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TER QUALITY ANALYSIS UNIT-PURIFICATION (WQAU-P)
TIPARAMETER SENSOR

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tract No. DAAK70-86-C-0106

Distribution Statement

DISTRIBUTION STATEMENT A

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pared for

ARMY RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
Belvoir, VA 22060-5606

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS None	
2a. SECURITY CLASSIFICATION AUTHORITY N/A		3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; Distribution Unlimited	
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE N/A			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) MER-0106-FM-8666-95		5. MONITORING ORGANIZATION REPORT NUMBER(S) N/A	
5a. NAME OF PERFORMING ORGANIZATION Foster Miller, Inc.	6b. OFFICE SYMBOL (If applicable) N/A	7a. NAME OF MONITORING ORGANIZATION Belvoir Research, Development and Engineering Center	
5c. ADDRESS (City, State, and ZIP Code) 350 Second Ave. Waltham, MA 02254		7b. ADDRESS (City, State, and ZIP Code) Fort Belvoir, VA 22060	
8a. NAME OF FUNDING / SPONSORING ORGANIZATION Same as block 7a.	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAK70-86-C-0106	
5c. ADDRESS (City, State, and ZIP Code) Same as block 7b.		10. SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO. 64717A	PROJECT NO. Customer
		TASK NO. DL39-46	WORK UNIT ACCESSION NO. EF
11. TITLE (Include Security Classification) Water Quality Analysis Unit - Purification Multiparameter Sensor			
12. PERSONAL AUTHOR(S) Leslie S. Rubin and Gerald Avarbock			
3a. TYPE OF REPORT Final Report	13b. TIME COVERED FROM 86/9/29 TO 87/9/25	14. DATE OF REPORT (Year, Month, Day) 87/12/15	15. PAGE COUNT
16. SUPPLEMENTARY NOTATION None			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	
09	03		
06	17		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The multiparameter sensor of the Water Quality Analysis Unit-Purification (WQAU-P) developed under contract DAAK70-85-C-0022 was replaced by a specially designed Foster-Miller, Inc., multiparameter sensor that is capable of measuring temperature, pH, TDS and turbidity. The original WQAU-P circuitry for these parameters as well as the microprocessor software was revised/redesigned. The high level of instrument automation incorporated into the WQAU-P design allows trained users to complete a calibration and measurement sequence in less than 5 minutes. The end product is capable of providing the quantitative measurements needed to establish the effectiveness of a Reverse Osmosis Water Purification Unit (ROWPU) and/or determine the treatability of a raw water source. The WQAU-P occupies 2.0 cubic feet and weighs 46 pounds.			
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☒ DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Leslie S. Rubin		22b. TELEPHONE (Include Area Code) (617) 890-3200	22c. OFFICE SYMBOL

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SUMMARY

↙ The U.S. Army, as well as other military branches, uses a Water Quality Analysis Set/Purification to determine the treatability of a raw water source and/or monitor the performance of a water purification system. This water quality analysis set weighs in excess of 55 lb, occupies approximately 4.4 ft and uses wet chemistry in the analysis process. Personnel must be well trained to perform these analytical procedures and normally require 45 to 60 min to perform a complete measurement routine which includes temperature, pH, TDS, turbidity and residual chlorine. With extensive user involvement, this wet chemistry approach is subject to human error. Replacement of the active chemicals also presents a materials logistics problem.

In an effort to reduce the weight, size and operational complexity of the WQAS/P, Foster-Miller, Inc. initially developed a Phase I prototype Water Quality Monitor (WQM) that demonstrated instrument feasibility. The successful Phase I WQM was then redesigned into a Phase II militarized unit. This Phase II unit, the Water Quality Analysis Unit - Purification (WQAU-P), like the Phase I WQM combined state-of-the-art electronic monitoring instrumentation with a powerful microprocessor. Calibration and measurement operations were greatly simplified. Personnel experienced in the WQAU-P's operation could perform a complete calibration and measurement sequence in less than 5 min. The potential for human error was greatly reduced by eliminating wet chemistry analyses and incorporating electronic calibration algorithms.

The Phase II WQAU-P, while meeting many of the contract goals, required improvements in two specific areas:

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- An improved multiparameter sensor to replace the commercially available Horiba Model U-7 sensor that measured temperature, pH, TDS and turbidity
- An improved case design to better withstand rough handling and harsh environments.

The follow-on Phase III WQAU-P contract (awarded to Foster-Miller) provided for the circuitry development and engineering needed to integrate the Foster-Miller multiparameter sensor into the existing Phase II WQAU-P and the redesign of the WQAU-P case.

The Phase III WQAU-P is shown in Figure S-1 in its closed/portable configuration. The WQAU-P weighs 6 lb and occupies 2.0 ft. The open WQAU-P with its new multiparameter sensor, existing chlorine sensor and accessories is shown in Figure S-2.

The ranges and sensitivities for each of the Phase III WQAU-P's parameters are listed in Table S-1.

The multiparameter sensor houses four of the five WQAU-P parameters (temperature, pH, TDS and turbidity). Compared to the troublesome multiparameter sensor used with the Phase II WQAU-P, this new multiparameter sensor provides the following advantages:

