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16. Abstract

As part of its research of integrated utility systems, NASA has undertaken the test operation of an automatic water monitor system with the objectives of assuring high-quality effluent standards and accelerating the practice of reclamation and reuse of water. The NASA water monitor system is described. Various components of the system, including the necessary sensors, the sample collection system, and the data acquisition and display system, are discussed. The test facility and the analysis methods are described. Test results are reviewed, and recommendations for water monitor system design improvement are presented.

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WATER MONITOR SYSTEM: PHASE I TEST REPORT

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WATER MONITOR SYSTEM: PHASE I TEST REPORT

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SUMMARY

As part of its continuing effort to transfer advanced technology to the community and in recognition of the increasing freshwater shortage problem and national concern about pollution, NASA has undertaken several programs in pollution monitoring and water reuse technology. A laboratory has been constructed at the NASA Lyndon B. Johnson Space Center in Houston, Texas, for experimentation with integrated municipal utility systems including advanced water and waste treatment technologies. As a result of its integrated utility involvement, NASA has undertaken the task of developing an automatic water monitor system that can assure conformance to projected high effluent quality standards and that can increase and accelerate the practice of reclamation and reuse of water. The objective of this water monitor program is to develop a system that includes the necessary sensors, sample collection system, and data acquisition and display system to monitor in real time the effluent discharge from water treatment plants and to provide the data that determine the water quality. The primary objective of the program is the demonstration and the technology transfer to the community of a water monitor system capable of providing a total water-quality picture including rapid microorganism detection using NASA-developed sensor technology. This technology was demonstrated within the framework of a multiparameter automated real-time monitoring system that included conventional and advanced inorganic and organic systems. This report documents NASA's initial phase (Phase I) of test operation with a breadboard configuration.

INTRODUCTION

Background

Since its inception in 1958, NASA has continually engaged in efforts to transfer technology to other sectors of the economy and community. The Aeronautics and Space Act of 1958, which created NASA, and its amendments directed NASA to provide the widest possible dissemination of knowledge and expertise gained from the aeronautics and space programs. The NASA has subsequently established a wealth of experience and expertise in numerous technological fields including materials, structures, energy and power generation, systems engineering, environmental control, guidance and control systems, bioengineering, microbiology, and life-support systems. Within each of these fields, there is a significant national resource and potential for applying that knowledge and experience to help solve current problems.

In compliance with its founding legislation, NASA has initiated a number of technology applications programs in which hardware or systems concepts have been designed, modified, or developed specifically to meet a need in the "civil sector." To effectively transfer this technology, NASA has undertaken to identify potential user organizations and agencies that might obtain maximum benefit and assist in the dissemination of the specific technology. Such groups would include Federal, State, municipal, and local agencies.

In recognition of the growing water-shortage problem in the United States and the national concern about pollution, NASA has undertaken a number of programs in pollution monitoring and water reuse technology. For example, NASA has used satellite scanners such as those onboard Landsat (formerly the Earth resources technology satellite) to identify stagnant or polluted waters, and more advanced sensors are being developed for later flights. A large part of the NASA water-quality technology, however, has been oriented toward life-support systems to meet manned-spacecraft system requirements. Much of this life-support technology has been found to have potential for land-based domestic application. In the past, this technology has been a natural evolution of spacecraft development rather than a response to or a design for crises issues concerning the environment. As such, moderate applicational redesign has often been necessary to use the technology in the community.

Since the beginning of manned space flight, NASA has been vitally concerned with the analysis, design, development, testing, and application of systems for water supply, water monitoring, and waste management. In preparation for long-duration flights, NASA has worked extensively in the development and demonstration of processes for (1) the recovery of water from all potential sources (humidity condensate, used wash water, urine, and fecal flush water), (2) the monitoring of spacecraft water quality for both chemical and biological contamination, and (3) the reduction of wastes to small-volume chemically and biologically inactive residues. The experience and facilities NASA has acquired in the course of this work are directly applicable to the development of compact and efficient water reclamation monitoring and waste management for domestic use. The application of these advanced water recovery and waste management closed-loop systems has been primarily in long-duration, manned, ground-based tests.

In 1971, NASA began a special study applying the technical approaches and design philosophies of these closed systems to the utility system of a 500-dwelling-unit garden apartment complex. These studies led to an interagency agreement between NASA and the Department of Housing and Urban Development (HUD) to design and develop a modular integrated utility system (MIUS). Basic functions to be supplied by the MIUS included (1) integration of electrical power generation, water processing, solid and liquid waste management, and environmental conditioning, and (2) use of residual energy for utility functions. Only production hardware items were to be incorporated in designs, and no building system changes were to be made.

Testing of the MIUS concept is being performed at the NASA Lyndon B. Johnson Space Center (JSC) in Houston, Texas. The MIUS integrated systems test (MIST) laboratory has been built at JSC and is being used for experimentation with advanced water- and waste-treatment technologies. The NASA support of this integration and test program, together with other JSC supporting studies (refs. 1 to 4), resulted in a project to develop an automatic water quality monitoring and control system to ensure the safety and quality of treated wastewater.

The NASA reviews of water supply planning and wastewater reclamation activities indicated a growing concern about future water resource needs. The NASA further noted that this concern had motivated responsible local, state, and national organizations and leaders to give serious consideration to reuse application. California, for example, had begun numerous reclamation and reuse projects. The most notable of these projects was the reuse of effluent from the Lake Tahoe Tertiary Treatment Facility for recreational application in the Indian Creek Reservoir. A study performed for NASA[1] further noted that many authorities in the water/wastewater management field were convinced that the long-term solution to the problem of insufficient water resources was in wastewater reclamation and reuse. The city of Denver, Colorado, is currently engaged in firm planning for facilities that will reclaim 378.5 Ml/day (100 Mgal/day) by 1986 for addition to the public water supply. The city of Denver hopes to supply 25 percent of its total water needs through reuse by the year 2000.[1]

Any analysis of the technical feasibility of wastewater reuse is complicated by the large number of potential uses that can be made and by the relative economic considerations. The uses can generally be categorized into industrial, agricultural, recreational, and municipal applications. As such, the degree of difficulty of application can and does vary depending on the definition of acceptable quality. The cost decision is usually based on (1) the costs for achieving the required level of quality, (2) the availability of a sufficient raw natural source, and (3) the cost of transporting the reclaimed effluent or the raw source to the application.

Many problems and questions remain to be resolved before extensive reuse can be proposed to and accepted by public health officials and the public at large. The most relevant question aside from esthetics concerns the availability of technology that can safely and reliably assure the public health and safety of the practice of reuse.

Although it is possible to remove certain undesirable constituents from an effluent using current advanced waste treatment technology, no methodology has yet been demonstrated and accepted that conclusively guarantees removal of all viruses, heavy metals, or refractory organics. Neither is there available a sensor or system that can monitor for the presence of these constituents "on line," in or near real time. Furthermore, the bacterial contamination standard (fecal coliform) for both water supply and wastewater treatment plants is still a laboratory test procedure that requires as many as 4 days to complete. This latter test procedure is not in itself an actual pathogenic measurement. Rather, the test indicates the presence of fecal matter that may contain pathogenic organisms. No procedures or measurements exist within the current technology inventory that can be used for on-line real-time monitoring and detection of specific pathogenic organisms.

There is little doubt that wastewater recycling and reuse will become a common practice in the United States and the world in the future. The extent and the timing will depend, as previously noted, on numerous factors. Although, from a technical perspective, numerous issues remain to be resolved, improvements must first be realized in both treatment and monitoring systems. As a result of its previous

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[1] G. Wade Miller, "Critical Issues Related to Wastewater Reuse," report to the Water/Wastewater Management User Requirements Committee, Public Technology, Inc., 1974.

spacecraft developments in these disciplines, NASA has been in the position of being aware of, and technically competent to use, technological spin-offs that could contribute to resolving problems related to water and wastewater.

This factor was considered to be especially true with respect to water monitoring sensors and systems. These considerations together with NASA's MIUS program commitments resulted in the program to develop a water monitor system (WMS). It is anticipated that the community demonstration system will incorporate the design flexibility to accept and demonstrate other NASA sensor developments being pursued to the applications stage and afford NASA and environmental agencies (national, state, and regional) a mobile test-bed capability that can be used to conduct continuing (jointly funded) sensor evaluations (aerospace and nonaerospace) in the field (or at an NASA site) following completion of formal demonstrations within the community.

Finally, it should also be noted that as highly supportive as the community demonstration WMS will be to the advancement and solution of critical environmental problems, the project is unique in that the technology also supports NASA's manned long-duration space missions. Such missions will necessitate substantial life-support capability relative to water. Unless the logistical penalties for providing "new" water are willingly assumed, treatment and reclamation of "gray" (nonfecal) water will be necessitated. Human consumption of treated waters will likely require rigorous monitoring to ensure crew safety even with appropriate disinfection processes. Such monitoring systems will at least ensure proper operation of both the treatment and the disinfection systems in the spacecraft. Additionally, monitoring of the potable water storage system to ensure continued integrity is also foreseen. Because fecal matter will probably be excluded in the spacecraft water reclamation system and because many elements and compounds found in community sanitary treatment systems are not common to the spacecraft, the task undertaken by the NASA WMS can be viewed as being much more complex than the equivalent spacecraft task. Key technological elements of the WMS that are foreseen as being supportive of future spacecraft designs include sample collection and processing, biological and selective ion electrode developments, organic sensor developments, automated sensor standardization, automated monitoring/system display, and data processing as it relates to water monitoring. This report documents NASA's initial phase of operation with the system in a basically breadboard configuration.

Program Objective

The NASA developmental concept for the WMS was orginally predicated on the premise that successful reclamation in MIUS and/or a separate community treatment facility would be highly dependent on adequate and timely verification of water quality. The NASA objective in this case was to perform this verification much as it would occur in a spacecraft, on-line and in real time. Because MIUS implementation would necessitate satisfying the Environmental Act, Public Law 92-500, in both a 1977 and a post-1983 time frame, it was decided to set design goals for MIUS wastewater treatment and monitoring systems that would assure conformance to undefined, but projected, high-quality effluent standards and accomplish the goal of elimination of discharges of pollutants by 1985. These criteria have guided the quality objectives of the design.

In-house NASA developments relative to near-real-time biological detection and monitoring were known to exist, including some with undefined potential for application to water and wastewater systems. These developments were as follows.

1. A water quality monitoring system (WQMS) for spacecraft application (ref. 5) that incorporated a chemiluminescence biosensor

2. A coliform detection concept using detection of metabolic gas evolution

3. Bioluminescence techniques sensitive to adenosine triphosphate (ATP)

4. A near-real-time virus detection system using the passive immune agglutination (PIA) principle

5. Techniques for detecting extraterrestrial life onboard unmanned spacecraft probes such as Viking

It was believed that the developments described in items 1, 2, and 3 offered relative near-term potential for application, and the WMS was defined in terms of the utilization of three classes of sensors: advanced biological, automated organic, and conventional. The conventional sensors were essentially commercially available off-the-shelf hardware. The NASA WQMS did provide this capability in terms of the sensors. The system was not, however, in an on-line configuration, nor did it provide for adequate data acquisition and display for use in either an MIUS or a community treatment facility. A data system concept for this application was developed. Fabrication of this system was performed under this contract together with modification of the WQMS and integration into a system capable of operating in an on-line mode.

The following program objectives were initially established for program development and continue as guidelines for the current program.

1. Develop an automated WMS for wastewater treatment system effluent monitoring.
    a. Use advanced real-time microorganism detection.
    b. Use conventional and advanced sensor technology for nonbiological parameters to provide a total effluent-quality picture.
    c. Initiate control effort in MIST.

2. Focus and accelerate development of real-time microorganism sensor technology transfer efforts within NASA.

3. Demonstrate feasibility and reliability by correlating data with standard laboratory techniques.

4. Develop the system to a field demonstration configuration and demonstrate to municipalities.

5. Develop model specification.

6. Publish and distribute results to Federal, State, and local agencies.

Program Scope

The WMS has, since inception, been planned and conducted as a phased development. The phases defined at the program outset and summarized in this report are as follows.

I. Assembly and test of a breadboard system in the MIST at JSC

II. Assembly and test of a field demonstration system in the MIST at JSC

III. System demonstration in a community wastewater treatment installation

The initial phase of the program, Phase I, which is documented in this report, encompassed the assembly of a breadboard system of advanced and conventional sensors, the assembly of a prototype data acquisition system, integration into a mobile trailer, and on-line real-time feasibility demonstration through monitoring and data collection in the wastewater treatment facility for the MIST. This early phase of testing, initiated approximately 9 months after program approval, was designed to identify fundamental and operational problems. This approach, used extensively in the NASA Apollo Program, will allow timely redesign/modification improvements to be incorporated in the next phase of the program. A block diagram of Phase I is shown in figure 1.

The scope of the application of the WMS has been modestly scaled to achieve early availability of the system for use as an effluent monitor in a wastewater reclamation plant. The results of early investigations indicated that efforts to design such a system for total plant control capability would necessitate a longer range developmental effort than was desired by NASA at the time. It was decided, however, that it would be highly desirable to have some control capability provided by the system. This capability would permit limited use of the WMS sensor outputs for control studies and later development, as necessary.

The scope of the WMS as an effluent monitor system was limited in the initial definition only to the extent that no more than 25 sensors (or sensor systems) would be required. For purposes of final quality definition at a treatment plant outfall, 25 separate parameters were considered adequate to provide a total water quality picture for MIUS or community treatment system application.

System requirements for the data acquisition system (DAS) were that it be, in its simplest form, relatively inexpensive, simple to operate, and able to use a unique cassette tape system with the capability of operating and accumulating data for at least 24 hours before cassette replacement would be necessitated. Phase I test demonstrations were to include only the MIST facility because the system was to be in a prototype/breadboard configuration. To facilitate the ultimate transfer of the final configuration to a field wastewater treatment installation, the requirement was added to install the system in a mobile trailer unit. An NASA trailer unit was provided for this purpose.

The Phase II effort, which was begun in March 1975, will not be discussed in great length herein. However, a generalized diagram is shown in figure 2. The primary aim of the Phase II effort is to complete the design and assembly of NASA biological detection systems capable of (1) sensing the presence of bacteria by using the chemiluminescence and bioluminescence developments, and (2) sensing coliform by using the detection of evolved metabolic gas. The on-line advanced application of organic detection systems is also planned similar to an early NASA effort with automated injection and sensing of total organic carbon (TOC). New "conventional" sensors will be procured to upgrade the early sensors used in the initial WQMS. Operational problems discovered during Phase I testing (and discussed in this report) will be corrected by redesign or modification. Additionally, ongoing studies are assessing system reliability requirements and systems needs and requirements in relation to user needs and requirements. Results from the NASA user advisory panel meeting (ref. 6) are available for use as a basis of analysis. An upgraded DAS is also being investigated that would provide processed real-time data display capability similar to that used during Apollo mission support operations. Use of a minicomputer/microprocessor with the Phase I DAS is contemplated. Subsequent system integration and installation in the NASA mobile trailer unit will be accomplished. Following a 1-month test period, the system will be deployed to the first of several community wastewater treatment facilities to initiate Phase III demonstrations and technology transfer operations.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

WATER MONITOR SYSTEM DESCRIPTION

The WMS capability is summarized as follows.

1. As many as 25 sensors may be used.

2. All sensor outputs are standardized to 0 to 5 volts with signal conditioning.

3. Each analog input is monitored for high-low condition in real time with variable set-point window comparators.

4. A visible/audible alarm indicates any out-of-tolerance condition.

5. Each measurement has an analog meter readout.

6. Analog signal multiplexing is accomplished as follows:

   a. Normal mode: Five measurements/minute (one data cycle in 15 minutes)

   b. Fast mode: One measurement/second (one data cycle in 75 seconds)

   c. Two emergency modes: Initiated by selected out-of-tolerance conditions

7. Digital conversion is accomplished as follows.

a. Day, time, measurement identification, and synchronization pulse are outputted serially in sequence with digital, multiplexed measurement values.

b. Day, time, measurement identification, and value are displayed on digital meters.

c. Data are recorded on a low-speed cassette tape recorder (24 to 48 hours of data on each tape).

The major elements of the WMS are the sensors and a DAS, which are described in the following sections.

Sensors

The WMS was designed as a multiparameter instrument in which sensors could be relocated in and about various wastewater treatment process units in the MIST facility. The parameters measured included TOC, dissolved oxygen, ammonium ion, total residual chlorine, chloride ion, conductivity, pH factor, total hardness, turbidity, sodium ion, and total and viable bacteria. New commercially available sensors were added to supplement the existing WQMS that had been developed by NASA to evaluate spacecraft water reclamation systems (ref. 3). The approach used in the selection of the new sensors was their applicability in an on-line near-real-time monitoring environment that would ultimately permit their output signals to be used in a computer to control the operation of unit processes. Figure 3 presents an overview of the total sensor system configuration and sample flow system. Individual sensors are described in the following paragraphs.

Total organic carbon sensor.- The Beckman model 915 total organic carbon analyzer provides analysis of a microsample of aqueous solution for determination of two quantities: total carbon (organic and inorganic carbon) and inorganic carbon (i.e., carbonates). The two analyses are performed on successive identical samples. The desired quantity, organic carbon, is the difference between the two values obtained. The analysis was performed with ranges varying from 0 to 50 mg/liter to 0 to 100 mg/liter.

This commercially available laboratory analyzer was modified to provide continuous on-line analysis with an automatic sample injection system. A flow diagram of the modified system is shown in figure 4. The sequence of the analysis, which required a 5-minute cycle time, is given in table I.

The analysis for TOC was based on the carbon combustion-infrared method. When the total water sample is automatically air injected into the analyzer, it flows into a packed high-temperature (1223 K (950° C)) combustion tube. The water is vaporized and the organic matter is oxidized to carbon dioxide (CO_2), which is measured by means of a Beckman model 215B infrared analyzer.

In the parallel inorganic carbon channel, a low-temperature furnace (423 K (150° C)) heats a packed tube that liberates carbon dioxide and steam from inorganic carbonates. The operating temperature is sufficiently high for the desired reaction but is substantially below that required to oxidize organic matter. The quantity of carbon dioxide produced is measured in the infrared analyzer. The sample for the total carbon channel is the first of the two samples to pass through the infrared analyzer and the peak signal is held in memory by the electronics. The sample from the inorganic carbon channel is then passed through the infrared analyzer. The difference in the two peak signals is displayed as the TOC concentration.

Modifications to the TOC analyzer to achieve automatic sample injection were as follows.

1. Two air-actuated sample injection valves

2. Two solenoid valves diverting either the inorganic or total carbon sample to the infrared analyzer

3. Automatic operation of the valves described in modifications 1 and 2 controlled by a cam-type timer/programer

4. Injection of the liquid sample, accomplished by forcing the sample through the injection valve and needle with 41.4 to 82.7 kN/m^2 (6 to 12 psig) zero-grade air

Chloride ion sensor.- Chloride ion concentration was determined by potentiometric measurement. The Orion model 401 specific ion meter was used in conjunction with an Orion model 94-17 chloride ion electrode and a Beckman 19033 Lazaran process reference electrode to provide a direct readout of chloride ion concentration in milligrams per liter on a two-cycle logarithmic scale of 10 to 1000 mg/liter. The electrodes were housed in a flow chamber that provided continuous on-line sampling capability. A buffer was added to the sample stream to maintain constant total ionic activity. Figure 5 shows the electrodes and a cross-section view of the electrode wells.

Hydrogen ion (pH) sensor.- Hydrogen ion concentration was determined by potentiometric measurement. A glass electrode system was used based on the theory that a change of one pH unit produces an electrical change of 59.1 millivolts at 298 K (25° C). The glass electrode is relatively immune to interference from color, turbidity, colloidal matter, free chlorine, oxidants, or reductants, as well as from high saline content.

The Orion model 401 specific ion meter provided a direct readout of pH using an Orion 91-01 pH electrode and a Beckman 19033 Lazaran process reference electrode. The pH electrode has a range of 2 to 11 pH units. The two electrodes were mounted in a small sample tank that provided on-line continuous monitoring capability as shown in figure 5. The Orion 401 meter will read 0 to 14 pH units full scale.

Ammonium ion sensor.- Ammonium ion concentration was determined by potentiometric measurement using a Corning 476220 monovalent cation electrode in combination with a Beckman Lazaran reference electrode in an electrode well as shown in figure 5. The two electrodes were connected to an Orion specific ion meter model

407 with a concentration range of 1 to 100 mg/liter. A buffer was added to the sample stream to maintain a pH of 7 and to maintain constant total ionic activity.

Trace sodium ion sensor.- The Beckman 194204 model 9415 sodium ion analyzer automatically and continuously measures concentrations of sodium ions in a water sample stream by the potentiometric method. The analyzer consists of a flow panel, a heat exchanger, an electrode flow chamber, an amplifier/transmitter module, an electrolyte reservoir, constant-head standard solution bottles, a Beckman 633951 sodium ion electrode, and a Beckman 19604 reference electrode.

Sodium determination is based on measurement of the difference in electrical potential developed between a sodium-sensing electrode and a reference electrode, both positioned in the sample stream. This electrode potential is directly proportional to the logarithm of the active sodium concentration. The response of the sodium ion electrode is not completely specific to the sodium ion but can be affected by several other monovalent cations if present. This electrode is more sensitive to hydrogen and silver ions than to sodium ions. Usually, the hydrogen ion is the only interfering ion encountered. To eliminate this hydrogen ion interference, all solutions are pH adjusted with ammonia to suppress the hydrogen ion concentration. The Beckman 19604 reference electrode provides a standard potential against which the potential of the sodium ion electrode is measured.

The sample flow is adjusted to pH 11 by addition of anhydrous ammonia. To adjust the temperature of the standard solutions used for calibration to that of the sample, the selected solution is passed through a heat exchanger before entry into the electrode flow chamber. The analyzer flow diagram is shown in figure 6.

Hardness sensor.- The Orion model 1132 hardness analyzer continuously monitors on-line samples for hardness by the potentiometric method. The analyzer pumps the sample and reagent into a magnetic mixing chamber and then into a constant-temperature chamber. The mixture passes between a copper ion electrode and a bromide ion electrode. The electrodes are connected to the electronics system of the analyzer, which gives a direct hardness reading on a four-cycle logarithmic scale meter. The meter scale was calibrated to read hardness from 0.1 to 1000 mg/liter. A flow diagram is presented in figure 7.

Water hardness is the analysis of calcium and magnesium ions in water. The hardness analysis requires a compound approach for selected detection of calcium ions, which is the basis for the analysis. A specific ion electrode for calcium does not have sufficient selectivity to eliminate all the interference from divalent ions. Hence, the complexing of all divalent ions with a chelate and the release into the species environment of a reactive ion that will release calcium ions from the complex (and no others) gives specificity to the analysis. Temperature control is effected by warming the environment 10 K (10° C) above ambient temperature. The control of pH is required in order to effect the selective electromotive replacement of the desired ion and protect the electrode from pH changes.

Detection of the calcium ions is indirect and the technique is proprietary knowledge of the Orion Instrument Company. However, in general terms, it is a highly specific detection in that, during the sample pretreatment, all the divalent ions are chelated and only the calcium ions are released from the complexing agent.

This is accomplished by the addition of a "tag ion" (in addition to the substitution ion) at a level of molar concentration 100 times greater than the maximum ionic strength variation possible. The reference electrode is then selective to the tag ion and the sensing electrode is selective to the substitution ion. The electromotive force is generated by the completion of the two galvanic half cells of the probes.

Dissolved oxygen sensor.- The Honeywell model 551011-00-01 dissolved oxygen sensor selectively analyzes the amount of oxygen dissolved in water without interference from ions of various dissolved solids that may be present. The sensor is mounted on top of a small flow chamber that enables the incoming continuous sample stream to strike the membrane located in the sensor head. The sensor generates a direct-current (dc) millivolt signal that is linearly proportional to the concentration of dissolved oxygen in the water. The sensor and flow tank are shown in figure 8.

The dissolved oxygen sensor is a polarographic transducer consisting of a gold-silver-platinum alloy cathode and a silver/silver chloride anode. These electrodes are immersed in an electrolyte cell. Using the polarographic technique, a voltage is applied across the electrodes and the resulting current is measured. The amount of current flowing between the electrodes is directly proportional to the amount of oxygen reduced at the cathode. The value of the voltage applied selects the constituent of interest (in this case oxygen), and the amount of current flowing indicates the concentration of that material in the solution. The electrolytic cell is enclosed in a polyvinyl chloride cell body in which the only entrance for oxygen is through the thin gas-permeable membrane covering the gold cathode. This construction isolates the electrolytic cell from the water, enables the oxygen to reach the cathode, and prevents ions of dissolved solids from entering.

Turbidity sensor.- The Honeywell Model 551201-02-01 turbidity sensor is a photoelectric device for measuring the turbidity of water. The turbidity sensor has two main components: an optical head and a sampling tank for on-line sample analysis. The optical head contains a lens system, an incandescent lamp, a constant-voltage transformer, and a photocell. As shown in figure 9, the optical head fits on top of the sampling tank. The water flows out through a spillway at the top and drains from the bottom to minimize the accumulation of sediment. The sensor has a nominal range of 0 to 500 Jackson turbidity units (Jtu) with a calibrated accuracy of ±5 percent full scale.

The turbidity sensor operates on the light-scattering (nephelometric) principle. A beam of light is focused by the lens system and directed down into the sample. The photocell detects the light reflected by the particles in suspension and supplies a proportional millivoltage to the signal conditioner. When the sample is entirely free of particles, little or no light reaches the photocell and the instrument reading is zero; an increase in turbidity increases the reading.

Specific conductance sensor.- The sensor used to measure the ionic content of the water sample is a Beckman type R15 Solu Bridge conductivity indicator with a temperature-compensated epoxy flow-through cell, type CEL-VDJ, with a cell constant of 2.0, permitting measurements in the range from 0 to 1000 μmhos/cm.

Specific conductance yields a measure of the capacity of a water sample to convey an electric current. This property is related to the total concentration of the ionized substances in a water sample and the temperature at which the measurement is made. By measuring the resistance within the water sample as it flows through the cell, a value of specific conductance can be obtained. Figure 10 shows the conductivity flow-through cell.

Total residual chlorine sensor.- The Orion model 1125 chlorine analyzer is capable of monitoring continuous on-line samples for total residual chlorine concentration by the potentiometric method. The analyzer is based on iodometric analysis, a method which uses the principle that chlorine will liberate free iodine from potassium iodine solutions when the pH is 8 or less. Figure 11 is a flow diagram of the analyzer. The analyzer pumps the sample from an overflow chamber and the reagent into a magnetic mixing chamber. The mixture is then pumped through a reaction heater into a constant-temperature analysis chamber. As the mixture is pumped through the chamber, it passes between a sodium ion electrode and a redox electrode. The electrodes are connected to the electronics system of the analyzer, which gives a direct total residual chlorine concentration on a four-cycle logarithmic scale meter. The meter scale was calibrated to read concentrations from 0.1 to 1000 mg/liter.

Biosensor.- The purpose of the biosensor is to detect and quantify bacterial cells, both living and dead, in a continuous water sample stream. Operation of the biosensor is based on the emission of light from a chemical mixture when the mixture is exposed to bacterial cells. Specifically, the detection is based on measuring the increase in light emission, or chemiluminescence, produced by the catalytic action of bacterial porphyrins on a luminol-hydrogen peroxide mixture (premix). The light emission is virtually instantaneous and occurs when a bacterial suspension is mixed with the aqueous reagents. In the biosensor, mixing of the sample and reagents is carried out within view of a photodetector that monitors light emitted by the reaction. In theory, the signals generated by the photodetector are directly proportional to the number of bacteria present in the reaction.

The major components of the biosensor are the fluid transport system, the bacterial concentration/filtration system, and the photomultiplier tube (PMT) with reactor cell. The fluid transport hardware consists of peristaltic pumps and associated valves and plumbing for transporting samples and reagents to the reaction cell and then to waste disposal. Bacterial concentration/filtration is accomplished using a membrane filter technique with 0.45-micrometer pore filters housed in stainless steel holders. The photomultiplier tube is housed such that its light-sensitive surface views the reaction cell in which reagent and sample mixing occurs. Light emission values are displayed on a strip-chart recorder, and the system operation is controlled manually or automatically by a programer.

Activation of the chemiluminescence reaction of luminol is not limited to the porphyrins of bacterial cells but can be promoted by metallic salts and some organic compounds. Thus, the reaction is not specific for bacteria and is vulnerable to interference from many compounds often found in water. The operation of the biosensor is such that this interference can be factored out of chemiluminescent values by filtering the samples and holding any bacteria present while passing the filtrate and reacting it with the luminol. After a background value is thus obtained, the filtrate and the bacteria are reacted with the luminol and the total value obtained minus the background value should represent the signal from the bacterial cells alone.

Before field testing at the MIST, a considerable amount of laboratory testing was performed to calibrate the biosensor and to determine reaction sensitivity to variations in reactant concentrations and flow rates. During testing, the sensor configuration was simplified to eliminate chronically unrepeatable and unreliable functions. The before and after configurations are shown in figure 12. The modification eliminated approximately one-half of the hardware. The original sensor design is documented in reference 3. Figure 13 is a flow diagram of the modified system, and table II gives the programed sequence.

The results of laboratory testing of the modified system are illustrated in figure 14. The data show that operating parameters may be varied to change output response; however, the range is basically limited to a one-decade proportional range. This limitation severely restricts the capability of the biosensor. Experience showed that the sensor output was easily saturated by hard-to-detect quantities of trace contaminants. A broader measuring range would allow more tolerance to trace interferences.

While testing was in progress at the MIST, a commercially available reactor cell/photomultiplier tube assembly was procured and tested in the laboratory. Test results show this system to have a four-decade linear range as shown in figure 15. This configuration will significantly increase the usability of the biosensor and will be incorporated in subsequent models.

Data Acquisition System

The DAS consists of an analog section, a digital section, a tape recorder, and appropriate power supplies. The analog section consists of input buffers, level detectors, special signal conditioners, a diode matrix, master alarm circuitry, an out-of-limit annunciator, and analog meters. The digital section includes the clock assembly, a multiplexer, an analog/digital (A/D) converter, data storage buffers, control circuitry, and displays. Flow diagrams of the DAS are shown in figure 16.

Input buffers.- The input buffers provide overvoltage protection for all subsequent circuitry, low-pass filtering, and electrical isolation. All external sensor signals with a full-scale range of 0 to 5 volts are applied directly to the buffer inputs. Sensor signals not in this range are processed by special signal conditioning and then applied to the buffer inputs. The buffer outputs are used to drive the analog meters, the level detectors, and the analog multiplexers on the logic board.

Level detectors.- The level detectors compare the input signal to reference voltages to determine if observed values exceed high or low limits. Annunciator lights then indicate which limit is exceeded. A reference comparison is also made to determine if the sensor is off. In this case, the annunciator lights will not illuminate. The level detector signals (high, low, off) are also routed to the logic board for insertion in the digital data. All level detector set points are individually adjustable.

Special signal conditioning.- The WMS electronics unit has been designed so that special signal-conditioning cards may be added to the analog section where required to convert a signal to a 0- to 5-volt range. Currently, special signal conditioning is provided for the chloride ion, ammonium ion, and pH Orion instruments;

conductivity; TOC; and chemiluminescence. The chloride ion, ammonium ion, and pH signal conditioning accepts a differential signal from a ±10-volt-millivolt-range source that is amplified and summed with a reference signal to result in an output of 0 to 5 volts. The 0- to 20-millivolt conductivity signal is amplified to provide the desired 0- to 5-volt output. The TOC signal is processed by a sample-and-hold circuit that will retain the TOC signal level for analog or digital display and for insertion in the output digital bit stream. The chemiluminescence electronics consist of a peak detector and sample-and-hold circuit similar to that used in TOC signal conditioner. The chemiluminescence electronics do not accept data until enabled by a command signal from the chemiluminescence process electronics.

Diode matrix.- The diode matrix cards accept out-of-tolerance signals from the level detectors and route the signals to illuminate the appropriate annunciators. Manual lamp testing capabilities are also controlled by these cards.

Master alarm.- The master alarm circuitry will detect a change in the state of any one high- or low-level out-of-tolerance signal for the 25 analog channels and visually and audibly display this information. The master alarm is reset by depressing the master alarm pushbutton/light. The warning tone may be disabled if desired by a front panel switch.

Annunciators.- Twenty-five annunciators are arranged in a 5 by 5 matrix on the front panel to display out-of-tolerance conditions as commanded from the level detector circuitry. Each annunciator is a three-section device that, when illuminated, will display "HI" or "LO" and the measurement name. The annunciator will remain illuminated as long as the out-of-tolerance condition exists.

Analog meters.- Five analog meters are located on the front panel. Rotary switches provide for the display of any one of five measurements on each meter.

Clock.- The clock assembly generates signals for the 24-hour time display, day counter, and timing signals for the digital electronics. The frequency reference is a 12-kilohertz temperature-compensated crystal oscillator. A countdown of the oscillator output is made to provide the appropriate timing signals to the system. The clock circuit accepts a 1-pps signal to generate time of day in hours, minutes, and seconds in binary-coded decimal (BCD) format, which is displayed and also inserted into the output data bit stream. Each digit may be set by front panel switches. The day counter is stepped by the clock or by front panel controls.

Digital electronics.- The digital electronics multiplexes the 25 analog-channel inputs, which are then converted to a 9-bit digital word by the analog/digital converter. The digitized measurement value is displayed together with the measurement channel number of the time-slot number on the front panel. A light-emitting diode (LED) matrix displays the measurement being sampled at a particular point in time. The digital data are stored until 75 measurement points have been accumulated. A command signal is then generated to activate the tape recorder, and the data frame is clocked at a 300-bps rate. The tape recorder is then deactivated until another data frame has been accumulated.

Scan patterns and speed.- Three scan patterns and two sampling speeds are provided and can be automatically or manually selected. Sampling may also be stopped manually if desired to observe one measurement value. Sampling speeds are normal (12 seconds/measurement) and fast (1 second/measurement). The scan patterns – normal, A, and B – are contained in three sets of read-only memories that are addressed by the time-slot counter to select the proper measurement channel. Automatic switching is provided so that scan pattern A/speed normal or scan pattern B/speed fast will be selected on receipt of an external command signal. Switches are provided to inhibit automatic switching if desired.

Data format.- The output data format for all modes and speeds is stored and outputted to the tape recorder at a 300-bps rate. Each frame consists of a 72-bit frame leader and 75 24-bit data words. The frame leader contains a 24-bit synchronization word, time of day and day of year, mode identifier, and zero fill. Each data word contains channel number, alarm status, data value, mode identifier, status identifier (not used), and zero fill.

Tape recorder.- The data output is recorded on a consumer-type stereophonic cassette recorder modified to operate in an incremental mode. The recorder motor is activated 1.7 seconds before data output to allow the motor to reach the operational level. Data transfer from the WMS data acquisition unit shift buffers takes 6.5 seconds, after which the motor is stopped. A carrier frequency of 6 kilohertz is used for both the data and strobe tracks.

Tape data converter.- A tape data converter has been provided to demonstrate the recorded data and convert it to a computer-compatible level. The converter is self-contained for use at remote locations. The electronics consist of a 6-kilohertz bandpass filter, a demodulator, a level converter, and buffers to deliver a signal with 0- to 10-volt logic levels.

Mechanics.- The electronics are housed in a standard 48-centimeter (19 inch) wide rack cabinet. The analog and digital electronics chassis are designed so that either chassis may be removed from the cabinet and tested independently of the remaining electronics. The 5- and 28-volt dc power supplies are mounted on the inside floor of the cabinet.

Electronics error calculations.- The primary components of the WMS data acquisition system that will contribute error to the final data value are the input buffer amplifier, the analog/digital converter buffer amplifier, and the analog/digital converter. The total error will consist of the component random error and a factor that is temperature dependent. Error components are as follows.

Random error, percent:

Input buffers	±0.5 maximum (±0.1 typical)
A/D buffer	±0.5 maximum (±0.1 typical)
A/D converter	±0.05 ±0.5 bit (±0.05 ±0.2)
Total root-mean-square error	±0.74

Temperature error, percent/K

Input buffers	0.002
A/D buffer	0.002
A/D converter	0.005
Total temperature error	0.009

Actual calibration data for the input buffers are presented in table III.

