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## An Investigation of Sewage Treatment Automation Techniques

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AN INVESTIGATION OF SEWAGE  
TREATMENT AUTOMATION TECHNIQUES

BY

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B.S., Pennsylvania State University, 1941

RESEARCH REPORT

Submitted in partial fulfillment of the requirements  
for the degree of Master of Science in  
the Graduate Studies Program of  
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## CHAPTER I

### INTRODUCTION

The problems encountered and the design-operation interaction occurring in wastewater treatment plants, was thoroughly reviewed by Andrews (1972b). It was his conclusion that a large number of wastewater treatment plants in the United States operate at overall efficiencies far below those at which they are capable of operating. Most sewage treatment plants are operated in a primitive manner as compared to controlled processes demonstrated in industrial processes, merely because of the human element involved.

In addition, there are many other operational problems involved. Andrews (1972b) cited a study of 1500 performance audits in which there were 499 instances of plant bypassing from such causes as stormwater and infiltration, shutdown for routine maintenance and for mechanical failures. Also, there were significant variations in treatment plant efficiency, not only from one plant to another, but also from day to day and hour to hour in the same plant. Daily variations from 60% to 95% efficiencies in BOD removal were not uncommon, which variations can have a significant effect on the water quality of the receiving stream.

The need for more adequate consideration of the interaction between design and operating personnel for wastewater treatment plants has become quite obvious. The lack of this consideration has resulted in inefficient plant operation and in pollution problems.

Some of the specific factors which must be considered in balancing



design to operation are noted.

1. Operating Personnel. The need for operation must be minimized through design when it is anticipated that plants will be operated by unskilled personnel or when labor problems, such as strikes, may be expected. In such cases, provisions must be made for automation so that plant management personnel may operate the plants for limited periods of time.

2. Process Stability. It is well recognized that some processes used for wastewater treatment are more stable than others and therefore require less attention and less skill to operate. Improved stability can be obtained by improving operational techniques which also decreases the need for oversizing of units.

Most engineers will agree that the trickling filter is more stable than the activated sludge process but would not place a quantitative value on the comparison.

3. Availability of Space. Decreases in sizes of plants through improved operation is of importance in the larger cities where space is costly. The interaction of wastewater transport cost with plant size must also be considered. Smaller and well operated plants can frequently be located nearer to the major wastewater sources thus decreasing transport costs.

4. Reliability. Bypassing of raw wastewater and gross process failures occur frequently. The effect on the receiving waters of short term or long term failures to achieve the proper degree of treatment must be considered. A high degree of reliability is required for a plant discharging into a stream with no latitude of variation. The required



additional reliability can be achieved either through design or by improved operation.

5. Financial. The balance between design and operation is influenced by the ability to invest capital as opposed to operating and maintenance costs. In a municipality the capital must be acquired by bond issue while the maintenance and operating costs come from an operating budget.

6. Flexibility. As technological advances are made in wastewater treatment and as more stringent controls are imposed by legislation, the design must have the capability of adapting to accept the new operating conditions.

7. Environment. The type of control system selected for a plant must be suited to the environment in which the plant will be operated. Use of a complex control system would be self defeating if proper instrument maintenance is unavailable or if qualified operators cannot be obtained.



## CHAPTER II

### EVOLUTION OF PROCESS CONTROL

Proper consideration of the factors involved causes the selection of proper process control to match the design to the operation. To properly catalog the degree of complexity desired or to be tolerated in the selected system, a historical review is provided of the evolution of process control.

#### Manual Control

In manual control the operator uses his senses to determine the status of the process or measure the quality of the results of the process. Any deviations from the desired operating conditions, when observed, are corrected by changing those variables which can be controlled. In general, in manual control these are limited to (a) return sludge flow rate, (b) sludge wasting rate, and (c) air flow rate.

After changing the system variables, the operator then observes if the correction is adequate and continues to make adjustments until the process is operating properly, recognizing the long time delay between adjustment and results and avoiding overshoot. The problem is complicated by the fact that quantitative and qualitative characteristics of the influent are changing with time.