- Extended parametric range
- Increased accuracy
- Reduced maintenance/servicing

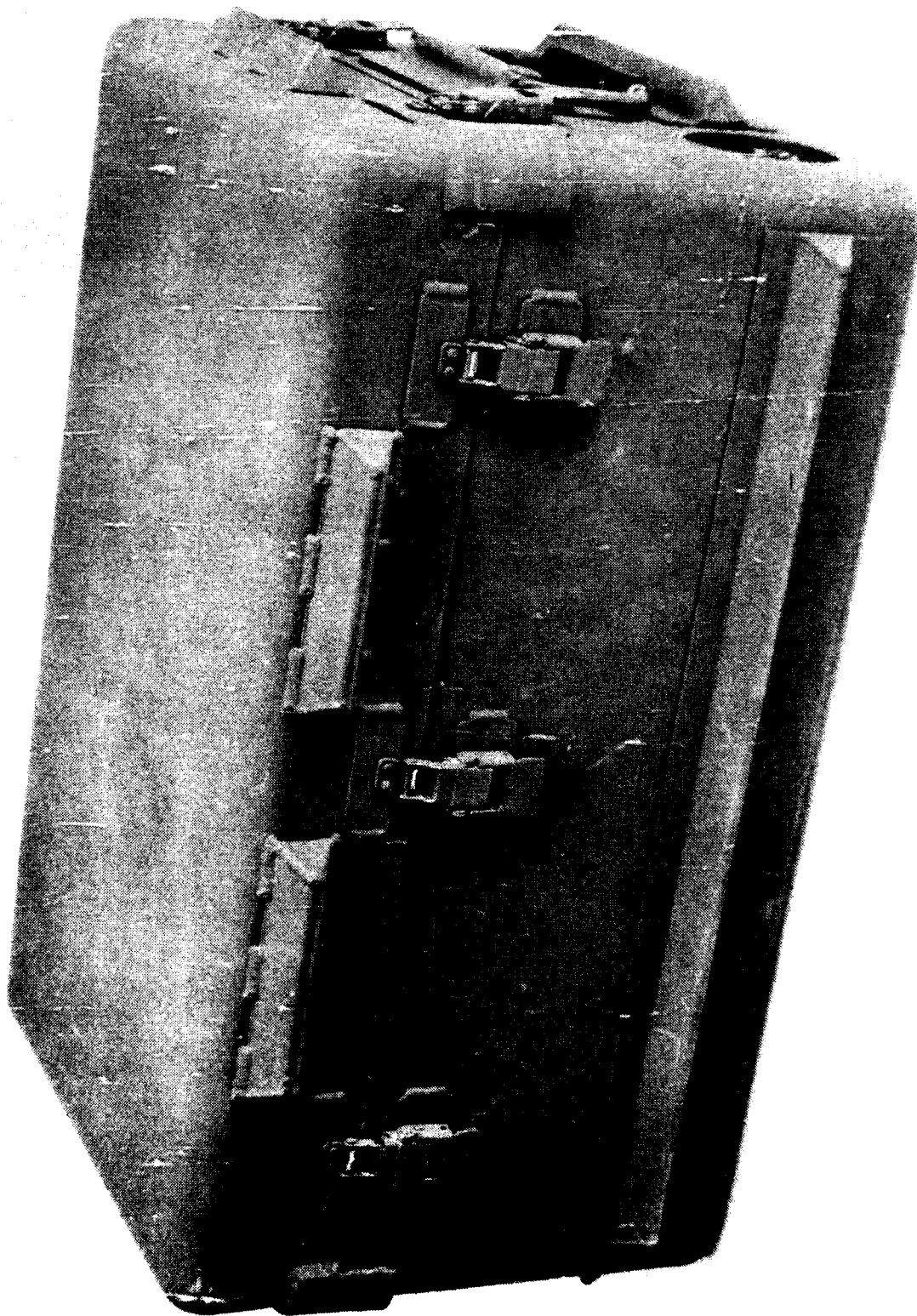


Figure S-1. WQAU-P in Closed Configuration

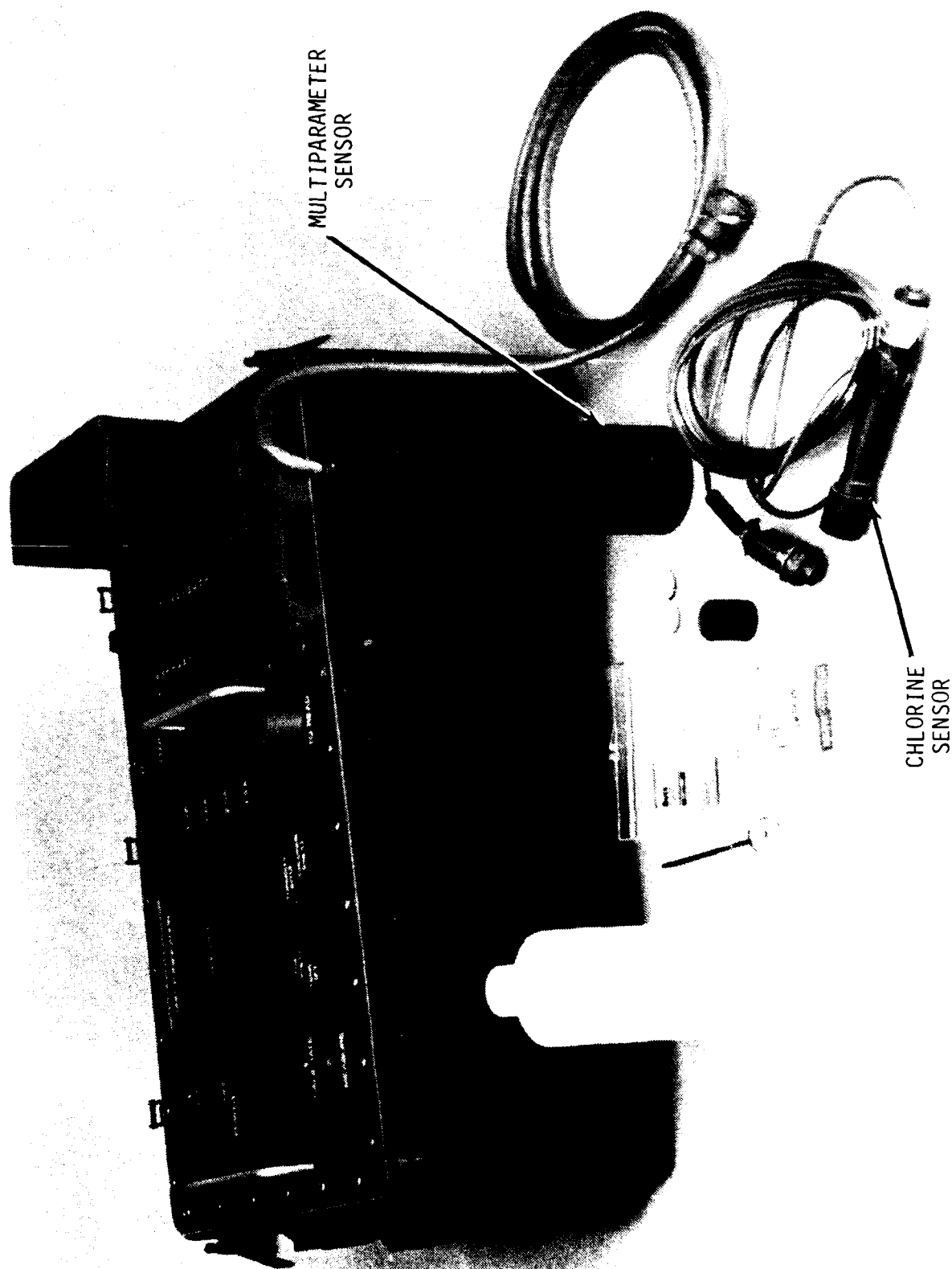


Figure S-2. WQAU-P with Top Cover Removed

Table S-1. Specifications for WQAU-P Parameters

<u>Parameter</u>	<u>Range</u>	<u>Accuracy</u>
Temperature (air)	0-160°F	±2°F
Temperature (water)	32-120°F	±2°F
pH	2-12 pH units	±0.5 pH units
Total Dissolved Solids	5,000-50,000 mg/l	±2,500 mg/l
	500- 5,000 mg/l	± 250 mg/l
	10- 500 mg/l	± 25 mg/l
Turbidity	0- 50 NTU	± 5 NTU
	50- 150 NTU	± 10 NTU
Chlorine Residual	1- 15 mg/l	± 1 mg/l
		(at pH less than 9)
(All water quality parameters must be measurable at fluid temperatures between 32°F and 120°F.)		

The multiparameter sensor is equipped with an outer housing that provides two functions:

- Sensor protection during storage and transport
- Calibration fluid container used during WQAU-P field calibration

The temperature, pH and TDS probes are replaceable elements. Figure S-3 illustrates the exact location of each multiparameter probe. Each of the replaceable probes are locked into the multiparameter sensor body by a spanner nut that is backed with a special gasket to provide a watertight assembly.

Since the multiparameter sensor is designed for submersible operation and does not utilize the outer housing during measurement operations, a light shield as shown in Figure S-4 is used to protect the light sensitive turbidity sensors (photo-diodes) from ambient light. This light shield can be removed to accommodate sensor cleaning.

