30	50
LB BOD/1000 FT^3	40	75	100
Reaeration Tank			
MAX MLSS (MG/L)	10,000	10,000	<7,000
F/M	0.10	0.15	0.20
Clarifier Load			
- SFC (GPSFD)	200	400	600
- WEIR (GPLFD)	8,000	12,000	16,000

*Aggregate of contactor and reaeration tanks

SECONDARY TREATMENT SYSTEM

Single Stage Trickling Filter
Two Stage Trickling Filter
Activated Bio-Filter (Secondary System Loading page)

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
Single Stage Trickling Filter			
FILTER LOADING (GPDSF)	200	800	1500
FILTER LOADING (#BOD/1000 FT^3)	10	25	40
RECIRCULATION RATIO (%)	0	100	200
Two Stage Trickling Filter (First Stage) and Activated Bio-Filter (Secondary System Loading page)			
FILTER LOADING (GPDSF)	200	800	1500
FILTER LOADING (#BOD/1000 FT^3)	50	100	150
RECIRCULATION RATIO (%)	0	100	200
Two Stage Trickling Filter (Second Stage)			
FILTER LOADING (GPDSF)	200	800	1500
FILTER LOADING (#BOD/1000 FT^3)	10	20	30
RECIRCULATION RATIO (%)	0	100	200
ALL TYPES			
CLARIFIER LOADINGS - SURFACE (GPDSF)	200	600	800
- WEIR (GPD/FT)	8,000	15,000	20,000

SECONDARY TREATMENT SYSTEM

Rotating Biological Contactors

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
STAGE LOADING*			
STAGE 1 (#BOD/1000 FT^2)	1.0	2.0	3.5
TOTAL (#BOD/1000 FT^2)	0.5	1.0	1.5
CLARIFIER LOADINGS - SURFACE (GPDSF)	200	600	800
-WEIR (GPD/FT)	8000	15,000	20,000

*Total BOD_5

SECONDARY TREATMENT SYSTEM

Roughing Filter/Activated Sludge

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
Roughing Filter			
FILTER LOADING (GPDSF)	800	1500	4000
FILTER LOADING (#BOD/1000 FT^3)	50	100	300
RECIRCULATION RATIO (%)	0	100	200
Activated Sludge			
MAX MLSS (MG/L)	2500	2500	<2500
MLVSS (%)	60	75	85
F/M	0.10	0.30	0.40
MCRT (DAYS)	20	7	3
SVI	100	100	>150
DET. TIME (HRS)	8	6	3
LB BOD/1000 FT^3	20	50	75
OUR (MG/L/HR)	10	20	40
CLARIFIER LOAD			
- SFC (GPSFD)	200	400	600
- WEIR (GPLFD)	8000	12,000	16,000

SLUDGE DIGESTION SYSTEM

PARAMETERS	LOW LOADING	NORMAL LOADING	HIGH LOADING
Aerobic Digesters (WAS only)			
VSS LOADING (LB/FT^3/DAY)	.05	.10	.15
MCRT (DAYS)	30	15	10
% VSS REDUCTION	60	40	20
Anaerobic Digesters (Standard Rate)			
VSS LOADING (LB/FT^3/DAY)	.05	.10	.15
MCRT (DAYS)	45	30	20
% VSS REDUCTION	75	60	40
Anaerobic Digesters (High Rate)			
VSS LOADING (LB/FT^3/DAY)	.10	.25	.40
MCRT (DAYS)	30	20	15
% VSSS REDUCTION	70	50	30

APPENDIX F

DO'S AND DON'TS OF COMPUTER OPERATION

DO'S AND DON'TS OF COMPUTER OPERATION

DO NOT remove circuit boards in computer while power is on.

DO NOT turn the computer on unless there is a diskette in Drive A or a hard disk is used.

DO NOT remove a diskette from a drive while the red "in use" light is on.

DO NOT hit control reset buttons while red "in use" light is on on either diskette drive.

DO turn printer on and place it "on line" before running programs.

DO have paper in printer before turning it on.

DO NOT manually advance printer paper while printer is on—use LF (line feed) or FF (form feed) buttons instead.

DO keep equipment in cool (<85°F), relatively dry area.

DO NOT expose diskettes to magnetic or electrical fields (such as from electric motors), heat, or sunlight.

DO NOT touch grey shiny surface of diskette with fingers or other object.

DO keep diskettes in paper envelope when not in use.

DO handle diskettes carefully by plastic cover only.