The operator is the feedback to control the process and good operation is therefore an art which is dependent on the experience, skill and the intuition of the operator. The control of many of the



treatment plants in use today has not advanced much beyond this stage.

### Indicating and Recording Instruments

The first part of the feedback loop to be mechanized was the sensing function. Human senses were replaced with indicating instruments and automatic recorders were added to provide a historical record and to aid in charting trends. However, these instruments serve only to assist the operator and it is still his judgment that determines the deviation and effects the necessary correction.

The sensing instruments are the key to the feedback loop. Accurate and reliable instruments are available for such measurements as pressure, temperature and flow rate. Instruments for more advanced systems, measuring biological properties, chemical quantities and some of the physical measurements needed for plant control are not completely developed to the same degree of reliability and are restrictive to application in the more complex control systems.

As an example, accurate reliable instrumentation has not been developed for the required evaluation parameters of BOD, suspended solids or coliform count. BOD and suspended solids are approximated on a comparative basis by other measurements, i.e., TOC, inorganic carbon, total carbon and turbidity.

### Local Automatic Control

The next step in the development of automatic control came with the advent of the automatic controller with its ability to remove the operator from continuous participation in the feedback loop. Utilizing the controller, it is possible to choose a set point for a process



variable and to have the controller maintain that set point. The controller then senses the deviation and makes the correction back to the desired operating point. However, the operator must still use his judgment to select the controller set points based on his judgment and experience.

Automatic controllers can be obtained with several different control modes. Included are (a) on-off control in which the control transducer is fully open or closed when the measured value of the variable deviates more than a predetermined fixed amount from the set value; (b) proportional control in which the transducer operation is proportional to the error or the difference between the measured value and the set value; (c) integral control where the transducer operation is proportional to the integral of the error signal with respect to time and so compensates for the length of time that the error has persisted; and (d) derivative control for which the transducer operation is proportional to the derivative of the error signal with respect to time and so reflects the rate of change of the error. Automatic controllers can be found in operation with any combination of modes of operation.

#### Centralized Automatic Control

Local automatic controllers are physically located near the process variable to be controlled. As their number increased, their maintenance and the monitoring of the set points became more difficult. This brought about the development of the centralized control room. Here the controllers are mounted together on a control panel which may include a graphic schematic flow diagram of the plant. This display assists



the operator in organizing and assimilating the data presented and also assists him to more quickly interpret the interaction between variables and to reach the right corrective action required under the circumstances.

### Computer Control, Data Processing, and Monitoring

Computer control can be installed in stages, and the first step is usually straightforward data processing and monitoring. The computer collects data, processes it into a more meaningful form and displays it to the operator. The operator then adjusts the set points of his automatic controllers. In this basic application of the use of the computer, the operator is still in the feedback loop and the computer merely assists him in running the plant.

Typical functions which may be performed by the computer are:

1. Scan process sensing instruments, check for instrument malfunction, and convert raw data to engineering unit.
2. Process data into a more meaningful form for the operator by smoothing, curve fitting, integration, differentiation, and statistical analysis.
3. Monitor and report on the status of process equipment. For example, the computer can monitor the on-off condition of pumps, valves, motors, and compressors. It can also check for other specific alarm conditions such as overheating of bearings, high or low wet well level, and excessive vibration of motors and compressors.
4. Compare process variables against high-low limits and sound alarms.
5. Prepare operating logs and display information to the opera-



tor. This can be in tabular form, plotted trend charts of particular variables, or graphical displays on a cathode ray tube.

6. Furnish the operator with an operating guide when he requests it, such as procedures to follow in case of a wide deviation or a process upset.

7. Furnish data for other computers or provide reduced operating data to higher management. Provide a complete, standardized operating report eliminating the operators clerical functions of written reports.