TEST SUPPORT

The MIST wastewater treatment system and the laboratory analyses performed for comparison to WMS values are described in this section.

MIST Wastewater Treatment Facility

The MIUS is being developed as part of a national program to provide the essential utility services of a community in an improved manner with advantages in increasing the efficiency in the use of energy and other natural resources, in decreasing the total impact of the community on the environment, and in reducing total costs. This system integrates the essential community utility services for the production of electric power, space heating and cooling, and potable water and for the processing of liquid (sewage) and solid (garbage and refuse) waste for maximum use in the production of water, electric power, and space heating and cooling. In the development of the MIUS, an MIST laboratory was built at JSC.

An integral part of the MIST is the wastewater treatment system. Figure 17 is a schematic representation of the MIST, including the wastewater treatment system. The purpose of the MIST laboratory is to develop and/or evaluate new process technology at the pilot-plant scale level in the treatment of wastewater of domestic origin for the maximum reuse potential of the water or for discharge into the environment with a minimum impact. The system includes a basic wastewater storage and hydrosieve-screen unit operation for the control of large suspended solids and an array of unit processes that can be operated in sequence or in parallel to provide a maximum degree of experimentation. The two major unit processes are the rotating biological disk, which is a rotating fixed-film aerobic biological reactor, and a physical-chemical reactor system. Additional advanced technologies are available for experimentation.

The biological reactor is designed to permit the growth of microorganisms on a rotating solid surface. The rotation of the microbial population periodically brings the culture into contact with the dissolved biodegradable organic pollutants and oxygen in the atmosphere. The microorganisms extract the organic pollutants from the wastewater and use these materials as a sole source of energy. The result is that these dissolved materials are converted in part to biomass, a suspended solid, which is subsequently separated from the wastewater flow by means of sedimentation. These suspended solids must then be chemically conditioned and dewatered for further processing in the solid-waste management component of the MIST.

The physical-chemical treatment system consists of a series of unit processes designed to remove dissolved inorganic pollutants such as hardness agents and phosphorus as well as suspended and colloidal solids and color. The system consists of a precipitation-flocculation-coagulation (PFC) reactor with a sedimentation basis. To control the concentration of dissolved organic pollutants from either the biological reactor or the PFC reactor, an active carbon absorption process was included. Similarly, a deep-bed granular-media filter was provided for the control of fine colloidal suspended solids. Dissolved inorganic chemical pollutants are removed by using a reverse-osmosis system. A disinfection process is used to ensure the bacterial quality of the effluent water from the total systems. Chlorine is used as the primary disinfectant. The maintenance of a chlorine level in the product water will minimize the regrowth of bacteria and also the magnitude of future contamination. Additionally, the system is configured to permit flow through a heat exchanger for testing the effectiveness of waste-heat utilization in the treatment cycle. A heat sterilization system is also included.

A sulfur dioxide (SO_2) stack gas scrubber/wastewater treatment system (not shown in the schematic) was tested in the MIST during the time period that the WMS was on line. The system was designed for removal of sulfur oxides and nitrogen oxides from engine exhaust. The sulfur dioxide is dissolved in raw wastewater and forms sulfurous acid at a pH of 2.5. Ferrous sulfate is then formed from the sulfurous acid contact with scrap iron. The low pH sterilizes wastewater and the iron salts are used as a coagulant in the physical-chemical process. The water is neutralized using lime.

Figure 18 depicts an integrated MIST/WMS wastewater treatment system configuration as tested during the WMS Phase I test effort. The NASA trailer used for housing the WMS sensors and the DAS was physically positioned south of the MIST facility building. The WMS used peristaltic pumps to draw effluent from selected sampling points in the wastewater process. Plastic tubing was used for connecting the treatment system to the WMS trailer. External power was supplied from the MIST electrical system. Figures 19 to 21 depict, respectively, the trailer unit stationed outside the MIST, one sensor console and the DAS assembly, and various WMS sensors.

Laboratory Analytical Methods

Samples were periodically taken for classical laboratory analyses and comparison with WMS measurement values. Table IV describes the laboratory analysis techniques for the laboratory 1 and laboratory 2 results reported in the following section.

TEST RESULTS

The WMS was operated at the MIST facility from December 10, 1974, through February 28, 1975. During the final 6 weeks of testing, the WMS was operated 24 hours per day, 4 days per week. The total operating time was almost 700 hours.

The data collected during the test period from the WMS sensors and from laboratory analyses of manually collected samples are summarized in figures 22 and 23. Average results are illustrated for each parameter, including (1) more than 6000 hourly readings from the WMS, (2) more than 2000 individual analyses by the JSC Environmental Health Services Laboratory (lab 2), and (3) more than 600 individual analyses using the Hach DR-EL2 analyzer (lab 1). Figures 22 and 23 show the change in concentration of the measured parameters as the water progresses through the cycle of consumer usage and the various stages of wastewater treatment. It should be noted that the differences in results presented in figure 23 do not necessarily represent deviations among the three data sources. The results are averages that represent, in most cases, a different number of samples from each data source and thus different sampling times. Actual deviations among data sources will be discussed later in this section.

Representative hourly WMS data are illustrated in figure 24. The results of comparable laboratory analyses are also shown. The figures illustrate the variations that typically occur in the water parameters during the treatment process. The data also demonstrate the performance of the WMS in responding to variations in concentration when sample sources were changed.

Table V summarizes the deviations among comparable WMS, laboratory 1, and laboratory 2 data. These data were obtained by reading the WMS output while manually collecting samples for later analysis by laboratory 1 and laboratory 2. The raw data from which table V was produced are presented in the appendix.

The deviations are expressed in parameter units and percent of the WMS full-scale range. Many of the WMS sensors are electrodes that have a logarithmic output; thus, data output sensitivity varies within the instrument range. The percentage deviation number relates the deviation to the WMS data sensitivity at the absolute values being compared. This allows evaluation of the deviations in terms of sensitivity and normal calibration drift of the instrument. In general, the deviations may be interpreted as follows.

1. A positive or negative mean deviation indicates a bias in the analysis technique. This deviation may result from differences in calibration standards, consistently nonrepresentative sampling, inadequately preserved water samples (in the case of laboratory analyses), or an interference in the water that affects one analysis more than another.

2. A high standard deviation of the observed measurement differences may indicate a variable interference or inconsistent calibration techniques.

3. A high maximum deviation usually indicates a nonrepresentative sample.

Table VI summarizes the calibration drift of the WMS sensors. Analysis of these data produced the unexpected result that, in general, no detectable relationship existed between magnitude of drift and calibration frequency. Typical results of this analysis are shown in figure 25.

The personnel involved in calibrating the sensors were powerplant operators or engineers who, in general, had little or no experience in operating chemical analyzers. Training before the start of testing was limited to less than 1 day. Thus, it was not surprising that a few "wild" points existed in the early data. As experience was gained, the data indicated improvement in operator skills. It may be assumed that any tendency of the sensors toward increasing error with time due to drift was masked by inconsistent calibration techniques. In addition, diurnal and short-term (trailer door opening) temperature variations were severe. Because of the high-gain circuitry used in certain measurements, temperature-induced drift was a significant source of error.

Linear regression analyses by the method of least squares were performed on certain organic loading parameters to determine if correlation occurred in the MIST wastewater. The following models were examined:

1. BOD_5 (5-day biochemical oxygen demand) = $C_a + C_b$ (turbidity)
2. $BOD_5 = C_c + C_d$ (chemical oxygen demand)
3. $BOD_5 = C_e + C_f$ (total organic carbon)
4. Turbidity = $C_g + C_h$ (total suspended solids)
5. TOC = $C_i + C_j$ (turbidity)

The results are illustrated in figure 26. Correlation coefficients were between 0.1 and 0.7. The correlations between BOD_5 and TOC (0.4 to 0.6) were not as good as have previously been reported (0.74 was reported for raw wastewater in reference 11). However, the authors of the referenced paper found it necessary to average multiple analyses (three to nine) of BOD_5 for each sample to minimize inherent variability of the BOD test. Multiple sample analyses were not performed in this test program; thus, a poorer correlation would be expected.

Sensor Problems

Ammonium ion sensor.- The electrode has a higher selectivity for potassium ion, hydrogen ion, and sodium ion than for ammonium ion. The hydrogen ion interference was eliminated by maintaining a pH of 7.0 with a buffer. However, the high variation of sodium (approximately 70 mg/liter) in the JSC water and wastewater systems prevented measurement of ammonium ions the concentration of which was usually less than 5 mg/liter.

Total organic carbon sensor.- The results from consecutive injections of a standard fluid typically varied by as much as 15 mg/liter. Figure 27 illustrates a representative calibration and the sample-to-sample variations. These variations are attributed to three primary causes.

1. Retention of a portion of the 40- to 45-microliter sample on the injection needle tip. Periodically, the retained drop was blown off the needle during the

injection of subsequent samples. Various needle tip configurations, including square cut/beveled and polished/roughened, were tried with no noticeable improvement. The air injection pressure was varied over a range of 35 to 138 kN/m^2 (5 to 20 psig) and, although the calibration curve shifted with pressure, no improvement in sample-to-sample variation was found.

2. Zero drift of the infrared analyzer. The zero point normally shifted when alternately exposed to the two combustion tubes. Some shift was predictable and could be accounted for in the calibration curve. However, the magnitude of the zero shift was at times inconsistent and contributed to the observed variations; an automatic zeroing circuit would have saved many man-hours of frustrating manual adjustment.

3. Ambient temperature variations. The infrared analyzer was noticeably sensitive to the change in temperature when the trailer door was opened, which occurred frequently.

Total residual chlorine sensor.- High chlorine readings were observed for unchlorinated process wastewater. Some oxidizing agents such as free halogens other than chlorine, as well as chlorine dioxide and nitrogen trichloride, will appear quantitatively as free chlorine, but it is more likely that the interfering effect in the iodometric method of ferric, manganic, and/or nitrite ions explains the high observed concentrations. Consistently good results were obtained for treated chlorinated water.

Total hardness sensor.- The ethylenediamine tetraacetic acid (EDTA) titrimetric method used by laboratories 1 and 2 for measuring hardness is susceptible to interference from some metal ions that cause fading or indistinct end points, especially if iron is present in the sample at a concentration greater than 30 mg/liter. The WMS hardness monitor is primarily susceptible to interference from sulfur ions only.

The MIST sulfur dioxide scrubber was used in conjunction with a ferrous/ferric ion mixture treatment stage. When the sampled water had passed this stage, the laboratory hardness readings became erratic. Although the iron concentration was not measured, it is likely that the iron concentration was responsible for the large disparity observed between the WMS hardness reading of 100 to 150 p/m and the laboratory 1 and 2 readings of 800 to 1000 p/m.

Midway through the test program, a new batch of hardness monitor reagent was produced and shipped by the manufacturer. The new reagent gave consistent results when water hardness was greater than 10 mg/liter. However, with purified water, distilled water, or reverse-osmosis effluent, the monitor failed to respond below 10 mg/liter. This problem had not been experienced with the previous batch of reagent and is assumed to be caused by contaminated raw materials or inadequate reagent processing.

Biosensor/chemiluminescence.- No usable bacterial data were obtained during the MIST program. Two related problems were experienced: (1) trace interferences including iron in the wastewater, and (2) the extremely narrow operating range of the sensor, usually resulting in either no signal or a saturated signal beyond the proportional range.

Laboratory testing is currently underway to define wastewater ingredients that interfere with the luminol reactions and to evolve methods to minimize or eliminate the interferences. As previously discussed in the subsection on the TOC sensor, the narrow one-decade operating range has been expanded in a laboratory model to four decades using a modified reactor/photomultipler tube configuration.

System contamination.- On three separate occasions during the test program, unscheduled MIST wastewater process upsets resulted in gross contamination of many of the sensors. It was necessary to completely disassemble and clean the individual parts. The small-diameter tubing, the electrodes, and the electrode wells of the WQMS were particularly affected. Future designs should incorporate, when possible, one, more, or all of the following provisions.

1. Filtering

2. Periodic clean-water flushing of supply lines and electrode wells (possibly with air augmentation)

3. Ultrasonic electrode cleaning with a jet-spray flush

Data Acquisition System Problems

Special signal conditioning.- Special signal conditioning was provided to condition sensor output signals that were not compatible with the standard 0- to 5-volt dc DAS buffer inputs. These sensors included the TOC; chemiluminescence; conductivity; and the pH, ammonium ion, and chloride ion Orion analyzers.

The problem of interfacing the pH, ammonium ion, and chloride ion sensors proved to be most troublesome. The analyzer electronics provided a -10 to +10 millivolt single-ended signal output. However, it was discovered that with a common signal ground point, tracking between these measurements occurred. A separate high-input impedance differential amplifier box was constructed and installed near the three Orion instruments. Measurement tracking was reduced, but bias drift increased as a result of the close proximity of motors and pumps.

Measurement drift was also a problem with these measurements. The sources of the drift were power supply and temperature variations. Because the Orion signals were symmetrical about zero, a bias voltage was introduced to provide a positive-going signal. However, because the voltage was derived from the power supply voltage, small variations in supply voltage could produce drift. More significantly, diurnal and short-term (door opening) temperature variations were severe. Because of the high-gain circuitry used at the Orion analyzer interface, temperature-induced drift was a significant source of error.

The interface for the conductivity measurement also used high amplification, but zero offset biasing was not required. A peculiarity of this measurement was that the conductivity electronics produced an output that included, together with the data signal, voltage spikes and lower frequency sinusoidal variations. Input buffering was installed at the input of the DAS conductivity signal interface to eliminate the undesirable signal characteristics.

Failure summary.- A list of the parts failures is given in table VII; significant failures are discussed here. (Failure numbers are keyed to table VII.)

Failure 1: The clock oscillator of the temperature-compensated crystal oscillator failed from unknown causes. A resistor/capacitor transistor-transistor logic oscillator was fabricated and installed as a temporary measure until a new crystal oscillator could be purchased. The temporary oscillator caused time accumulation errors that required periodic resetting of the real-time clock.

Failures 3 and 5: The analog/digital buffer was observed to contribute a bias error of approximately 5-percent worst case. The WMS electronics will be modified to include a precision operational amplifier.

Failure 6: A short circuit developed that resulted in feeding the clock signal to both tracks of the cassette recorder. The recorder level meters were monitored to verify a signal on both tracks of the recorder, but a difference between the clock signal and the data signal could not be distinguished.

Data recording.- Failure 6 occurred after cassette 1 had been recorded and resulted in only one cassette having usable data. After this cassette had been played several times to develop data processing techniques, the quality of the tape had degraded to the point of being unusable. However, an oscillogram that had been made of one frame before tape degradation was manually reduced and presented in a typical WMS printout format. The data are presented in table VIII.

Because data retrieval was still uncertain at that time, a plan was formulated to verify that incrementally recorded WMS data could be retrieved. The plan consisted of recording a tape cassette with known data, processing the tape, and comparing the resultant data with the known input data. The results are shown in table IX. The bit error of the cassette data was estimated to be approximately 10 percent. This error results from audio-type recorder deficiencies such as excessive tape wear, digital signal/noise ratio degradation resulting from audio volume limiting, momentary loss of tape-to-head contact, or false bits caused by recorder-generated noise. This test sequence did verify that incrementally recorded digital data can be retrieved, but the high bit-error rate is not acceptable for reliable data.

RECOMMENDATIONS

Significant findings and conclusions were derived from the less positive (or adverse) operating experiences and conditions that occurred during the test period. Such conditions not only were anticipated but were considered desirable to maximize the design improvements and reliability that are considered essential to the Phase II field demonstration. The valuable experience that was gained will be applied in the Phase II system design. The recommendations and a summary of the conditions that prevailed to bring about their considerations are as follows.

1. Provide automated standardization to improve operational simplicity. The relatively large number of sensors in the system resulted in a high manpower time demand for manual standardization (calibration) of the instruments. This condition

led to the consideration and recommendation for automated standardization to approach a more effective automated system.

2. Provide automated data logging, evaluation, and reporting. The need to statistically correlate and report the substantial amount of data collected during the test period resulted in a time-consuming engineering effort. This factor, in addition to delays in obtaining processed data from a centralized data processing station, resulted in the manual compilation and analysis of engineering data. These two circumstances readily convinced the test team of the utility and potential advantages of having on-site data, a computerized data logging and evaluation capability (including statistical compilation), and combined parameter trending for plant control, load billing (to a customer), etc.

3. Reduce fluid system susceptibility to contamination. Occasional unexpected plant upsets and planned special wastewater treatment system tests resulted in severe system contamination problems that necessitated extensive system purging and decontamination procedures that interrupted monitoring operations. As a result, the test team recommended the design of a sample processing system to be used upstream of the sensor instrumentation but within the confines of the WMS envelope.

4. Improve system/sensor reliability relative to sample or reagent flow indication. Fluid system flow (either sample or reagent) to the sensors was occasionally interrupted, and failed to be noted by the operator. Data continued to be logged during these interruptions. These occurrences revealed a need not only to improve the fluid system but also to signal the operator of a flow breakdown. (Breakdowns occurred either because of air entrainment, contamination, or depletion of a reagent bottle.)

5. Improve (reduce) susceptibility of the biosensor to an interfering agent with additional development effort. Biosensor response to system contamination, high inherent light, and interferences in the sample continually plagued the operations. Although anticipated, the test period proved to be too short and the environment too inefficient to resolve the problems encountered. Laboratory development support was offered by experienced luminescence researchers at the NASA Goddard Space Flight Center and supporting efforts were initiated.

6. Provide improved environmental conditioning. Infrared detection systems in the TOC system proved to be highly susceptible to environmental (temperature/humidity) conditions in the small trailer which housed the WMS. This condition was aggravated by the proximity of the TOC unit to the door of the trailer, but the unit could not be located because of space limitations. Results definitely indicate the need for increased space, improved environmental control, and increased attention to equipment placement and access control.

7. Provide additional/improved sensors to upgrade the total water quality concept. The Phase I WMS sensor selection was largely determined by the availability of sensors in the NASA Langley Research Center WQMS and by the limited resources of the Phase I effort. Additional sensors are desirable to effect a more comprehensive total water quality picture and also to replace some of the original sensors that were either no longer providing satisfactory service or no longer representative of adequate state of the art. Incorporation of two additional NASA biological detection methods (bioluminescence and coliform) into a flow system is also recommended.

8. Replace DAS audio tape recorders with commercial digital incremental recorders. As previously discussed, the inexpensive audio recorders selected and used for the Phase I effort were found to be inadequate for this application because of the high bit-error rate. Replacement with higher grade equipment is essential to the successful application of the cassette approach to the WMS.

CONCLUDING REMARKS

Phase I of the NASA water monitor system project was concluded on February 28, 1975, with the completion of the test program described herein. The primary overall objectives achieved during Phase I are as follows.

1. Refurbishment and augmentation of the Langley Research Center water quality monitoring system for use as a community wastewater treatment facility and water quality monitoring system

2. Conceptualization and initial design, development, and fabrication of an advanced data acquisition system capable of data compression and storage on inexpensive cassette-type tape

3. Assembly and initial demonstration of an integrated system package capable of collecting the samples, sensing the respective water parameters, and displaying and recording the data so as to provide a total water quality picture in real time

4. Demonstration of the Phase I system approach in an NASA wastewater treatment pilot facility preparatory to design and fabrication of the Phase II field demonstration water monitor system

5. Application and evaluation of on-line organic monitoring in a wastewater treatment facility environment

6. Initial application and evaluation of on-line near-real-time biological monitoring in a wastewater treatment facility environment

Although the calendar duration of the test period was relatively short, a substantial quantity of data and operational experience with the system approach was realized as a result of the decision by NASA to operate the system on a continuous, around-the-clock basis as would be the case in actual field conditions. This schedule allowed most of the equipment to operate on a near-continuous basis and the data acquisition system (which remained continuously powered up) to operate for more than 1600 hours with only a nominal number of electronic burn-in failures. Evaluation of the overall system performance relative to the specific task requirements very quickly indicated the potential and actual usefulness of the approach to the NASA wastewater treatment unit in the MIST facility or in a community wastewater treatment facility. Previous water quality testing in the MIST facility had been conducted primarily on a laboratory basis as is done in most treatment plants. Often, results from the laboratory take from 1 to 2 weeks because of priority conflicts; also, the identification of some parameters such as BOD_5 and Escherichia coli requires 4 to 5 days. The availability of real-time data significantly assisted the NASA research engineer responsible for MIST's wastewater system in evaluations of the system and in close-in control of the operating conditions of the plant.

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National Aeronautics and Space Administration
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TABLE I.- TOC PROGRAM SEQUENCE

Step	Activity	Total carbon channel		Inorganic carbon channel		Comments
		Sample injection valve	Sample selection valve	Sample injection valve	Sample selection valve	
1	Open total carbon selection valve	Off	Open to analyzer	Off	Open to vent	Carrier gas flows into port 1 and out port 6 of each sample inlet valve en route to the combustion tubes. The sample liquid flows into port 3, through the sample loop, and out port 4 of each sample inlet valve.
2	Inject sample into total carbon channel	On	Open to analyzer	Off	Open to vent	Carrier gas flows into port 1 of the sample inlet valve, through the sample loop, and forces the liquid through port 6 to the total carbon furnace combustion tube.
3	Close total carbon injection valve	Off	Open to analyzer	Off	Open to vent	
4	Open inorganic carbon selection valve	Off	Open to vent	Off	Open to analyzer	Total carbon channel carrier gas is now vented to the atmosphere while the inorganic carbon channel carrier gas is routed to the infrared analyzer.
5	Inject sample into inorganic carbon channel	Off	Open to vent	On	Open to analyzer	Carrier gas flows into port 1 of the sample inlet valve, through the sample loop, and forces the liquid through port 6 to the total carbon furnace combustion tube.
6	Close inorganic carbon injection valve	Off	Open to vent	Off	Open to analyzer	

TABLE II.- BIOSENSOR/CHEMILUMINESCENCE PROGRAMED SEQUENCE

Step	Operation	Time	Component function[a]											Switch alarm contacts	Sample	Timers		
			P5 High	P5 Low	P4	P3	V1	V2	V4	V6	V7	V12	V11			Integrate	Sample	Incubate
1	Collect sample	30 min	X					X				X	X				X	
2	Collect sample	10 min	X					X				X	X					
3	Collect sample	30 min	X					X				X	X				X	
4	Water wash (total sample) Nutrient fill (viable sample)	3 min		X		X	X	X	X			X						
5	Water wash (total sample) Incubate (viable sample)	5 min		X		X		X		X								
6	Sample baseline (total sample) Incubate (viable sample)	5 sec		X		X		X		X					X			
7	Sample/integrate (total sample) Incubate (viable sample)	3 min		X		X				X						X		
8	Filter wash (total sample) Incubate (viable sample)	10 min		X		X				X								
9	Collect water blank (total sample) Incubate (viable sample)	2 hr		X				X										X
10	Water wash	5 min		X		X		X		X		X						
11	Sample baseline (total sample) Water wash (viable sample)	5 sec		X		X		X		X		X			X			
12	Sample/integrate (total sample) Water wash (viable sample)	3 min		X		X				X		X				X		
13	Water wash (viable sample)	5 min		X		X					X	X						
14	Sample baseline (viable sample)	5 sec		X		X					X	X		X	X			
15	Sample/integrate (viable sample)	3 min		X		X					X			X		X		
16	Filter wash	10 min		X		X					X			X				
17	Filter wash	10 min		X		X				X								
18	Reset				X													

[a] P = pump, V = valve; numbers are component identification in the schematic shown in figure 13.

TABLE III.- THE DAS ANALOG BUFFER POSTASSEMBLY TEST RESULTS

Channel no.	Test results, V	
	2.500 V input	5.000 V input
Card 1		
1	2.488	4.996
2	2.490	4.998
3	2.501	5.001
4	2.500	5.000
5	2.498	4.998
6	2.498	4.999
7	2.498	4.999
8	2.500	5.000
9	2.499	5.000
10	2.497	4.997
11	2.498	4.998
12	2.498	4.997
13	2.496	4.997
Card 2		
1	2.502	5.002
2	2.500	5.001
3	2.499	5.000
4	2.497	4.998
5	2.500	4.999
6	(a)	(a)
7	2.502	5.001
8	2.501	5.002
9	2.500	5.000
10	2.498	4.999
11	2.500	5.001
12	(a)	(a)
13	2.499	5.001

[a] Postassembly defective channels; subsequently repaired.

TABLE IV.- ANALYTICAL METHODS FOR LABORATORY RESULTS

Analysis	Procedure	Reference	Sensitivity
Laboratory 1 (Hach DR-EL/2 analyzer)			
Chemical oxygen demand	Dichromate reflux method for wastewater	Ref. 7	10 mg/liter
Chloride	Titration - mercuric nitrate	Ref. 7	1 mg/liter
Chlorine	Orthotolidine-O-Toliver	Ref. 7	0.1 mg/liter
Dissolved oxygen	Modified azide-Winkler method	Ref. 7	1 mg/liter
Nitrate	Cadmium reduction - nitraver V	Ref. 7	1 mg/liter
pH	Direct colorimetric	Ref. 7	0.1 pH unit
Phosphate	Ascorbic acid - phosver III	Ref. 7	1 mg/liter
Total hardness	Titration - titraver (EDTA)[a]	Ref. 7	1 mg/liter
Turbidity	Absorptometric	Ref. 7	10 Jtu
Ammonia	Nessler's method	Ref. 7	0.1 mg/liter
Laboratory 2 (JSC Environmental Health Services Laboratory)			
Ammonia	Nessler's method	Ref. 8, pp. 222 and 453; ref. 9, p. 159	0.1 mg/liter
Biochemical oxygen demand (BOD)	Membrane electrode method	Ref. 8, p. 484	1 mg/liter
Chloride	Mercuric nitrate method	Ref. 8, p. 97	0.5 mg/liter
Nitrate	Cadmium reduction method	Ref. 8, p. 458	1 mg/liter
pH	Fisher pH meter	Ref. 8, p. 500	0.1 pH unit
Sodium	Atomic absorption	Ref. 10	5 for 140 mg/liter
Specific conductivity	YSI conductivity bridge	Ref. 8, p. 323	10 µmhos for 1000-µmhos sample
Sulfate	Barium chloride turbidimetric method	Ref. 8, p. 334	1 mg/liter
Total dissolved solids (TDS)	Filtration method	Ref. 8, p. 539	1 for a 100-ml sample
Total hardness	EDTA method	Ref. 8, p. 179	1 mg/liter
TOC	Beckman model 915 carbon analyzer	Ref. 8, p. 257	1 for 100 mg/liter full-scale reading
Total phosphorus	Persulfate digestion - stannous chloride method	Ref. 8, p. 526	0.1 mg/liter for total phosphorus ≥ 0.1; 0.01 mg/liter for total phosphorus <0.1
Turbidity	Photometric method	Ref. 9, p. 295	10 Jtu, Hach kit standard curve

[a] Ethylenedeamine tetraacetic acid.

TABLE V.- DEVIATIONS AMONG DATA SOURCES

Measurement	WMS/lab 1		WMS/lab 2		Labs 1 and 2
	Parameter units	Percent full scale (WMS)	Parameter units	Percent full scale (WMS)	Parameter units
TOC, mg/liter:					
Mean	--	--	8	8	--
Standard deviation	--	--	9	9	--
Maximum	--	--	37	37	--
Minimum	--	--	0	0	--
Samples	--	--	55	55	--
Turbidity, Jtu:					
Mean	11	4	6	2	0
Standard deviation	27	10	24	9	33
Maximum	153	56	143	52	55
Minimum	0	0	0	0	0
Samples	69	69	72	72	48
Conductivity, µmhos/cm (MIST configuration I/II):					
Mean	--	--	37	1	--
Standard deviation	--	--	52	2	--
Maximum	--	--	180	6	--
Minimum	--	--	0	0	--
Samples	--	--	69	69	--
Conductivity, µmhos/cm (MIST configuration III - SO_2 scrubber):					
Mean	--	--	-85	-1	--
Standard deviation	--	--	394	9	--
Maximum	--	--	-1100	-22	--
Minimum	--	--	60	2	--
Samples	--	--	13	13	--
Ammonia, mg/liter (as N):					
Mean	--	--	--	--	0.7
Standard deviation	--	--	--	--	3.4
Maximum	--	--	--	--	15.5
Minimum	--	--	--	--	0
Samples	--	--	--	--	49
Nitrate, mg/liter (as N):					
Mean	--	--	--	--	0
Standard deviation	--	--	--	--	1.2
Maximum	--	--	--	--	2.9
Minimum	--	--	--	--	0
Samples	--	--	--	--	13
Total hardness, mg/liter (MIST configuration I/II):					
Mean	1	0	-3	-1	-5
Standard deviation	10	5	8	4	6
Maximum	-27	-8	-34	-27	-23
Minimum	0	0	0	0	0
Samples	38	38	51	51	43
Total hardness, mg/liter (MIST configuration III - SO_2 scrubber):					
Mean	-69	-3	-353	-11	-3
Standard deviation	183	7	420	11	4
Maximum	-484	-18	-990	-27	-10
Minimum	0	0	-1	-1	0
Samples	7	7	11	11	8

TABLE V.- Concluded

Measurement	WMS/lab 1		WMS/lab 2		Labs 1 and 2
	Parameter units	Percent full scale (WMS)	Parameter units	Percent full scale (WMS)	Parameter units
Chloride, mg/liter (MIST configuration I/II):					
Mean	19	3	17	2	-1
Standard deviation	31	5	32	6	9
Maximum	102	14	111	15	30
Minimum	1	0	0	0	0
Samples	47	47	80	80	46
Chloride, mg/liter (MIST configuration III - SO_2 scrubber):					
Mean	68	8	86	9	3
Standard deviation	67	6	72	6	11
Maximum	192	19	211	20	-22
Minimum	8	2	-1	0	-1
Samples	8	8	13	13	7
Sodium, mg/liter:					
Mean	--	--	16	3	--
Standard deviation	--	--	20	4	--
Maximum	--	--	88	15	--
Minimum	--	--	1	0	--
Samples	--	--	92	92	--
pH, units:					
Mean	-.2	-1.0	-1.1	-8.4	-1.1
Standard deviation	.4	3.1	1.4	5.[illegible]	.8
Maximum	-1.1	--	-2.7	-19.0	-2.2
Minimum	0	--	0	0	0
Samples	66	66	86	86	62
Residual chlorine, mg/liter (in-process water):					
Mean	18.5	48.3	--	--	--
Standard deviation	23.3	22.3	--	--	--
Maximum	35.0	64.0	--	--	--
Minimum	2.0	32.5	--	--	--
Samples	2	2	--	--	--
Residual chlorine, mg/liter (chlorinated water):					
Mean	-.6	-1.0	--	--	--
Standard deviation	3.5	16.0	--	--	--
Maximum	-6.2	-26.0	--	--	--
Minimum	.1	-1.3	--	--	--
Samples	9	9	--	--	--
Dissolved oxygen, mg/liter:					
Mean	-1.5	-12.8	--	--	--
Standard deviation	1.7	14.2	--	--	--
Maximum	-8.1	-68.0	--	--	--
Minimum	0	0	--	--	--
Samples	40	40	--	--	--

TABLE VI.- CALIBRATION PERFORMANCE

(a) Hardness sensor

Date	Time, hr: min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale	Slope drift, percent at full scale
Jan. 14, 1975	5: 25 p.m.	3.5	10/100	0.6	1.6
Jan. 15	1: 30 a.m.	8.0	10/100	-3.7	2.0
	8: 10 a.m.	6.5	10/100	5.7	-5.8
	2: 00 p.m.	6.0	10/100	-8.3	10.2
	5: 10 p.m.	3.0	10/100	-3.7	10.4
Jan. 16	1: 00 a.m.	8.0	10/100	1.6	-2.0
	8: 20 a.m.	7.5	10/100	.8	-4.8
	3: 20 p.m.	7.0	10/100	-1.0	1.2
Jan. 17	1: 35 a.m.	10.5	10/100	0	0
	9: 14 a.m.	7.5	10/100	9.0	.4
	2: 08 p.m.	5.0	10/100	-2.6	-1.6
Jan. 21	5: 05 a.m.	87.0	10/100	3.6	-2.0
	11: 12 a.m.	6.0	10/100	-3.6	.8
Jan. 23	9: 10 a.m.	46.0	10/1	-3.8	-10.8
Jan. 24	9: 30 a.m.	24.5	10/1	.2	-2.0
Jan. 27	6: 30 p.m.	81.0	10/100	11.0	-8.4
Jan. 28	9: 50 p.m.	27.5	10/100	-3.3	.8
Jan. 29	6: 45 p.m.	21.0	10/100	-4.0	4.0
Jan. 30	11: 30 a.m.	17.0	10/100	0	-2.0
Jan. 31	2: 00 p.m.	26.5	10/100	-1.0	4.8
Feb. 3	4: 00 p.m.	74.0	10/100	3.4	0
Feb. 4	8: 45 a.m.	17.0	10/100	.4	-4.0
	4: 00 p.m.	7.5	10/100	-4.5	14.2

TABLE VI.- Continued

(a) Concluded

Date	Time, hr: min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale (a)	Slope drift, percent at full scale (a)
Feb. 5, 1975	8:55 a.m.	17.0	10/100	-2.4	-1.2
	4:00 p.m.	7.0	10/100	4.6	-.4
Feb. 11	11:00 a.m.	139.0	10/100	(-.2)	(0)
Feb. 12	10:30 a.m.	23.5	10/100	2.6	-2.0
	6:00 p.m.	7.5	10/100	1.0	-4.8
Feb. 13	8:15 a.m.	14.5	10/100	(1.2)	(-4.0)
Feb. 14	8:20 a.m.	24.0	10/100	3.0	-2.8
Feb. 18	2:00 p.m.	101.5	10/100	5.8	0
Feb. 19	12:20 p.m.	22.5	10/100	1.0	-4.0
Feb. 20	5:00 p.m.	28.5	10/100	-1.2	3.2
	7:00 p.m.	2.0	10/100	.8	1.2
Feb. 21	10:00 a.m.	15.0	10/100	0	2.4
Feb. 24	10:00 a.m.	72.0	10/100	.8	0
	5:00 p.m.	7.0	10/100	.4	-1.6
Feb. 25	11:30 a.m.	18.5	10/100	0	-1.6
Feb. 27	10:30 a.m.	47.0	10/100	-.2	-2.0
Feb. 28	2:50 p.m.	28.5	10/100	-1.0	2.8

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(b) Sodium sensor

Date	Time, hr:min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale (a)	Slope drift, percent at full scale (a)
Jan. 14, 1975	2:00 p.m.	4.0	10/1000	--	0
	5:25 p.m.	3.5	10/1000	-0.2	-4.8
Jan. 15	1:30 a.m.	8.0	10/1000	21.2	-.4
	8:10 a.m.	6.5	10/1000	(-1.0)	-.6
	5:10 p.m.	9.0	10/1000	(3.6)	3.0
Jan. 16	1:00 a.m.	8.0	10/1000	-5.5	1.6
	3:20 p.m.	14.5	10/1000	.8	-1.2
Jan. 17	1:35 a.m.	10.5	10/1000	.4	-.2
	9:14 a.m.	7.5	10/1000	3.2	1.8
	2:08 p.m.	5.0	10/1000	(.4)	(-.4)
Jan. 21	5:05 a.m.	87.0	10/1000	1.0	2.0
	11:12 a.m.	6.0	10/1000	9.8	-4.0
Jan. 23	9:10 a.m.	46.0	10/1000	1.6	1.2
Jan. 24	9:30 a.m.	24.5	10/1000	0	0
Jan. 27	6:30 p.m.	81.0	10/1000	-2.0	2.0
Jan. 28	9:50 p.m.	27.5	10/1000	2.0	-2.0
Jan. 29	6:45 p.m.	21.0	10/1000	-5.4	1.0
Jan. 30	11:30 a.m.	17.0	10/1000	1.0	-.2
Jan. 31	2:00 p.m.	26.5	10/1000	0	0.2
Feb. 3	4:00 p.m.	74.0	10/1000	4.2	-3.8