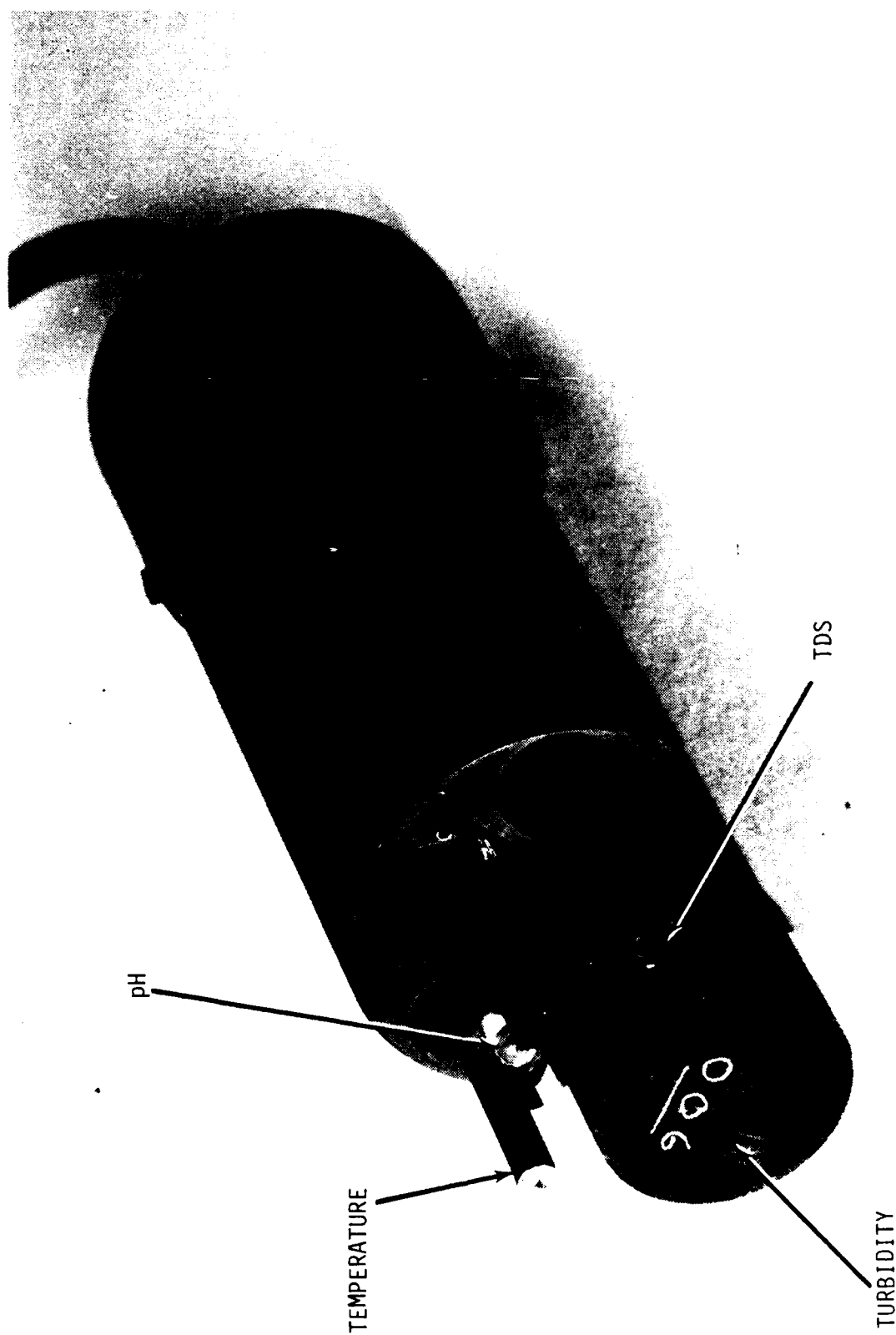


Figure S-3. Multiparameter Sensor



Figure S-4. Multiparameter Sensor with Turbidity
Light Shield Removed

The WQAU-P case/enclosure was also modified during this contract to provide better transit drop (4 ft), EMP and chemical/biological decontamination protection. Primary modifications included:

- Adding six case latches (two each, front and back, one on each side)
- Adding guard rails to all sides of lower case and cover
- Replacing case handles with handles that lock at 90 deg for ease in handling and are spring tensioned to lie flush with case side when not in use
- Adding corner shearlocks to corners of cover
- Replacing the existing EMP gasket with a solid core silver impregnated EMP gasket
- Adding 16 control panel screws.

Operation of the WQAU-P begins with the field calibration procedure. Temperature and TDS are calibrated with dry sensors. Turbidity, pH and residual chlorine are calibrated using the only calibration fluid carried in the WQAU-P (one 500 ml bottle of buffer solution). Calibration is accomplished by setting the parameter switch to the appropriate parameter, placing the calibrate/measure switch to the calibration position, keeping the sensor dry or placing it in the calibration fluid (depending on the parameter being calibrated), and pressing the read button once for each parametric calibration.

The measurement sequence is performed by placing the appropriate sensor in the fluid to be monitored, placing the calibrate/measure switch in the measure mode, selecting the

appropriate parameter on the selector switch and pressing the read button for each measurement.

Each of the WQAU-Ps with individual multiparameter sensors were subjected to an extended matrix of tests. This validation test matrix and validation test results are summarized in Table S-2. More than 5400 measurements were taken/recorded with the Phase III WQAU-P. Over 95 percent of the readings fell within the accuracy requirements for the parametric measurements. The multiparameter sensor provided over a 97 percent accuracy rate. Residual chlorine was less impressive, logging an 89 percent accuracy rate.

Phase III WQAU-P conclusions/recommendations, as summarized below, reflect Foster-Miller's WQAU-P experience generated during fabrication, assembly, validation testing and field service activities.

- Even though 97 percent of all multiparameter sensor measurements obtained during validation testing were within the contractual accuracy tolerances, various mechanical improvements can be made to improve the sensor's performance. Components requiring redesign include:
 - The seal between the interchangeable probes and the body of the multiparameter sensor (eliminate leakage)
 - The electrical connector for the temperature and TDS probes (easier assembly)
 - The TDS probe (eliminate internal fluid trap that can cause sample contamination)

Table S-2. Summary of Validation Testing

WQAU-P/Multiparameter Sensor		1/1	3/8	6/5	7/4	5/3	4/6	Cumulative Average	
Parameter	Standards Tested	Numbers of Total Readings/Percent Correct							
		Required Accuracy							
Temperature	320°F, 68°F 100°F, & 120°F	±2°F	83/94	78/99	78/96	84/96	86/98	84/99	493/97
Extreme Temperature	10°F, 20°F 140°F, & 160°F	±2°F	40/98	40/75	40/85	40/95	40/60	40/98	240/85
Total Dissolved Solids*	50 & 100 mg/l 500, 1,500, & } 3,000 mg/l 30,000 & } 50,000 mg/l	±25mg/l ±250 mg/l ±2,500 mg/l	280/100	280/98	280/93	280/100	280/100	280/100	1,680/98
pH*	4, 7 & 10	±0.5	120/100	120/100	120/100	120/100	120/100	120/100	720/100
Turbidity*	3, 10 & 50 NTU 100 & 150 NTU	±5 NTU ±10 NTU	200/99	200/99	200/98	200/89	200/97	200/90	1,200/95
Residual** Chlorine	1, 7.5 & 15 mg/l at pH 5.5 & 7.0	±10 mg/l	180/78	180/85	180/93	180/92	180/97	180/88	1,080/89

* Standards tested at temperatures of 32°F, 68°F, 100°F, and 120°F.

**Standards tested at temperatures of 32°F, 68°F, and 90°F.

* Standards tested at temperatures of 32°F, 68°F, 100°F, and 120°F.

**Standards tested at temperatures of 32°F, 68°F, and 90°F.

- The turbidity probe (accommodate deeper submersion into sample chamber)
- The pH probe (protective enclosure for probe tip)
- The modified WQAU-P case with the improved EMP gasket successfully passed the EMP tests conducted at White Sands. No further action is required
- EMI, transit drop, chemical/biological decontamination and shock tests were not conducted prior to the publication date of this final report. Completion of these tests would be very useful in guiding further WQAU-P design activities
- Residual chlorine measurement technique/sensor needs to be investigated further.

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PREFACE

This report details the engineering activities that were performed in integrating the Foster-Miller multiparameter sensor into the Phase II WQAU-P developed under contract DAAK70-85-C-0022 and in modifying the outer case to improve the WQAU-P's ability to survive in harsh environments. The work has been performed by Foster-Miller, Inc. of Waltham, MA under contract DAAK70-86-C-0106 for the Fuel and Water Supply Division of the U.S. Army Belvoir Research, Development and Engineering Center.

The contract has been administered by Mr. Robert E. Tobey, Procurement Contracting Officer, and Mr. Robert S. Spratling, Contract Specialist. Technical support and assistance has been provided by Mr. Gerald Eskelund, Team Chief for the Water Technology Division, and by Ms. Janet Hall and Mr. Amos Coleman, Contracting Officer's Representatives.

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TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1. INTRODUCTION.....	1
2. WQAU-P PARAMETERS.....	5
2.1 Standard Parameters.....	5
2.1.1 Total Dissolved Solids.....	5
2.1.2 pH.....	6
2.1.3 Turbidity.....	7
2.1.4 Temperature.....	7
2.1.5 Residual Chlorine.....	8
2.2 Optional Parameters.....	8
2.2.1 Chlorides.....	8
2.2.2 Sulfates.....	9
3. MEASURING METHODOLOGIES.....	11
3.1 Standard Parameters.....	11
3.1.1 Total Dissolved Solids.....	11
3.1.2 pH.....	12
3.1.3 Turbidity.....	13
3.1.4 Temperature.....	14
3.1.5 Free Residual Chlorine.....	15
3.2 Optional Parameters.....	16
3.2.1 Chlorides.....	16
3.2.2 Sulfates.....	17
4. MULTIPARAMETER SENSOR.....	21
4.1 Multiparameter Assembly.....	21
4.2 Multiparameter Sensors.....	26
4.2.1 Total Dissolved Solids.....	26
4.2.2 pH.....	28
4.2.3 Turbidity.....	29
4.2.4 Temperature.....	33