#### Optimal Control

In this mode of control, the computer takes over operation of the plant and controls it so that the overall operation is optimum. However, before this can happen, it is necessary to tell the computer the definition of "optimum." For a typical example, in a treatment plant, "optimum" might mean to control the plant at minimum operating cost but with the constraint that the effluent BOD always be equal to or less than 20 mg/l. The computer would take into account all significant process variables including the interaction of the process variables on each other, calculate the process conditions and control changes necessary to obtain the optimum performance, and then initiate the necessary changes.

In this mode of operation, the automatic controllers can be eliminated with the computer furnishing signals directly to manipulate process variables and to operate the transducers. In processes where a large number of variables must be controlled, this can result in a considerable savings for instrumentation.



Feedforward control, using a dynamic mathematical model stored in the computer, can be incorporated to take control action before process upset occurs. Information for feedforward control is obtained by measuring the inputs to the plant. Some feedback control, utilizing information from the plant outputs is also incorporated since the initial mathematical model of the plant is susceptible to error. The model is corrected as history indicates the true results of controlled inputs.

Exact knowledge of the true process is not required for feedback control; however, considerable time may elapse after the control action is initiated before the process is restored to proper operating conditions. Although this disadvantage can be minimized by the use of feedforward control, the computer itself will have to gather history of response to improve the accuracy of the mathematical model.

Because of the high speed of operation of the digital computer, there is a widespread number of additional functions which can be imposed upon the computer to be performed in its spare time.

As an example, the computer in the optimal mode can also perform all of the functions enumerated in the data processing and control mode as spare time functions. In addition, it is possible, using the mathematical model, to game the system by providing a fictitious change in an operating variable and receiving a detailed report of all of the operating variables in the system's probable response. These game results also become more accurate as the computer becomes more educated with the system's actual response to changes in operating variables.



## CHAPTER III

### BASIC CONTROL SYSTEMS

The original control systems utilized with sewage collection and sewage treatment operations were local systems with a signal designated for each pump at each site. This type of system, still in use at many locations, required the operator to make continuous checks on the system. The operator often would not realize a system failure until the results were catastrophic, such as a flooded station or loss of flow.

To correct this problem, it was necessary to provide wiring from the operation device to a central point, which would allow rapid scan of possible trouble sources and would greatly improve the response time in responding to system problems. However, in addition to the requirement for individual wires for each desired signal, it was only a receiving system for indications without capability for control.

Systems for automatic central control were needed. First, electro-mechanical principles were used. Although these systems worked, the reliability was in question and they required continuous maintenance. More recently, the advent of solid state circuitry has increased system reliability and reduced the cost to allow central control of a large number of signals from a central location. Brown (1974) has provided an analysis of the telemetry systems that are in use in conjunction with sewage collection and sewage treatment plants.



## Types of Signals

### On-Off

Typical on-off signals would be pump call, pump run, high temperature, low wet well level, station entry, etc. The on-off type signals are sometimes further classified as:

1. Status - signals from remote site showing pump running, check valve open, etc.
2. Alarms - signals from remote site showing pump failure, high temperature, high wet well level, etc.
3. Commands - signals to the remote site to start pump, open check valve, etc.

### Variable Signals

The variable signals are any process signals that are continuously varying, such as system pressure or flow, or any signal to the remote site such as valve position or motor speed. Typical variable signals are tank level, pump flow rate, valve position, amps, volts.

## Telemetry

### D.C. Lines

On a D.C. line we can send current levels which pull in relays to perform commands or to provide status indication. The simplest system is one in which closing the switch at one end of a D.C. line will operate a circuit at the other end of the D.C. line.

By the use of diodes to identify polarity and by using different current levels, it is possible on a D.C. line pair to achieve two independent signals in either direction plus a line failure monitor.

### Voice Grade Line

When voice grade telephone lines are used, a tone system must



also be used since amplifiers with transformers are used by the telephone company which do not allow D.C. to pass. Each tone channel constitutes a separate circuit capable of sending a signal to its receiver. Many signals may be sent in either direction, limited only by channel spacing. From a practical point of view, because of the problems of interchannel interference and crosstalk, six to eight channels is the limit of transmission on one pair of telephone lines.