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(b) Concluded

Date	Time, hr:min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale (a)	Slope drift, percent at full scale (a)
Feb. 4, 1975	8:45 a.m.	17.0	10/1000	.2	0
	4:00 p.m.	7.5	10/1000	4.2	-2.6
Feb. 5	8:55 a.m.	17.0	10/1000	.2	-2.6
	4:00 p.m.	7.0	10/1000	1.2	2.0
Feb. 6	9:00 a.m.	17.0	100/1000	.2	-1.4
	5:10 p.m.	8.0	100/1000	11.5	(.2)
Feb. 7	9:30 a.m.	16.5	100/1000	(-6.0)	(1.1)
Feb. 10	6:10 p.m.	80.5	100/500	4.9	(.2)
Feb. 12	10:30 a.m.	40.5	100/500	(.3)	(-2.5)
Feb. 13	8:15 a.m.	22.0	100/500	-2.3	1.2
Feb. 14	8:20 a.m.	24.0	100/500	-2.0	-2.6
Feb. 18	2:00 p.m.	101.5	100/500	2.6	-2.9
Feb. 19	12:20 p.m.	22.5	100/500	1.8	.9
Feb. 20	5:17 p.m.	29.0	50/250	-.5	.1
	7:00 p.m.	1.5	20/200	-.8	0
Feb. 21	10:00 a.m.	15.0	20/200	3.2	3.7
Feb. 24	10:00 a.m.	72.0	20/200	-10.4	0
	5:00 p.m.	7.0	20/200	5.0	1.5
Feb. 25	10:00 a.m.	17.0	20/200	1.6	-1.5
Feb. 27	10:30 a.m.	24.5	20/200	(-1.3)	(-.6)
Feb. 28	2:50 p.m.	28.5	20/200	-.5	-.9

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(c) Chlorine sensor

Date	Time, hr:min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale (a)	Slope drift, percent at full scale (a)
Jan. 21, 1975	11:12 a.m.	6.0	10/1	1.2	52.4
Jan. 22	5:45 p.m.	30.5	10/1	-24.2	4.4
Jan. 23	9:10 a.m.	15.5	10/1	(2.0)	(4.4)
Jan. 24	9:30 a.m.	24.5	10/1	0	.8
Jan. 27	6:30 p.m.	81.0	10/1	-10.2	-4.8
Jan. 28	9:50 p.m.	27.5	10/1	0	8.8
Jan. 29	6:45 p.m.	21.0	10/1	8.3	-7.6
Jan. 30	11:30 a.m.	17.0	10/1	5.8	-6.8
Jan. 31	2:00 p.m.	26.5	10/1	-5.2	-1.2
Feb. 3	4:00 p.m.	74.0	10/1	(0)	(0)
Feb. 4	8:45 a.m.	17.0	10/1	0	0
	4:00 p.m.	7.5	10/1	0	2.0
Feb. 5	8:55 a.m.	17.0	10/100	-3.6	5.2
	4:00 p.m.	7.0	10/100	-1.4	2.4
Feb. 6	5:10 p.m.	25.0	10/100	-2.8	-2.4
Feb. 7	9:30 a.m.	16.5	10/100	(4.0)	(0)
Feb. 12	10:30 a.m.	121.0	10/100	-.6	8.0
	6:00 p.m.	7.5	10/1	0	4.4
Feb. 13	8:15 a.m.	14.5	10/1	0	-7.6

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(c) Concluded

Date	Time, hr: min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale (a)	Slope drift, percent at full scale (a)
Feb. 14, 1975	8: 20 a.m.	24.0	10/1	-0.2	6.0
Feb. 18	2: 00 p.m.	101.5	10/1	1.4	7.6
Feb. 19	12: 20 p.m.	22.5	10/1	-7.4	-2.8
Feb. 20	5: 17 p.m.	29.0	10/1	(0)	-2.0
Feb. 21	10: 00 a.m.	16.5	10/1	(3.8)	(0)
Feb. 24	10: 00 a.m.	72.0	10/1	-20.6	1.6
	5: 00 p.m.	7.0	10/1	(-4.4)	(4.8)
Feb. 25	11: 30 a.m.	18.5	10/1	0	-4.3
Feb. 27	10: 30 a.m.	47.0	10/1	0	0
Feb. 28	2: 50 p.m.	28.5	10/1	-26.8	6.0

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(d) Chloride sensor

Date	Time, hr:min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale			Slope drift, percent at full scale		
				Analyzer (a)	Signal conditioning (a)	Total (a)	Analyzer (a)	Signal conditioning (a)	Total (a)
Jan. 14, 1975	2:00 p.m.	4.0	100/1000	-7.1	-0.3	-7.4	0	0	0
	5:25 p.m.	3.5	100/1000	-1.1	.5	-.6	0	-.2	-.2
Jan. 15	1:00 a.m.	7.5	100/1000	14.1	-.9	13.2	-7.1	0	-7.1
	8:10 a.m.	7.0	100/1000	0	-.2	-.2	0	.2	.2
	2:00 p.m.	6.0	100/1000	-2.8	2.0	-.8	-2.8	1.2	-1.6
	5:10 p.m.	3.0	100/1000	6.0	1.0	7.0	0	2.6	2.6
Jan. 16	1:00 a.m.	8.0	100/1000	-4.3	1.3	-3.0	0	-.2	-.2
	8:20 a.m.	7.5	100/1000	2.1	-.5	1.6	-2.1	-.3	-2.4
	3:20 p.m.	7.0	100/1000	-1.3	-.3	-1.6	-1.3	-.5	-1.8
Jan. 17	1:35 a.m.	10.5	100/1000	5.7	-.4	5.3	0	-.4	-.4
	9:14 a.m.	7.5	100/1000	-3.3	-.1	-3.4	-2.1	.3	-1.8
	2:08 p.m.	5.0	100/1000	-3.8	-.6	-4.4	0	.6	.6
Jan. 21	5:05 a.m.	87.0	100/1000	.6	.2	.8	0	0	0
	11:12 a.m.	6.0	100/1000	1.1	-.3	.8	-2.3	-.1	-2.4
Jan. 22	8:40 p.m.	33.5	100/1000	4.0	-.8	3.2	0	2.0	2.0
Jan. 23	9:10 a.m.	12.5	100/1000	-1.1	.1	-1.0	-3.0	-.2	-3.2
Jan. 24	9:30 a.m.	24.5	100/1000	-1.6	-.6	-2.2	0	-.6	-.6
Jan. 27	6:30 p.m.	81.0	100/1000	(0)	(0)	(0)	0	1.6	1.6
Jan. 28	9:50 p.m.	27.5	100/1000	(0)	(0)	(0)	(0)	(0)	(0)

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(d) Continued

Date	Time, hr:min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale			Slope drift, percent at full scale		
				Analyzer (a)	Signal conditioning (a)	Total (a)	Analyzer (a)	Signal conditioning (a)	Total (a)
Jan. 29, 1975	6:45 p.m.	21.0	100/1000	3.6	--	--	-0.7	--	--
Jan. 30	11:30 a.m.	17.0	100/1000	21.6	-5.5	16.1	-7.4	1.5	-5.9
Jan. 31	2:00 p.m.	26.5	100/1000	19.0	(-.3)	(18.7)	-6.5	.9	(-5.6)
Feb. 3	4:00 p.m.	74.0	100/1000	.0	-1.8	-1.8	0	-.8	-.8
	9:00 p.m.	5.0	100/1000	-11.8	-.6	-12.4	.4	--	--
Feb. 4	3:00 a.m.	6.0	100/1000	-18.8	1.2	-17.6	0	--	--
	8:45 a.m.	6.0	100/1000	7.6	.6	8.2	-4.3	-.1	-4.4
	4:00 p.m.	7.5	100/1000	1.7	.9	2.6	-1.5	.1	-1.4
Feb. 5	3:00 a.m.	11.0	100/1000	1.5	-.1	1.4	-.2	-4.4	-4.6
	8:55 a.m.	6.0	100/1000	1.1	-1.9	-.8	-.4	-1.8	-2.2
	4:00 p.m.	7.0	100/1000	-2.8	14.5	11.7	0	1.2	1.2
	10:00 p.m.	6.0	100/1000	-11.5	3.5	-8.0	0	0.8	.8
Feb. 6	9:00 a.m.	11.0	100/1000	.4	2.0	2.4	(0)	(0)	(0)
	5:10 p.m.	8.0	100/1000	5.7	--	--	-6.0	--	--
Feb. 7	9:30 a.m.	16.5	100/1000	(0)	(0)	(0)	(0)	(0)	(0)
Feb. 10	6:10 p.m.	80.5	100/1000	-3.8	.2	-3.6	0	0	0
Feb. 12	10:30 a.m.	40.5	100/1000	-5.1	.1	-5.0	0	0	0
	6:00 p.m.	7.5	100/1000	0	0	0	--	--	--

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(d) Concluded

Date	Time, hr:min	Calibration interval, hr	Standard, mg/liter	Bias drift, percent full scale			Slope drift, percent at full scale		
				Analyzer (a)	Signal conditioning (a)	Total (a)	Analyzer (a)	Signal conditioning (a)	Total (a)
Feb. 13, 1975	5:00 a.m.	11.0	100/1000	4.0	(-0.2)	(3.8)	--	--	--
Feb. 14	8:20 a.m.	27.5	100/1000	.2	(.4)	(.6)	0	(0.2)	(0.2)
Feb. 18	2:00 p.m.	101.5	100/250	-7.1	.7	-6.4	-2.3	-.5	-2.8
Feb. 19	12:20 p.m.	22.5	100/250	.4	0	.4	2.3	-.3	2.0
Feb. 20	5:17 p.m.	29.0	100/250	8.8	-.2	8.6	-4.0	-1.0	-5.0
	7:00 p.m.	1.5	100/50	3.8	-.6	3.2	5.6	-.3	5.3
Feb. 21	10:00 a.m.	15.0	100/50	-8.4	1.6	-6.8	4.3	36.9	41.2
Feb. 24	10:00 a.m.	72.0	100/50	.6	(.2)	(.8)	-16.2	.3	-15.9
	5:00 p.m.	7.0	100/50	-5.4	(0)	(-5.4)	-9.7	--	--
Feb. 25	11:30 a.m.	18.5	100/50	0	0	0	-25.9	7.0	-18.9
	2:00 p.m.	2.5	100/50	-8.4	--	--	--	--	--
Feb. 27	10:30 a.m.	44.5	100/50	2.5	--	--	-2.8	--	--
Feb. 28	2:50 p.m.	28.5	100/50	3.4	-.4	3.0	--	--	--

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(e) pH sensor

Date	Time, hr:min	Calibration interval, hr	Standard, pH units	Bias drift, percent full scale			Slope drift, percent at full scale		
				Analyzer (a)	Signal conditioning (a)	Total (a)	Analyzer (a)	Signal conditioning (a)	Total (a)
Jan. 14, 1975	5:25 p.m.	3.5	6.50	0.7	(-0.3)	(0.4)	--	--	--
Jan. 15	1:30 a.m.	8.0	6.50	.7	(.5)	(1.2)	--	--	--
	8:10 a.m.	6.5	6.50	2.9	(-3.4)	(-.5)	--	--	--
	2:00 p.m.	6.0	6.50	2.5	2.9	5.4	--	--	--
	5:05 p.m.	3.0	7.00/10.00	-2.1	(-2.6)	(-4.7)	0	(-14.7)	(-14.7)
	7:00 p.m.	2.0	6.90	0	-1.4	-1.4	--	--	--
Jan. 16	1:00 a.m.	6.0	6.90	-2.5	(.7)	(-1.8)	--	--	--
	8:20 a.m.	7.5	6.90	0	(-1.0)	(-1.0)	--	--	--
	3:20 p.m.	7.0	6.90	-.4	(-.6)	(-1.0)	--	--	--
Jan. 17	1:35 a.m.	10.5	6.90	0	(.6)	(.6)	--	--	--
	9:14 a.m.	7.5	6.90	-1.8	(-.2)	(-2.0)	--	--	--
	2:08 p.m.	5.0	6.90	-.7	(.1)	(-.6)	--	--	--
Jan. 21	5:05 a.m.	87.0	6.90	3.6	(1.0)	(4.6)	--	--	--
	11:12 a.m.	6.0	7.00/4.00	1.1	(-1.0)	(.1)	2.1	(-.7)	(1.4)
Jan. 22	8:40 p.m.	33.5	6.90	2.1	22.1	24.2	--	--	--
Jan. 23	9:10 a.m.	12.5	7.00/4.00	-2.1	(0)	(-2.1)	0	(-.5)	(-.5)
Jan. 24	9:30 a.m.	24.5	7.00	0	21.4	21.4	--	--	--
Jan. 27	6:30 p.m.	81.0	7.00/4.00	0	(0)	(0)	0	(0)	(0)
Jan. 28	9:50 p.m.	27.5	7.00/4.00	3.6	-3.6	(0)	0	(0)	(0)

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(e) Continued

Date	Time, hr:min	Calibration interval, hr	Standard, pH units	Bias drift, percent full scale			Slope drift, percent at full scale		
				Analyzer (a)	Signal conditioning (a)	Total (a)	Analyzer (a)	Signal conditioning (a)	Total (a)
Jan. 29, 1975	6:45 p.m.	21.0	7.00/4.00	0	--	--	0	0	0
Jan. 31	2:00 p.m.	43.5	7.00/4.00	.7	3.9	4.6	0	0	0
Feb. 3	4:00 p.m.	74.0	7.00/4.00	0	2.0	2.0	0	0	0
Feb. 4	8:45 a.m. 4:00 p.m.	17.0 7.5	7.00/4.00 7.00/4.00	0 .7	-1.4 -2.7	-1.4 -2.0	0 1.6	2.8 1.2	2.8 2.8
Feb. 5	4:00 p.m.	24.0	7.00/4.00	-.7	-0.7	-1.4	1.0	3.7	4.7
Feb. 6	5:10 p.m.	25.0	7.00/4.00	(0)	(0)	(0)	(0)	(0)	(0)
Feb. 7	9:30 a.m.	16.5	7.00/4.00	(0)	(-.1)	(-.1)	0	.5	.5
Feb. 10	6:10 p.m.	80.5	7.00/4.00	-.2	0	-.2	0	.5	.5
Feb. 12	10:30 a.m. 6:00 p.m.	40.5 7.5	7.00/4.00 7.00/10.00	.7 0	-1.5 0	-.8 0	0 --	(0) --	(0) --
Feb. 13	8:15 a.m.	14.5	7.00/10.00	-.7	(-.1)	(-.8)	3.3	(-1.9)	(1.4)
Feb. 14	8:20 a.m.	24.0	7.00/10.00	-.3	.1	-.2	0	.5	.5
Feb. 18	2:00 p.m.	101.5	7.00/4.00	.6	-.2	.4	-.3	1.2	.9
Feb. 19	12:20 p.m.	22.5	7.00/4.00	.6	-1.6	-1.0	0	3.3	3.3
Feb. 20	5:17 p.m.	29.5	7.00/4.00	0	-2.0	-2.0	0	5.1	5.1
Feb. 21	10:00 a.m.	16.5	7.00/4.00	-.6	-3.8	-4.4	1.4	4.2	5.6

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(e) Concluded

Date	Time, hr: min	Calibration interval, hr	Standard, pH units	Bias drift, percent full scale			Slope drift, percent at full scale		
				Analyzer (a)	Signal conditioning (a)	Total (a)	Analyzer (a)	Signal conditioning (a)	Total (a)
Feb. 24, 1975	10: 00 a.m.	72.0	7.00/4.00	0.7	0.9	1.6	0	0	0
	5: 00 p.m.	7.0	7.00/10.00	-.6	-.8	-1.4	2.1	.2	2.3
Feb. 25	11: 30 a.m.	18.5	7.00/10.00	0	0	0	0	0	0
Feb. 27	10: 30 a.m.	47.0	7.00/10.00	0	0	0	-.9	.9	0
Feb. 28	2: 50 p.m.	28.5	7.00/10.00	.1	.1	.2	0	3.5	3.5

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(f) Dissolved oxygen signal conditioner

Date	Time, hr: min	Calibration interval, hr	Drift, percent full scale	
			10-percent standard (a)	90-percent standard
Jan. 14, 1975	5: 25 p.m.	3.5	0	0
Jan. 15	1: 30 a.m.	8.0	-.2	-1.2
	8: 10 a.m.	6.5	(0)	1.8
	2: 00 p.m.	6.0	.2	-1.4
	5: 10 p.m.	3.0	-.2	-.4
Jan. 16	1: 00 a.m.	8.0	1.6	1.6
	8: 20 a.m.	7.5	-1.6	-.6
	3: 20 p.m.	7.0	0	.4
Jan. 17	1: 35 a.m.	10.5	0	0
	9: 14 a.m.	7.5	0	-.6
	2: 08 p.m.	5.0	0	.6
Jan 21	5: 05 a.m.	87.0	0	.4
	11: 12 a.m.	6.0	0	.6
Jan. 23	9: 10 a.m.	46.0	0	-1.2
Jan. 24	9: 30 a.m.	24.5	0	0
Jan. 27	6: 30 p.m.	81.0	0	0
Jan. 28	9: 50 p.m.	27.5	3.4	2.8
Jan. 29	6: 45 p.m.	21.0	(1.8)	.6
Jan. 30	11: 30 a.m.	17.0	-4.0	-1.8
Jan. 31	2: 00 p.m.	26.5	0	0
Feb. 3	4: 00 p.m.	74.0	0	0
Feb. 4	8: 45 a.m.	17.0	0	.2
	4: 00 p.m.	7.5	0	.8
Feb. 5	8: 55 a.m.	17.0	0	-.6
	4: 00 p.m.	7.0	0	1.6
Feb. 6	9: 00 a.m.	17.0	3.2	--
	5: 10 p.m.	8.0	(0)	(-1.4)

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(f) Concluded

Date	Time, hr: min	Calibration interval, hr	Drift, percent full scale	
			10-percent standard (a)	90-percent standard
Feb. 7, 1975	9: 30 a.m.	16.5	0	0.8
Feb. 10	6: 10 p.m.	80.5	0	0
Feb. 12	10: 30 a.m.	40.5	0	-1.2
Feb. 13	8: 15 a.m.	22.0	0	-.4
Feb. 14	8: 20 a.m.	24.0	0	.2
Feb. 18	2: 00 p.m.	101.5	0	-.2
Feb. 19	12: 20 p.m.	22.5	-.2	-1.0
Feb. 20	5: 17 p.m.	29.0	0	-.2
Feb. 21	10: 00 a.m.	16.5	0	.8
Feb. 24	10: 00 a.m.	72.0	0	-1.2
Feb. 25	11: 30 a.m.	25.5	0	0
Feb. 27	10: 30 a.m.	47.0	0	-.2
Feb. 28	2: 50 p.m.	28.5	0	0

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(g) Turbidity signal conditioner

Date	Time, hr:min	Calibration interval, hr	Drift, percent full scale	
			10-percent standard (a)	90-percent standard
Jan. 14, 1975	5:25 p.m.	3.5	0	0
Jan. 15	1:30 a.m.	8.0	0	0
	8:10 a.m.	6.5	0	0
	2:00 p.m.	6.0	1.6	.8
	5:10 p.m.	3.0	-3.4	-1.0
	10:09 p.m.	5.0	2.2	.8
Jan. 16	1:00 a.m.	3.0	.4	.4
	8:20 a.m.	7.5	-2.0	.8
	3:20 p.m.	7.0	0	0
Jan. 17	1:35 a.m.	10.5	0	0
	9:14 a.m.	7.5	-.2	-.2
	2:08 p.m.	5.0	0	.2
Jan. 21	5:05 a.m.	87.0	.2	0
	11:12 a.m.	6.0	0	.4
Jan. 23	9:10 a.m.	46.0	0	-.2
Jan. 24	9:30 a.m.	24.5	0	.2
Jan. 27	6:30 p.m.	81.0	0	0
Jan. 28	9:50 p.m.	27.5	4.0	3.4
Jan. 29	6:45 p.m.	21.0	0	1.0
Jan. 30	11:30 a.m.	17.0	-4.0	-2.4

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VI.- Continued

(g) Concluded

Date	Time, hr:min	Calibration interval, hr	Drift, percent full scale	
			10-percent standard (a)	90-percent standard
Jan. 31, 1975	2:00 p.m.	26.5	0	0
Feb. 3	4:00 p.m.	74.0	0	-.4
Feb. 4	8:45 a.m.	17.0	0	.2
	4:00 p.m.	7.5	2.8	0
Feb. 5	8:55 a.m.	17.0	.2	0
	4:00 p.m.	7.0	(-.2)	(0)
Feb. 6	5:10 p.m.	25.0	0	.6
Feb. 7	9:30 a.m.	16.5	0	0
Feb. 10	6:10 p.m.	80.5	-1.4	-1.0
Feb. 12	10:30 a.m.	40.5	0	0
Feb. 13	8:15 a.m.	22.0	0	0
Feb. 14	6:00 a.m.	22.0	.2	0
Feb. 18	2:00 p.m.	104.0	.2	0
Feb. 19	12:20 p.m.	22.5	0	.2
Feb. 20	5:17 p.m.	29.0	0	-.2
Feb. 21	10:00 a.m.	16.5	0	0
Feb. 24	10:00 a.m.	72.0	0	0
	5:00 p.m.	7.0	0	0
Feb. 25	11:30 a.m.	18.5	0	0
Feb. 27	10:30 a.m.	47.0	0	0
Feb. 28	2:50 p.m.	28.5	0	0

[a] Numbers in parentheses indicate data log incomplete; assumes operator followed standard procedure.

TABLE VII.- DATA ACQUISITION SYSTEM FAILURE SUMMARY

Failure	Date	Part	Symptom	Corrective action
1	Nov. 1974	Clock oscillator of the temperature-compensated crystal oscillator	No time or measurement update	Fabricate and install transistor-transistor logic oscillator
2	Nov. 1974	74154	LED 14 dim	Remove and replace
3	Dec. 1974	741 A/D buffer amplifier	-0.22-volt bias on digitized data	Remove and replace
4	Jan. 1975	2527 shift register	Data not shifting through registers	Remove and replace
5	Feb. 1975	741 A/D buffer amplifier	0.13-volt bias on digitized data	Remove and replace
6	Unknown	7400 logic gate and/or wire short	Two tracks of clock on tape instead of data and clock	Remove and replace

TABLE VIII.- WMS MEASUREMENT REPORT

DAY OF YEAR 014 DATE 14 JAN 75 SPEED FAST MODE NORM

TIME	TIME SLOT	MEAS NO	MEAS NAME	VOLTS	VALUE	UNITS	ALARM
15.15.10	53	7	NA+	3.13	179	MG/L	
15.15.11	54	2	HARD	3.25	39.8	MG/L	
15.15.12	55	4	BLANK	0.10	*		
15.15.13	56	16	TURB	0.20	9.48	JTU	
15.15.14	57	21	DO	4.80	11.5	MG/L	
15.15.15	58	22	CL-	2.92	147	MG/L	
15.15.16	59	8	BLANK	0.04	*		
15.15.17	60	11	CL2	2.93	*		
15.15.18	61	16	TURB	0.19	9.00	JTU	
15.15.19	62	1	PH	2.14	5.99	PH	
15.15.20	63	17	COND	5.04	1.00	µMHOS/CM	
15.15.21	64	12	TOC	0.59	11.8	MG/L	
15.15.22	65	14	BLANK	0.16	*		
15.15.23	66	16	TURB	0.20	9.48	JTU	
15.15.24	67	6	NH4+	2.09	*		
15.15.25	68	7	NA+	3.13	179	MG/L	
15.15.26	69	20	BLANK	0.17	*		
15.15.27	70	23	BLANK	0.23	*		
15.15.28	71	16	TURB	0.21	9.95	JTU	
15.15.29	72	21	DO	4.61	11.1	MG/L	
15.15.30	73	22	CL-	2.90	145	MG/L	
15.15.31	74	24	BLANK	0.19	*		
15.15.32	75	25	BLANK	1.91	*		

*INDICATES MEASUREMENT INOPERATIVE

TABLE VIII.- Continued

DAY OF YEAR 014 DATE 14 JAN 75 SPEED FAST MODE NORM

TIME	TIME SLOT	MEAS NO	MEAS NAME	VOLTS	VALUE	UNITS	ALARM
15.14.44	27	21	DO	4.64	11.1	MG/L	
15.14.45	28	22	CL-	2.92	147	MG/L	
15.14.46	29	2	HARD	3.25	39.8	MG/L	
15.14.47	30	4	BLANK	0.20	*		
15.14.48	31	16	TURB	0.21	9.95	JTU	
15.14.49	32	1	PH	2.14	5.99	PH	
15.14.50	33	17	COND	5.01	1.00	μMHOS/CM	
15.14.51	34	8	BLANK	0.04	*		
15.14.52	35	11	CL2	2.98	*		
15.14.53	36	16	TURB	0.23	10.9	JTU	
15.14.54	37	6	NH4+	2.09	*		
15.14.55	38	7	NA+	3.12	177	MG/L	
15.14.56	39	12	TOC	0.59	11.8	MG/L	
15.14.57	40	14	BLANK	0.16	*		
15.14.58	41	16	TURB	0.22	10.4	JTU	
15.14.59	42	21	DO	4.64	11.1	MG/L	
15.15.00	43	22	CL-	2.91	146	MG/L	
15.15.01	44	13	BLANK	0.16	*		
15.15.02	45	15	BLANK	0.22	*		
15.15.03	46	16	TURB	0.21	9.95	JTU	
15.15.04	47	1	PH	2.13	5.96	PH	
15.15.05	48	17	COND	5.01	1.00	μMHOS/CM	
15.15.06	49	18	BLANK	0.15	*		
15.15.07	50	19	BLANK	0.21	*		
15.15.08	51	16	TURB	0.21	9.95	JTU	
15.15.09	52	6	NH4+	2.09	*		

TABLE VIII.- Concluded

DAY OF YEAR 014 DATE 14 JAN 75 SPEED FAST MODE NORM

TIME	TIME SLOT	MEAS NO	MEAS NAME	VOLTS	VALUE	UNITS	ALARM
15.14.18	1	16	TURB	0.25	11.9	JTU	
15.14.19	2	1	PH	3.11	8.70	PH	
15.14.20	3	17	COND	5.04	1.00	µMHOS/CM	
15.14.21	4	2	HARD	3.26	40.5	MG/L	
15.14.22	5	4	BLANK	0.04	*		
15.14.23	6	16	TURB	0.24	11.4	JTU	
15.14.24	7	6	NH4+	2.10	*	MG/L	
15.14.25	8	7	NA+	3.12	177	MG/L	
15.14.26	9	8	BLANK	0.04	*		
15.14.27	10	11	CL2	2.77	*		
15.14.28	11	16	TURB	0.24	11.4	JTU	
15.14.29	12	21	DO	4.63	11.1	MG/L	
15.14.30	13	22	CL-	2.92	147	MG/L	
15.14.31	14	12	TOC	0.71	14.2	MG/L	
15.14.32	15	14	BLANK	0.15	*		
15.14.33	16	16	TURB	0.23	10.9	JTU	
15.14.34	17	1	PH	2.12	5.94	PH	
15.14.35	18	17	COND	5.04	1.00	µMHOS/CM	
15.14.36	19	3	CHEMLUM	0.21	*		
15.14.37	20	5	BLANK	0.23	*		
15.14.38	21	16	TURB	0.22	10.4	JTU	
15.14.39	22	6	NH4+	2.08	*		
15.14.40	23	7	NA+	3.11	175	MG/L	
15.14.41	24	9	BLANK	0.19	*		
15.14.42	25	10	BLANK	0.22	*		
15.14.43	26	16	TURB	0.21	9.95	JTU	

TABLE IX.- TYPICAL PROCESSED DATA

Time slot	Measurement number	Tape value, V	Input value, V
1	16	4.60	4.51
2	1	2.30	2.25
3	17	.21	.24
4	2	1.30	1.16
5	4	1.27	1.13
6	16	4.54	4.51
7	6	3.02	2.97
8	7	.60	.52
9	8	1.30	1.18
10	19	1.32	1.20
11	16	4.60	4.51
12	21	4.66	4.52
13	22	(a)	2.51
14	12	1.14	1.10
15	14	1.30	1.17
16	16	4.57	4.51
17	1	2.29	2.25
18	17	(a)	.24
19	3	(a)	.99
20	5	1.32	1.27
21	16	4.60	4.51
22	6	3.04	2.97
23	7	.60	.52
24	9	1.32	1.17
25	10	1.31	1.28
26	16	4.59	4.51
27	21	4.66	4.52
28	22	2.64	2.51
29	2	1.30	1.16
30	4	1.29	1.13
31	16	4.59	4.51
32	1	2.29	2.25
33	17	.19	.24
34	8	(a)	1.18
35	11	(a)	1.17
36	16	4.60	4.51
37	6	(a)	2.97
38	7	(a)	.52
39	12	1.12	1.10
40	14	1.31	1.17
41	16	4.55	4.51
42	21	4.66	4.52
43	22	2.60	2.51
44	13	1.30	1.17
45	15	1.28	1.17
46	16	4.59	4.51
47	1	2.30	2.25
48	17	.21	.24
49	18	1.34	1.19
50	19	1.34	1.20
51	16	4.59	4.51
52	6	3.05	2.97
53	7	.59	.52
54	2	1.30	1.16
55	4	1.30	1.13
56	16	4.60	4.51
57	21	4.66	4.52
58	22	2.63	2.51
59	8	1.32	1.18
60	11	1.31	1.18
61	16	(a)	4.51
62	1	(a)	2.25
63	17	.21	.24
64	12	1.14	1.17
65	14	1.30	1.17
66	16	4.60	4.51
67	6	3.05	2.92
68	7	.60	.52
69	20	.06	.09
70	23	.04	.08
71	16	4.60	4.51
72	21	4.66	4.52
73	22	(a)	2.51
74	24	(a)	.06
75	25	(a)	.14

[a] Erroneous data.

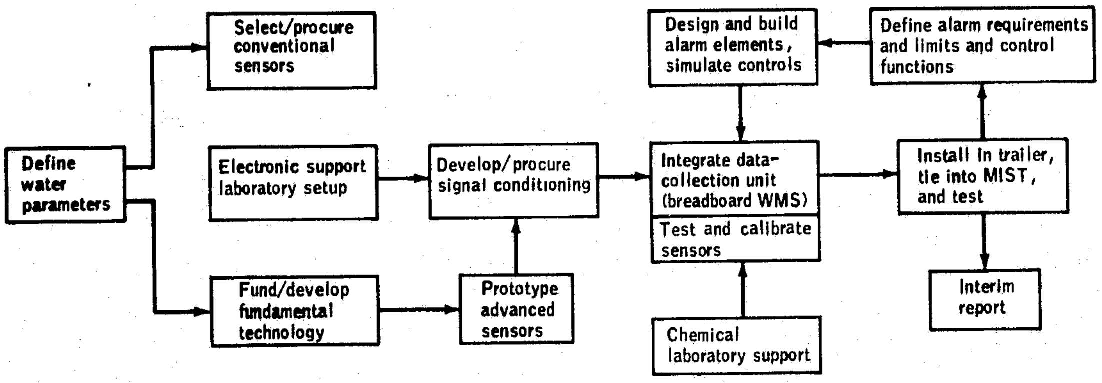


Figure 1.- Block diagram of the WMS Phase I.

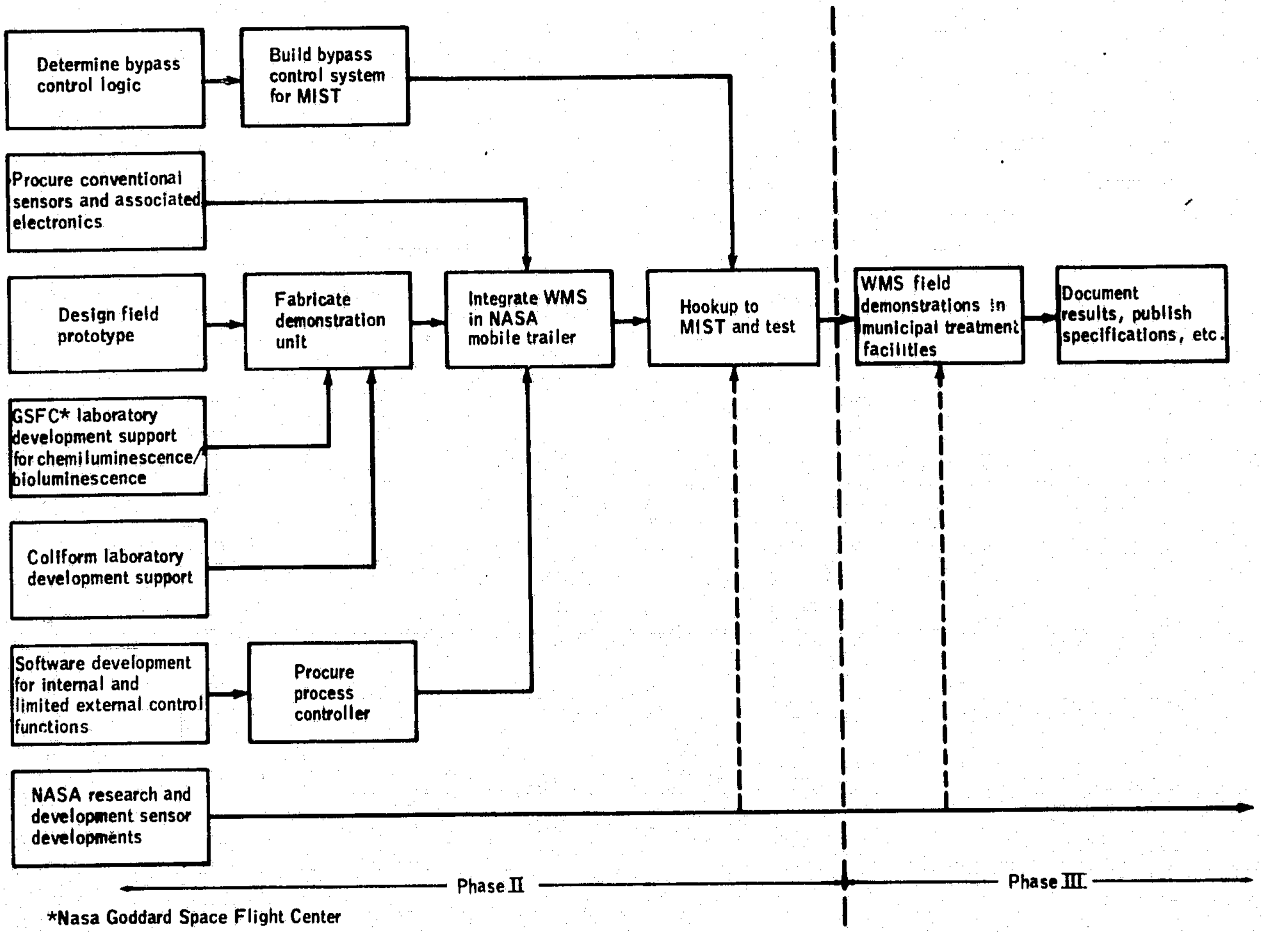


Figure 2.- Block diagram of the WMS Phase II and Phase III.