DO NOT force diskettes into drives—they should enter smoothly with little effort.

DO NOT leave diskettes stored in drives overnight.

IDEALIZED MATHEMATICAL MODEL OF EL CENTRO, CALIFORNIA PRIMARY WASTEWATER TREATMENT SYSTEM

APPENDIX G

Prepared by ES Environmental Services,
by contract with Boise State
University, Boise, Idaho. Through a grant from the
Environmental Protection Agency, Region X,
Seattle Washington.

DATE:
TIME: :

WASTEWATER CHARACTERIZATION

AVERAGE DRY WEATHER FLOW	MGD:	3
PEAK DRY WEATHER FLOW	MGD:	5
DESIGN FLOW	MGD:	6
INFLUENT BOD	MG/L:	210
INFLUENT TSS	MG/L:	235
INFLUENT VSS	(%):	83
TEMPERATURE	'C:	22
TKN	MG/L:	30 *
ALKALINITY	MG/L:	100 *
PH	:	7 *
PO4-P	MG/L:	8 *

* DEFAULT VALUE USED

PLANT CONFIGURATION AND DIMENSIONS

DESIGN AVERAGE DAILY FLOW (MGD) : 5
DESIGN PEAK WET WEATHER FLOW (MGD): 10

PRIMARY CLARIFICATION

NUMBER OF ROUND CLARIFIERS: 2

DIMENSIONS	EACH	TOTAL
DIAMETER (FT):	65	
DEPTH (FT):	8.5	
WEIR LTH (FT):	205	205
SFC AREA (FT2):	6636	6636

DATE:
TIME: :

SLUDGE HANDLING

TYPE OF DIGESTION: ANAEROBIC

NUMBER OF PRIMARY DIGESTERS: 1

#1

VOLUME (GAL): 187000
DIGESTER HEATED Y
DIGESTER MIXED Y

NUMBER OF SECONDARY DIGESTERS: 1

VOLUME FOR DIGESTER #1 GAL: 187000

EL CENTRO, CALIFORNIA
MATHEMATICAL MODEL

DATE:
TIME: :
BOD: 210
TSS: 235
TEMP 22

PRIMARY SYSTEM LOADINGS

FLOW MGD	CLAR. LOADINGS SURFACE GPDSF	WEIR GDP/FT	SOLIDS #/SF/DAY	DETN TIME HRS.
2.25	339	5487	.58	4.50
2.54	383	6195	.66	3.99
2.83	426	6902	.74	3.58
3.13	472	7634	.82	3.24
3.42	515	8341	.89	2.96
3.71	559	9048	.97	2.73
4.00	603	9756	1.05	2.53
4.29	646	10463	1.12	2.36
4.59	692	11195	1.20	2.21
4.88	735	11902	1.28	2.08
5.17	779	12609	1.35	1.96
5.46	823	13317	1.43	1.85
5.76	868	14048	1.51	1.76
6.05	912	14756	1.59	1.67
6.34	955	15463	1.66	1.60
6.63	999	16170	1.74	1.53
6.92	1043	16878	1.82	1.46
7.22	1088	17609	1.90	1.40
7.51	1132	18317	1.97	1.35
7.80	1175	19024	2.04	1.30

EL CENTRO, CALIFORNIA

DATE:
TIME: :
BOD: 210
TSS: 235
TEMP 22

PRIMARY SYSTEM PERFORMANCE

OW)	% REMOVAL BOD	% REMOVAL TSS	P.C. EFF MG/L BOD	P.C. EFF MG/L TSS	PRIMARY SLUDGE PROD. LBS TSS	PRIMARY SLUDGE PROD. LBS VSS	PRIMARY SLUDGE PROD. % SOL	PRIMARY SLUDGE PROD. GDP
25	55	65	95	82	2866	2379	5.71	6019
64	54	65	98	82	3236	2686	5.71	6795
83	51	64	103	84	3573	2966	5.71	7502
13	49	62	107	89	3810	3162	5.71	8000
42	47	60	111	94	4023	3339	5.71	8448
71	45	58	115	99	4223	3505	5.71	8868
00	44	56	118	103	4411	3661	5.71	9263
29	42	55	121	107	4588	3808	5.71	9634
59	41	53	124	111	4761	3951	5.71	9996
88	40	51	127	114	4918	4082	5.71	10327
17	39	50	129	117	5067	4205	5.71	10639
46	38	49	131	121	5208	4323	5.71	10936
76	37	47	133	124	5347	4438	5.71	11227
05	36	46	135	127	5474	4544	5.71	11495
34	35	45	137	129	5596	4645	5.71	11751
63	34	44	138	132	5712	4741	5.71	11994
92	33	43	140	134	5823	4833	5.71	12228
22	33	42	141	136	5933	4924	5.71	12458
51	32	41	143	139	6035	5009	5.71	12672
80	31	40	144	141	6132	5090	5.71	12877