### Scanners

When larger amounts of data are to be telemetered from a remote site to a central control point, a scanner must be used. The scanner is a device which uses either D.C. lines or voice grade lines and converts many parallel inputs to a string of signals in series for putting on the line either as D.C. pulses or tone signals. At the receiver, these are converted back to parallel on-off outputs, each signal going to its own assigned channel.

The amount of data transmitted in this system is limited only by the time of response required. At a typical rate of 360 bits per second, sixteen channels of information could be telemetered and each channel would be corrected ten times per second.

If it is desired to use the system in both directions, the system can be duplicated, and if tone is used, two different frequencies can be used.

### Telemetering Variables

#### Time Duration

In the time duration system, the level or pressure is converted



to an electrical voltage which represents the quantity measured. This voltage is converted to an on-off pulse, the length of pulse dependent on the quantity of the voltage and the parameter measured. The pulse is reconverted at the receiver back to the quantity transmitted.

This system has a built in unreliability which must be considered. Each converter has zero and span adjustments both of which are subject to error and drift. The system must be continuously checked with test signals to verify its accuracy.

#### Digital

With the digital system the variables are converted to a digital number or Binary Coded Decimal (BCD). This means that a quantity of on-off signals are transmitted instead of a variable duration pulse. The system has no inherent error due to the telemetering.

After being converted to a BCD signal, the signal is converted to a digital word for serial transmission over the phone line. This transmission may be either D.C. pulses for short distances (less than ten miles) or frequency shift tone signals for longer lines. The data receiver demultiplexes the signal and converts it back to a BCD parallel output after checking the word for validity by receiving the data twice in a row and comparing. Only valid data will be accepted. If valid data are not received within a guard period, an alarm is sounded.



## CHAPTER IV

## AUTOMATION IN ORANGE COUNTY, FLORIDA

At the present time, there is work in progress to expand the Orange County wastewater treatment facility located at Sand Lake Road. Population projections show that even before the work is completed, the facility will be inadequate for the projected growth of Orange County. Further, the construction costs and the operating costs are expanding quite rapidly. The plan for future expansion must be made to meet the requirement for wastewater treatment, but with minimum capital expansion, minimum increase in operating costs and operating personnel and with the capability of improved secondary and tertiary treatment.

The capacity for which the Sand Lake facility must be planned is to provide treatment for 15 million gallons per day, (MGD) to an effluent quality of 5 milligrams per liter, (mg/l) of Biochemical Oxygen Demand at 5 days, ( $BOD_5$ ), 5 mg/l of suspended solids, 3 mg/l total nitrogen and 1 mg/l of total phosphorus. It is expected that with 15 MGD capacity, the facility will be able to handle peak load variations up to 30 MGD while maintaining the design efficiency and to handle the required load at reduced costs.

The proposed treatment consists of the following processes which will be discussed in Chapter V.

1. Pumping and preliminary treatment
2. Grit removal
3. Activated sludge
4. Secondary clarification
5. Intermediate lift station



6. Nitrification
7. Tertiary clarification
8. Denitrification
9. Gravity rapid filtration
10. Reaeration
11. Chlorination
12. Sludge disposal

Operation of the proposed facility will be primarily by means of a computer directed process control system. The functional performance of the computer control system will be as follows:

1. The automatic collection of operating data from the remote sensors. Included in this data are contact closure signals and feedback from operational controls of the mechanical devices. In addition, data will be supplied from measured parameters of the biological processes under control.
2. Processing of all incoming data by a digital computer.
3. Display, on demand, all pertinent operating parameters on a centrally located cathode ray tube monitor.
4. Logging of all required data for historical records or reports.
5. Execution of all automatic control commands through the proper transducers.
6. Direct digital control of the required process loops.
7. Log running time for specific plant equipment and schedule periodic maintenance.
8. Maintain inventory of computer controlled chemicals and provide reordering instructions.

The philosophy of the operation of the computer controlled system indicates that some of the processes should be manual/automatic under a local or remote control while others which can most profitably be directed by the computer will be under direct digital control.