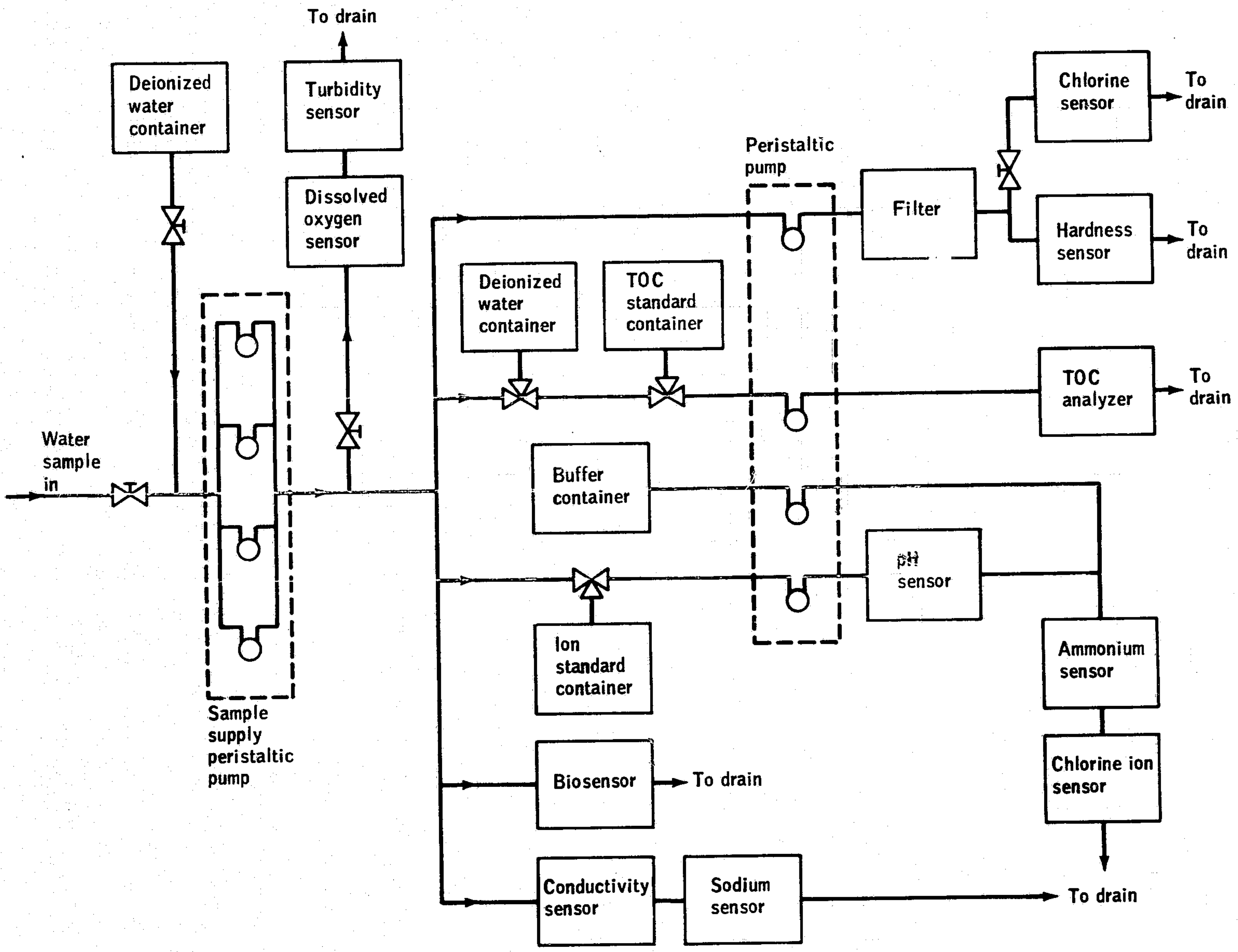


Figure 3.- Flow diagram of the WMS sample distribution.

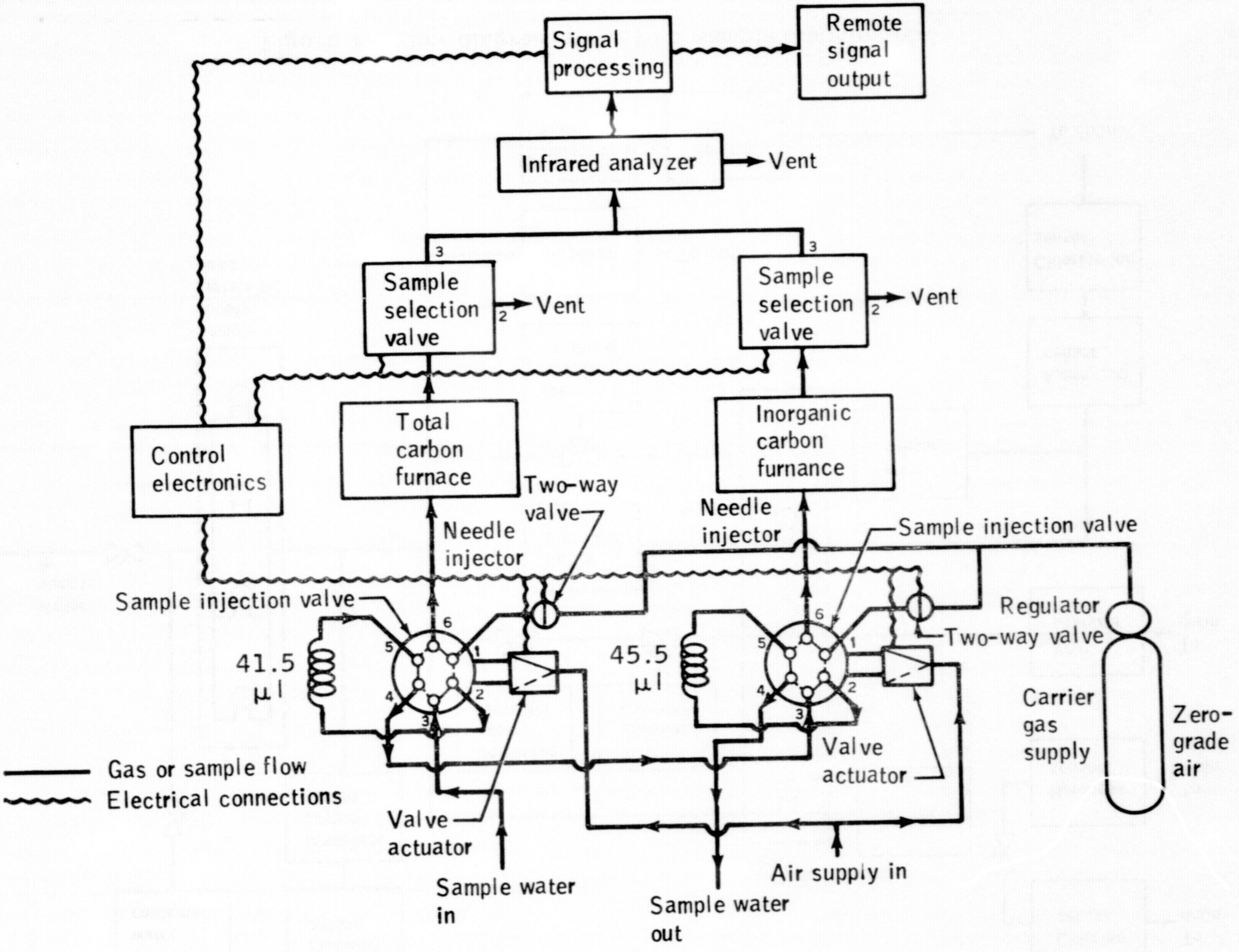


Figure 4.- Flow diagram of the modified TOC analyzer.

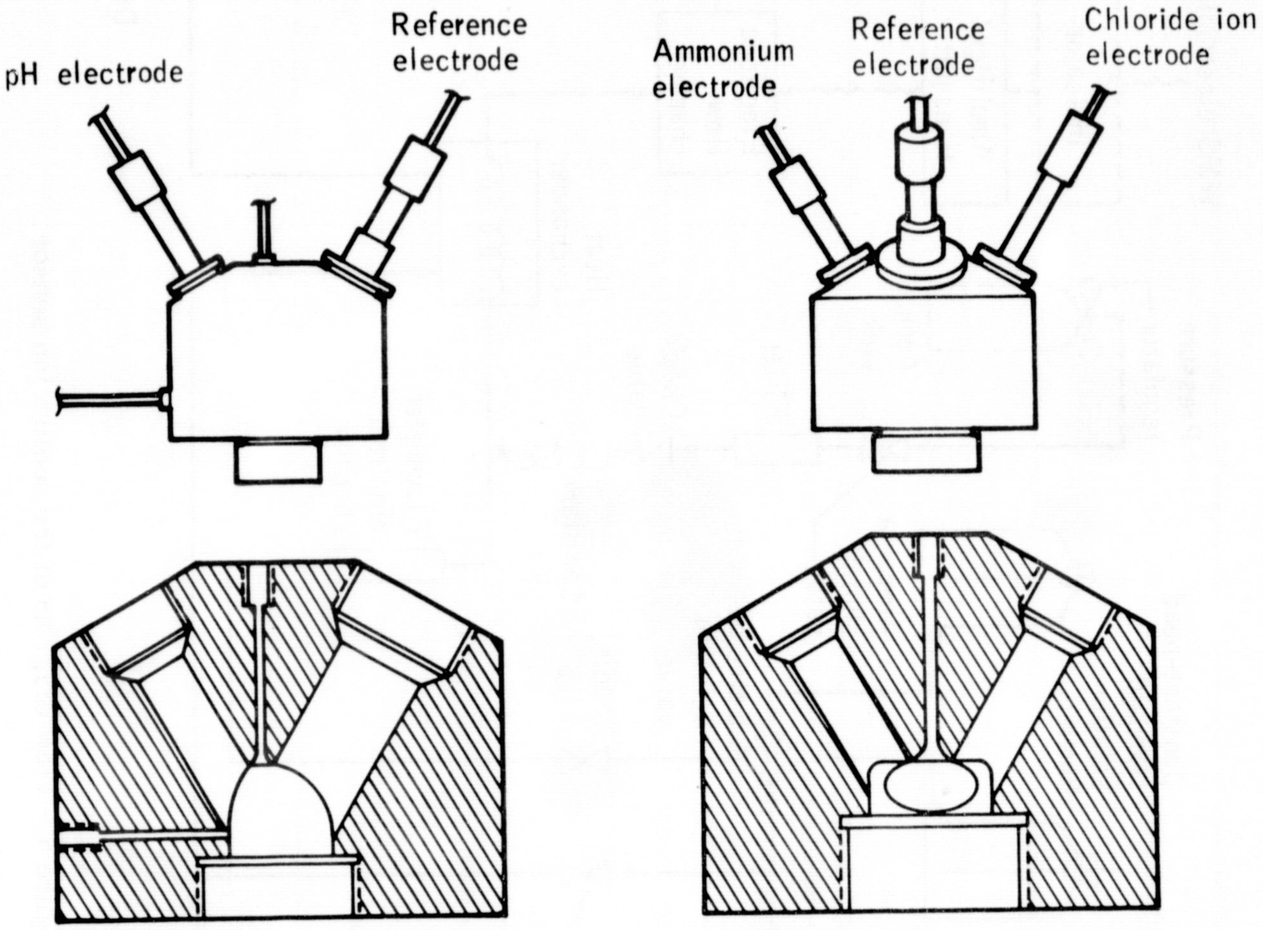


Figure 5.- Polypropylene electrode wells.

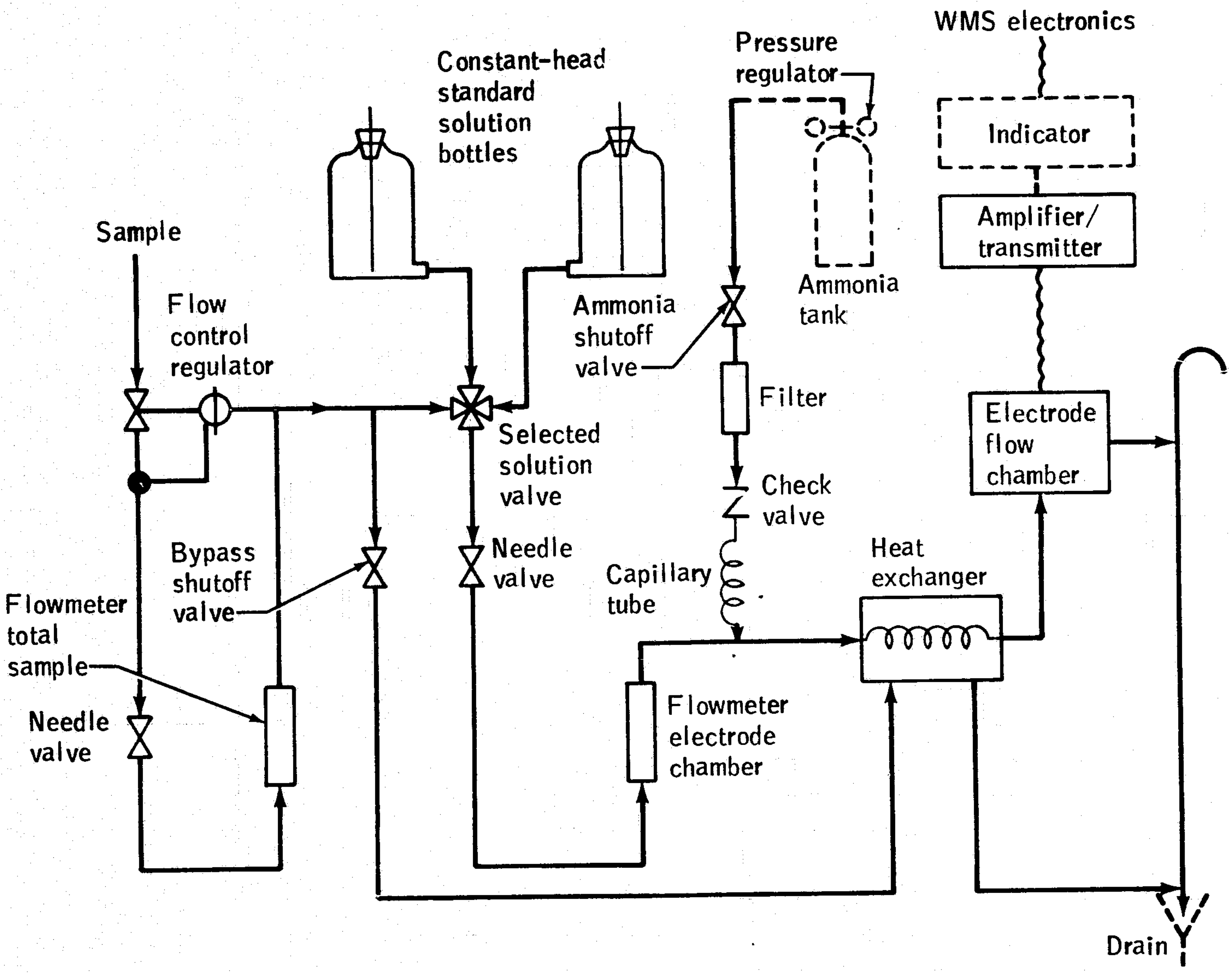


Figure 6.- Flow diagram of the sodium ion sensor.

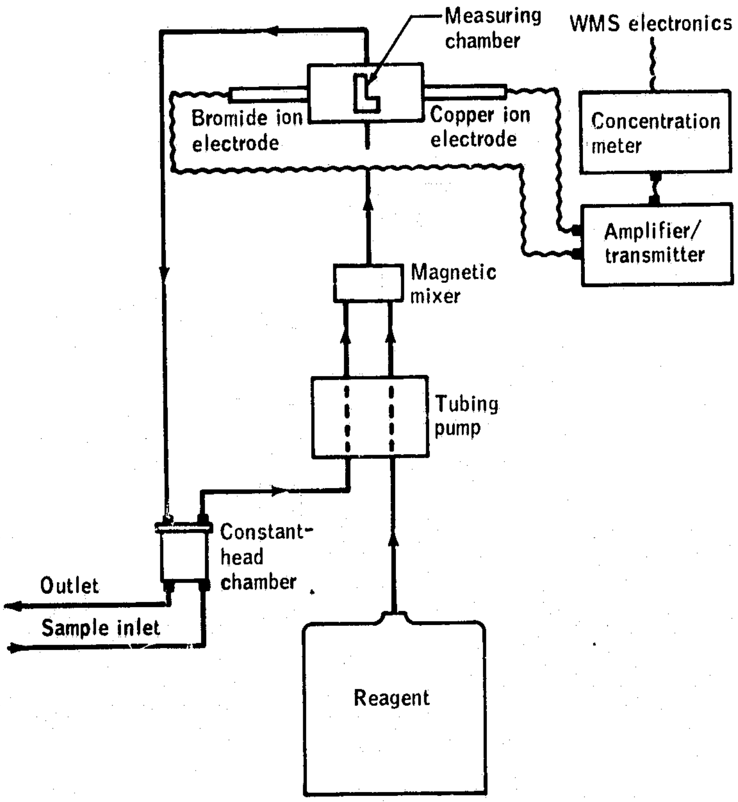


Figure 7.- Flow diagram of the hardness sensor.

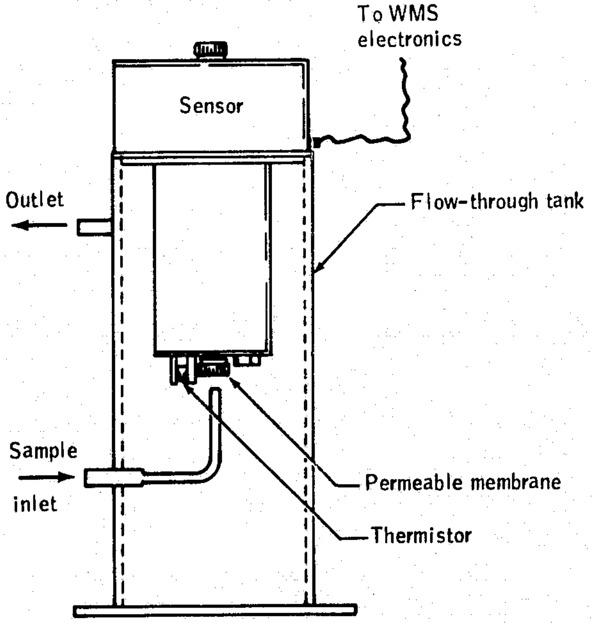


Figure 8.- Flow diagram of the dissolved oxygen sensor.

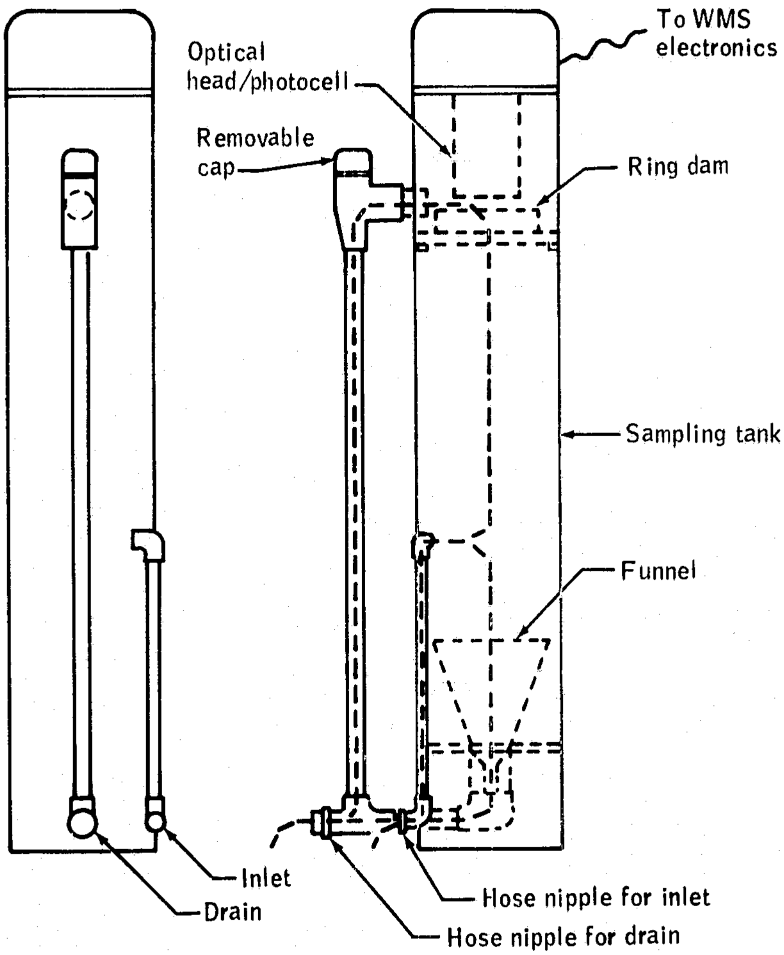


Figure 9.- Flow diagram of the turbidity sensor.

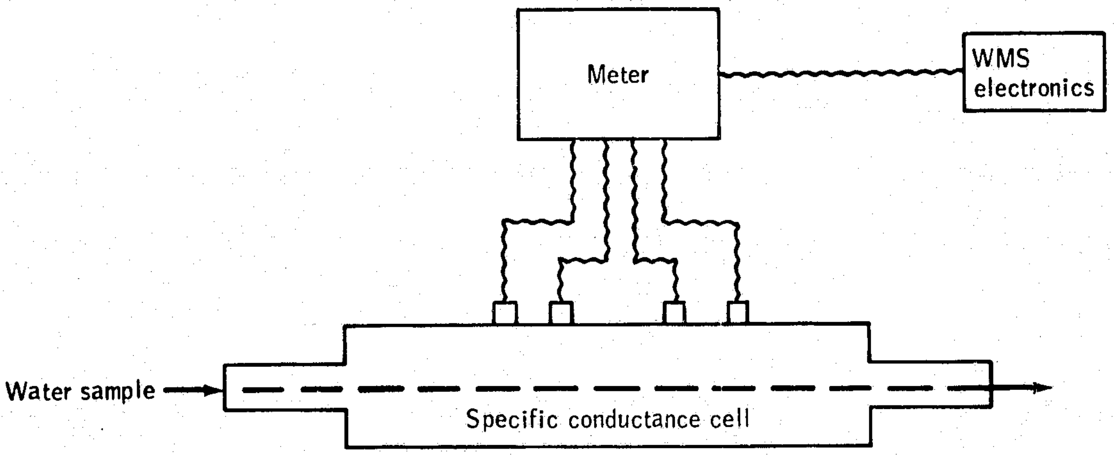


Figure 10.- Diagram of the specific conductance analyzer.

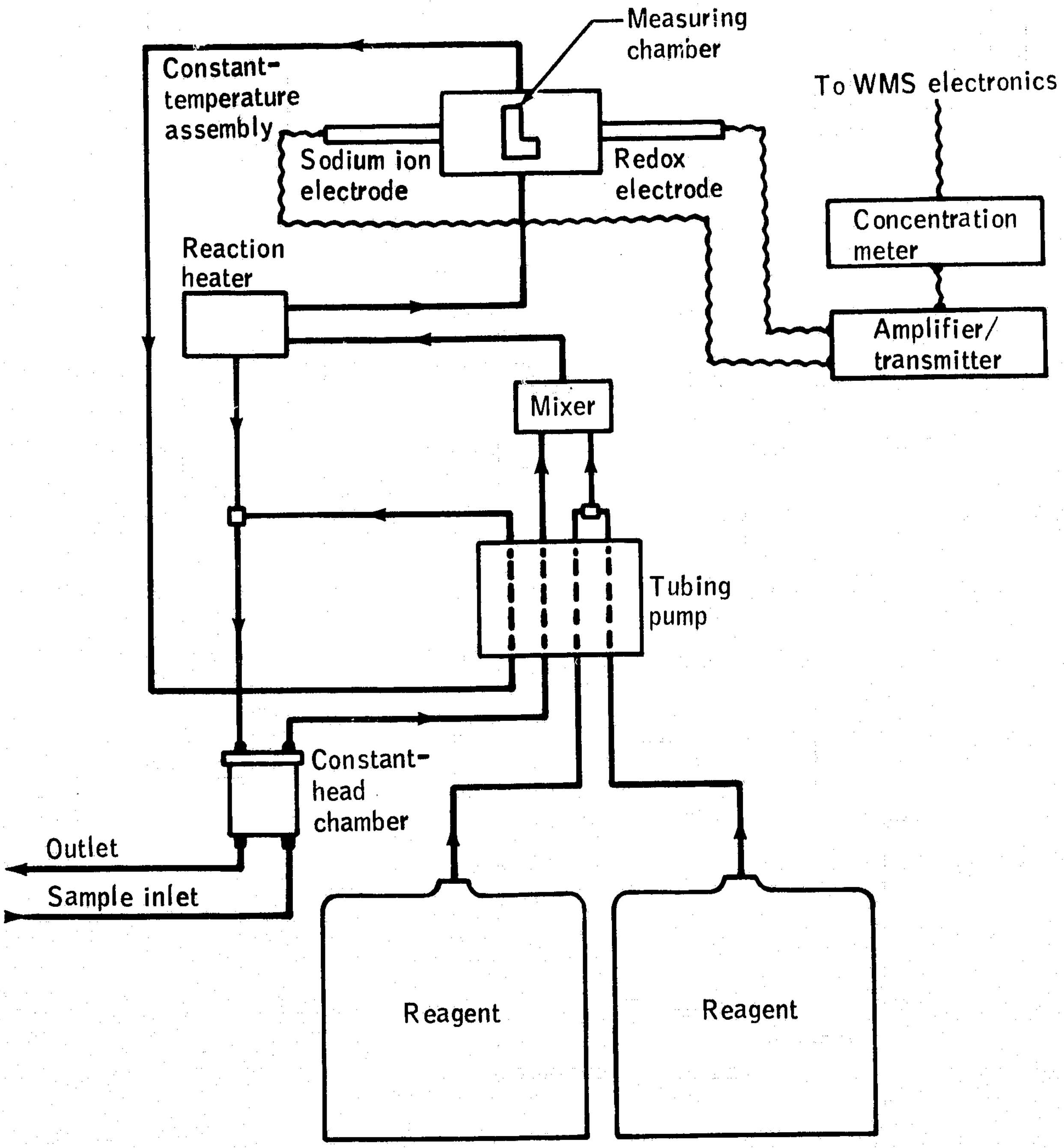
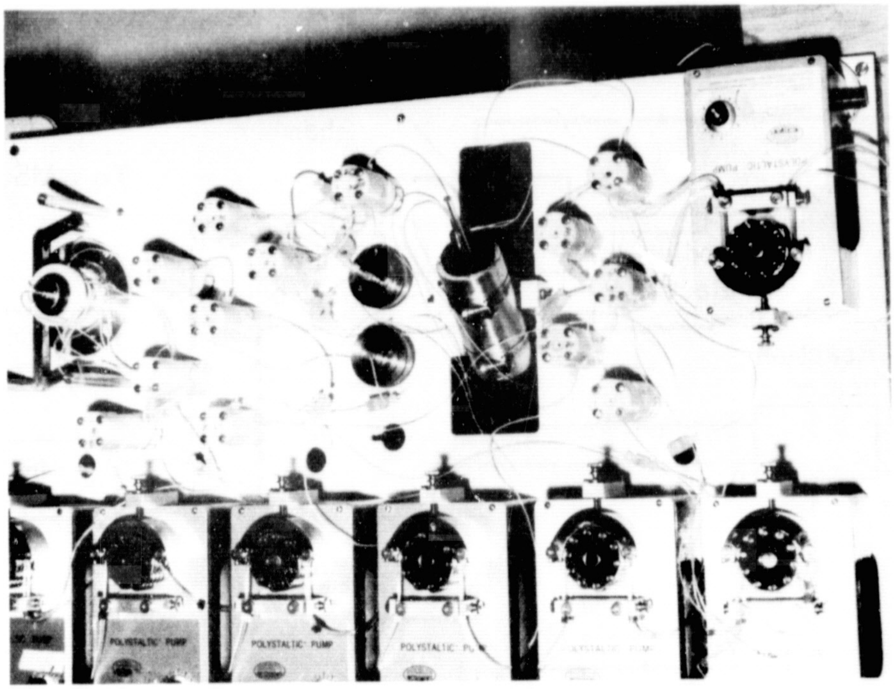
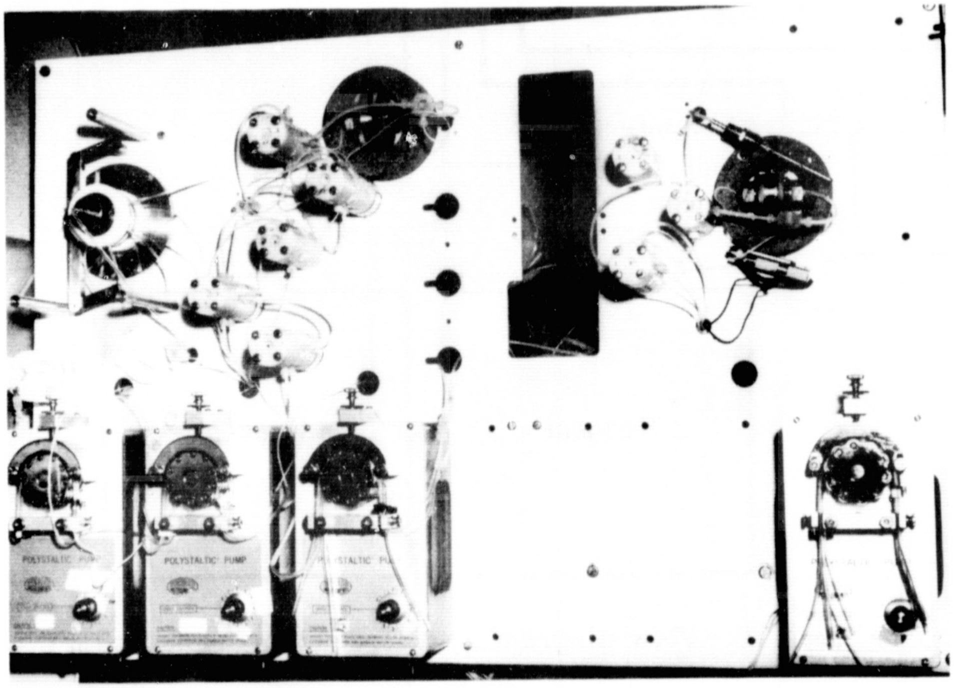


Figure 11.- Flow diagram of the free chlorine sensor.



(a) Before modification.



(b) After modification.

Figure 12.- Biosensor.

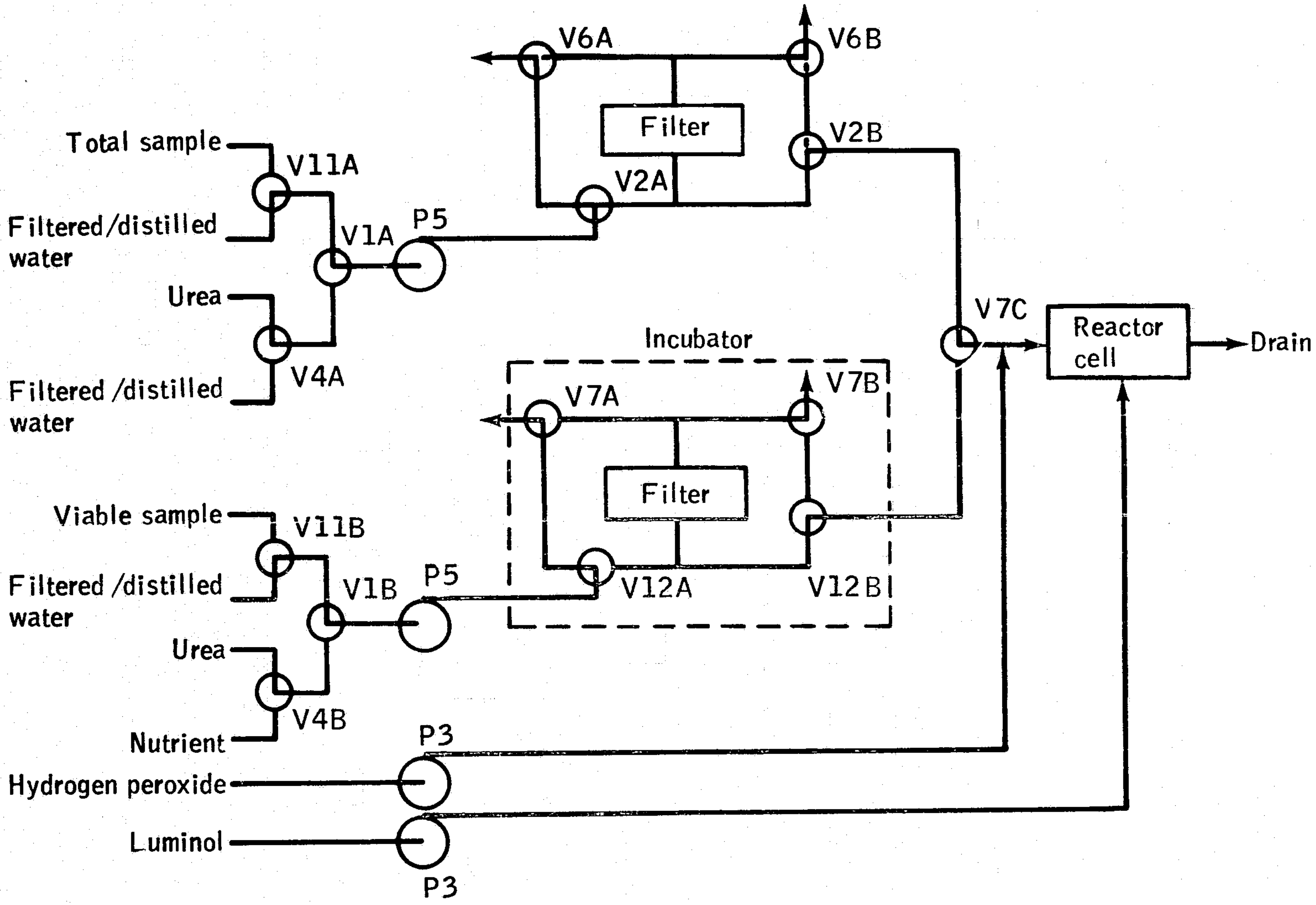
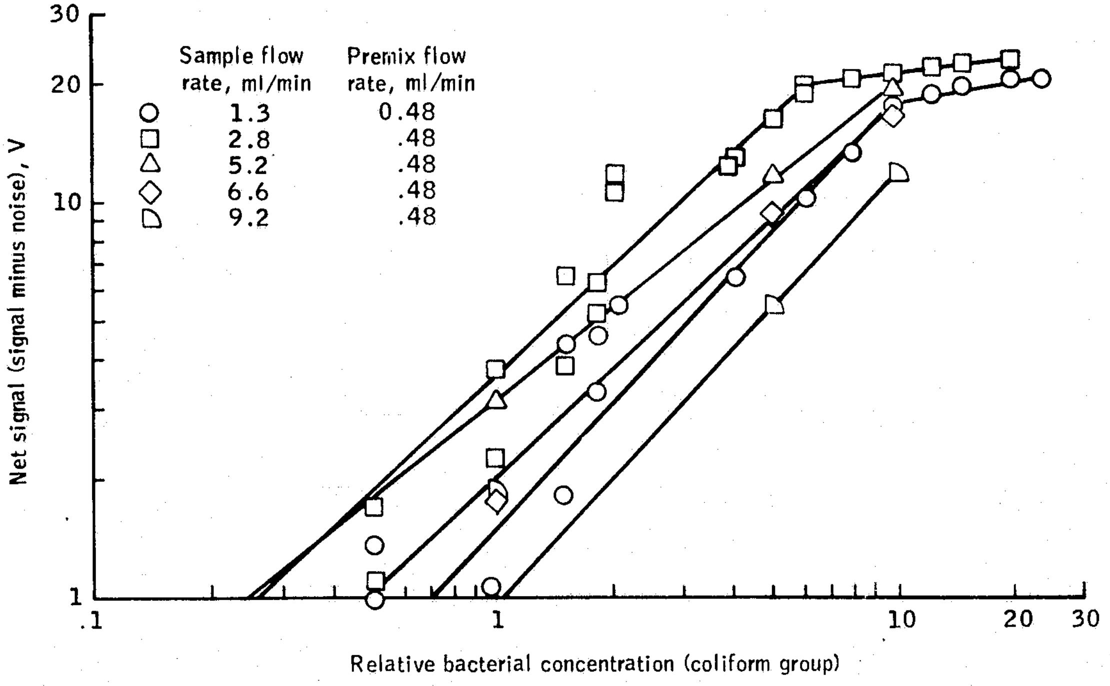
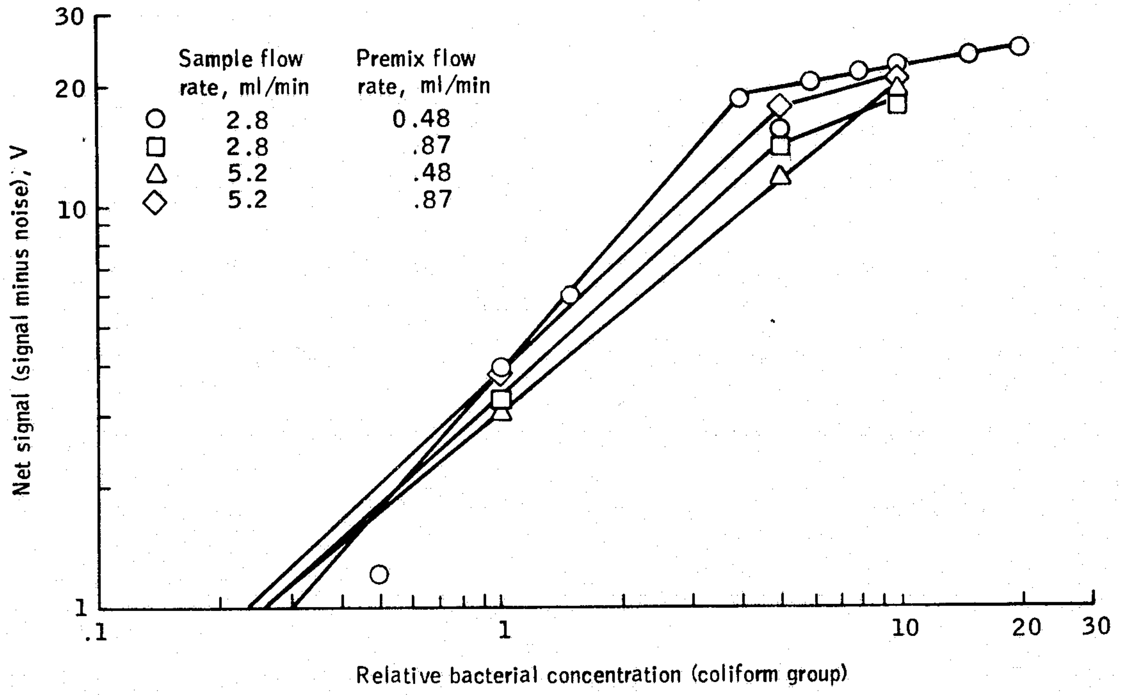


Figure 13.- Flow diagram of the biosensor/chemiluminescence. All valves are shown in the off position.