APPENDIX H

ZONE SETTLING VELOCITY

APPENDIX H

ZONE SETTLING VELOCITY

The zone settling velocity or rate of activated sludge settling is an extremely important parameter in evaluating activated sludge system performance. Obviously if the mixed liquor does not settle well then poor performance can be expected. On the other hand, if the mixed liquor settles well and the effluent quality is poor, then the probable cause is poor clarifier hydraulics or clarifier overload.

The zone settling velocity is determined by measuring the settling rate of the activated sludge reactor effluent in a one or two liter graduated cylinder. The interface height is measured at various time intervals (see work sheet), plotted on a graph, the slope estimated, and then data is converted to feet per hour. Settling velocities can be characterized as follows:

Condition	Range, ft/hr
Poor	<3
Fair	3-5
Good	6-9
Excellent	>10

When evaluating a treatment plant, the final clarifier surface area is also a significant element and should be used in conjunction with the zone settling velocity. As an example, the reactor effluent solids could have a settling rate of 3 feet per hour but at the same time the final clarifier surface loading could be low enough to compensate for the poor settling. There have been many theories and equations developed to determine the required surface area or maximum surface loading based on zone settling velocity. Many of these equations are highly theoretical and extremely complex, and are beyond the scope of this manual.

A very simplified approach to determine the maximum final clarifier surface loading is to multiply the zone settling velocity by 180. As an example, if the zone settling was determined to be 5 ft/hr then the maximum final clarifier surface loading would be 5 x 180 = 900 gallons per square foot per day. This is the maximum loading. If the average to peak flow factor were 1.5 then the average loading would be 900/1.5 = 600 gallons per square foot per day.

PROCEDURE (One Liter Graduate Method)

Measure the distance between each 100 ml mark and record in feet. Fill the graduated cylinder with mixed liquor. If the mixed liquor concentration is in excess of 3000 mg/l use a stirring apparatus consisting of 3 vertical elements long enough to reach the bottom of the cylinder. The stirrer should be connected to a clock motor that rotates at about 12 revolutions per hour.

Record the height of the interface at the time intervals indicated on the work sheet. After data is recorded, plot the data graph sheet provided and draw the best fit curve. Then draw a straight line through the first part of the curve starting at zero time. Note where the approximate tangent point is on the curve, then draw a horizontal line from that point to determine the interface height at that time. Record this data and compute the zone settling as indicated on the work sheet. Note the two sheets marked "sample" to be used as an example. The next two sheets are forms that can be copied and utilized for the zone settling velocity test.

ZONE SETTLING VELOCITY

WORK SHEET

Date ______________

Location ______________

Analyst ______________

Time minutes	Interface height, mls
1	______
2	______
3	______
4	______
5	______
7	______
9	______
11	______
13	______
15	______
20	______
25	______
30	______

Distance between 100 mls ______ ft.

MLSS conc. ______ mg/L

tangent point ______ ml

time ______ minutes

Computations

$$\frac{(1000 - \text{tang. point})(100\text{ml dist})(60)}{\text{time min}} = \text{ZSV, ft/hr}$$

$$\frac{(1000 - \_\_\_\_\_\_)(\_\_\_\_\_\_)(0.6)}{(\_\_\_\_\_\_)} = \_\_\_\_\_\_ \text{ ZSV, ft/hr}$$