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
5. WQAU-P DESIGN.....	37
5.1 WQAU-P Specifications.....	37
5.1.1 Parametric Specifications.....	37
5.1.2 Design Criteria.....	38
5.2 Mechanical Design.....	38
5.2.1 Sensor/Accessory Compartment.....	42
5.2.2 Electrical Compartment.....	46
5.3 Electrical Design.....	49
5.3.1 Sensor Control Circuit Board.....	49
5.3.2 Display Circuit Board.....	54
5.3.3 I/O Circuit Board.....	54
5.3.4 CPU Circuit Board.....	57
5.3.5 Memory Expansion Circuit Board.....	57
5.3.6 Power Supply Circuit Board.....	61
5.4 Software.....	61
5.5 Processing Algorithms.....	63
5.5.1 Turbidity.....	64
5.5.2 TDS.....	65
5.5.3 Free Available Chlorine.....	66
6. WQAU-P OPERATIONS.....	69
7. RESULTS OF WQAU-P VALIDATION TESTING.....	71
8. CONCLUSIONS.....	75
9. RECOMMENDATIONS.....	77
APPENDIX A - WQAU-P SOFTWARE.....	A-1

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
4-1	Foster-Miller Multiparameter Sensor.....	22
4-2	Multiparameter Sensor Components and Tool.....	23
4-3	Location of Sensor Elements.....	25
4-4	Multiparameter Sensor with TLS Removed.....	27
4-5	Conductivity (TDS) Sensor.....	28
4-6	pH Sensor.....	29
4-7	Turbidity Sensor.....	30
4-8	Four Beam Turbidity Sensor.....	34
4-9	Influence of Fluid Temperature on Turbidity.....	34
4-10	Temperature Sensor.....	35
5-1	WQAU-P in Closed Configuration.....	40
5-2	Case Guard Rails.....	41
5-3	Case Handles.....	42
5-4	WQAU-P with Top Cover Removed.....	43
5-5	WQAU-P Sensors/Accessories.....	43
5-6	Free Available Residual Chlorine Sensor.....	44
5-7	Multiparameter Sensor Connector.....	46
5-8	WQAU-P Power Connector.....	47
5-9	Control Panel.....	47
5-10	Schematic of Sensor Control Circuit Board.....	50
5-11	Schematic of Sensor Control Circuit Board.....	51
5-12	Schematic of display Circuit Board.....	55
5-13	Schematic of Pro-Log I/O Circuit Board.....	56
5-14	Schematic of Pro-Log CPU Circuit Board.....	58
5-15	Schematic of Memory Expansion Circuit Board.....	59
5-16	Schematic of Memory Expansion CB (continued)....	60
5-17	Schematic of Power Supply Circuit Board.....	62
5-18	Distribution of Hypochlorous Acid and Hypochlorite Ion in Water at Different pH Values and Temperatures.....	67

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1. INTRODUCTION

The objective of this contract was to replace the Horiba multiparameter sensor that was integrated into the WQAU-P developed under contract DAAK70-85-C-0022 with a specially designed Foster-Miller multiparameter sensor that is capable of measuring temperature, pH, TDS and turbidity. To achieve this objective the existing circuitry for these parameteric measurements as well as the microprocessor software had to be redesigned/revised. The ultimate goal was the development of a WQAU-P that is capable of providing the quantitative measurements needed to establish the effectiveness of a Reverse Osmosis Water Purification Unit (ROWPU) and/or determine the treatability of a raw water source.

The desired ranges and sensitivities of each parameter, as set forth in the contract, are listed in Table 1-1.

Table 1-1. Specifications for WQAU-P Parameters

<u>Parameter</u>	<u>Range</u>	<u>Accuracy</u>
Temperature (air)	0 - 160°F	+ 2°F
Temperature (water)	32 - 120°F	+ 2°F
pH	2 - 12 pH units	+ 0.5 pH units
Total Dissolved Solids	5,000 - 50,000 mg/l	+ 2,500 mg/l
	500 - 5,000 mg/l	+ 250 mg/l
	10 - 500 mg/l	+ 25 mg/l
Turbidity	0 - 50 NTU	+ 5 NTU
	50 - 150 NTU	+ 10 NTU
Chlorine Residual	1 - 15 mg/l	+ 1 mg/l
(at pH less than 9)		
<u>Expandable Parameters</u>		
Chloride	10 - 1,500 mg/l	+ 10%
Sulfate	0 - 3,000 mg/l	+ 10%
(All water quality parameters must be measurable at fluid temperatures between 32°F and 120°F)		

In addition to these parametric requirements, there were various qualitative and quantitative criteria which influenced the design of the WQAU-P multiparameter sensor. These design parameters/considerations include:

- Capable of being stored in ambient air temperatures that range from -20°F to 160°F
- Compatible and functional with the WQAU-P including weight and size of the configuration developed under contract DAAK70-85-C-0022
- Modular in design to permit the replacement of a single parametric sensor for troubleshooting or repair.

The six WQAU-Ps delivered as GFE to the contactor were required to meet the following criteria:

- Time to complete a complete set of analyses (except chemical agent analyses) including standardization, must be less than 5 min
- One internal battery rechargeable by 12 and/or 24V dc or 24V dc or 110 and/or 220V ac shall be capable of providing 50 complete analyses between recharging operations
- The WQAU-P case must meet the requirements of high altitude electromagnetic pulse (HAEMP) protection as defined in AR 70-60 Nuclear Survivability of Army Material and impact resistance from shock effects of transit drop as specified in MIL-STD-810D paragraph 516.3 and aerial landing of 20 G's for a duration of 75 msec

- The WQAU-P cases must have a chemical agent resistant coating
- The WQAU-P must be capable of operating in climatic categories basic and hot as defined in AR 70-38
- The WQAU-P must conform with the applicable portions of Human Factors Engineering regulations as stated in MIL STD 1472. The WQAU-P is required to be operable and maintainable by soldiers who are dressed in Mission Oriented Protective IV ensemble
- The WQAU-P control panel gasket must be improved to ensure watertight and EMI protection
- All internal components added to the WQAU-P must be in accordance with the most recent MPCAG PPSL or in accordance with MIL-P-11268.

In addition to the multiparameter sensor and WQAU-P requirements just described, the contractor was also responsible for the following studies/reports:

- Feasibility study outlining the best measurement techniques that can be added to the WQAU-P to provide chloride and sulfate capabilities
- Failure Mode Effect and Criticality Analysis
- Environmental Stress Screening Plan
- Test plan to determine the operational performance of the WQAU-P
- Test and Demonstration report documenting the results of WQAU-P testing

- Feasibility study for reduction in WQAU-P weight and size
- Maintenance and Operations Manual.

Each of these seven topics have been documented in separate reports and accordingly, are not detailed in this final report. Brief summaries, however, have been included in this document when appropriate.

Section 2 of this final report describes how the monitored parameters (standard and optional) influence/affect the functional goals of the WQAU-P (i.e., evaluate ROWPU performance and raw water treatability). Existing measurement technologies and equipment are described in Section 3. The Foster-Miller multiparameter sensor is described in Section 4. Section 5 describes the mechanical and electrical design of the WQAU-P. Section 6 details the WQAU-P calibration, measurement and maintenance routines. The WQAU-P test program and test results are summarized in Section 7. Conclusions and recommendations are presented in Section 8 and 9, respectively.

2. WQAU-P PARAMETERS

2.1 Standard Parameters

Before embarking on a functional discussion of the WQAU-P, it is constructive to review the monitored WQAU-P parameters in terms of how they:

- Affect the treatability of a raw water source by reverse osmosis
- Provide a foundation for monitoring the operation of a reverse osmosis system
- Establish the general quality of potable water

The parametric ranges and sensitivities described in this subsection are not necessarily the final ranges selected, but are what Foster-Miller feels to be ideal or most appropriate for this application.

2.1.1 Total Dissolved Solids (TDS)

This parameter provides a general indication of the level of inorganic salts in solution. Pure, deionized water has a TDS value of zero, while seawater ranges from about 35,000 mg/l in the open ocean to 41,000 mg/l in the Red Sea. (The concentration of solids in the Dead Sea ranges from 195,000 to 266,000 mg/l, but is not considered a likely source of raw water). The TDS of drinking water must be below 1,500 mg/l in accordance with TB MED 229, Sanitary Control and Surveillance of Supplies at Fixed and Field Installations, and ideally should fall in the 100 to 300 mg/l range.

A knowledge of TDS in the feed to a reverse osmosis unit is of concern as:

- High TDS means high osmotic pressure and lower production rates
- Recovery rates with high TDS waters may have to be reduced to avoid scaling
- As membrane salt rejection is (approximately) independent of feedwater concentrations, high TDS feeds may require multiple passes to achieve the desired product quality. This reduces the capacity of the reverse osmosis unit.

Membrane salt rejections range from 95 to more than 99 percent, so the permeate from a single pass reverse osmosis module may have a TDS value ranging from less than 10 for a good quality surface water feed, to several thousand for a seawater feed.