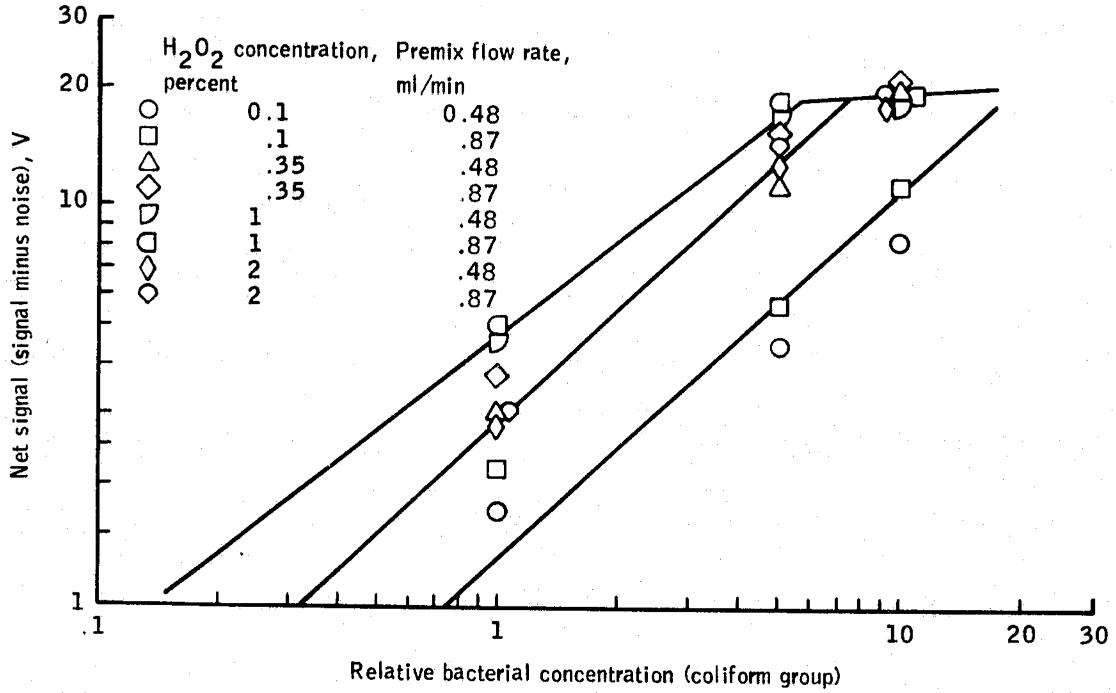


(a) Effect of sample flow rate with 0.35 percent hydrogen peroxide (H_2O_2).

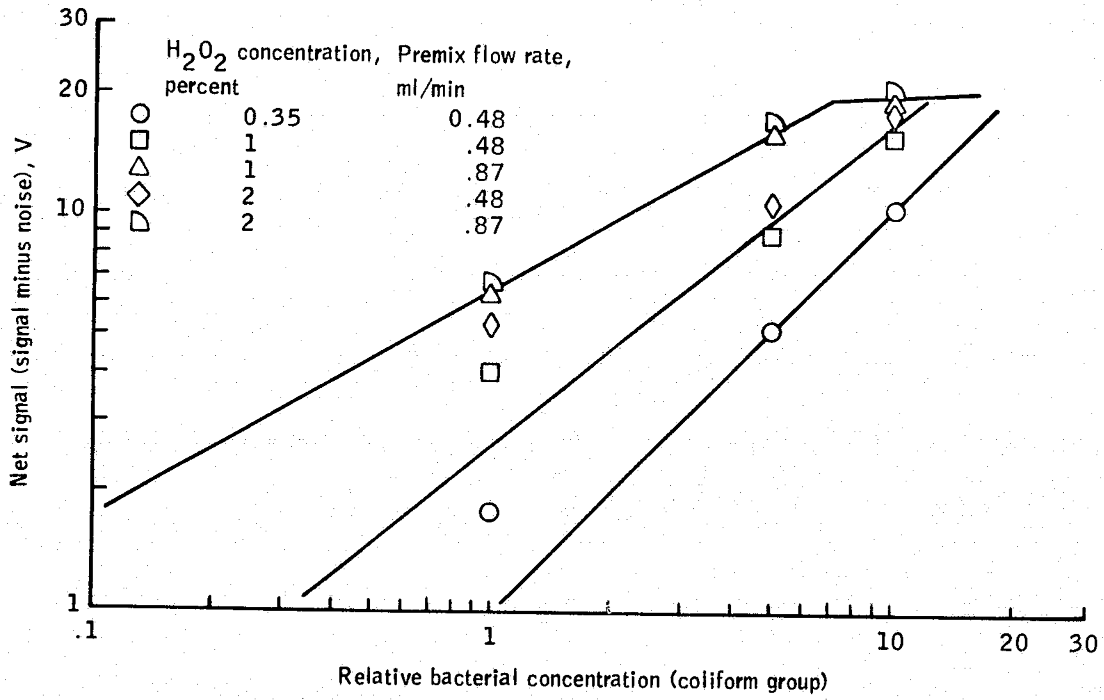


(b) Effect of PREMIX flow rate with 0.35 percent hydrogen peroxide.

Figure 14.- Biosensor test data.

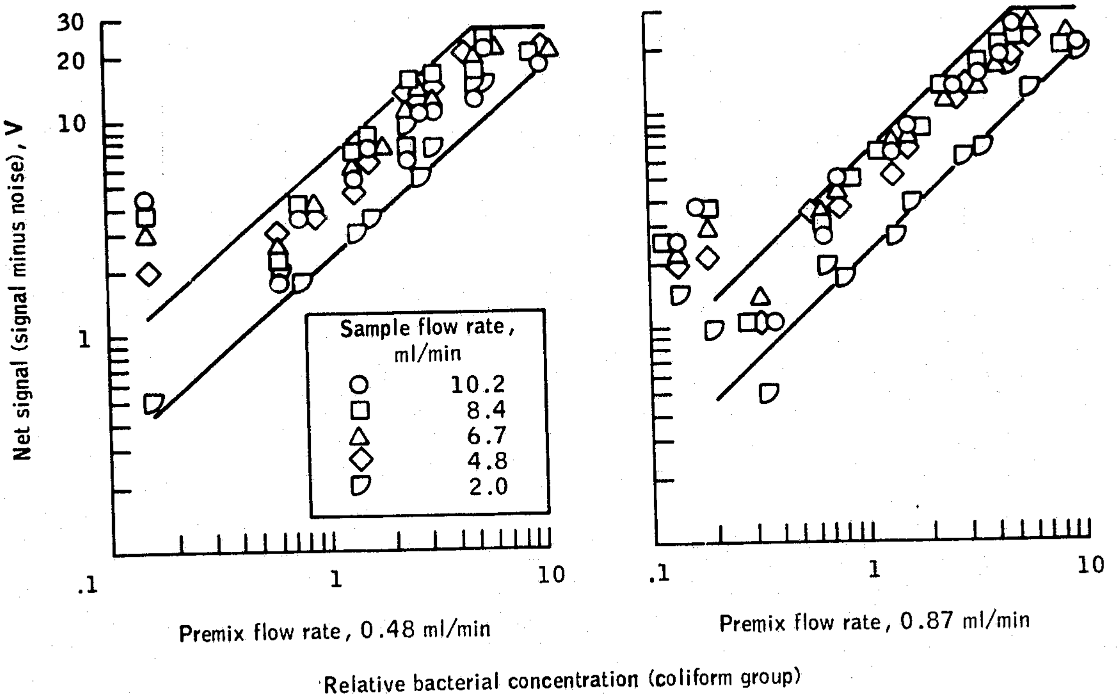


(c) Effect of hydrogen peroxide concentration at sample flow rate of 5.2 ml/min.

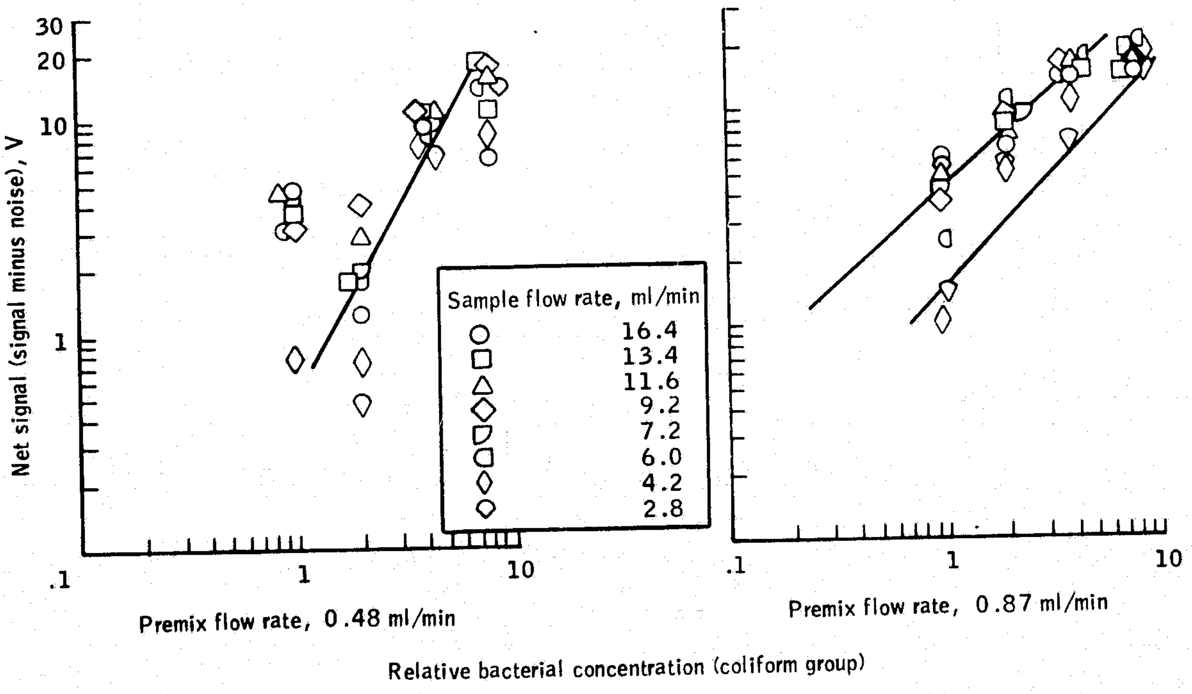


(d) Effect of hydrogen peroxide concentration at sample flow rate of 9.2 ml/min.

Figure 14.- Continued.



(e) Effect of sample flow rate at 1 percent hydrogen peroxide.



(f) Effect of sample flow rate at 1 percent hydrogen peroxide with reactor volume doubled.

Figure 14.- Concluded.

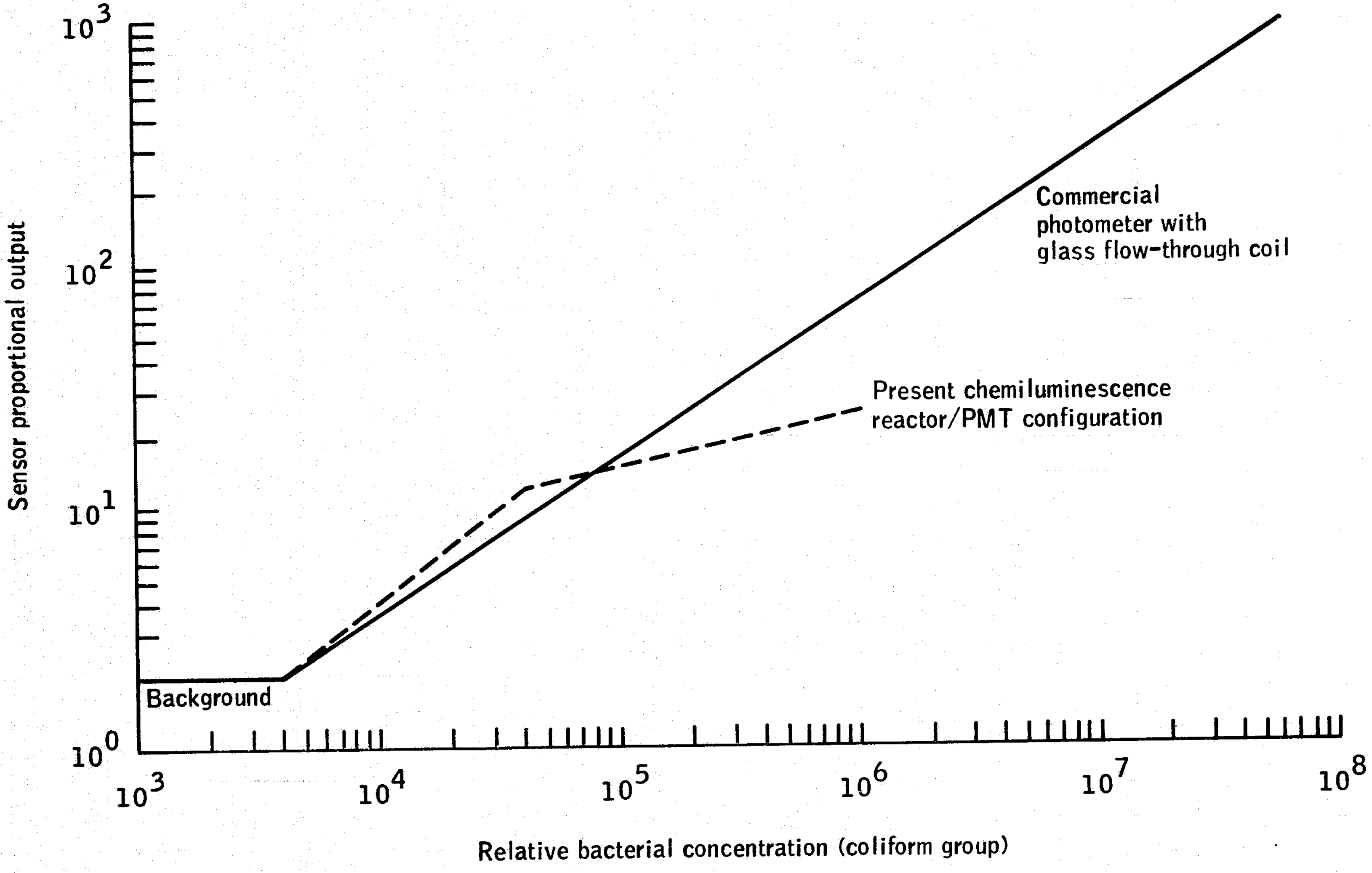
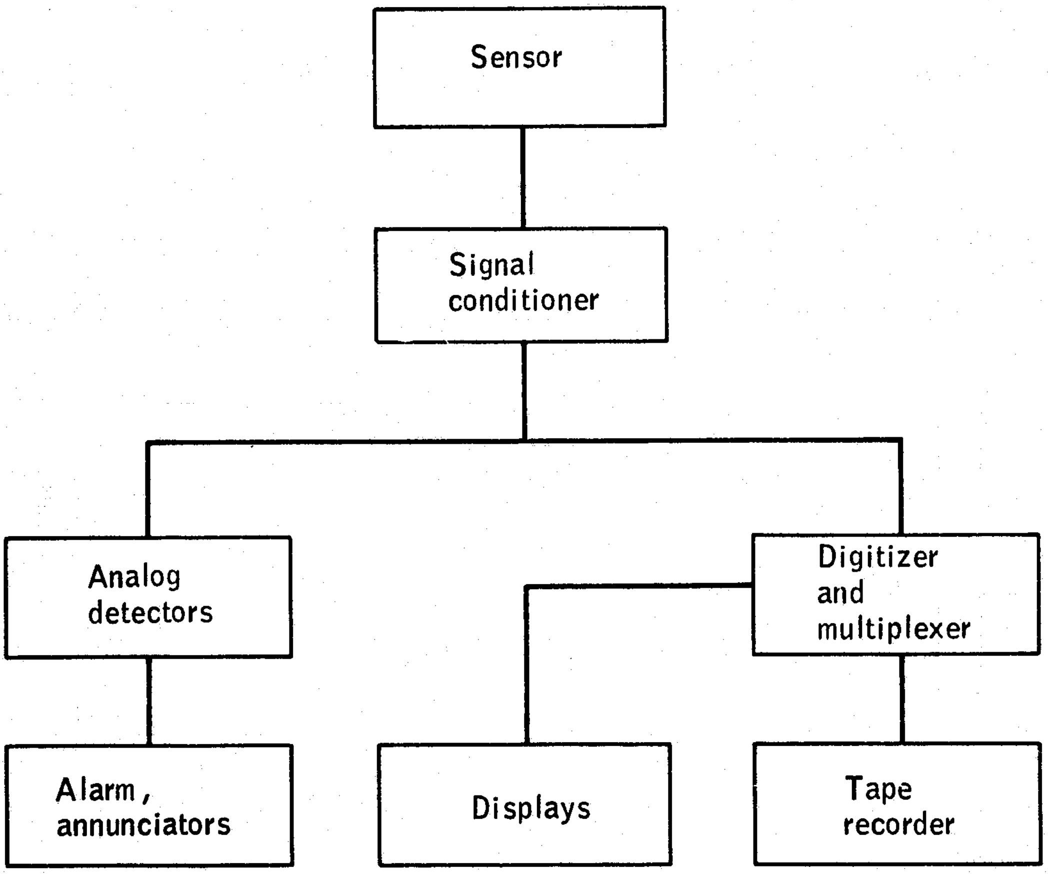
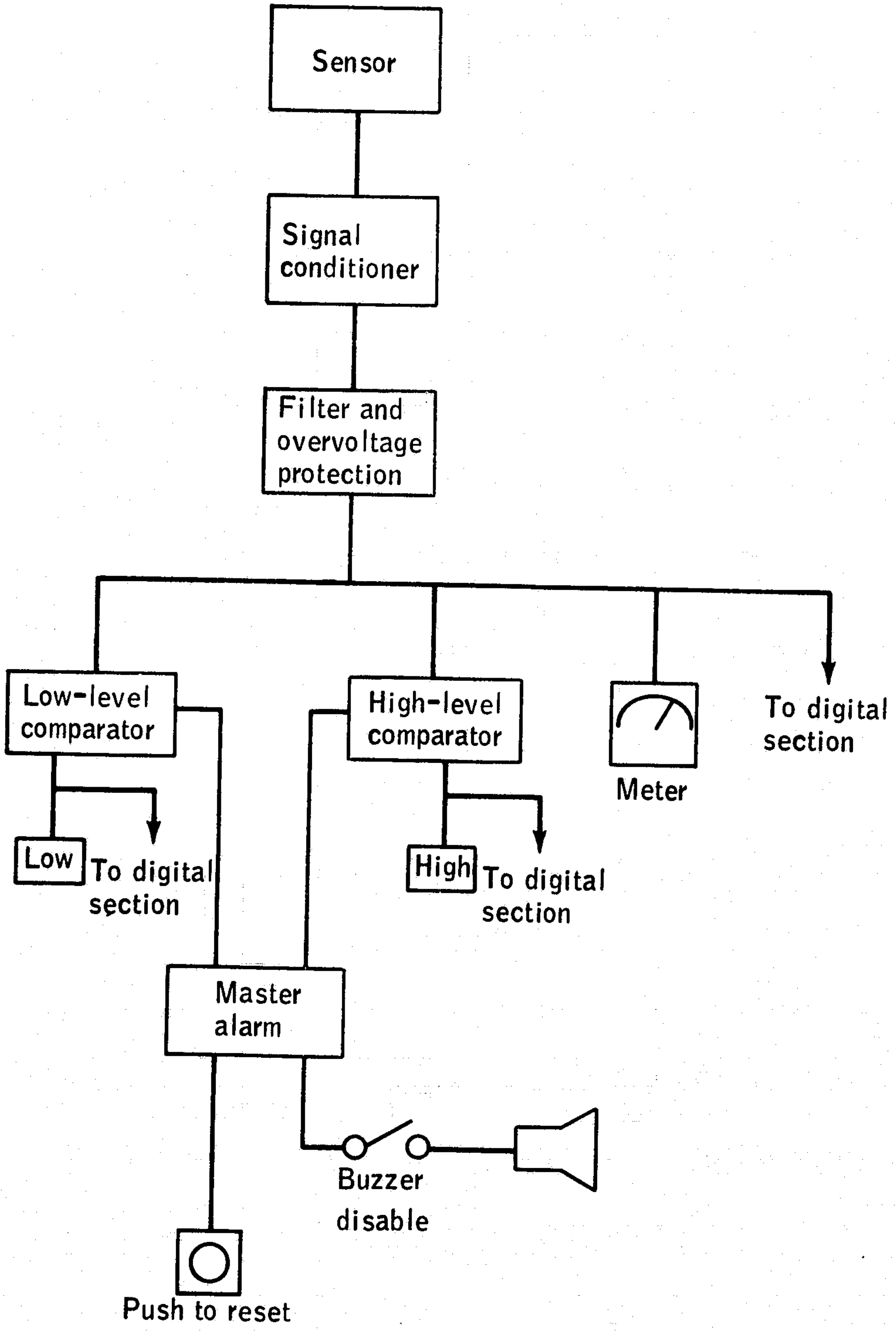


Figure 15.- Proportional output range of photometers.



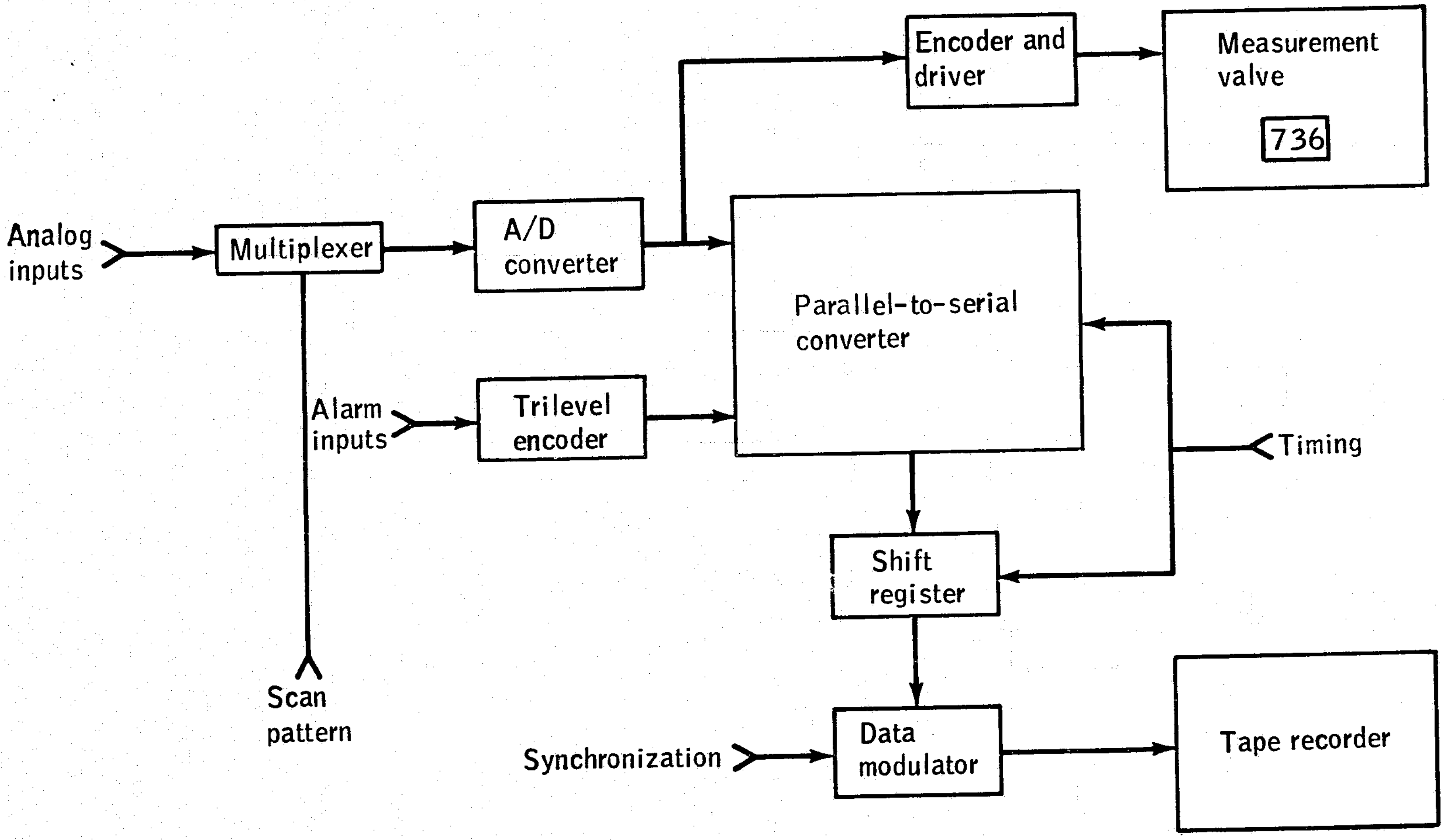
(a) Typical signal flow (25 analog channel capability).

Figure 16.- Data acquisition system.



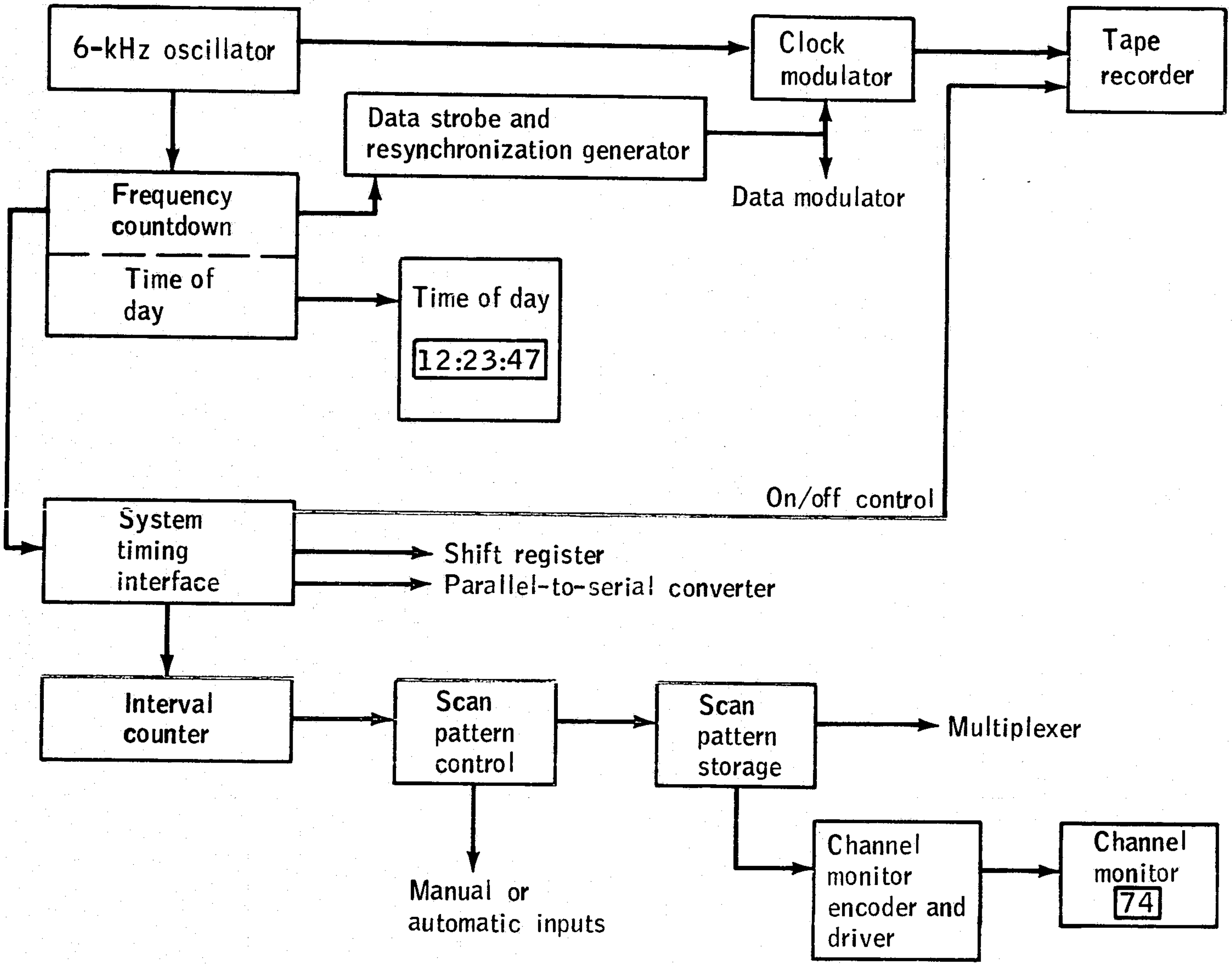
(b) Analog signal flow.

Figure 16.- Continued.



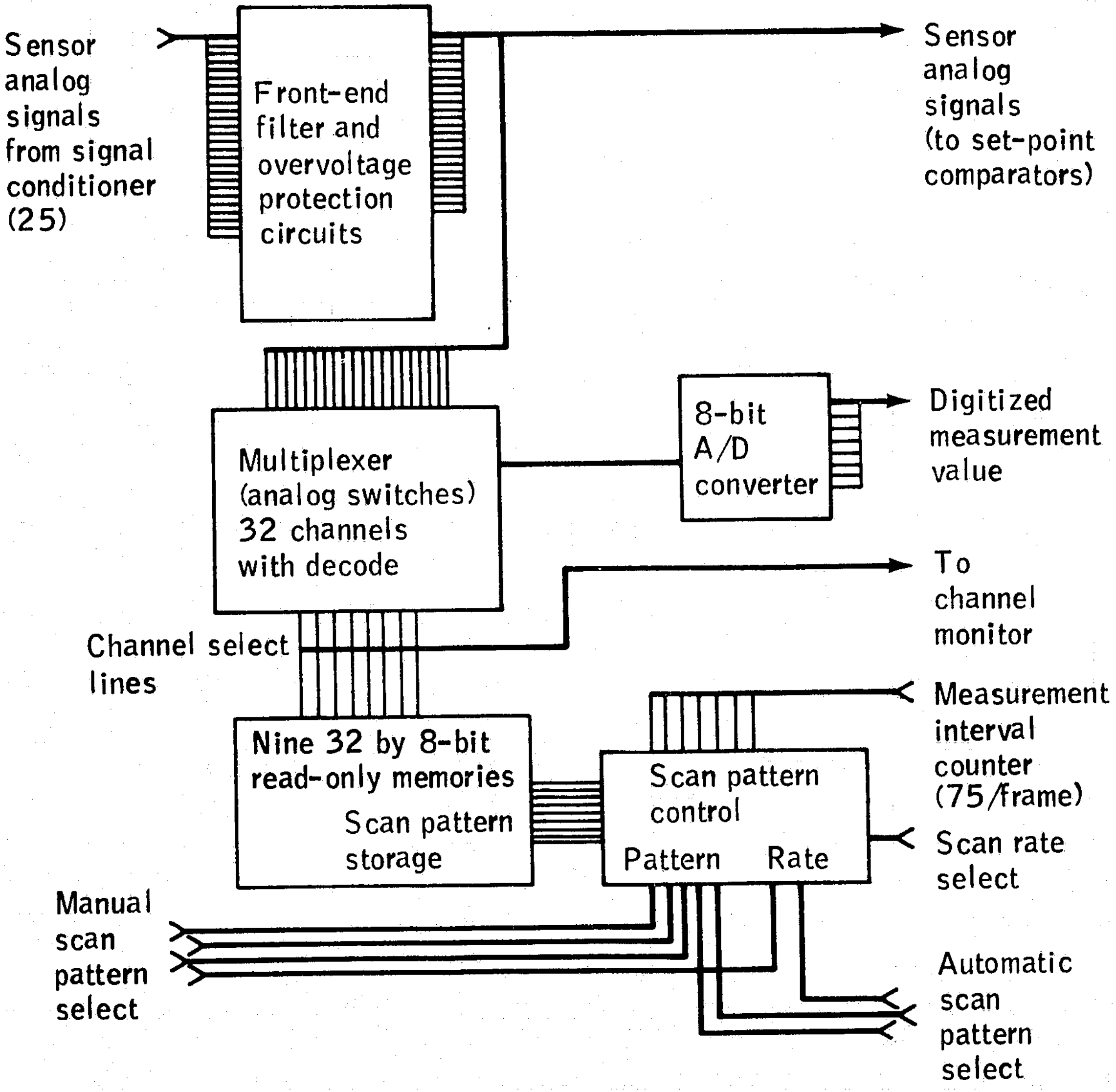
(c) Digital signal flow.

Figure 16.- Continued.



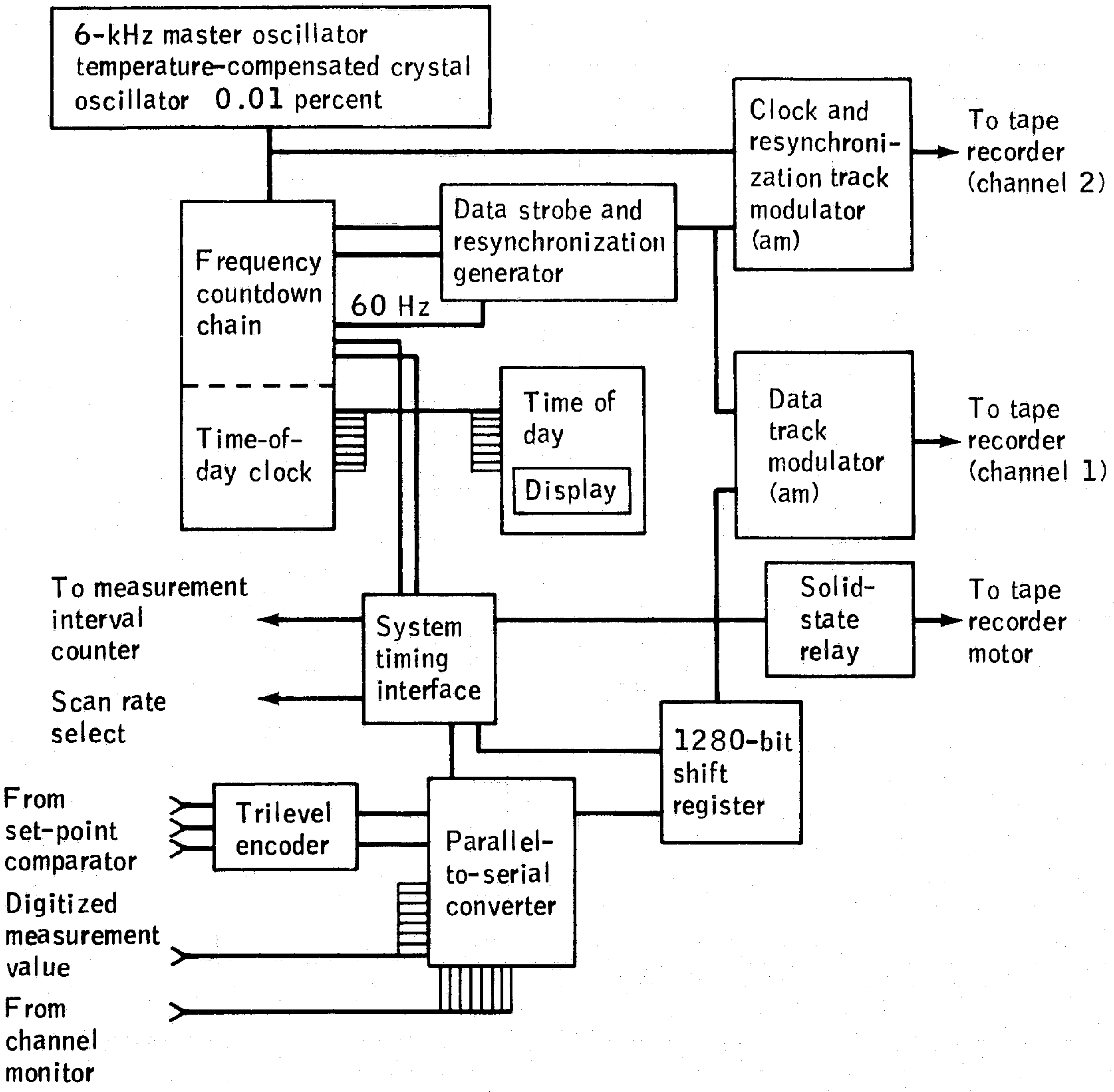
(d) Timing and control signal flow.