Manual/automatic control treatment under a local or remote control will be the primary mode of operation of the following processes:



1. Pumping and preliminary treatment
2. Grit removal
3. Gravity rapid filtration
4. Backwash
5. Reaeration
6. Chlorination
7. Centrifuge
8. Sludge return
9. Miscellaneous (i.e., backwash waste pump, nonpotable water, scum pumps)

In direct digital control treatment, the computer system will receive all analog and contact closure information from throughout the plant. The computer will process the inputs to match the control algorithms and will output the required commands to the proper transducers.

In the use of direct digital process control, there will be three modes of control available to the operator:

1. Direct digital control. In this mode full utilization is made of the computer. The computer will calculate all required setpoints and control the equipment automatically.
2. Operator setpoint control. In this mode the operator will set the flow setpoints as required. The operator will operate or turn off any pump or mechanical device as required. If the operator sets a particular flow setpoint, that setting will not interfere with the proper operation of other setpoints which he did not manually adjust. If one of the other setpoints require resetting because of manual adjustment, the computer will advise him of the necessity by means of a printed message.
3. Local manual control. In this mode the operator can take control of any device and set the output to a desired value from local panels in the field. As an example, if the operator needed to control



the flow of air to the aeration and nitrification tanks, he would dial a switch on the local panel from automatic to manual and adjust the increase or decrease of air flow by positioning the modulating butterfly valves. The panel switch alerts the computer that manual takeover has taken place and the computer stops calculating and adjusting the set-points.

The following listed processes will be controlled by direct digital control as the primary mode. For each of these control loops, in addition to providing the control, the computer will continuously advise the operator of status and signal him alarm conditions if required.

1. Aeration
2. Intermediate lift station
3. Denitrification
4. Waste sludge pumping
5. Alum feed
6. Lime feed
7. Methanol feed

Input data to the computer will be supplied by contact closure signals and feedback from operational controls of the mechanical devices. In addition, the computer will be supplied with data from the biological processes under control.

The following parameters will be monitored on a continuous basis, displayed to the operator and reported to the computer for processing in the algorithms to derive the proper execution signal.

1. Ammonia nitrogen from:
  - a. Grit Chamber
  - b. Secondary clarifier effluent
  - c. Denitrification influent
  - d. Filter effluent
  - e. Final effluent



2. Nitrate/nitrite from:
  - a. Grit chamber
  - b. Secondary clarifier effluent
  - c. Denitrification influent
  - d. Filter effluent
  - e. Final effluent
3. Total phosphorus from:
  - a. Secondary clarifier effluent
  - b. Denitrification influent
  - c. Final effluent
4. Total Organic Carbon, inorganic carbon and total carbon from:
  - a. Denitrification influent
  - b. Filter effluent
  - c. Final effluent
5. pH from:
  - a. Secondary clarifier effluent
  - b. Return nitrification sludge
  - c. Tertiary clarifier feed flume prior to clarifiers
  - d. Final effluent
6. Turbidity from:
  - a. Denitrification influent
  - b. Filter effluent
  - c. Final effluent
7. Oxidation reduction potential from:
  - a. Return activated sludge flume
  - b. Return nitrification sludge flume
8. Dissolved oxygen and temperature from:
  - a. First stage aeration (8 sample points)
  - b. Second stage aeration (12 sample points)
  - c. Final effluent (1 sample point)
9. Chlorine residual from:
  - a. Effluent of chlorine contact tank
  - b. Effluent of chlorine contact chamber for waste back-wash water



It should be noted that the measurements of the legal control parameters will still be required to be done on an individual basis by laboratory personnel to acquire the data for control agency evaluations. The automatic sampling and analysis system referenced here provides comparative data for control that allows evaluation of segments of the process, such as chlorine residual, ammonia nitrogen, nitrate/nitrite, and total phosphorus.

BOD and suspended solids are not monitored by the system except as a comparative functional measurement derived from the measurements of total organic carbon, inorganic carbon, total carbon and turbidity.