It is clear that while the range in TDS that may be encountered is wide (approximately zero to 50,000 mg/l), a knowledge of the absolute value is not critical for any of the above considerations. However, it is useful to be able to monitor small changes in permeate quality, as this can be used as a check on the condition of the membranes.

2.1.2 pH

pH is defined as the negative logarithm of the hydrogen ion concentration. It is a measure of how acidic or basic the water is. A pH of 7 is neutral, while a value of zero is the most acid end of the pH scale, and 14 the most basic. Because the scale is logarithmic, a pH of 3, for example, is 10 times

more acidic than a pH of 4. The pH of natural waters is generally in the range of 4 to 9. The pH of drinking water should be between 5.0 and 9.0 in accordance with TB MED 577.

All reverse osmosis membranes have pH limitations, and the pH further influences the degree of degradation by other agents such as iron and chlorine. Cellulose acetate membranes are hydrolyzed below pH 2 and above pH 8, while polyamide and composite membranes can be operated over a pH range of 3 to 11. As the WQAU-P is to be used with raw water supplies rather than chemical process streams, we feel that an accurate indication of pH is important in the 4 to 9 range.

2.1.3 Turbidity

Water used for drinking should be clear, with a turbidity below 5 nephelometric turbidity units (NTU) as per TB MED 577. Turbidity in the feedwater to reverse osmosis can result in rapid fouling and failure of the membranes. Hollow fiber-type membranes are particularly prone to physical blocking due to the particulate matter in the feed. It is clear that the sensitivity of the turbidity sensor should be geared towards the lower end of the range.

2.1.4 Temperature

This is an important parameter when monitoring the operation of reverse osmosis units. All membranes have temperature limits; as a general guide these are 95° for polyamide membranes, 122°F for cellulose acetate membranes, and up to 140°F for some modern composite membranes. A lower limit of 32° is usually specified. The higher the temperature, the higher the production rate, all other factors being equal. On the other hand, the rate of a chemical reaction increases exponentially with temperature, so relatively small temperature

risers can significantly increase membrane degradation rates. The required 2°F sensitivity over a 25° to 160°F as stated in the contract specifications range should be more than adequate for protecting the reverse osmosis membranes.

2.1.5 Residual Chlorine

Free chlorine is generally not present in natural waters. It is a strong oxidant and biocide and is added during treatment to kill bacteria and oxidize undesirable chemicals such as iron and sulfides. Polyamide membranes are very sensitive to chlorine, especially at low pHs. Below pH 8, they should not be exposed continuously to more than 0.1 mg/l; while above pH 8, the limit becomes 0.25 mg/l. Composite membranes have a slightly better tolerance, and the limit for cellulose acetate membranes is set at 2 to 5 mg/l. It is clear that an accurate indication of free chlorine is needed to:

- Insure destruction of all bacteria (a dosage of 5 mg/l should provide adequate disinfection)
- Protect membranes against accidental addition of chlorine to the raw water source.

2.2 Optional Parameters

2.2.1 Chlorides

Chlorides are present in all water supplies, usually as a metallic salt (i.e., NaCl). High chloride waters are not known to have toxic effects on humans, but generally have an objectionable salty taste when present in chloride concentrations in excess of 250 mg/liter. When present as a calcium or magnesium salt, the detection level may be as high as 1,000 mg/liter.

Generally, the maximum allowable chloride concentration for public water supplies is 250 mg/liter, and is based primarily on taste criteria.

2.2.2 Sulfates

Sulfates appear in natural waters in a wide range of concentrations. On occasions, high concentrations of sulfate can have cathartic effects; however, acclimatization is very rapid. The taste threshold of magnesium sulfate is 400 to 600 mg/liter and for calcium sulfate is 250 to 800 mg/liter. Drinking water standards generally do not exceed 250 mg/liter and are based primarily on taste and laxative effects criteria.

A knowledge of the sulfate concentrations in the raw water is important for operation of the reverse osmosis module since at high concentrations of calcium sulfate, the membranes tend to foul and the addition of inhibitors is required to prevent this problem from occurring.

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3. MEASURING METHODOLOGIES

3.1 Standard Parameters

3.1.1 Total Dissolved Solids (TDS)

Instrumental determination of TDS is done by measuring the conductivity of the water sample, and relating the conductivity to a dissolved solids concentration. The relationship between conductivity and concentration varies with the type of salts present in the water, is nonlinear with concentration, and is temperature-dependent. In practice, a standard mixture of salts representative of typical natural waters is selected as the basis for the conductivity-concentration correlation, and the non-linearity and temperature-dependence are compensated for electronically.

The conductivity transducer, or conductivity cell, consists essentially of two electrodes in an insulating chamber. The water sample may either flow through the cell, or the cell may be immersed in the water. The resistance of the water between the electrodes is measured by making the cell one arm of an alternating current Wheatstone bridge. The conductivity, usually expressed in micromhos per centimeter, is the inverse of this resistance multiplied by a cell constant, which is a function of the size of the electrode/cell assembly.

A common error arising in conductivity measurements is due to the fouling of the electrode surfaces. Electrodeless systems incorporating imbedded transformer coils have been devised, and are useful for reducing calibration and maintenance requirements in adverse operating environments. Periodic calibration to ensure accuracy is nevertheless

required. The buffer solution used for pH calibration can serve as a span check for the conductivity cell. Deionized water is used as the standard for zero conductivity.

3.1.2 pH

The glass electrode is the transducer universally used to determine pH. In simplistic terms, the difference in hydrogen concentration in the water sample and in a standard solution inside the glass electrode produces a potential that can be expressed as pH. The potential must be measured relative to the standard potential of a reference electrode. In addition, the potential developed by the electrode is temperature dependent, so a knowledge of the temperature is required to accurately determine the pH. Combination electrode assemblies that house both the glass and reference electrodes, as well as a temperature sensor, are available. Automatic temperature compensation is accomplished in the signal processing section, which is basically a very high impedance voltage amplifier (millivoltmeter).

Because pH measurement is very widely used in the chemical process industry, rugged electrode systems and highly reliable electronic circuits have been developed. In addition, pH measurement is relatively free from interference, so sample conditioning is not required. However, the standard solutions in some electrode types leak slowly into the sample, so they have to be refilled occasionally. Because electrodes degrade with time, and to avoid problems associated with refilling and rejuvenating in the field, we recommend periodic replacement of the electrode assembly.

Fouling of the electrode surface and other changes in the electrodes and potentiometer can be expected to occur in normal use. These changes are corrected by calibration with buffer (fixed pH) solutions.

3.1.3 Turbidity

Turbidity is caused by suspended particles in the water and is measured quantitatively as the fraction of light that is absorbed and scattered, rather than transmitted through a sample. It is not a direct measure of the amount of suspended solids present as the absorption and scattering of a light beam is dependent on the size of the particles present, as well as on their number.

The transducer element used to measure turbidity consists of a light source, a photoelectric detector, and a cell for holding the sample. In many modern instruments, the detector is placed at 90 deg to the light path and, therefore, measures the amount of light scattered by the suspended particles. This arrangement is called a nephelometer. The nephelometric method avoids many of the errors related to particle size and solution color that arise when measuring transmitted light, and is also more accurate at low turbidities.

Periodic calibration is required to correct for changes in the strength of the light source and for other instrument variations. The zero reading can be set with deionized water or with an empty cell. A screen or grid with known light scattering characteristics may be used to adjust the span. This method is claimed to be accurate to within 5 percent in the higher (>100 NTU) turbidity ranges, but may not be satisfactory for calibrating at low turbidities. Improved accuracy can be achieved by calibrating with a standard formazin solution, but the procedure is relatively complex and formazin has a relatively short shelf-life. A more stable turbidity standard exists which consists of suspended polystyrene beads in a water based fluid. Validation testing of this polystyrene standard is presently being conducted by Horiba, Inc.

The turbidity measured in a nephelometer is expressed in NTUs as opposed to JTUs (Jackson turbidity units) measured in an instrument measuring transmitted light. NTU and JTU units are, approximately, interchangeable. Expressing turbidity as "ppm units" derives from the method of standardizing instruments with a silica suspension of known concentration. This method is no longer used in the United States, and relating turbidity to particle concentration is not recommended.