Figure 16.- Continued.



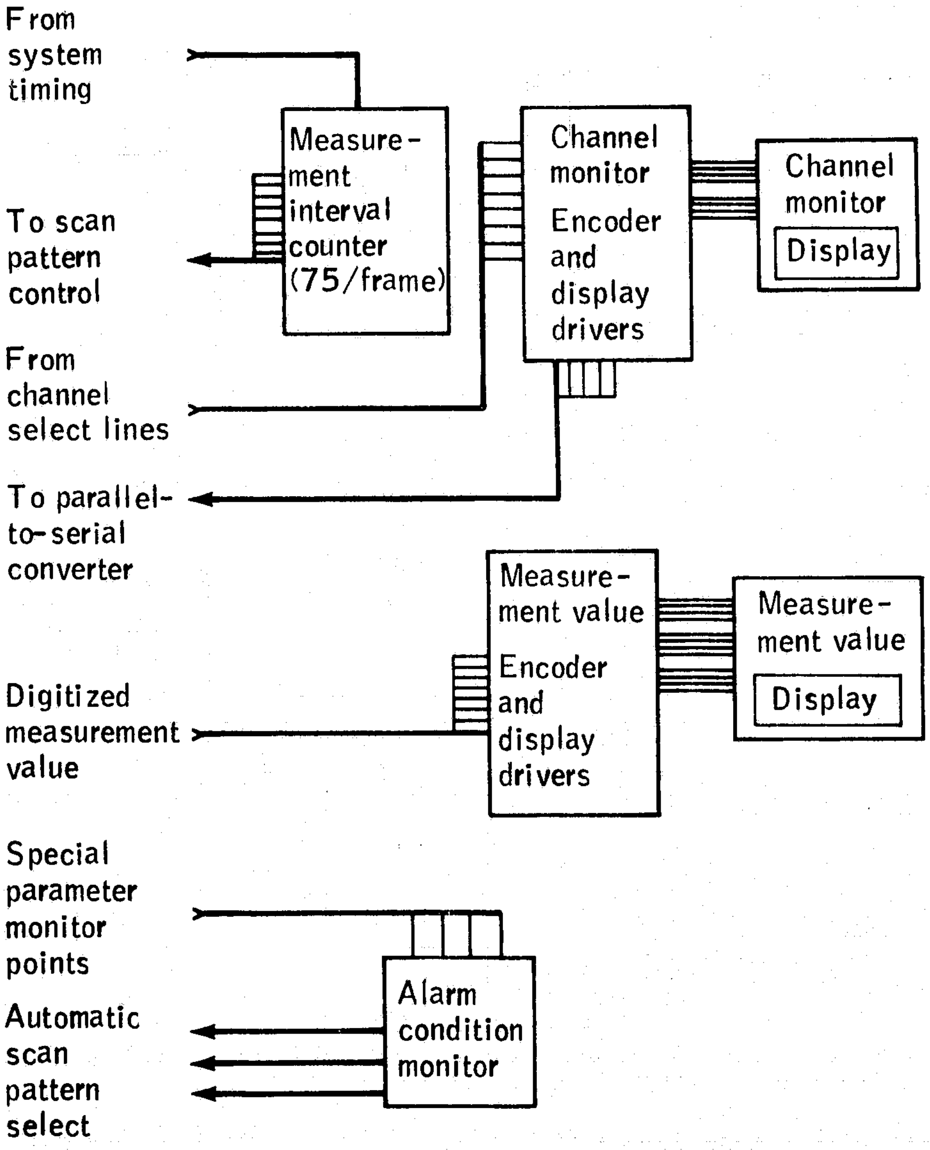
(e) Signal multiplexer and multiplexer control.

Figure 16.- Continued.



(f) Data handling.

Figure 16.- Continued.



(g) Displays and automatic control.

Figure 16.- Concluded.

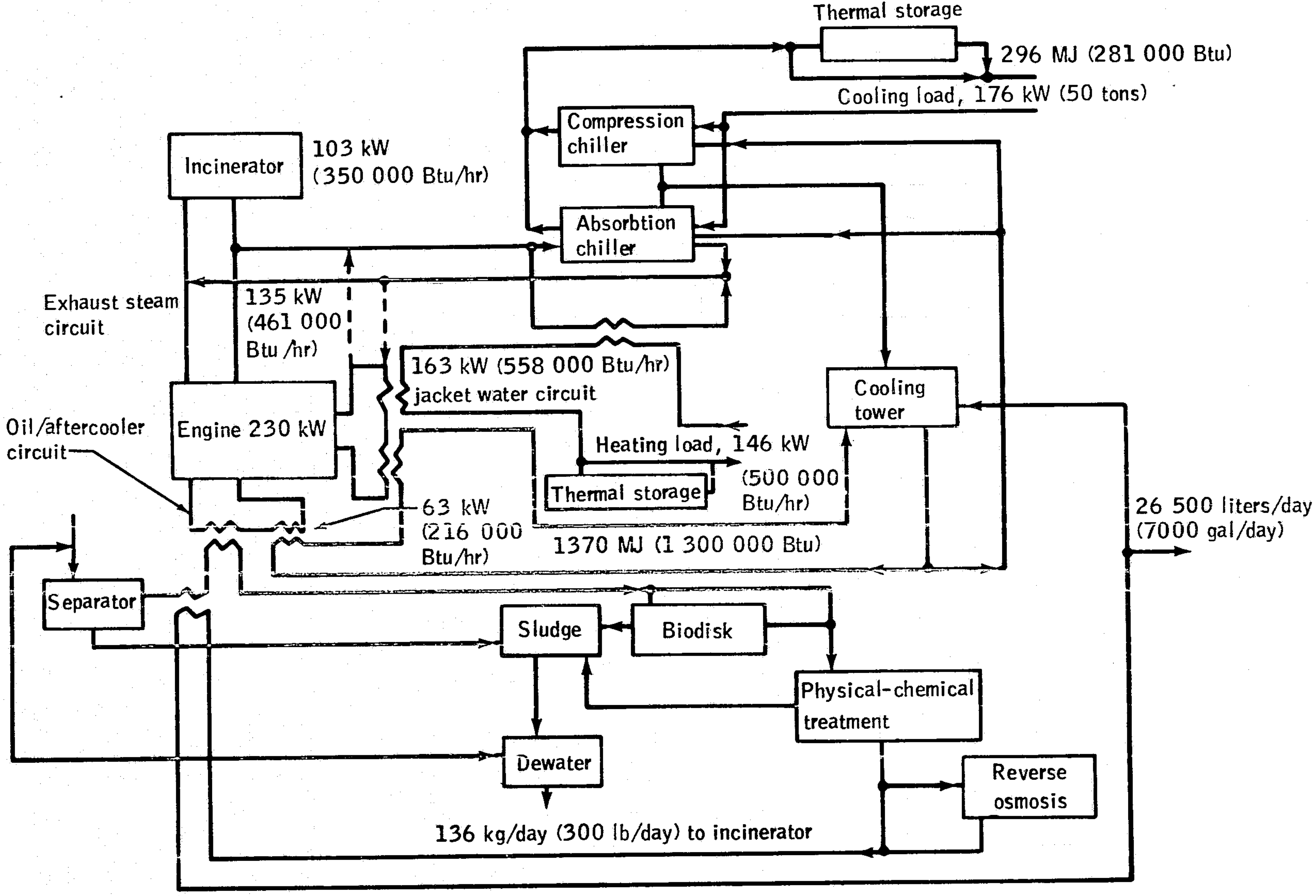


Figure 17.- Schematic diagram of the MIST system.

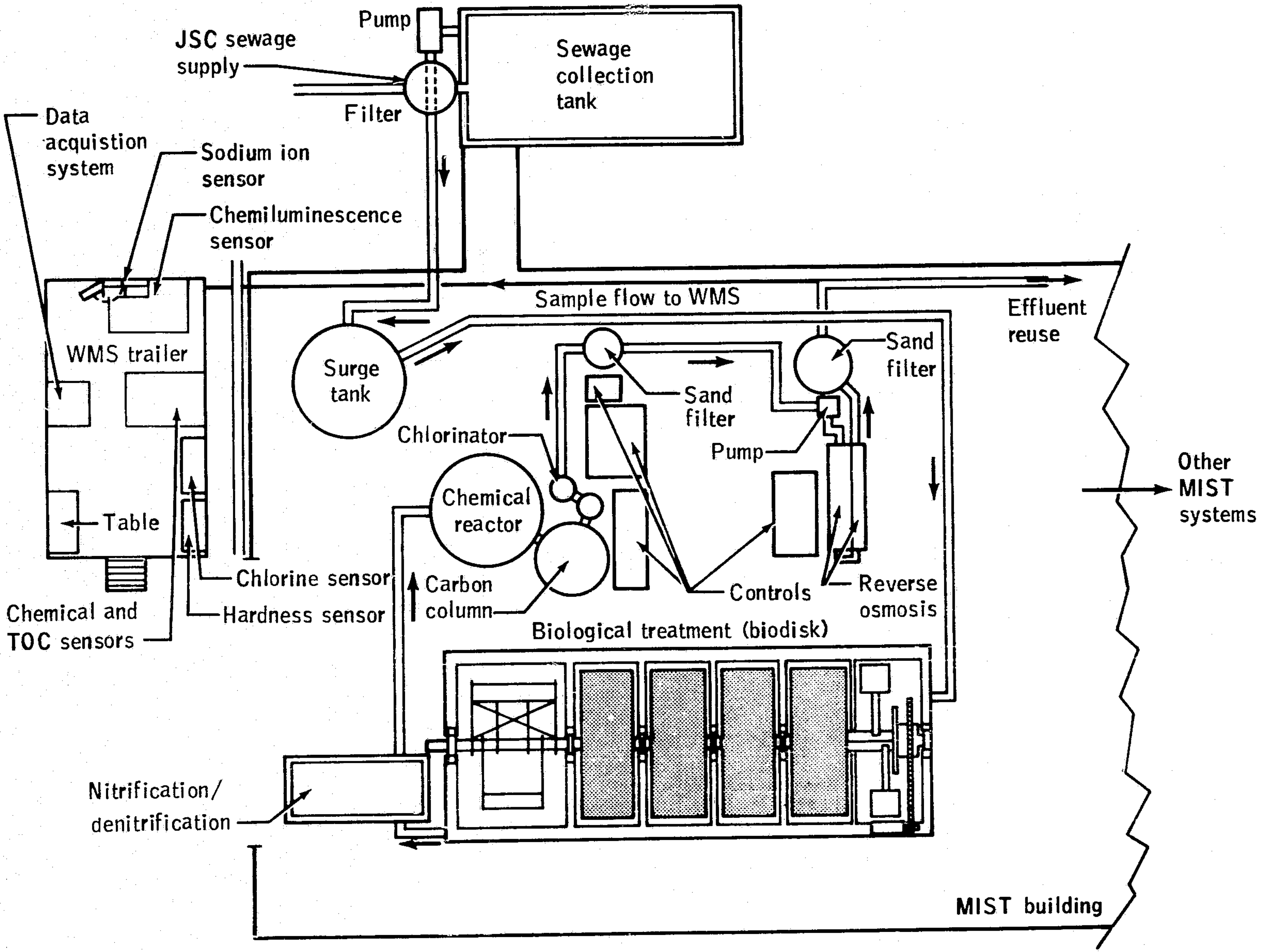


Figure 18.- Flow diagram of the MIST/WMS.

Figure 19.- The WMS trailer located outside the MIST facility.

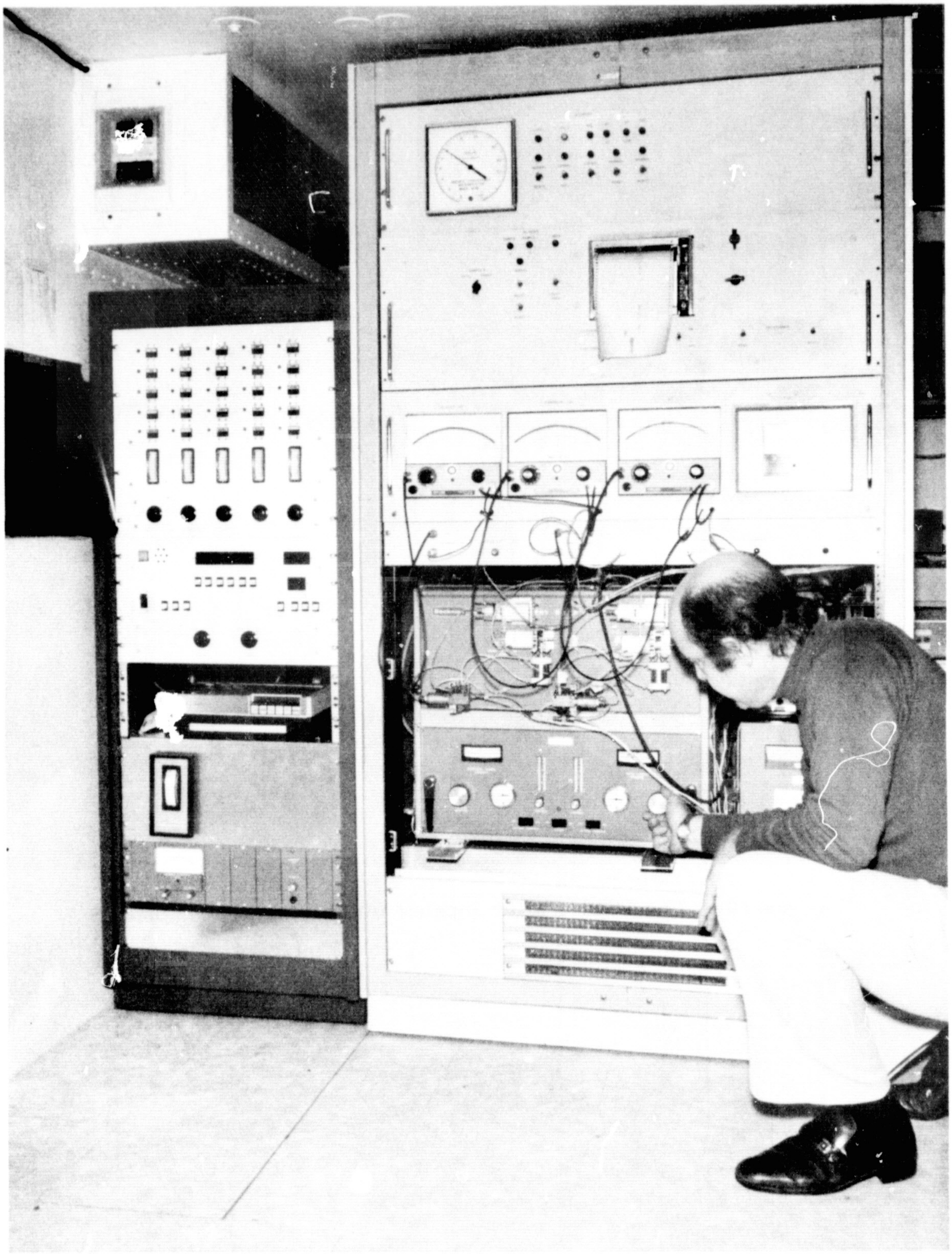


Figure 20.- Sensor console and DAS assembly located in the WMS trailer.

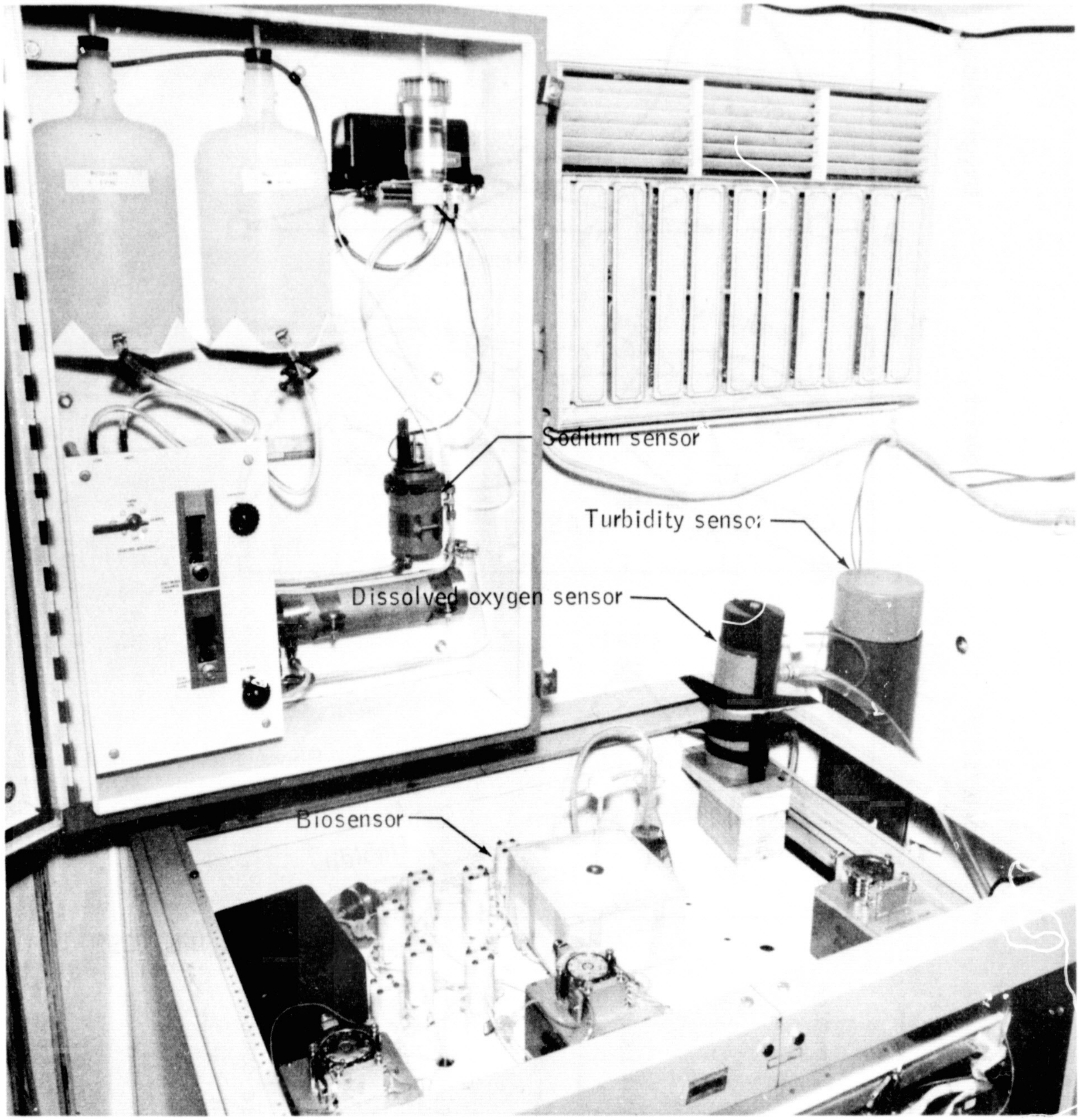


Figure 21.- The WMS sensors located in the trailer.

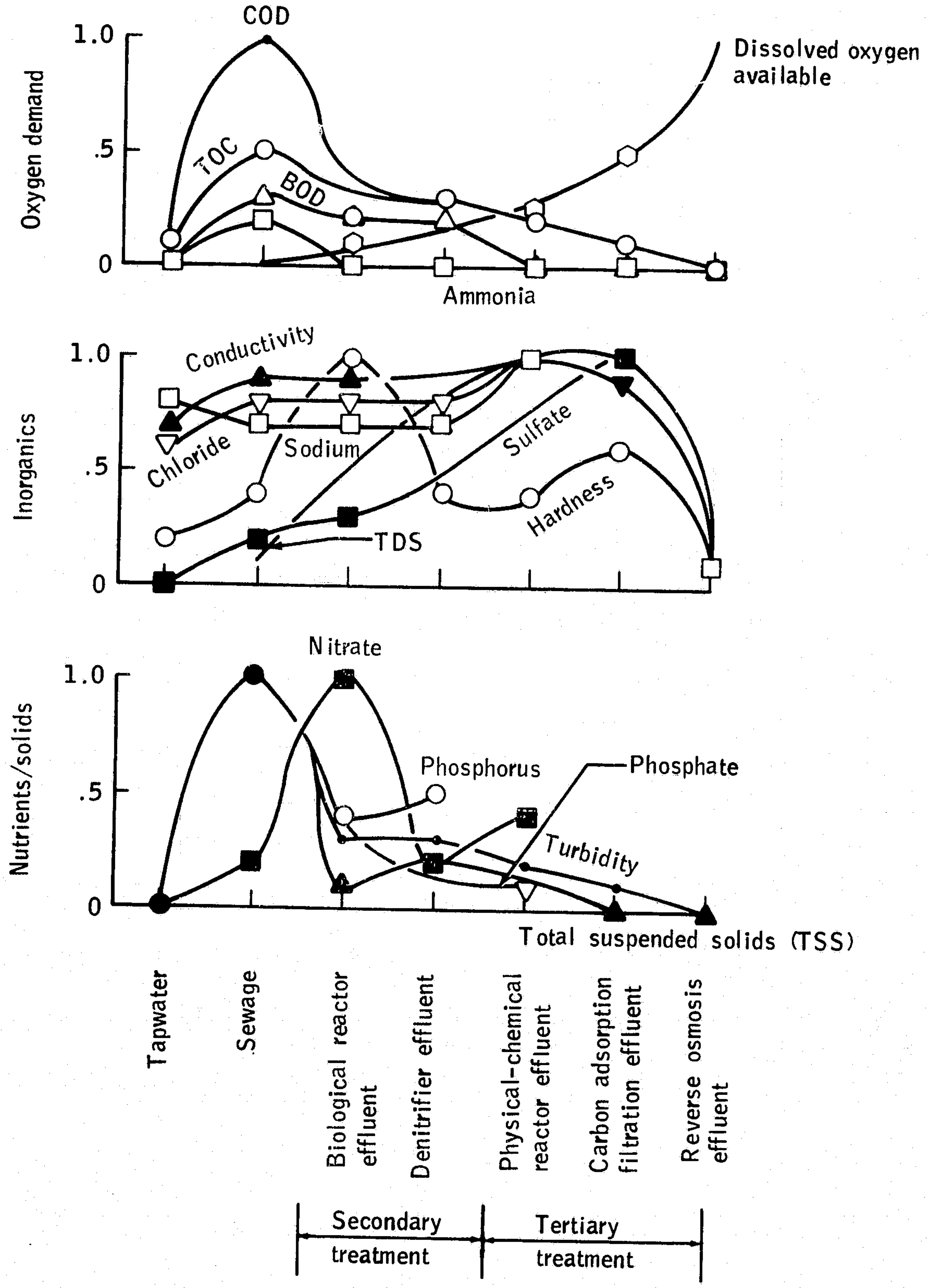
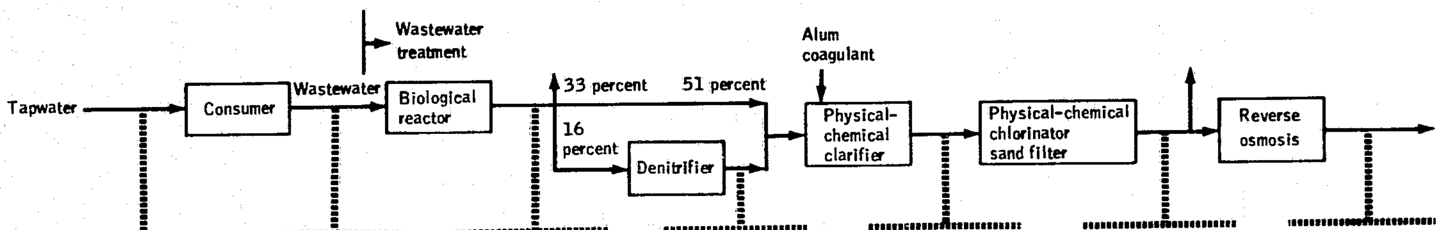


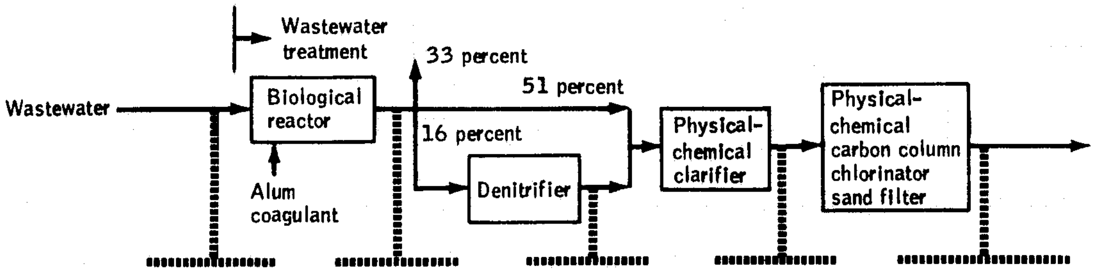
Figure 22.- Normalized wastewater parameters for MIST configuration I.



	Lab 1	WMS	Lab 2	Lab 1	WMS	Lab 2	Lab 1	WMS	Lab 2	Lab 1	WMS	Lab 2	Lab 1	WMS	Lab 2	Lab 1	WMS	Lab 2	Lab 1	WMS	Lab 2
BOD, mg/liter	--	--	<2 (7)	--	--	64 (51)	--	--	19 (52)	--	--	54 (38)	--	--	5 (23)	--	--	5 (48)	--	--	<2 (4)
COD, mg/liter	--	--	--	247 (20)	--	--	60 (20)	--	--	--	--	--	32 (12)	--	--	22 (15)	--	--	--	--	--
TOC, mg/liter	--	14 (183)	4 (7)	--	51 (3)	48 (1)	--	19 (7)	13 (2)	--	22 (3)	30 (1)	--	17 (139)	6 (23)	--	7 (190)	4 (20)	--	4 (17)	<2 (2)
Turbidity, Jtu	1 (8)	4 (183)	<10 (7)	89 (23)	--	97 (49)	18 (21)	30 (4)	26 (47)	--	--	29 (34)	9 (27)	27 (157)	8 (23)	2 (15)	10 (272)	5 (53)	0 (1)	1 (17)	<10 (12)
TSS, mg/liter	--	--	--	--	--	197 (48)	--	--	28 (47)	--	--	38 (34)	--	--	--	--	--	5 (32)	--	--	1 (10)
TDS, mg/liter	--	--	--	--	--	84 (1)	--	--	--	--	--	--	--	--	605 (8)	--	--	519 (14)	--	--	88 (10)
Conductivity, μmho/cm	--	741 (183)	651 (7)	--	--	875 (2)	--	1000 (4)	765 (2)	--	--	--	--	988 (157)	944 (23)	--	988 (272)	964 (22)	--	105 (17)	99 (7)
Ammonia, mg/liter	0 (3)	--	0 (7)	14.3 (31)	--	17.0 (53)	3.5 (32)	--	3.4 (52)	3.2 (31)	--	2.7 (39)	0.7 (11)	--	1.3 (23)	3.1 (12)	--	1.1 (51)	--	--	0.5 (7)
Nitrate, mg/liter	--	--	--	1.9 (15)	--	1.9 (53)	9.1 (12)	--	9.6 (53)	0.8 (30)	--	2.7 (40)	4.1 (5)	--	--	--	--	--	--	--	--
Phosphorus, mg/liter	--	--	--	--	--	4.2 (47)	--	--	1.8 (47)	--	--	2.1 (34)	--	--	--	--	--	--	--	--	--
Phosphate, mg/liter	--	--	--	3.4 (15)	--	--	--	--	--	--	--	--	0.4 (4)	--	--	--	--	--	--	--	--
Sulfate, mg/liter	--	--	--	--	--	34 (47)	--	--	58 (47)	--	--	--	--	--	--	--	--	179 (29)	--	--	--
Hardness, mg/liter	19 (9)	25 (183)	22 (7)	--	--	36 (1)	80 (1)	115 (4)	63 (2)	--	--	36 (1)	38 (8)	35 (126)	39 (23)	39 (11)	55 (259)	44 (20)	0 (1)	10 (17)	--
Chloride, mg/liter	99 (7)	99 (183)	90 (7)	--	--	132 (2)	115 (1)	140 (4)	113 (2)	--	--	118 (1)	121 (12)	165 (157)	117 (23)	129 (13)	141 (272)	126 (24)	40 (1)	13 (17)	13 (12)
Sodium, mg/liter	--	164 (183)	132 (7)	--	--	135 (2)	--	205 (4)	148 (2)	--	--	145 (1)	--	189 (157)	170 (23)	--	196 (272)	165 (22)	--	21 (17)	12 (14)
pH, units	7.5 (8)	7.4 (183)	8.2 (7)	--	--	7.6 (2)	8.2 (1)	7.7 (4)	8.0 (2)	--	--	7.7 (1)	6.3 (16)	6.1 (157)	7.5 (23)	6.7 (15)	6.7 (272)	7.8 (22)	6.4 (1)	5.5 (17)	6.3 (4)
Chlorine, mg/liter	1.1 (5)	1.5 (183)	--	--	--	--	--	11.0 (4)	--	--	--	--	0.1 (3)	15.8 (129)	--	4.0 (6)	2.1 (179)	--	--	0.1 (8)	--
Dissolved oxygen, mg/liter	5 (6)	2 (183)	--	--	--	--	--	6 (4)	--	--	--	--	11 (12)	8 (157)	--	10 (9)	10 (272)	--	9 (1)	12 (17)	--

(a) MIST configuration I (test period, Dec. 10, 1974, to Feb. 27, 1975).

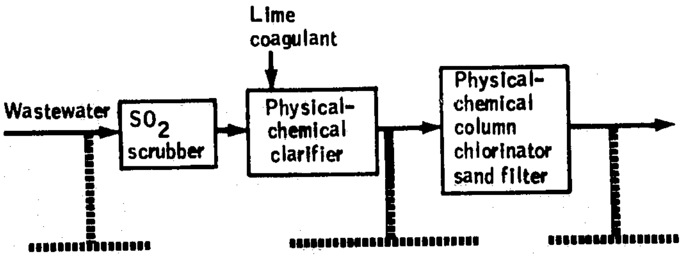
Figure 23.- Average WMS and laboratory results. Numbers in parentheses indicate number of samples.



	Lab 1	Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	Lab 1	WMS	Lab 2
BOD, mg/liter	--	30 (9)	--	8 (10)	--	34 (7)	--	17 (1)	--	--	7 (14)
COD,mg/liter	150 (1)	--	50 (1)	--	--	--	0 (1)	--	--	--	--
TOC, mg/liter	--	--	--	--	--	--	--	15 (1)	--	30 (8)	16 (2)
Turbidity, Jtu	107 (10)	53 (9)	14 (9)	13 (10)	--	15 (7)	16 (10)	12 (1)	--	9 (8)	13 (15)
TSS, mg/liter	--	188 (9)	--	22 (10)	--	47 (7)	--	--	--	--	26 (12)
TDS, mg/liter	--	--	--	--	--	--	--	--	--	--	--
Conductivity, μmho/cm	--	--	--	--	--	--	--	920 (1)	--	950 (8)	930 (2)
Ammonia, mg/liter	16.3 (10)	15.2 (9)	7.4 (10)	5.8 (10)	5.4 (9)	6.9 (7)	--	10 (1)	--	--	15 (14)
Nitrate, mg/liter	--	1.3 (9)	--	5.7 (10)	1.5 (10)	< 1 (7)	0.8 (1)	--	--	--	--
Phosphorus, mg/liter	--	2.7 (9)	--	0.4 (10)	--	1.4 (7)	--	--	--	--	0.3 (12)
Phosphate, mg/liter	3.7 (10)	--	--	--	--	--	0.3 (10)	--	--	--	--
Sulfate, mg/liter	--	57 (9)	--	163 (10)	--	115 (7)	--	--	--	--	177 (12)
Hardness, mg/liter	--	--	--	--	--	--	40 (1)	50 (1)	65 (1)	60 (8)	56 (2)
Chloride, mg/liter	--	--	--	--	--	--	115 (1)	125 (1)	110 (1)	150 (8)	103 (2)
Sodium, mg/liter	--	--	--	--	--	--	--	160 (1)	--	169 (8)	165 (2)
pH, units	--	--	--	--	--	--	7.1 (1)	8.6 (1)	6.6 (2)	7.0 (8)	6.9 (2)
Chlorine, mg/liter	--	--	--	--	--	--	--	--	4.0 (1)	3.5 (8)	--
Dissolved oxygen, mg/liter.	--	--	--	--	--	--	9 (1)	--	12 (1)	16 (8)	--

(b) MIST configuration II (test period, Feb. 22 to Feb. 28, 1975).

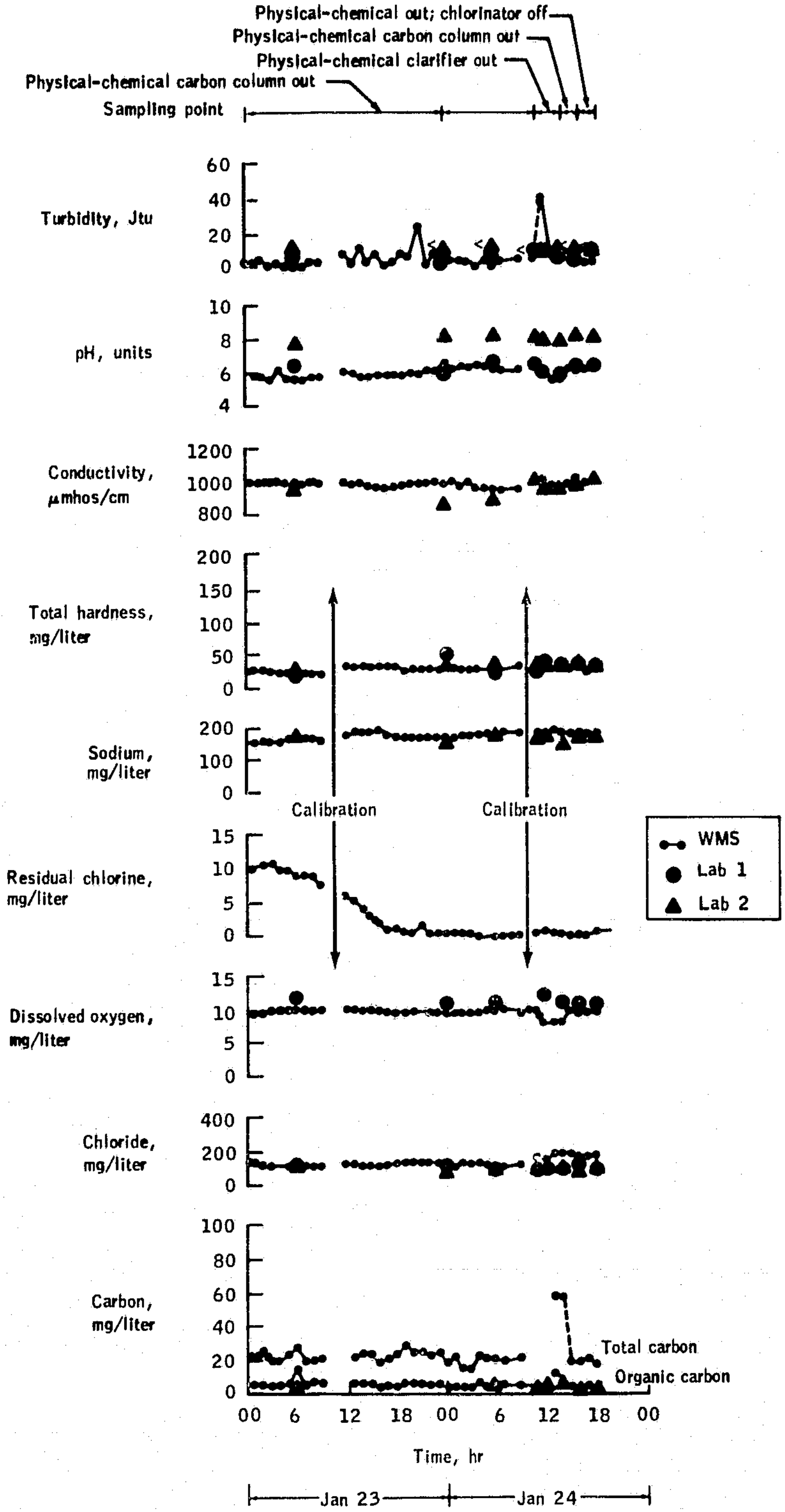
Figure 23.- Continued.