## CHAPTER V

### AUTOMATED PROCESSES

In the following descriptions of operating processes, it is not possible to enumerate all of the sensor, control, feedback and transducer interactions which occur in the various control loops, but it has been attempted to include an example of each type of sensory control loop and to identify man versus machine operation.

#### Pumping and Preliminary Treatment

The influent pump station is under construction and will be in use in a few months. The flows into the pump station from the several sources enter a distribution box, then to a flume and to one of two mechanical bar screens. The mechanical bar screen removes all rags, sticks and other material to a container by a moving chain conveyor. The screen will be modified to be float operated, operating when the head loss through the screen increases to a preset level. Alarms will be displayed in the control room if the screen fails to operate properly.

From the bar screen, the flow enters the split wet well. Four variable speed centrifugal pumps are planned, two on each channel, to move the raw sewage to the aerated grit chamber. The speed of the variable speed centrifugal pumps will be regulated by the head in the wet well so that, as near as possible, effluent will match influent and the pumps will run constantly at the required speed. This will minimize the start and stop of these large motors.



### Grit Removal

The grit chamber is aerated to keep organic matter in suspension but allowing the grit to settle to the bottom of the chamber. A bucket drag system will collect the grit and convey it to the hoppers above the chamber where a screw conveyor will deliver the grit to a container or a truck positioned alongside.

The grit chamber may be bypassed for maintenance if necessary. Flow from the grit chamber enters the flume feeding the activated sludge aeration tanks.

A pressure switch on the air line will operate a control relay which starts one of the compressor motors on a time shared basis. The control relay is connected through a time delay relay to the supervisory control panel and to the computer to provide an alarm signal if either compressor fails to supply air when energized.

The scraper and screw conveyor will be controlled automatically by a time programmer with adjustable on and off time periods. Provisions are available for manual operation when desired. If either drive motor fails to operate when called for by the time programmer, or if either shear pin fails, an alarm will be displayed on the supervisory control panel and will be logged by the computer.

### Air Supply

Air will be supplied by three operating and one standby 13,000 CFM blowers. The air flow to the aeration and nitrification tanks will be regulated by motor operated butterfly valves in the main air lines controlled by the computer. Feedback is supplied to the computer by dissolved



oxygen probes located in the first and second stage aerators and the final effluent. All of the air supply control can be performed manually from the panel near the blower, if necessary to override the computer.

### Activated Sludge

The sludge return rate will be controlled by manual adjustment of the variable speed drive on the sludge pumps located on the moving bridge carriage collectors. The sludge return flow depth in each flume will be displayed by an indicator at the flume. A signal proportional to depth will be transmitted from a liquid level sensor in each flume to the computer. The computer will calculate the flow rate of the Return Activated Sludge flume in gallons per minute and will continuously display the rate of each flume on the supervisory control panel. The computer will also totalize the flow of each flume and the combined flow, log the totals and print out the results daily.

The flow from the grit chamber, after mixing with the return activated sludge, will be distributed to the four aeration tanks. The mixed liquor will enter each tank through ports along one side wall and will be discharged over weirs along the opposite side wall which will provide a completely mixed tank. In each aeration tank, there will be two dissolved oxygen probes located near the effluent weirs to monitor the D.O. which will be displayed on a panel near the blowers for easy observation and control.

### Secondary Clarifiers

The sludge from the complete mix activated sludge tanks will flow to the clarifier feed flume by way of the aerated flumes. The sludge will



flow into each clarifier through four ports designed to give uniform distribution. Each clarifier will be equipped with a sludge collector and pumps to draw and discharge return activated sludge as discussed in the activated sludge process.

#### Intermediate Lift Station

The purpose of this station is to pump the secondary clarifier effluent to the nitrification tanks. The propellor pumps are modulated by the discharge valves to maintain the wet well level at a constant value.