Errors in turbidity measurement include those due to stray light reaching the detector; dirt or condensed water vapor fouling the light source, detector, or cell walls; variations in the strength of the light source; and air bubbles in the sample. Fouling problems can be reduced by scattering the light from the free (top) surface of the sample, so eliminating contact between the sample and system optics. The turbidity reading is not significantly affected by temperature, and other than eliminating air bubbles, no sample conditioning is required for the intended application.

3.1.4 Temperature

Temperature sensors suitable for instrumental monitoring may be either thermocouples or resistance thermometers. Thermocouples operate on the Seebeck principle. When the junctions of two dissimilar metals forming a closed circuit are held at different temperatures, a potential difference is generated between the junctions that can be related to the temperature difference. In order to determine the absolute temperature at the measuring junction, the temperature at the reference junction must be known. Commercial instruments are available which incorporate reference junction temperature compensation and provide direct temperature readout.

Resistance thermometers are elements whose electrical resistance varies with temperature. The platinum resistance thermometer has become an industry temperature standard, but it is not suitable for field monitoring. Thermistors are semiconductor beads that fall into the resistance thermometer category, and which are now widely used in industry for monitoring temperature. They have the advantage of small size, quick response, and provide an easily processed signal in a Wheatstone bridge configuration. Like thermocouples, they are stable and require no field calibration. Their temperature range is generally less than that for thermocouples, but still more than adequate for the WQAU-P.

3.1.5 Free Residual Chlorine

Due to the importance of chlorine measurement at municipal treatment plants, several manufacturers have developed units for continuous on-line monitoring. Three methods are in general use. The first is a colorimetric method in which an indicator (N,N-diethyl-p-phenylene-diamine or DPD) is added to the water together with a buffer to reduce pH. At low pH values, the DPD reacts with free chlorine to produce a red color. The intensity of the color is determined colorimetrically and can be expressed directly as free chlorine concentration. The same method can be used to determine total residual chlorine by additionally adding potassium iodide to the sample. The potassium iodide reacts with both free and combined chlorine releasing iodine, and the iodine reacts with the DPD indicator to produce the red color. The need to add conditioning reagents to the sample is considered to be a major drawback in applying the colorimetric method to field use.

The second method used for chlorine determination uses a specification electrode (similar in many ways to the pH electrode which may be regarded as a specific ion electrode for

hydrogen ions). Unfortunately, commercially available specification electrodes for chlorine are geared towards total residual chlorine and also require addition of conditioning reagents to the sample. Both above methods require frequent calibration.

The method we consider most appropriate to the intended application is an amperometric method. The sensor is similar to a conductivity cell described previously, but is separated from the bulk sample by a chlorine pervious membrane. Migration of the free available chlorine through the membrane produces a current between the electrodes in the cell, which is proportional to the concentration of chlorine in the sample. The current signal is temperature sensitive; and as in the case of the conductivity cell, automatic temperature compensation is provided by inclusion of a temperature sensor in the cell. Amperometric chlorine sensors are also very sensitive to pH and require appropriate adjustments based on the acid/base level of the monitored fluid.

The amperometric chlorine sensors are manufactured to operate in harsh environments with minimal maintenance and calibration requirements. Annual or bi-annual calibration may be sufficient to remain within the 1 mg/l sensitivity specification stated in the contract.

3.2 Optional Parameters

3.2.1 Chlorides

Chloride concentrations can be determined using ion specific electrodes (ISE). This type of sensor is similar to the pH electrode and its voltage signal can be processed by circuitry similar to the pH circuitry used in the WQAU-P. To the best of our knowledge, commercially available chloride ion

specific electrodes are not available with built-in reference electrodes or temperature sensors. The reference electrode typically requires periodic (weekly) maintenance.

The recommended analytical procedure for chloride ISE measurements requires the addition of a conditioning agent (ionic strength adjuster - ISA) to the water sample in equal parts. In addition, two chloride standards are also required for the generation of a semilogarithmic calibration curve of sensor millivolt potential versus chloride concentration. Due to the wide accuracy requirements set forth in this contract (± 150 mg/liter), this calibration curve can most likely be preset during the detailed laboratory calibration of the WQAU-P. Generation of and reference to the calibration curve for obtaining chloride concentration measurements can be controlled by the WQAU-P's CPU. For laboratory applications this calibration curve is typically generated on a daily basis. At worst it should be possible to limit the chloride calibration fluids to one standard, as it appears that the millivolt versus concentration slope of the calibration curve remains fairly constant over a period of time.

3.2.2 Sulfates

Although there is no ISE for sulfate, a sulfate quantification procedure has been developed that utilizes a lead ISE. This procedure is relatively complex and requires the use of methanol formaldehyde and lead perchlorate. The water sample is diluted 1:1 with methanol formaldehyde solution before performing the lead perchlorate titration. The titrant is slowly added to the water sample as the titrant volume and millivolt potential of the lead electrode is carefully monitored. The point of inflection from a plot of electrode millivolt potential versus titrant volume is used to locate the end point for the titrant (ml of lead perchlorate). The

sulfate ion concentration is then calculated based on the volume of lead perchlorate added at the end point, the concentration of the lead perchlorate and the volume of water sample used before addition of methanol formaldehyde.

Colorimetric determination of sulfates is possible, but appears to be unsuitable for this application as many species interfere with the measurement. The types and number of conditioning reagents needed to evaluate a water source will vary from source to source.

The turbidimetric approach for measuring sulfates is somewhat less complicated and could utilize the existing turbidity sensor. No added sensors would be required. All signal processing could be handled by the CPU. Only software changes and minor rewiring of the WQAU-P would be required. Two reagents, however, would be required to perform the turbidity analysis for sulfate concentration. One is a liquid that is a mixture of glycerol, hydrochloric acid, water, ethyl alcohol and sodium chloride. The second reagent is barium chloride crystals.

Before sulfate readings can be obtained, a turbidity versus sulfate concentration calibration curve must be developed. Calibration curves are typically regenerated for each new batch (lot) of barium chloride. For laboratory applications the calibration curve is developed using a 5 mg of sulfate per liter of water increment. The upper concentration does not exceed 40 mg/liter, for beyond this point the barium sulfate suspension (the precipitate that generates the concentration related turbidity becomes unstable. Sample dilution will frequently be required to obtain measurements over the desired range.

The generation of new calibration curves will probably have very little influence on the quality of the WQAU-P readings given the ± 10 percent accuracy requirement for the specified range of 0 to 3000 mg/liter. Calibration curves are typically regenerated to ensure accuracies in the 1 to 5 mg/liter range.

Sample preparation is achieved by adding 5 ml of liquid reagent per 100 ml of water sample. While being agitated a spoonful of barium crystals is added to the water sample. Stirring should continue for 1 min from the time barium chloride is added. The stirring intensity should match the level of agitation that was used when generating the calibration curve.

After 1 min of stirring the turbidity is monitored for the next 4 min. The largest reading obtained during this period of time is used to calculate the sulfate concentration. The WQAU-P CPU should be able to handle this operation.

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4. MULTIPARAMETER SENSOR

4.1 Multiparameter Assembly

The Foster-Miller multiparameter sensor (shown in Figure 4-1) houses four of the five WQAU-P sensors (temperature, pH, TDS and turbidity). The basic features of this novel assembly include:

- 3 of the 4 sensors are replaceable
- The assembly is designed for submerged operation when the outer protective housing is removed
- The assembly's design philosophy can be expanded to accommodate additional sensors.

Compared to the troublesome multiparameter sensor used with the Phase II WQAU-P, the Foster-Miller multiparameter sensor provides the following advantages:

- Extended parameteric ranges
- Increased accuracy
- Reduced maintenance/servicing.