	Lab 1	Lab 2	Lab 1	WMS	Lab 2	Lab 1	Lab 2
BOD, mg/liter	--	86 (4)	--	--	17 (8)	--	19 (3)
COD,mg/liter	--	144 (4)	60 (2)	--	--	--	--
TOC, mg/liter	--	48 (1)	--	26 (46)	12 (11)	--	--
Turbidity, Jtu	--	101 (4)	8 (6)	5 (46)	10 (11)	--	26 (3)
TSS, mg/liter	--	154 (3)	--	--	--	--	4 (3)
TDS, mg/liter	--	--	--	--	--	--	--
Conductivity, μmho/cm	--	750 (1)	--	986 (46)	1166 (11)	--	--
Ammonia, mg/liter	10.7 (4)	22.6 (4)	--	--	16.6 (11)	--	12 (3)
Nitrate, mg/liter	1.7 (4)	2.4 (3)	--	--	--	--	--
Phosphorus, mg/liter	--	3.7 (3)	--	--	--	--	< 0.05 (3)
Phosphate, mg/liter	--	--	--	--	--	--	--
Sulfate, mg/liter	--	52 (3)	--	--	--	--	377 (3)
Hardness, mg/liter	--	36 (1)	223 (3)	89 (46)	504 (11)	--	--
Chloride, mg/liter	--	123 (1)	139 (5)	252 (46)	147 (11)	--	--
Sodium, mg/liter	--	150 (1)	--	184 (46)	158 (11)	--	--
pH, units	--	7.7 (1)	7.2 (4)	7.4 (46)	8.2 (11)	--	--
Chlorine, mg/liter	--	--	0.1 (2)	<0.1 (46)	--	--	--
Dissolved oxygen, mg/liter	--	--	4 (2)	6 (46)	--	--	--

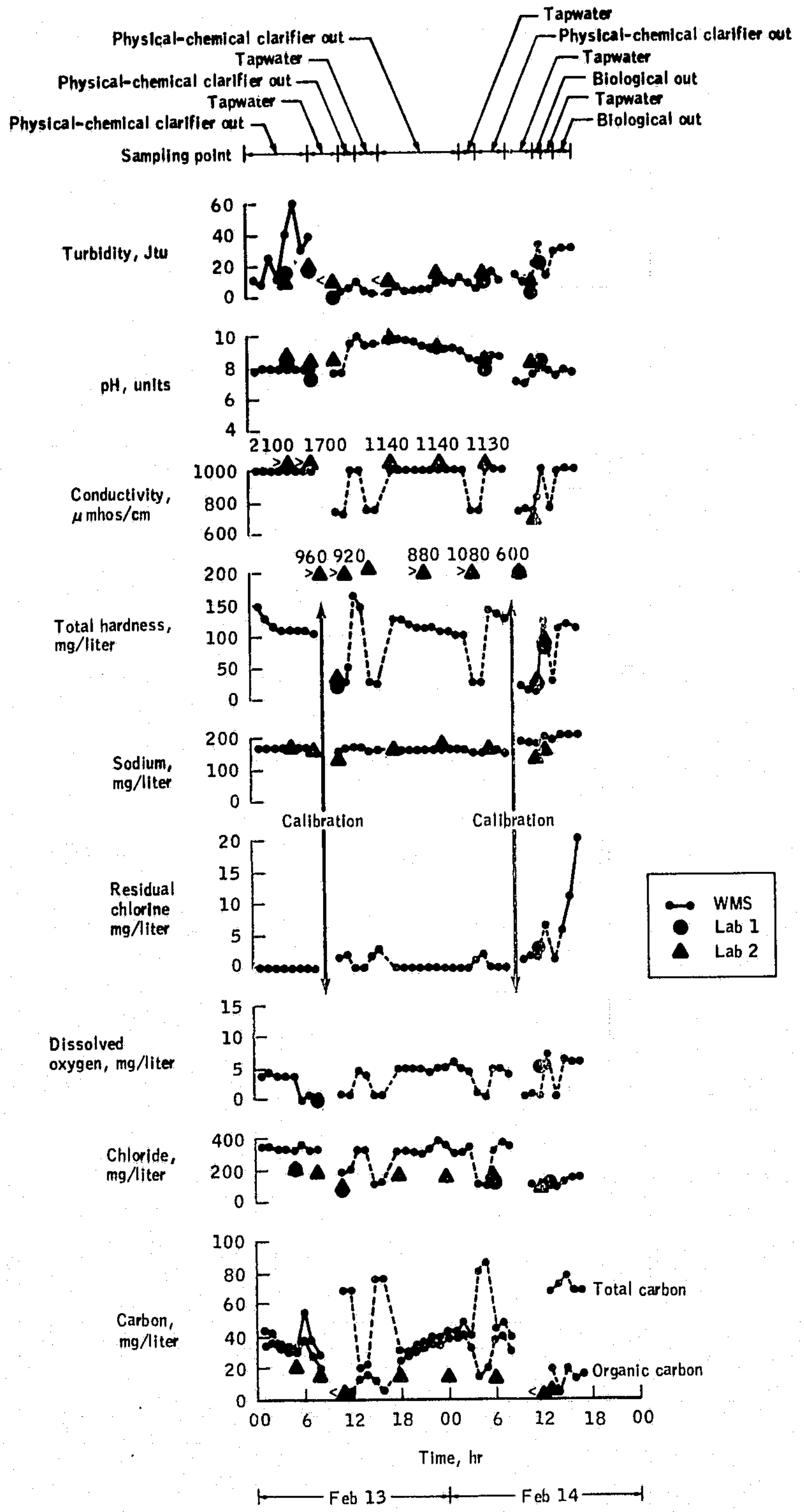
(c) MIST configuration III (test period, Feb. 11 to Feb. 14, 1975).

Figure 23.- Concluded.



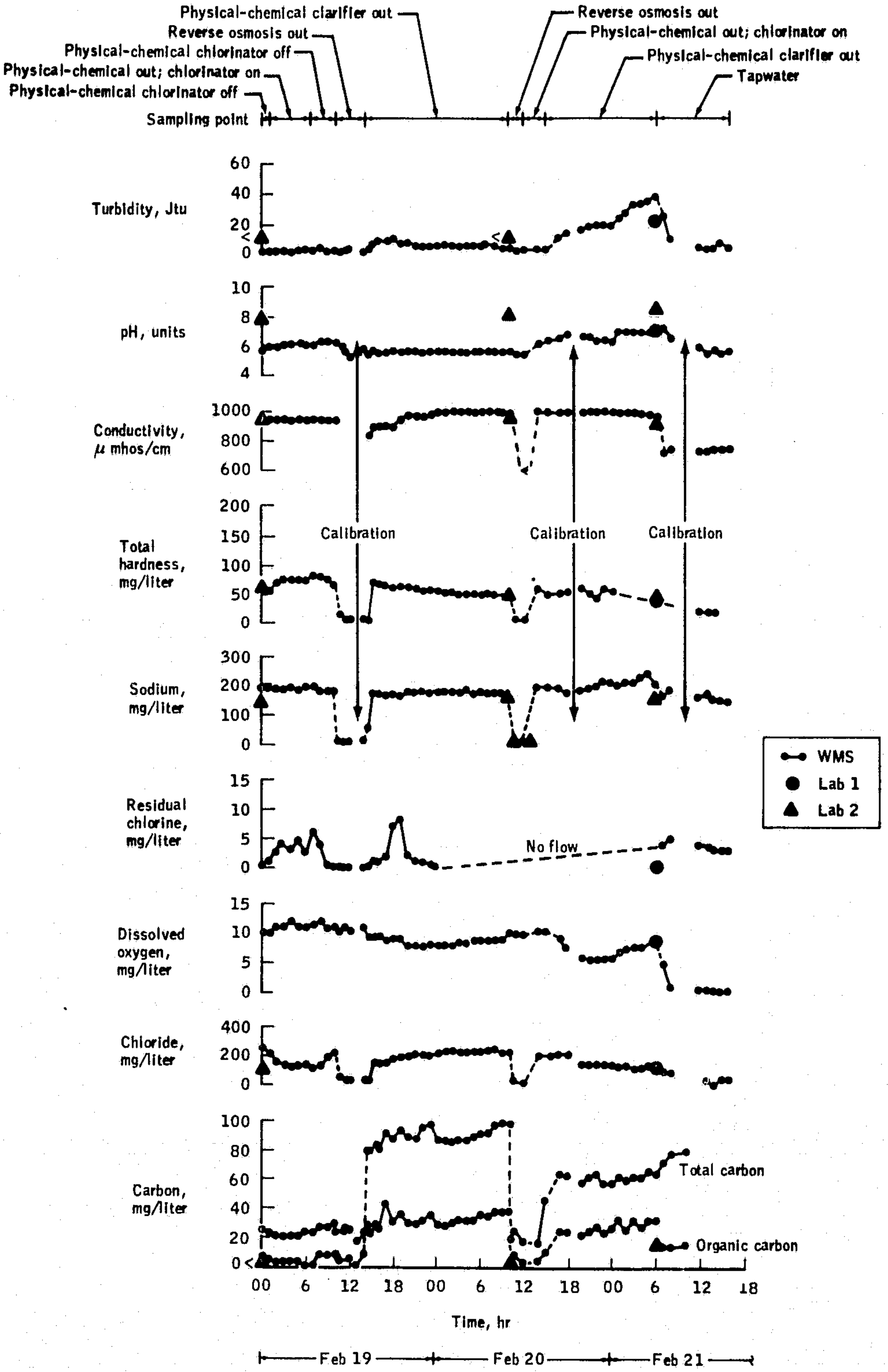
(a) MIST configuration I.

Figure 24.- Representative hourly WMS data.



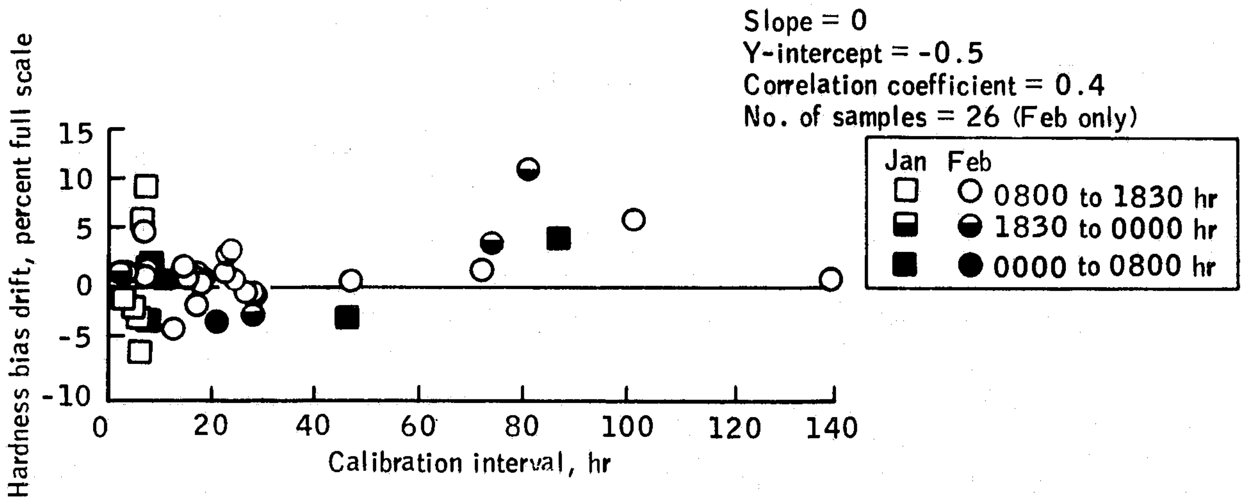
(b) MIST configuration III.

Figure 24.- Continued.

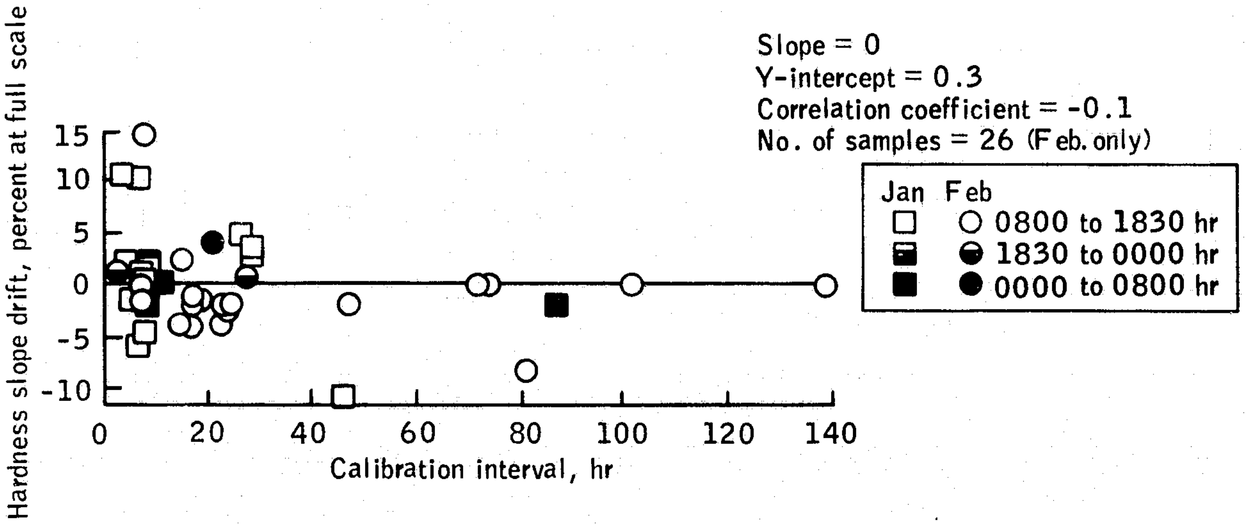


(c) MIST configuration I - BOD overload test.

Figure 24.- Concluded.

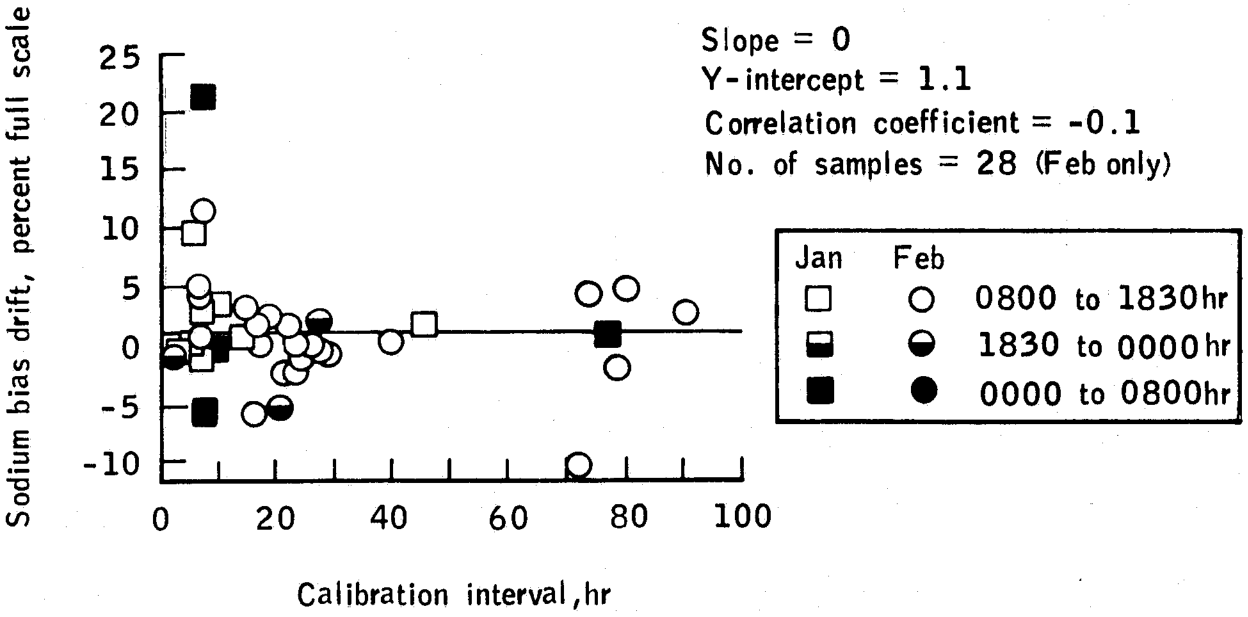


(a) Hardness bias drift.

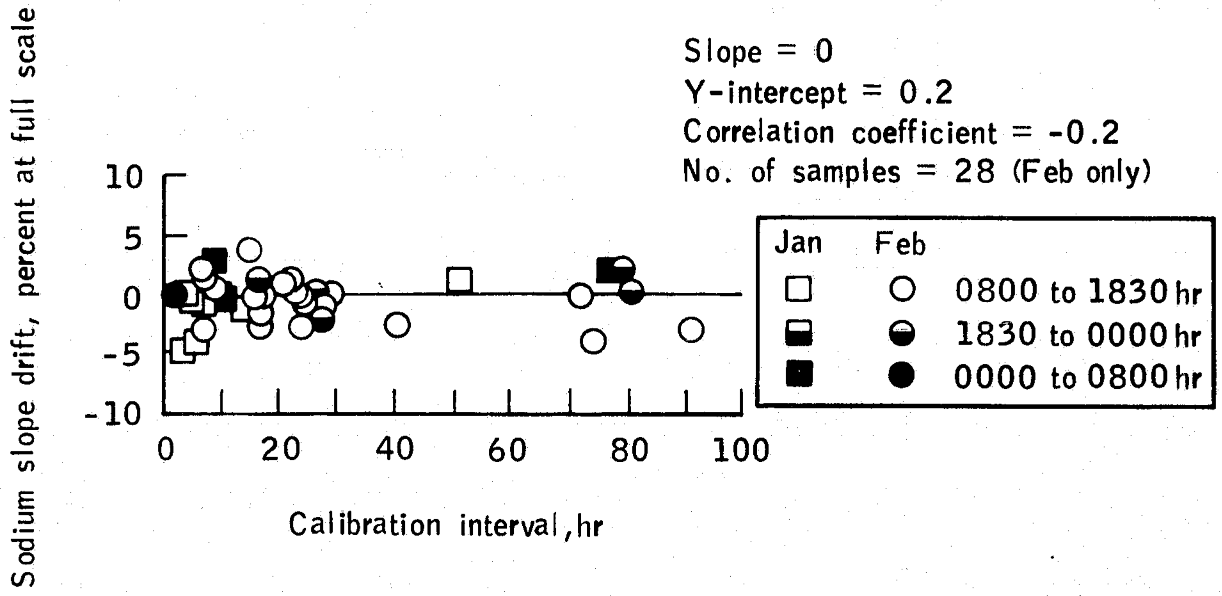


(b) Hardness slope drift.

Figure 25.- Calibration drift as a function of frequency.

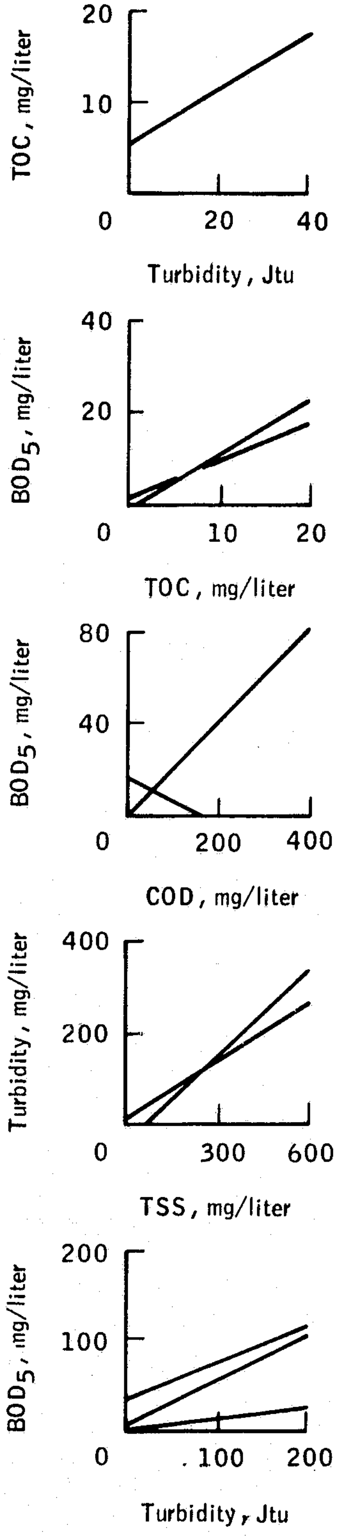


(c) Sodium bias drift.



(d) Sodium slope drift.

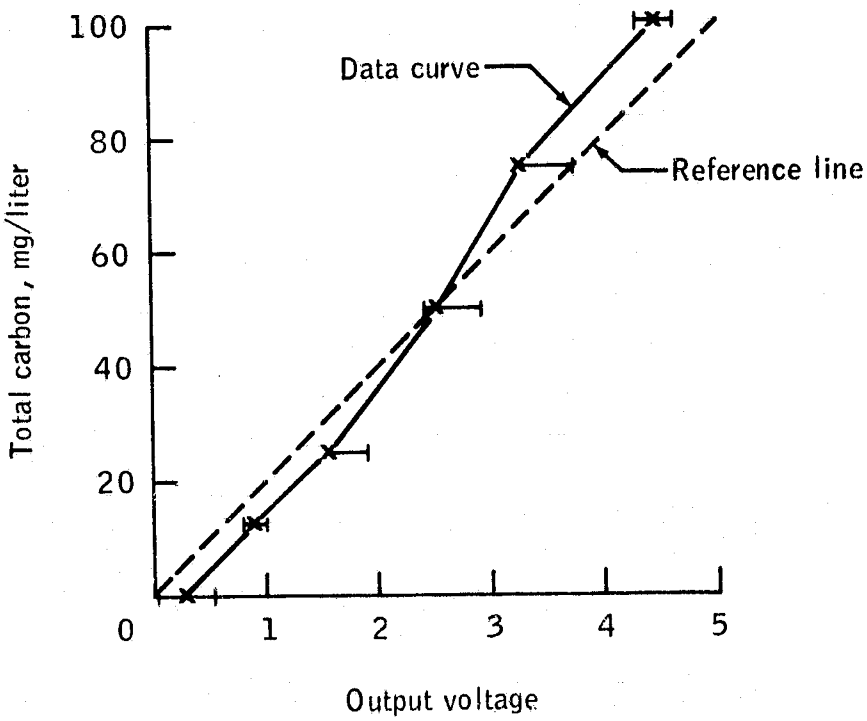
Figure 25.- Concluded.



Parameter	Range of values	No. of samples	Correlation coefficient
P-C* clarifier effluent TOC = 0.3 (turbidity) + 5.3	Turbidity: <4 to 45 Jtu TOC: 2 to 21 mg/liter	35	0.6
P-C clarifier effluent BOD_5 = 1.2 (TOC) - 1.8	TOC: 2 to 21 mg/liter BOD_5: <2 to 44 mg/liter	32	0.6
P-C carbon tower effluent BOD_5 = 0.8 (TOC) + 1.0	TOC: 2 to 5 mg/liter BOD_5: <2 to 8 mg/liter	22	0.4
Biological influent BOD_5 = 0.2 (COD) - 1.2	COD: 80 to 475 mg/liter BOD_5: 8 to 85 mg/liter	12	0.7
Biological effluent BOD_5 = 15.7 - 0.1 (COD)	COD: 30 to 130 mg/liter BOD_5: 7 to 17 mg/liter	13	0.6
Biological influent Turbidity = 0.7 (TSS) - 40	TSS: 10 to 602 mg/liter Turbidity: 10 to 200 Jtu	48	0.7
Biological effluent Turbidity = 0.4 (TSS) + 16	TSS: 10 to 89 mg/liter Turbidity: 8 to 60 Jtu	46	0.4
Biological influent BOD_5 = 0.4 (turbidity) + 33	Turbidity: 10 to 200 Jtu BOD_5: 5 to 211 mg/liter	48	0.3
Biological effluent BOD_5 = 0.5 (turbidity) + 7	Turbidity: 8 to 60 Jtu BOD_5: 2 to 62 mg/liter	47	0.4
P-C effluent BOD_5 = 0.1 (turbidity) + 5	Turbidity: <4 to 65 Jtu BOD_5: <2 to 43 Jtu	65	0.1

*P-C = physical-chemical

Figure 26.- Correlation of MIST wastewater parameters.



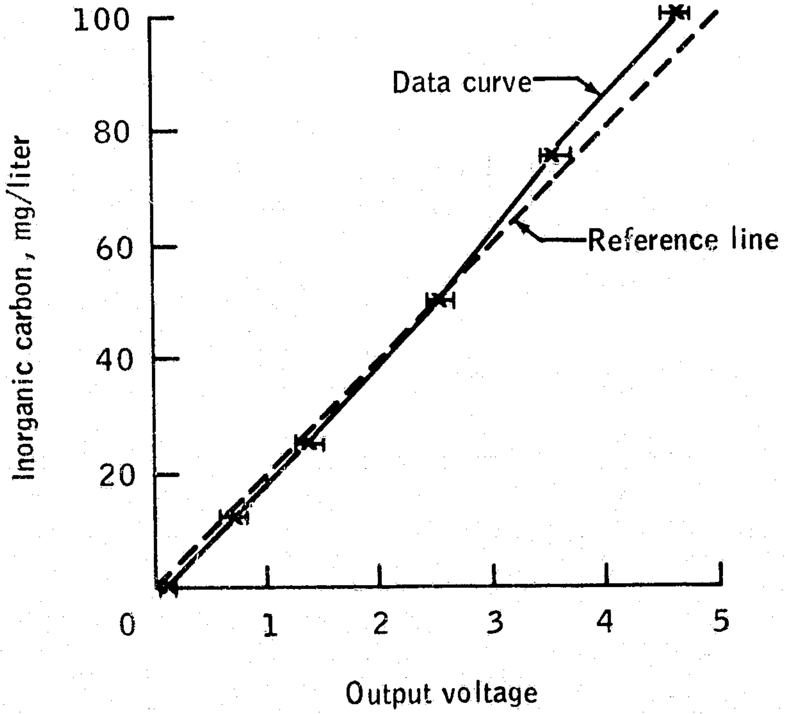


Figure 27.- Representative TOC response curve.

APPENDIX

TEST DATA

TABLE X.- WATER MONITOR SYSTEM, LABORATORY 1, AND LABORATORY 2 DATA

[Results in milligrams per liter unless otherwise specified]

(a) Reverse osmosis effluent

Date	Time	BOD$_5$[a]	BOD$_5$ with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, μmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Dec. 10, 1974	2:25 p.m.					2		<10		2	19		101				
Dec. 10	2:25 p.m.					2		<10		1	153		101				
Dec. 10	3:58 p.m.					4		<10		1	196		111				
Dec. 10	3:58 p.m.					4		<10		<1	51		111				
Dec. 11	10:00 a.m.					4		<10		1	39	95	111		0.1		
Dec. 11	11:45 a.m.					5		<10		<1	44	92	102		<.1		
Dec. 11	2:30 p.m.					5		<10		1	57	100	105		<.1		
Dec. 12	10:01 a.m.	1.4				3		<10		1	76	100	104		1.2		
Dec. 12	11:32 a.m.	.3				0		<10		1	55	120	127		.2		
Dec. 13	3:15 p.m.					9		<10		1	194		105				
Dec. 18	11:20 a.m.																
Dec. 18	1:20 p.m.																
Feb. 20, 1975	11:00 a.m.					5											
Feb. 20	1:00 p.m.																
Feb. 27	1:00 p.m.	<2.0			<2	5		<4	1			89	84		.6		
Feb. 27	3:30 p.m.	<2.0			<2	5	0	<4	0			100	102		1.1		

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.

(b) Tapwater

Date	Time	BOD$_5$[a]	BOD$_5$ with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, μmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Jan. 29, 1975	10:00 a.m.					17	1		2				730				
Jan. 29	11:00 a.m.					17	1		2				730				
Feb. 3	7:00 p.m.	<2			6	6	0	<10	24			720	750		<0.05		
Feb. 12	4:00 a.m.	<2			3	8	0	<10	4			590	720	0	<.05		
Feb. 12	9:00 a.m.	<2			8	12	0	<10	5			620	730	0	<.05		
Feb. 13	11:00 a.m.	<2			<2	5	0	<10	9			620	742		<.05		
Feb. 14	12:00 a.m.	<2			<2	20	2	<10	7			680	740		<.05		
Feb. 24	1:00 p.m.	<2			4	10	2	<4	10			670	775	0	<.05		
Feb. 25	10:00 a.m.	<2			<2	27		<4	6			660	760		1.10		

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.

TABLE X.- WATER MONITOR SYSTEM, LABORATORY 1, AND LABORATORY 2 DATA

[Results in milligrams per liter unless otherwise specified]

(a) Reverse osmosis effluent

Total phosphorus	Phosphate	Sulfate	Total hardness (as CaCO$_3$)^h			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
							13	13	15	22			5.4				12.9
							13	13	16	22			5.4				12.9
							13	13	15	25			5.4				12.5
							12	13	16	25			5.4				12.5
							13	13	13	20			5.4				12.5
							12	10	13	19			5.4				13.0
							13	9	13	20			5.4				12.4
							13	9	13	20		5.8	5.5				12.5
							19	13	16	22		5.2	5.1				12.5
							12	13	16	21			5.4				11.0
									7								
									7				5.6				
					10		12	20	10	17		7.1	6.8			9	11.5
			0		9	40	11	17	10	20	6.4	6.9	5.7				

(b) Tapwater

Total phosphorus	Phosphate	Sulfate	Total hardness (as CaCO$_3$)^h			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
			10		20			105		146	7.9		7.6		4.5	2	2.0
			12		20	88		105		146	6.8		7.6		1.3	4	2.0
			10	21	26	95	90	84	135	158	7.6	8.4	7.2	1.1	.1	8	4.8
			20	22	20	90	91	98	125	171		7.9	6.7	.6	1.2		1.2
			20	22	21	88	91	96	130	160	7.2	8.2	7.0	1.2	1.1		.9
			20	28	20	85	95	94	130	167	7.3	8.5	7.6		1.6		.8
			20	24	11		83	96	130	178	8.0	8.1	7.4	2.6	1.5	5	.7
			15	18	15	115	88	113	140	164	8.0	8.2	7.6	.2	.3	9	.9
				20	17		95	94	135	170		8.4	8.0		.5	4	1.1

TABLE X.- Continued

(c) Physical-chemical reactor effluent

Date	Time	BOD$_5^a$	BOD$_5$ with ATU^b	COD^c	TOC^d		Turbidity, Jtu			TSS^f	TDS^g	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS^e	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Dec. 12, 1974	3:01 p.m.					7		15		4	57	820	1000		1.0		
Dec. 13	12:10 p.m.					1		<10		2	792		1000				
Dec. 13	4:29 p.m.					18		<10		1	821		1000				
Dec. 18	12:15 p.m.					5		<10		12	37	920	1000		.7		
Jan. 9, 1975	12:00 m.	<2						10		7					.6		
Jan. 9	(i)	<2						<10		0					.7		
Jan. 13	Comp.^{j}	12						20			17				.5		
Jan. 14	11:00 a.m.			11	3		8	10	6			930	960		.2		
Jan. 14	Comp.	4						<10		6					.6		
Jan. 15	12:00 m.	3		75	4		2	<10	1		645	920	1000		.5		
Jan. 15	4:50 p.m.	4			4		1	<10	4		596	1020	1000		.6		
Jan. 15	Comp.	5						10		3					.6		
Jan. 16	3:00 p.m.	5			5			<10	3		568	890	1000		.7		
Jan. 17	12:00 m.	<2		5	2		2	<10	5		549	880	910	0.1	.9		
Jan. 17	Comp.	4						<10		8					.3		
Jan. 20	Comp.	7						<10		4					.7		
Jan. 21	Comp.	7						30		23					3.0		
Jan. 21	Comp.	5						10		5					1.8		
Jan. 23	Comp.	3						<10		2					1.0		
Jan. 23	Comp.	<2						<10		2					.6		
Jan. 24	6:00 p.m.	<2		11	2	2	10	<10	3		649	1000	990		.6		
Jan. 28	Comp.	3						20		4					.5		
Jan. 29	Comp.	<2						10		4					1.2		
Jan. 30	6:00 a.m.	2			0	3	0	15			655	980	1000		1.4		
Jan. 30	Comp.	2						15		2					1.2		
Jan. 31	6:00 a.m.	<2			0	14	0	<10			644	1000	1000		1.6		
Jan. 31	9:00 a.m.	<2			4	6	0	<10			616	1000	1000		.4		
Jan. 31	12:00 m.	<2		5	4	6	3	<10			626	1000			.4		
Jan. 31	Comp.	<2						<10		4					1.1		
Feb. 3	6:00 a.m.	5						<10		<1					.8		
Feb. 4	1:00 a.m.	<2		10	5	8	0	<10	35			1000	1000		<.05		
Feb. 4	6:00 a.m.	<2			7	6	1	<10	45			1100	1000		<.05		
Feb. 4	7:00 a.m.	<2			4	4	0	<10	29			1000	1000		.5		
Feb. 4	12:00 m.	4			4	6	5	<10	5			950	1000		1.1		
Feb. 4	Comp.	<2						<10		<1					<.05		
Feb. 4	Comp.	<2						<10		1					2.4		
Feb. 5	6:00 a.m.	2			3	5		<10	5			1000	1000		4.6		
Feb. 5	12:00 m.	24			12	20		<10	4			980	1000		4.5		
Feb. 5	10:00 p.m.	<2			4	5	3	<10	6			980	962		<.05		

[a] Biochemical oxygen demand.

[b] Allyl thiourea.

[c] Chemical oxygen demand.

[d] Total organic carbon.

[e] Water monitor system.

[f] Total suspended solids.

[g] Total dissolved solids.

[h] Calcium carbonate.

[i] No time; data lost.

[j] Comp. = composite; no specific time.