Lime slurry is added in sufficient quantity to maintain a suitable pH to achieve an adequate nitrification. The lime feed rate will be automatically controlled by the computer to adjust the pH of the secondary effluent in turn to optimize the tertiary treatment. The pH of the return nitrification sludge and the flow rate of the pump station will be used to calculate and control the lime feed rate. If the pH becomes too high or too low an alarm signal will be generated and displayed. In addition, if the lime level in storage should fall below a minimum level, an alarm signal will be generated and displayed. Also, an alarm will be displayed if the mixing paddles or the grit conveyor of the lime slaker should fail to operate for any reason.

The computer will assimilate the appropriate information relative to lime use rate, inventory, storage capability, etc., and will compute and print the lime reorder instructions as well as reorder instructions for alum, methanol, and all other chemicals that are computer controlled.

The alum feed rate will be paced to the pump station flow and



will be adjusted by the total phosphorus analysis to achieve a minimum total phosphorus in the effluent. Note controls and alarms as discussed for lime feed.

### Nitrification

Since the nitrification reaction rate is slow, the inlets and outlets of these tanks are arranged to encourage plug flow. Twelve dissolved oxygen probes are located in the four tanks to provide sensing signals to the computer as part of the calculation of the required aeration rate as discussed in the activated sludge and air supply process sections.

### Tertiary Clarifier

The tertiary clarifiers are identical in design and operation to the secondary clarifiers. The effluent of the tertiary clarifiers will flow to the denitrification pump station.

### Denitrification

Flow to the denitrification contact tanks is provided by a denitrification pump station which operates in conjunction with a surge pond. When the flow exceeds a preset pumping rate, the excess water flows into the surge pond. When the effluent of the tertiary clarifier is less than the preset pumping rate, the flow is augmented by flow from the surge pond. The pumps are modulated by their discharge valves to maintain the preset flow rate.

Methanol is added at this pump station to provide carbon for the denitrification process. The methanol rate is computer controlled to



match the flow and adjusted by the results of the nitrate/nitrite analysis.

The flow from the denitrification pump station enters each of six denitrification contact tanks at the bottom, moves upward through bio-oxidation media where the nitrate radical is reduced to nitrogen gas which is released at the surface. The effluent flows over the edge of the contact tanks to the gravity rapid filters.

#### Gravity Rapid Filtration

The system will use six gravity filters utilizing a four media filtering material which can be backwashed remotely by manual control. The computer will tabulate the accumulated time and maintain a log of the time between backwash operations for each individual filter.

The backwash water will be pumped from the chlorine contact chamber and the waste backwash water will flow to a holding tank, to a backwash clarifier, to chlorination and discharge to a polishing pond.

#### Reaeration

The effluent from the gravity filter flows into the reaeration tanks. The requirement and control is set that the effluent should maintain a D.O. of 5.0 mg/l minimum. The compressors for the reaerator tanks will be manually controlled by push button on the reaeration tank control panel with an alarm signal if either compressor fails to supply air when energized.

The computer algorithm for the reaeration tanks assumes that the initial D.O. in the tanks is zero. The detention time in the tanks is 30 minutes at average flow. The nominal aeration rate is 540 cu. ft. per



minute with a 31.3 pounds of oxygen per hour transfer rate.

### Chlorination

The effluent of the reaeration tank enters the chlorine contact tank to be chlorinated prior to final discharge. The detention time in the chlorine contact chamber will be fifteen minutes at peak flow.

The chlorination feedback loop will automatically control the chlorine feed rate proportional to the water flow rate through the flow meter in the influent line to the chlorine contact tank. In addition, the chlorine feed rate will be automatically adjusted to maintain the desired residual chlorine level in the effluent as measured by the residual chlorine analyzer.

If the residual chlorine falls below a preset level, an alarm will be displayed on the supervisory control panel and it will be logged by the computer. A chlorine leak detector, independent of the analysis system, will also actuate an alarm on the panel if the chlorine concentration in the air in the chlorinator room exceeds 1 part per million.

The chlorine leak detection alarm will also actuate a visible and audible alarm in the chlorine building.

The distribution of chlorine solution can also be controlled manually by valves on the chlorine solution manifold panel. Provision will also be provided for manual control of the chlorine feed rate in the event of a failure in the automatic control system.