The temperature, pH and conductivity (TDS) sensors are replaceable elements. Figure 4-2 illustrates the exact location of each of these probes in the multiparameter sensor assembly. The temperature and conductivity sensors have pin socket connectors at their electrical end and are keyed to aid alignment with the mating internal pins. The pH sensor utilizes a threaded coaxial connector at its electrical end. Each of the replaceable sensors is locked into the multiparameter sensor body by a spanner nut that is backed with a

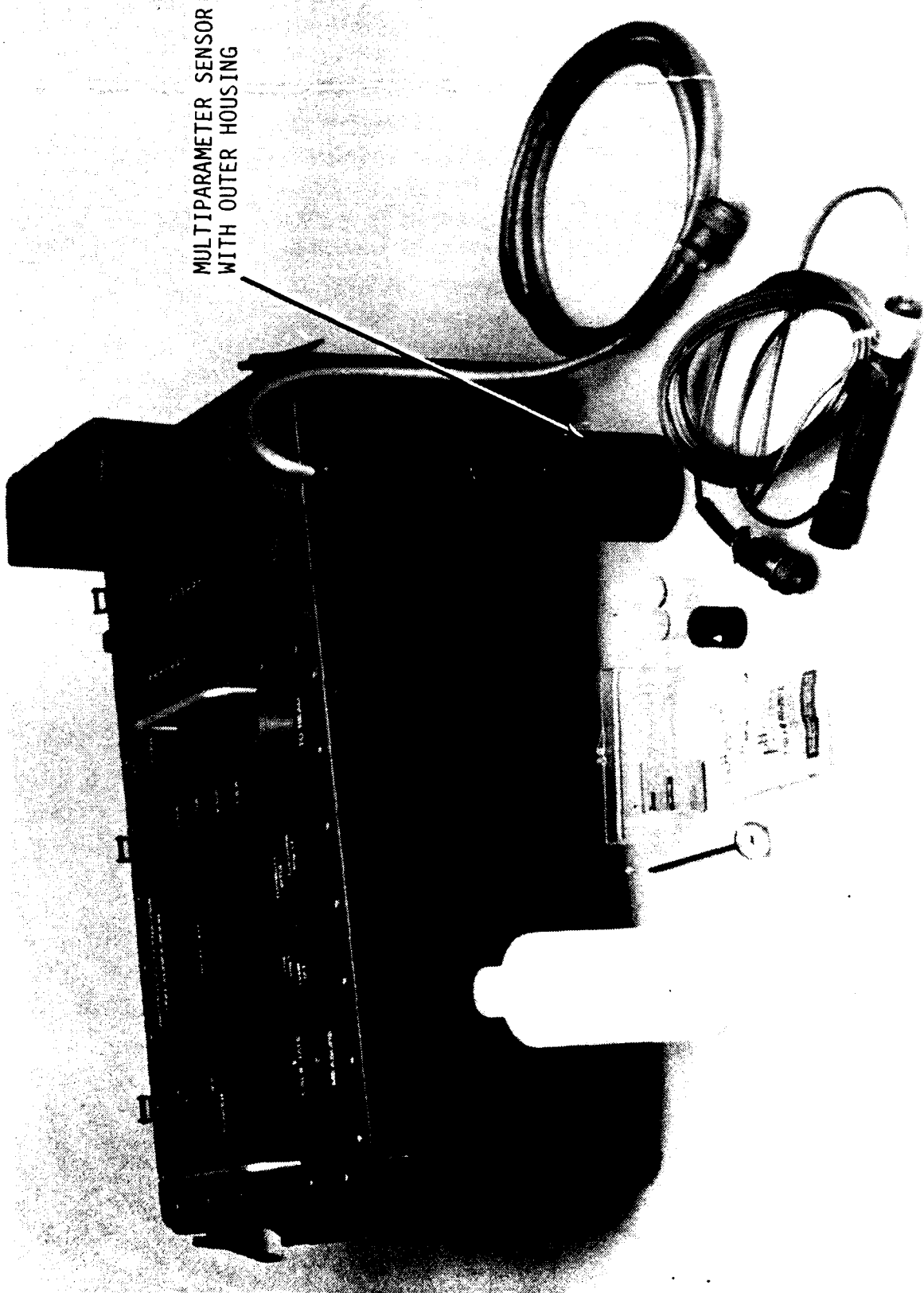


Figure 4-1. Foster-Miller Multiparameter Sensor

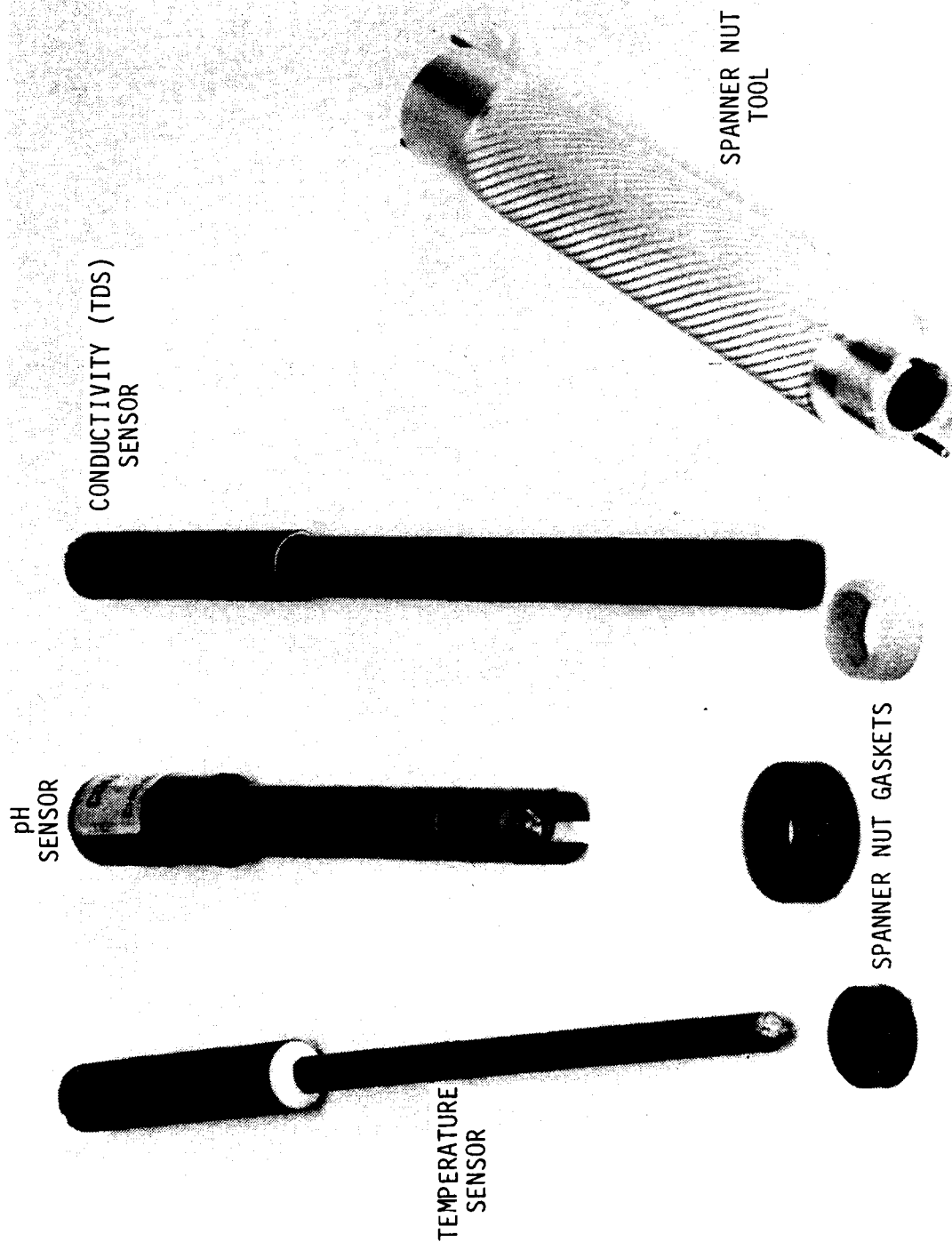


Figure 4-2. Multiparameter Sensor Components and Tool

special gasket to provide a water tight assembly. Figure 4-3 illustrates each of the replaceable sensors, the spanner nut gaskets and spanner nut tool.

The turbidity sensor has not been designed as a replaceable element. There are several reasons for this design approach.

- Sealing this large diameter sensor against water leakage is difficult; this in turn could lead to decreased reliability
- A cumbersome connector would be required to accommodate the seven active leads of the turbidity probe. Enhanced multiparameter sensor reliability is attained by molding the turbidity sensor and multiparameter assembly as one integral unit
- The turbidity probe is a molded assembly and cannot be repaired
- The cost of the turbidity probe is a large fraction of the total cost of the multiparamter sensor assembly.

Should the turbidity probe fail, the three repalceable sensors are removed and the turbidity probe and sensor assembly are discarded as a single component.

Although the multiparameter sensor is designed for submersible operation it still comes equipped with an outer housing that provides two functions.

- Sensor protection during storage and transport
- Container for holding the single WQAU-P calibration fluid used during WQAU-P field calibration.