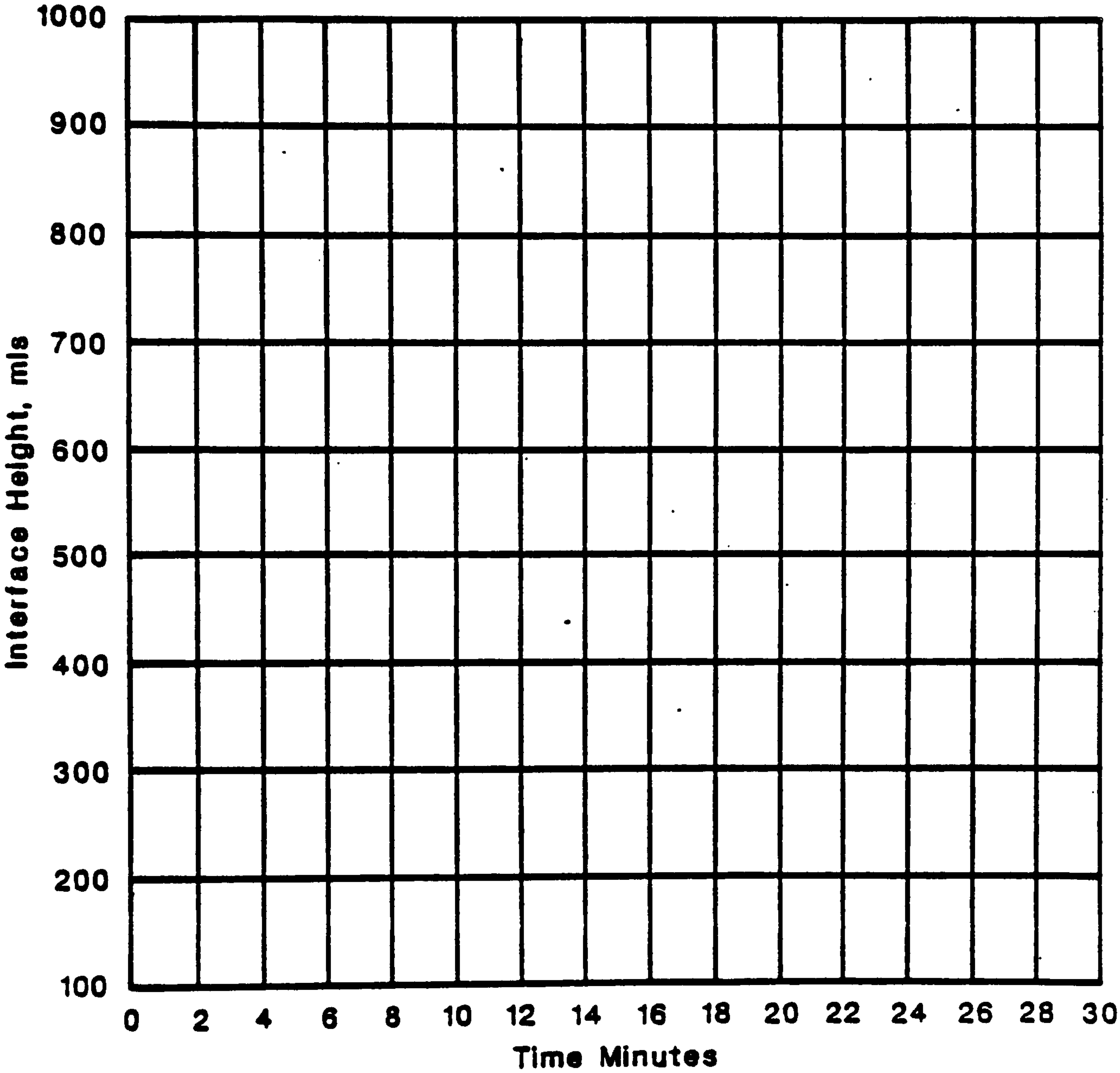
(ZSV)(179.5) = ______ maximum surface loading gpdsf