TABLE X.- Continued

(c) Physical-chemical reactor effluent

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
							127	187	190	278		7.0	7.4				19.8
							120	150		222			7.0				11.9
							118	158		250			7.2				10.0
							182	189	152			6.9	6.9				8.6
<0.05		250															
<.05		38															
.05		235															
			40	46	43	110	118	91	150	141	6.0	8.2	5.9	0		11.0	11.1
<.05		240															
			35	37	26	115	121	100	165		6.6	7.8	5.8				10.8
			50	58	41	140	153	125	175	182	6.3	7.8	7.1			12.0	9.7
<.05		188															
				39	34		120	95	165	163		7.9	6.3				9.6
			35	39	39	115	110	98	160	165	7.1	7.9	7.0				10.0
<.05		150															
<.05		200															
		212															
<.05		182															
<.05		172															
<.05		172															
			35	36	33	120	120	192	170	180	6.5	8.2	6.3			11.0	9.6
<.05		175															
<.05		170															
			25	40	45	125	125	170	180	179	7.1	7.6	6.2			10.0	9.2
<.05		165															
			30	34	46	120	120	130	155	182	7.4	8.1	7.3			10.0	9.7
			30	35	41	125	120	140	150	181	7.1	7.5	7.0			10.0	9.1
			35	34	39	125	125	157	155	186	7.1	7.7	7.5	.1	1.1	10.0	9.5
<.05		160															
<.05		205															
			55	59		133	135	74	160	183	6.0	8.1	6.2	9.0	4.0		
			55	62		135	140	108	160	197	6.5	8.2	6.4	7.0		11.0	
			40	44		118	120	138	165	188	6.5	8.2	6.3	.1			3.9
				40	49		118	148	165	163	6.6	6.5	6.1				
<.05		218															
<.05		203															
				36	37		123	142	170	167		6.9	6.6				
				37	40		120	149	175	183		8.0	6.8			8.0	7.2
				48	54		125	127	175	183		8.2	7.1				

TABLE X.- Continued

(c) Concluded

Date	Time	BOD$_5$[a]	BOD$_5$ with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Feb. 6, 1975	1:00 p.m.	<2			7			<10				980			2.3		
Feb. 6	2:30 p.m.			5													
Feb. 6	Comp.[j]	<2						15		5					1.3		
Feb. 6	(i)	<2						<10		4					.8		
Feb. 7	1:15 p.m.	<2			4	4	0	<10	4			920	1000		<.05		
Feb. 11	Comp.	8						.65		9					3.8		
Feb. 13	Comp.	7						10		2					4.6		
Feb. 14	Comp.	43						<10		2					27.5		
Feb. 18	12:30 p.m.			30										0.9			
Feb. 18	4:00 p.m.	7		75				<10		8				.15	1.0		
Feb. 18	7:00 p.m.	8		10				15		7				0	4.0		
Feb. 18	10:00 p.m.	7		75				10		7				0	.75		
Feb. 19	12:01 a.m.	<2			<2	6		<10	0			940	950		<.05		
Feb. 19	1:00 a.m.	6		25				<5		9				0	1.3		
Feb. 19	12:30 p.m.	8		25				<5		9				0	.8		
Feb. 19	4:00 p.m.	12		10				<5		8				0	.8		
Feb. 19	7:00 p.m.	11		20				<5		5				.3	1.2		
Feb. 19	10:00 p.m.	8						<4		5				.8	1.1		
Feb. 20	1:00 a.m.	5		10				<5		5				.7	1.1		
Feb. 20	9:30 a.m.			10										.4			
Feb. 21	8:00 a.m.	17						12		33					.8		
Feb. 21	12:00 m.	2						5		2					<.05		
Feb. 22	8:00 p.m.	12						24		45					1.2		
Feb. 22	8:00 p.m.	12						8		23					<.05		
Feb. 23	8:00 p.m.	9						14		23					<.05		
Feb. 24	8:00 a.m.	6						22		33					1.7		
Feb. 24	8:00 p.m.	15						17		24					24.5		
Feb. 25	8:00 a.m.	10						17		32					25.5		
Feb. 25	8:00 p.m.	3						8		32					7.0		
Feb. 27	Comp.	<2						<4		3							
Feb. 27	Comp.	2						38		51					7.5		
Feb. 28	11:00 a.m.	<2			<2	3		<4	9			880	1000		10.0		
Feb. 28	2:30 p.m.	<2			30	56		6				980	1000		115.0		
Feb. 28	Comp.	4						10		12					8.5		
Feb. 28	Comp.							6							6.5		

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.
[i] No time; data lost.
[j] Comp. = composite; no specific time.

TABLE X.- Continued

(c) Concluded

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)^h			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
				46			135		175			8.3					
<0.05		165															
<.05		175															
				45			128	126	175	205	7.5	7.7	6.4	7.5	1.3		
<.05		175															
<.05		155															
<.05		800															
<.05		190															
<.05		170															
<.05		170															
				60	71		110	221	145	183		7.8	5.7				
<.05		175															
.05		150															
<.05		175															
<.05		155															
<.05		165															
<.05		160															
.9		100															
<.05		135															
.9		105															
.3		145															
.2		190															
.1		135															
.1		295															
.4		190															
.1		225															
		178															
.4		210															
				46	58		95	150	165	177	6.4	7.1	5.7		1.0		
			65	65	51	110	111	118	165	182	6.7	6.7	6.7	4.0	10.0	12.0	9.0
.2		220															
.05																	

TABLE X.- Continued

(d) Carbon adsorption/filtration effluent

Date	Time	BOD_5[a]	BOD_5 with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Dec. 18, 1974	2:46 p.m.					5		10		3		820	1000		0.4		
Jan. 14, 1975	7:10 p.m.	6			4		5	10	2		597	870	985	0.9	.7		
Jan. 14	11:20 p.m.	4			3		2	10	17		621	900	1000		.8		
Jan. 15	6:00 a.m.	6			2		5	15	8		612	900	1000		.7		
Jan. 15	11:00 a.m.	3			4		3	10	6		627	920	1000		.7		
Jan. 15	7:50 p.m.	5			3		2	10	51		618	980	1000	.1	.7		
Jan. 15	10:50 p.m.	3			3		0	10	153		593	1000	1000		1.0		
Jan. 16	11:00 a.m.	<2			5		2	<10	1		597	1000	1000		.5		
Jan. 16	5:55 p.m.	6															
Jan. 16	10:55 p.m.	4			4		15	<10	3		521	900	998		.5		
Jan. 17	5:55 a.m.	6			4		2	<10	9		561				.3		
Jan. 17	11:00 a.m.	<2			3		2	<10	5		587	880	910		<.1		
Jan. 21	6:00 a.m.	8			5		5	<10	12		650	940	1000	1.4	1.1		
Jan. 21	12:00 p.m.	5			4		5	10	3			980	1000	3.5	2.4		
Jan. 22	6:00 a.m.	5			4		5	10	4		692	980	1000	3.2	1.8		
Jan. 22	12:00 p.m.	2			3		5	10	3		685	960	1000	1.6	1.0		
Jan. 23	6:00 a.m.	2			3	13	5	10	1		667	950	990		.8		
Jan. 23	12:00 p.m.	<2			2	3	5	<10	8		639	850	985		.5		
Jan. 24	6:00 a.m.	<2			4	5	8	<10	1		637	885	950		.6		
Jan. 24	11:00 a.m.	<2			3	5	5	<10	4		539	980	960		.4		
Jan. 24	4:00 p.m.	<2			2	0	5	<10	1		716	970	965		.4		
Jan. 28	6:00 a.m.	4			4	7	35	85	21		595	980	960		.6		
Jan. 29	6:00 a.m.	<2		25	4		30	50			611	970			2.5		

[a] Biochemical oxygen demand.

[b] Allyl thiourea.

[c] Chemical oxygen demand.

[d] Total organic carbon.

[e] Water monitor system.

[f] Total suspended solids.

[g] Total dissolved solids.

[h] Calcium carbonate.

TABLE X.- Continued

(d) Carbon adsorption/filtration effluent

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
							163	163	176	187		6.6	6.6				7.9
			40	39	37	105	114	155	150	174	6.4	7.8	6.1	0.02			11.0
			40	39	33	110	118	132	165	154	5.8	6.9	5.7	.04			8.8
			40	37	26	115	119	138	170	157	6.8	7.3	6.2				9.3
			40	36	29	115	122	113	165		6.8	7.9	6.1				
			50	45	42	130	158	153	175	173	5.9	7.8	6.6				9.7
			40	48	40	135	150	139	165	180	6.5	7.7	6.3				9.7
			40	44	39	125	135	232	175	152	6.5	7.6	6.6				
			30	40	33	113	115	102	160	157	5.9	7.9	6.8				9.5
			30	37	30	115	110	123	160	153	6.9	8.0	6.7				9.8
			30	37	3	120	114	111	165	171	6.6		6.8				9.8
			35	39	39	110	110	100	160	165	6.9	7.9	7.0				9.7
			20	43	44	120	115		175	163	6.0	7.9	5.8	0	2.0		10.0
			25	41	35	125	120	163	175	169	5.8	7.9	6.0		7.0		9.7
			30	38	31	120	122	155	180	171	6.4	7.8	5.9		9.8		9.7
			30	38	30	115	121	155	175	163	6.4	7.9	6.1		10.2		9.5
			25	37	27	125	120	131	175	167	6.4	7.9	5.9		9.0		10.2
			40	35	31	120	115	145	160	169	6.0	8.2	6.2		.5		9.7
			30	36	32	115	118	133	175	182	6.7	8.3	6.3		.4		9.8
			30	34	30	120	115	177	170	184	6.7	8.2	6.6		.4		9.7
			35	37	34	125	116	185	165	184	6.5	8.3	6.2		.3		9.5
			35	41	35	130	125	180	170	180	7.4	7.8	7.7		2.2		10.0
			40	38		135	120		170		7.4	7.3					

TABLE X.- Continued

(e) Clarifier effluent

Date	Time	BOD$_5$[a]	BOD$_5$ with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, μmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Jan. 14, 1975	11:50 p.m.	6			3		1	15	2		622	890	1000		1.3		
Jan. 15	4:00 a.m.	5			4		3	20	65			920	1000		.7		
Jan. 15	12:00 p.m.						0		86					0.3			
Jan. 16	4:55 a.m.	3			3		10	10	89		630	970	1000		1.1		
Jan. 16	5:55 a.m.	<2			4		5	<10	72		586	970	1000		1.7		
Jan. 16	11:55 p.m.	4			4		2	10	2		587	960	998		.7		
Jan. 16	11:55 p.m.	7			4		2	<10	2		558	890	998		1.0		
Jan. 17	4:55 a.m.	5			2		0	<10	4		558	900	990		.3		
Jan. 24	12:00 m.	4			4	13	65	<10	43		642	950	984		.5		
Jan. 24	2:00 p.m.	4			6	11	5	<10	6		656	940	960		.4		
Feb. 4	3:30 p.m.	10			9	12		<10	15			960	1000		1.1		
Feb. 4	6:00 p.m.	3			3	12		<10	8			940	1000		1.3		
Feb. 4	6:15 p.m.	11			11	12		<10	8			960	1000		2.7		
Feb. 5	1:00 a.m.	<2			4	21		<10	3			1000	1000		4.6		
Feb. 5	7:00 a.m.	8			9	20		<10	16			1000	1000		4.4		
Feb. 6	8:00 a.m.	<2			5	5	5	<10	23			950	1000		1.1		
Feb. 6	8:20 a.m.	<2			8	5	10	<10	10			960	1000		1.6		
Feb. 6	2:30 p.m.			15													
Feb. 6	11:00 p.m.	<2			4	13		<10	4			980	960		<.05		
Feb. 6	Comp.[j]	<2			3			<10				960			1.2		
Feb. 7	12:01 a.m.	6			12	15	10	10	7			900	950		1.2		
Feb. 7	6:00 a.m.	11			21	30	45	45	82			920	960		.9		
Feb. 7	8:38 a.m.	<2			10	20	8	<10	7			900	960		.8		
Feb. 7	12:15 p.m.	<2			11	20	5	<10	6			900	960		.9		
Feb. 10	(i)			15													
Feb. 11	4:00 a.m.	12			9	20	0	<10	8			920	1000		4.8		
Feb. 11	8:00 a.m.					12			1								
Feb. 11	2:00 p.m.	3			8	45	0	<10	1			700	980		1.8		
Feb. 11	8:00 p.m.	4			11	18	5	<10	1			700	940		2.2		
Feb. 11	10:00 p.m.	11			7	22		<10	1			870	950		4.6		
Feb. 11	Comp.	4			9			<10				720			2.7		
Feb. 11	(i)			20													
Feb. 13	5:00 a.m.				20	30	15	10	40			2100	1000		30.0		
Feb. 13	8:00 a.m.	44			15	20	18	20	38			1700	1000		25.5		
Feb. 13	6:00 p.m.	11			14	24		<10	3			1140	1000		22.0		
Feb. 13	12:00 p.m.				14	32		15	9			1140	1000		33.0		
Feb. 13	Comp.	44			15			20				1700			25.5		

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.
[i] No time; data lost.
[j] Comp. = composite; no specific time.

TABLE X.- Continued

(e) Clarifier effluent

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)^h			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
			40	38	34	115	118	128	170	163	6.7	7.8	6.3	0.10			8.6
			35	37	28	110	119	135	165	166	6.0	7.5	5.6	.18			8.0
			45		38	130		151			5.9		5.8	.5			7.6
			35	44	39	125	138	137	180	194	6.0	7.6	6.2				7.7
			40	45	34	125	140	126	170	194	6.7	7.8	6.6				7.7
				48	33	110	140	135	165	153	6.4	7.5	6.3				7.1
				37	33	110	115	135	160	153	6.4	7.8	6.3				7.1
			30	38		113	110	125	165	166	6.0	7.8	6.2				6.8
			40	35	30	120	117	168	170	180	6.0	8.1	6.1		0.8		8.4
			35	36	36	120	117	209	150	185	6.0	8.0	5.7		.7		8.4
				40	39		113	174	165	167		6.0	5.5		2.0		8.5
				39	37		115	162	165	174		6.6	6.6		.5		8.0
				40	37		115	162	165	174		6.1	6.1		1.0		8.0
				38	45		125	126	170	166		6.6	6.2		6.0		10.0
				37	41		125	148	170	175		6.2	6.0		17.0		8.0
				36			123	100	175	211	6.6	8.4	5.9		19.0	9.0	7.8
				40			120	100	175	211	6.9	8.1	5.9		16.0		8.0
				48			125	131	175	226		8.2	6.2		23.0		6.0
				38			120		180			8.2					
				37			118	148	175	214	6.7	7.9	6.1		23.0		6.0
				36			120	140	180	236	6.7	8.0	6.1		20.0		7.0
				36		123	123	102	175	232	6.4	7.5	6.1		14.0		7.0
				34		125	120	105	180	215	6.5	7.4	6.3		8.0	9.0	7.3
				37			115	196	165	208		7.6	6.2				
						120		184			6.0		5.9	0			7.5
			35	36	39	115	108	203	145	178		7.3	6.2			9	5.3
			35	34	41	125	113	166	140	183	6.6	7.3	6.2	0	35.0		5.5
				40			110	156	140	184		7.6	6.2		52.0		5.5
				34			115		145			7.3					
				960	110	200	205	331	165	167	8.3	8.7	8.0		<.1		4.0
				920	120		195	337	165	167		8.4	8.1			0	1.2
				880	129		160	325	165	164		9.8	9.8		<.1		4.9
				1080	91		145	356	175	186		9.2	9.0		<.1		5.1
				920			195		165			8.4					

TABLE X.- Continued

(e) Concluded

Date	Time	BOD$_5$[a]	BOD$_5$ with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, μmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Feb. 14, 1975	6:00 a.m.				13	38	10	15	9			1130	1000		30.5		
Feb. 14	(i)			100													
Feb. 15	12:00 p.m.																
Feb. 18	12:30 p.m.			30			8							1.0		5.0	
Feb. 18	4:00 p.m.			25			5							.4		3.5	
Feb. 18	7:00 p.m.			20			10							.3		3.8	
Feb. 18	10:00 p.m.			30			3							.5		4.5	
Feb. 19	1:00 a.m.			40			2							.7		3.5	
Feb. 19	12:30 p.m.			25			0							.2			
Feb. 19	4:00 p.m.			50		27	2		7				910	.2			
Feb. 19	7:00 p.m.			70		35	2		6				950	1.1			
Feb. 19	10:00 p.m.					33	0		4				990	1.3			
Feb. 20	1:00 a.m.			40		28	5		4				1000	1.0			
Feb. 20	9:30 a.m.			25		38	10		3				1000	.8			
Feb. 20	10:00 a.m.	3			3	38		<4	3			990	1000		<.05		
Feb. 20	12:00 m.						0										
Feb. 20	11:00 p.m.						10										
Feb. 21	6:00 a.m.	17			15	32	22	30	38			920	980		10.0		
Feb. 21	8:00 a.m.						20									.8	
Feb. 21	8:00 p.m.						25										
Feb. 22	8:00 a.m.						8										
Feb. 22	8:00 p.m.			0			10										
Feb. 23	8:00 a.m.						8										
Feb. 23	8:00 p.m.						8										
Feb. 24	8:00 a.m.						18										
Feb. 24	8:00 p.m.						20										
Feb. 25	8:00 a.m.						20										
Feb. 25	8:00 p.m.						18										

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.
[i] No time; data lost.

TABLE X.- Continued

(e) Concluded

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
			600	600	116	133	155	325	165	161	7.8	8.5	8.7		<0.1		4.6
			37			130					5.9			.05		10	
					70			150		170			5.5		.9		9.4
					65			180		170			5.6		8.1		8.7
					60			200		175			5.6		.4		8.1
	0.10				54			220		180			5.6		.3		8.2
	.13				53			230		180			5.6				8.9
				50	53		120	225	165	180		8.3	5.6				9.2
	.05																
	1.20				62			155		215			6.5		140.0		6.2
			40	50	55	115	125	126	160	210	7.1	8.6	7.1	0		9	8.9
	.90																
	.60																
	0																
	.20																
	.10																
	.10																
	.08																
	.05																
	.35																
	.20																

TABLE X.- Continued

(f) Denitrifier effluent

Date	Time	BOD$_5^a$	BOD$_5$ with ATU^b	COD^c	TOC^d		Turbidity, Jtu			TSS^f	TDS^g	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS^e	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Dec. 14, 1974	Comp.^{j}																3
Dec. 15	Comp.														1.5		1
Dec. 16	Comp.														1.4		1
Dec. 17	Comp.					16											2
Dec. 19	Comp.	7													.5		4
Dec. 19	Comp.	8															
Dec. 19	Comp.	12													.7		2
Dec. 20	Comp.					22											
Dec. 22	Comp.					29											
Jan. 6, 1975	12:00 m.	43													.9		2
Jan. 9	(i)	44													1.8		8
Jan. 13	Comp.	60													1.2		1
Jan. 14	Comp.	31													.8		5
Jan. 15	Comp.	95													.6		10
Jan. 16	Comp.	42													.8		3
Jan. 17	Comp.	58													1.4		1
Jan. 20	Comp.	193													3.7		1
Jan. 21	(i)	81													3.1		1
Jan. 21	Comp.	30													1.4		4
Jan. 23	Comp.	57													.8		15
Jan. 23	Comp.	24													2.0		3
Jan. 27	Comp.	62													.5		<1
Jan. 28	Comp.	35													1.0		<1
Jan. 29	Comp.	6													1.0		6
Jan. 30	Comp.	103													1.2		8
Jan. 31	Comp.	24													.9		4
Feb. 3	6:00 a.m.	95													3.0		1
Feb. 4	Comp.	124													3.8		2
Feb. 5	Comp.	149													4.3		2.5
Feb. 5	(i)													5.0			
Feb. 6	8:00 a.m.													2.1			
Feb. 6	10:30 a.m.													2.15		1.0	
Feb. 6	2:30 p.m.													1.0		1.0	
Feb. 6	Comp.	25													2.2		3.0
Feb. 6	(i)	58													1.3		<1
Feb. 10	(i)													.55		.3	
Feb. 11	Comp.	116													3.0		2.2
Feb. 11	Comp.	69			30			25				680			3.2		

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.
[i] No time; data lost.
[j] Comp. = composite; no specific time.

TABLE X.- Continued

(f) Denitrifier effluent

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
4.9		46															
3.0		55															
1.2		36															
1.7		38															
1.8		32															
1.9		26															
2.4		<5															
2.6		<5															
3.3		31															
1.8		23															
2.0		25															
1.9		17															
2.6		<5															
1.7		24															
3.2		38															
2.5		36															
2.5		31															
3.2		23															
2.5		46															
2.5		37															
2.2		28															
2.5		33															
1.9		<10															
				36			118		145			7.7					

TABLE X.- Continued

(f) Concluded

Date	Time	BOD_5[a]	BOD_5 with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Feb. 1 , 1975	(i)													5,5		0.4	
Feb. 12	(i)													1.5		.6	
Feb. 13	Comp.[j]	84													3.6		<1
Feb. 13	(i)													5.6		1.0	
Feb. 14	Comp.	39													3.8		<1
Feb. 14	(i)													4.5		1.0	
Feb. 18	12:30 p.m.	48												1.1	2.1	.3	<1
Feb. 18	4:00 p.m.							6						2.5		.1	
Feb. 18	7:00 p.m.													1.3		.1	
Feb. 18	10:00 p.m.													1.5		.05	
Feb. 19	1:00 a.m.													2.75		.2	
Feb. 19	12:30 p.m.													1.0		.5	
Feb. 19	4:00 p.m.													4.5		0	
Feb. 19, 1975	7:00 p.m.													1.5		0.0	
Feb. 19	10:00 p.m.													1.5		.2	
Feb. 20	1:00 a.m.													2.0		.3	
Feb. 20	9:30 a.m.	8												1.0	1.3	1.0	<1
Feb. 20	12:00 m.							6						.7		.8	
Feb. 20	11:00 p.m.													.4		.50	
Feb. 21	8:00 a.m.	39													1.1	.5	<1
Feb. 21	8:00 p.m.							6						.1		.4	
Feb. 22	8:00 a.m.	14												-.4	1.7	.5	<1
Feb. 22	8:00 p.m.													.15		1.0	
Feb. 23	8:00 a.m.	19						<4						.5	1.5	.8	<1
Feb. 23	8:00 p.m.													.5		.2	
Feb. 24	8:00 a.m.	65												1.0	1.3	.5	<1
Feb. 24	8:00 p.m.							25						17.5		.5	
Feb. 25	8:00 a.m.	77												18.8	25.5	1.0	<1
Feb. 25	8:00 p.m.							32						10.0		10.0	
Feb. 27	Comp.	7													8.5		1
Feb. 28	Comp.	17													8.5		<1

[a] Biochemical oxygen demand.

[b] Allyl thiourea.

[c] Chemical oxygen demand.

[d] Total organic carbon.

[e] Water monitor system.

[f] Total suspended solids.

[g] Total dissolved solids.

[h] Calcium carbonate.

[i] No time; data lost.

[j] Comp. = composite; no specific time.

TABLE X.- Continued

(f) Concluded

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)^h			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
2.2		10															
1.2		70															
1.4		25															
1.1		23															
3.8		80															
1.3		135															
.5		162															
		225															
.8		165															
1.5		<10															
2.0		31															

TABLE X.- Continued

(g) Biological reactor effluent

Date	Time	BOD$_5$[a]	BOD$_5$ with ATU[b]	COD[c]	TOC[d]		Turbidity, Jtu			TSS[f]	TDS[g]	Conductivity, μmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS[e]	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Dec. 14, 1974	Comp.[j]																15
Dec. 15	Comp.														55.0		1
Dec. 16	Comp.														1.9		3
Dec. 17	Comp.					16											12
Dec. 19	Comp.														.7		22
Dec. 19	Comp.														.8		16
Dec. 19	Comp.																
Dec. 20	Comp.					22											
Dec. 23	Comp.					23											
Jan. 9, 1975	(i)	10						15		12					.8		9
Jan. 9	12:00 m.	13						60		89					.9		13
Jan. 13	Comp.	23						30		19					.3		4
Jan. 14	Comp.	15						35		20					.4		7
Jan. 15	Comp.	16						25		24					.9		13
Jan. 16	Comp.	15						30		16					.7		8
Jan. 17	Comp.	13						30		16					2.7		7
Jan. 20	Comp.	42						20		15					.4		3
Jan. 21	Comp.	23						40		23					2.0		14
Jan. 21	Comp.	42						30		24					3.0		13
Jan. 23	Comp.	17						30		14					1.0		<1
Jan. 23	Comp.	17						10		16					4.6		11
Jan. 27	Comp.	58						20		65					1.3		<1
Jan. 28	Comp.	62						45		70					5.5		4
Jan. 29	Comp.	17						45		23					1.5		15
Jan. 30	Comp.	53						45		18					2.5		15
Jan. 31	Comp.	20						25		21					2.0		15
Feb. 3	6:00 a.m.	32						25		30					.4		11
Feb. 4	Comp.	24						30		15					.8		11
Feb. 5	Comp.	33						35		27					4.4		21
Feb. 5	(i)			60										4.0			
Feb. 6	8:00 a.m.													2.0			
Feb. 6	10:30 a.m.													3.25		12.5	
Feb. 6	2:30 p.m.			75										1.0		8.2	
Feb. 6	Comp.	26						35		28					1.8		12
Feb. 6	(i)	28						35		29					1.9		11
Feb. 10	(i)			60										.25		2.8	
Feb. 11	Comp.	34						35		25					3.7		13.6
Feb. 11	Comp.	29		107	21			30				670			2.8		

[a] Biochemical oxygen demand.

[b] Allyl thiourea.

[c] Chemical oxygen demand.

[d] Total organic carbon.

[e] Water monitor system.

[f] Total suspended solids.

[g] Total dissolved solids.

[h] Calcium carbonate.

[i] No time; data lost.

[j] Comp. = composite; no specific time.

TABLE X.- Continued

(g) Biological reactor effluent

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride		Sodium			pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
2.5		24															
3.7		56															
1.8		36															
1.7		36															
1.8		36															
1.4		24															
1.5		10															
.8		16															
1.9		25															
2.1		33															
1.8		16															
2.0		10															
2.5		<5															
2.2		24															
2.5		38															
2.5		39															
2.8		36															
2.2		33															
2.3		51															
2.9		35															
2.1		28															
2.8		26															
2.5		<10															
				36			120		140			7.9					

TABLE X.- Continued

(g) Concluded

Date	Time	BOD$_5^a$	BOD$_5$ with ATU^b	COD^c	TOC^d		Turbidity, Jtu			TSS^f	TDS^g	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS^e	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Feb. 11, 1975	(i)			70										4.5		14.0	
Feb. 12	(i)													1.15		13.0	
Feb. 13	Comp.^{j}	13						25		27					3.5		9
Feb. 13	(i)			80										5.0		14.0	
Feb. 14	01:00 p.m.	29			5	19			32			860	1000		.5		
Feb. 14	Comp.	22	10					25		16					4.4		22
Feb. 14	(i)			50										4.75		16.0	
Feb. 18	12:30 p.m.	11	8	50			18	25		32				1.0	<.05	6.0	5
Feb. 18	4:00 p.m.	16	8	50			10	35		35				.5	<.05	6.0	6
Feb. 18	7:00 p.m.	17	3	40			15	40		39				.05	<.05	6.0	4
Feb. 18	10:00 p.m.	12	3	50			20	35		23				.3	<.05	5.1	8
Feb. 19	1:00 a.m.	15	2	30			20	10		32				1.0	.5	5.0	8
Feb. 19	12:30 p.m.	7	8	60			15			29				.18			7
Feb. 19	4:00 p.m.	10	11	60			25	32		48				1.5	<.05		11
Feb. 19	7:00 p.m.	8	23	130			30	30		37				2.0	<.05		14
Feb. 19	10:00 p.m.	8	9	60			20	32		55				1.75	<.05		12
Feb. 20	1:00 a.m.	9	6	45			25	22		32				1.5	<.05		16
Feb. 20	9:30 a.m.	8	19	80			25	12		30				2.0	1.0		13
Feb. 20	12:00 m.	10	10	70			20	10		20				.8	1.0		13
Feb. 20	11:00 p.m.			20										.5			
Feb. 21	8:00 a.m.	11	5				15	10		17				.3	1.0		13
Feb. 21	8:00 p.m.	10	7				10	12		23				.6	.7		9
Feb. 22	8:00 a.m.	10	5				10	8		10				.1	.6		8
Feb. 22	8:00 p.m.	6	9				10	8		15				.1	<.05		3
Feb. 23	8:00 a.m.	5	4				5	8		12				.4	1.0		3
Feb. 23	8:00 p.m.	6	3				10	20		27				0	<.05		2
Feb. 24	8:00 a.m.	5	<2				20	16		33				1.2	1.0		2
Feb. 24	8:00 p.m.	12	12				20	20		28				37.5	22.0		3
Feb. 25	8:00 a.m.	13	11	50			30	14		34				25.0	24.5		3
Feb. 25	8:00 p.m.	2	.2					12		24				8.75	7.5		11

[a] Biochemical oxygen demand.

[b] Allyl thiourea.

[c] Chemical oxygen demand.

[d] Total organic carbon.

[e] Water monitor system.

[f] Total suspended solids.

[g] Total dissolved solids.

[h] Calcium carbonate.

[i] No time; data lost.

[j] Comp. = composite; no specific time.

TABLE X.- Continued

(g) Concluded

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
2.0		23															
			80	90	120	115	105	100	155	205	8.2	8.0	7.8		6.5		
1.4		55															
		32															
1.3		41															
2.0		41															
2.0		41															
1.5		44															
1.4		24															
1.7		24															
4.9		24															
2.4		24															
3.0		22															
2.3		27															
1.7		24															
1.4		27															
.6		80															
.9		119															
.3		147															
.4		143															
.3		180															
.4		180															
.1		130															
.2		270															
.5		175															
.2		210															

TABLE X.- Continued

(h) Biological reactor influent

Date	Time	BOD$_5^a$	BOD$_5$ with ATU^b	COD^c	TOC^d		Turbidity, Jtu			TSS^f	TDS^g	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 1	Lab 2	WMS^e	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Dec. 12, 1974	03:10 p.m.							1000		752	84	1000			21.0		
Dec. 14	Comp.^{j}																2
Dec. 15	Comp.																9
Dec. 16	Comp.																4
Dec. 17	Comp.					56											1
Dec. 19	Comp.	71													21.0		3
Dec. 19	Comp.	69															
Dec. 19	Comp.	72													27.5		1
Dec. 20	Comp.					33											
Dec. 23	Comp.					63											
Jan. 9, 1975	12:00 m.	7						20		10					20.5		3
Jan. 9	(i)	37						65		117					23.0		3
Jan. 13	Comp.	187						140		276					.7		3
Jan. 14	Comp.	110						100		186					19.0		<1
Jan. 15	Comp.	64						85		166					20.0		<1
Jan. 16	Comp.	64						75		113					17.0		<1
Jan. 17	Comp.	62						75		50					17.0		<1
Jan. 20	Comp.	178						70		126					14.0		1
Jan. 21	Comp.	58						110		131					24.0		1
Jan. 21	Comp.	93						90		148					21.5		<1
Jan. 23	Comp.	67						75		119					23.5		<1
Jan. 23	Comp.	61						35		159					37.0		<1
Jan. 27	Comp.^{k}	15						10		14					1.9		3
Jan. 28	Comp.	77						50		113					13.0		2
Jan. 29	Comp.	109						110		324					22.5		<1
Jan. 30	Comp.	211						115		222					30.0		<1
Jan. 31	Comp.	88						75		139					22.0		<1
Feb.3	6:00 a.m.	103						45		110					10.5		3
Feb. 4	Comp.	63						65		135					14.5		4
Feb. 5	Comp.	81						85		119					26.5		4
Feb. 5	(i)			160										15.0			1
Feb. 6	10:30 a.m.													20.0		1.5	
Feb. 6	Comp.	88						105		216					23.0		1
Feb. 6	(i)	132						95		231					15.0		1
Feb. 6	2:30 p.m.			300										16.8		3.5	
Feb. 10	(i)			60										5.0		3.8	
Feb. 11	Comp.	100						50		190					16.5		5.1
Feb. 11	Comp.	108			48			75				750			22.5		
Feb. 11	(i)			90										7.5		1.2	

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.
[i] No time; data lost.
[j] Comp. = composite; no specific time.
[k] 12 hr.

TABLE X.- Continued

(h) Biological reactor influent

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
							140		120			7.5					
		63															
4.0		25															
3.5		30															
4.3		31															
4.2		38															
2.8		24															
3.5		5															
2.9		25															
4.2		25															
4.8		28															
3.7		5															
3.7		5															
.8		26															
4.1		26															
4.5		35															
6.0		32															
4.8		30															
2.3		16															
4.9		53															
4.3		26															
4.1		26															
5.3		31															
3.9		24															
				36			123		150			7.7					

TABLE X.- Concluded

(h) Concluded

Date	Time	BOD$_5^a$	BOD$_5$ with ATU^b	COD^c	TOC^d		Turbidity, Jtu			TSS^f	TDS^g	Conductivity, µmhos/cm		Nitrogen, ammonia (as N)		Nitrogen, nitrate (as N)	
		Lab 2	Lab 2	Lab 2	Lab 2	WMS^e	Lab 1	Lab 2	WMS	Lab 2	Lab 2	Lab 2	WMS	Lab 1	Lab 2	Lab 1	Lab 2
Feb. 12, 1975	(i)			155										4.0		2.2	
Feb. 13	Comp.^{j}	63						115		156					27.5		1
Feb. 13	(i)			130										16.9		1.5	
Feb. 14	Comp.	72	81					165		117					24.0		<1
Feb. 14	(i)			200										14.4		1.8	
Feb. 18	12:30 p.m.	53	6	200			70	85		170				10.0	6.0	3.0	1
Feb. 18	4:00 p.m.	53	9	360			50	200		340				11.3	9.0	2.0	2
Feb. 18	7:00 p.m.	27	8	290			105	135		304				7.5	9.0	2.0	<1
Feb. 18	10:00 p.m.	14	2	180			70	135		286				8.8	7.0	1.5	1
Feb. 19	1:00 a.m.	8	12	170			80	40		286				9.4	7.5	1.3	<1
Feb. 19	12:30 p.m.	12	8	200			25	24		94				6.3	6.5	1.3	1
Feb. 19	4:00 p.m.	60	53	475			180	118		402				18.8	20.0	1.5	3
Feb. 19	7:00 p.m.	42	32				50	134		386				18.8	19.0	.5	2
Feb. 19	8:00 p.m.	29	45					70		186					17.5		<1
Feb. 19	10:00 p.m.	81	20	280			115	113		348				20.0	17.0		2
Feb. 20	1:00 a.m.	18	11	250			80	82		224				17.5	17.0		1
Feb. 20	9:30 a.m.	18	21	80			30	14		44				16.3	15.0		<1
Feb. 20	12:00 m.	85	80	450			60	44		264				18.8	19.5		3
Feb. 20	11:00 p.m.						70							18.8			
Feb. 21	8:00 a.m.	32	11				50	23		86				9.5	9.5		<1
Feb. 21	8:00 p.m.						80							18.8			
Feb. 22	8:00 a.m.	5	7				100	84		224				13.8	13.0		1
Feb. 22	8:00 p.m.	42	8				40	20		72				11.3	8.5		<1
Feb. 23	8:00 a.m.	7	8				100	78		186				8.8	7.0		1
Feb. 23	8:00 p.m.	6	5				25	12		46				3.8	6.0		2
Feb. 24	8:00 a.m.	30	5				220	10		26				4.5	2.5		<1
Feb. 24	8:00 p.m.	79	50				250	113		602				45.0	35.0		3
Feb. 25	8:00 a.m.	37	21	150			110	56		146				25.0	35.0		<1
Feb. 25	8:00 p.m.	31	28				90	79		306				22.5	20.0		<1

[a] Biochemical oxygen demand.
[b] Allyl thiourea.
[c] Chemical oxygen demand.
[d] Total organic carbon.
[e] Water monitor system.
[f] Total suspended solids.
[g] Total dissolved solids.
[h] Calcium carbonate.
[i] No time; data lost.
[j] Comp. = composite; no specific time.

TABLE X.- Concluded

(h) Concluded

Total phosphorus	Phosphate	Sulfate	Total hardness (as $CaCO_3$)[h]			Chloride			Sodium		pH, units			Free chlorine		Dissolved oxygen	
Lab 2	Lab 1	Lab 2	Lab 1	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 2	WMS	Lab 1	Lab 2	WMS	Lab 1	WMS	Lab 1	WMS
4.1		50															
3.0		83															
4.0		32															
8.2		33															
6.2		34															
5.0		36															
7.5	3.75	18															
2.8		23															
7.0		10															
7.3		10															
3.0	3.0	31															
8.4	0	23															
7.5	3.75	18															
2.0	3.5	24															
4.0	6.0	21															
	1.5																
1.1	3.5	10															
	4.5																
2.9	0	195															
3.0	3.0	31															
2.2	.2	175															
.9	1.5	22															
1.0	.13	10															
4.2	10.0	28															
5.0	9.0	10															
3.7	5.0	34															

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