### Sludge Disposal

The sludge return rate will be controlled by the adjustment of the speed of variable speed drive sludge pumps. The sludge return flow



depth will be measured and displayed to the operator and transmitted to the computer. The computer will calculate and control the flow rate of each Return Activated Sludge flume and will maintain the trend history.

The two sludge centrifuges will separate the solids from the sludge, returning the concentrate to the influent pumping station, where the solids will be stored until they can be removed by truck to a sanitary landfill.

The centrifuge cycle will be automatically controlled by an adjustable timer. The cycle will include an acceleration period to full speed, during a portion of which period sludge will be fed into the unit. The cycle will include a running time at full speed, a skimming period, a deceleration period and an unload period. If the pinch valves fail to operate during the unload period, an alarm will be displayed by the computer.

Automatic interlocks will prevent the feed sludge pumps from starting if the sludge feed hopper is empty or if the centrifuges are not operating. If sludge stops flowing, the pumps will stop. An automatic interlock will prevent each discharge sludge pump from starting if it hopper is empty.

The sludge flow into the feed hopper will be controlled by a pneumatic pinch valve. The valve will be open to permit sludge flow until the hopper is full. When the hopper is full, the valve will automatically close.

Pump failure alarms, by-pass valve failure alarm, and air compressor failure alarms will be displayed on the control panel when appropriate.



## CHAPTER VI

### CONCLUSION

The evolution of the control system and the advancement of the computer sciences has led to the marriage of the computer to the control system and the application to wastewater treatment. Blakely and Thompson (1974) forecast a very rapid increase in the use of computer systems for wastewater treatment. They estimated that the usage will triple in the next ten years.

The proposed installation at the Crange County wastewater treatment facility at Sand Lake Road will utilize a combination of instrumentation, telemetering and computer control, together with remote or local control, either automatic or manual, to attempt a balanced operation which can maximize treatment efficiency while minimizing operational costs and the requirements for large numbers of skilled operators.

It is recognized that the proper operation of the system is dependent on the accuracy of the algorithms supplied to the computer and that the initial approximations of the algorithms will contain built in errors which can be found only after experience has shown the true operational characteristics of the system.

It is hoped that by judicious use of the control limits and secondary and tertiary adjustments to the primary controls that the effects of the errors cannot cause any major errors or system upsets and that the algorithms can then be rapidly corrected to match the as built system.



There must be some reservations on moving so far so fast. It must be noted that in some quarters there are some misgivings as to the reliability of the completely automated system. According to Liptak (1973) the use of pollution control monitors increased by 30% in the past three years and 50% of the monitors failed to perform satisfactorily after installation.

Brezanik (1974) has done a rather complete current literature review on automated analysis and monitoring. He recognizes that completely automated qualitative and quantitative analyses of wastewater pollution is not yet feasible. However, there have been great strides made in marrying the computer to the mass spectrometer and to the gas chromatograph which allows automation of a very large portion of the wastewater treatment process with confidence.

The question may be raised that the improvement of plant performance by the use of modern control systems would be uneconomical. Andrews (1972b) concludes that calculations of BOD costs per pound extrapolated to the BOD content of the improved efficiency would make the investment worthwhile, without considering any improvements in the cost of labor, materials or power.

Blakely and Thompson (1974) indicate that 10% savings in power is not unusual in plants that have converted to automatic control. They find other factors allowing reductions in operating costs which are more dramatic. Additional power savings can be realized by off loading peak demands.

Reduced motor and pump running time reduces routine and emergency maintenance. A constant monitor of operating conditions allows a trend analysis of decreasing efficiency from which the computer can recommend the



replacement of worn parts such as bearings, blades and impellers. And most critical is the immediate recognition of a failure which can allow interruption of operation prior to the incidence of any subsidiary damage.

Good management and the intelligent use of available instrumentation, control systems and personnel can enhance the overall efficiency, economic performance and the reliability of wastewater treatment facilities.



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