(____)(179.5) = ______ maximum surface loading gpdsf

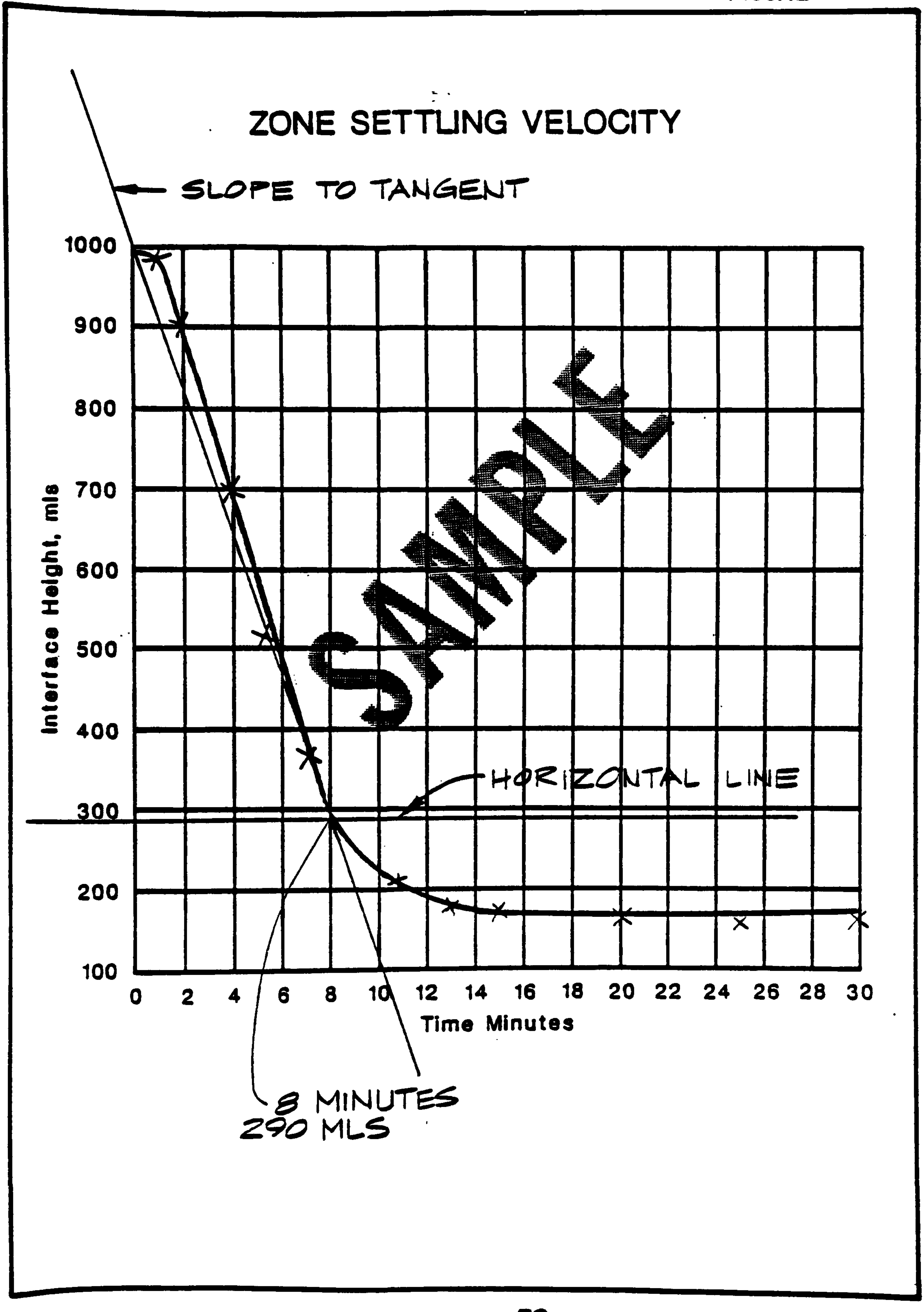
$$\frac{(1000)(\text{ml settled, 30min})}{\text{MLSS, mg/L}} = \text{SVI, g/100ml}$$

$$\frac{(1000)(\_\_\_\_\_\_)}{(\_\_\_\_\_\_)} = \_\_\_\_\_\_ \text{ SVI, g/100ml}$$

ZONE SETTLING VELOCITY



FIGURE


ZONE SETTLING VELOCITY
SLOPE TO TANGENT
Interface Height, mls
1000
900
800
700
600
500
400
300
200
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Time Minutes
HORIZONTAL LINE
SAMPLE
8 MINUTES
290 MLS

ZONE SETTLING VELOCITY

WORK SHEET

Date 3 AUGUST 1985
Location REACTOR NO. 1
Analyst JESS FINE

Time minutes	Interface height, mls
1	980
2	900
3	800
4	675
5	520
7	360
9	250
11	200
13	195
15	190
20	190
25	[illegible]
30	190

Distance between 100mls 0.115 ft.

MLSS conc. 2100 mg/L
tangent point 290 ml
time 8 minutes

Computations

(1000 − tang. point)(100ml dist)(60) / time min = ZSV, ft/hr

(1000 − 290)(0.115)(0.6) / (8) = 6.12 ZSV, ft/hr

(ZSV)(179.5) = ________ maximum surface loading gpdsf
(6.12)(179.5) = 1098 maximum surface loading gpdsf

(1000)(ml settled, 30min) / MLSS, mg/L = SVI, g/100ml

(1000)(190) / (2100) = 90 SVI, g/100ml