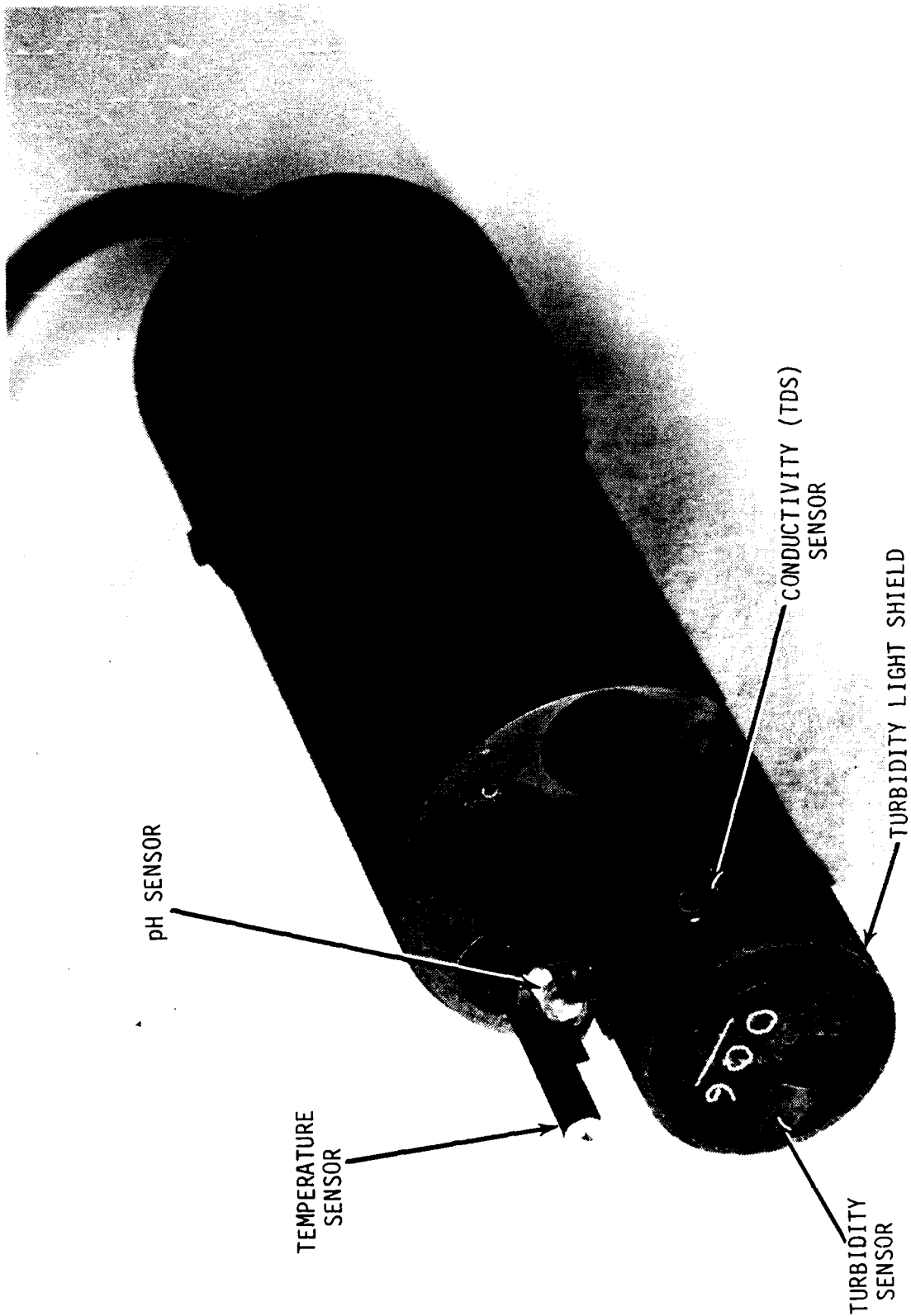


Figure 4-3. Location of Sensor Elements

The housing should always be removed when making an in situ measurement. This is the normal operating procedure to ensure that all sensors reach thermal equilibrium with the water sample. Since the multiparamter sensor is designed to operate without the protective housing, a removable light shield as shown in Figure 4-4 is used to protect the turbidity sensor from ambient light. This is removeable to accommodate turbidity sensor cleaining.

4.2 Multiparameter Sensors

4.2.1 Total Dissolved Solids (TDS)

The conductivity cell used by Foster-Miller (Figure 4-5) in their multiparameter sensor consists of two electrodes and an internal negative temperature compensation thermistor (NTC) for temperature compensation to within $\pm 2^{\circ}\text{F}$. Both electrodes are located in the inner open core of the sensor's epoxy housing. This open core passes through the entire length of the sensor and allows displaced air to be vented during sensor submersion. Specifications for the conductivity sensor are as follows:

- Operating range - 0 - 2000 $\mu\text{ohms/cm}$
0 - 20,000 $\mu\text{ohms/cm}$
0 - 200,000 $\mu\text{ohms/cm}$
- Temperature range - 32 - 180 $^{\circ}\text{F}$
- Accuracy - $\pm 2\%$ of full scale
- Length - 6 in.
- Diameter - 0.375 in.



Figure 4-4. Multiparameter Sensor with Turbidity
Light Shield Removed



Figure 4-5. Conductivity (TDS) Sensor

It is important to note that the conductivity of a salt solution varies with temperature. The conductivity reading provided by this sensor must, therefore, be converted to a concentration based on a particular salt. For the WQAU-P the reference salt is NaCl. The relationship between conductivity and NaCl concentration is temperature dependent. This well established relationship has been converted into an algorithm that is handled by the WQAU-P's CPU. Details are provided in subsection 5.5.2.

4.2.2 pH

The pH sensor selected by Foster-Miller (Figure 4-6) is a combination type probe that includes a glass measuring electrode and a Ag-AgCl reference electrode in one sensor body. The outer shell of this sensor is constructed from a rugged epoxy plastic that extends beyond the sensing bulb to protect the sensor against damage. This permanently sealed sensor is filled with a 2 M KCl gel that is saturated with AgCl. Specifications for the pH sensor are:

- Operating range - 0 to 14 pH
- Temperature range - 32 to 180°F



Figure 4-6. pH Sensor

- Accuracy - ± 0.02 pH within 3.0 pH units of calibration point
- Length - 5 in.
- Diameter - 0.5 in.

4.2.3 Turbidity

The turbidity sensor pictured in Figure 4-7 is a specially fabricated submersible probe. This turbidity probe features:

- No moving parts - low maintenance
- Practically insensitive to film build-up on sensor windows
- High ambient light rejection (achieved electronically)
- Long life due to 100% solid state circuitry.

The probe is constructed from a filled epoxy resin with a fixed reinforcing member through the length of the probe for rigidity. At either end the optical components are fixed in a



Figure 4-7. Turbidity Sensor

translucent resin that includes a light diffusing material for the windows.

Process specifications are as follows:

- Operating fluid temperature - 28 to 180°F
- Operating ambient temperature - -58 to 150°F
- Measuring range - 0 to 20 NTU minimum, 0 to 4000 NTU maximum.
- Accuracy - to within less than 1.0% full scale
- Optics - two 880nm light emitting diodes near-infrared range; two silicon photodiodes with interference filters limiting spectral response to 880nm $\pm$ 20 nm.

This turbidity sensor uses a four beam alternating light principle to negate the effects of variations in light source intensity, variations in the sensitivity of the photocell diodes and build-up of solids on the sensor windows. This four beam principle which is discussed below in detail provides a truly self-compensating turbidity sensor.

4.2.3.1 Four Beam Theory

The Lamber-Beer Law shows that the light lost during transmission through a medium is proportional to the concentration of the medium. The Lamber-Beer Law as applied to this sensor can be expressed as:

$$I_T = LS e^{-CD}$$

where

I_T = light transmitted through water sample

L = light source intensity

S = detector sensitivity

C = concentration (turbidity) of water sample

D = distance between light source and detector

Note that if L or S changes, the measurement will change. The effects of the light source and detector must be eliminated in order for the measurement to be accurate.

Figure 4-8 shows the physical arrangement of the turbidity sensor elements. Note that the distances D and d are precisely fixed.

Four discrete measurements can be obtained where I_{xy} equals the light transmitted from LED x and picked-up by detector y .

$$\begin{aligned} I_{1,1} &= L_1 S_1 e^{-CD} \\ I_{1,2} &= L_1 S_2 e^{-Cd} \\ I_{2,1} &= L_2 S_1 e^{-Cd} \\ I_{2,2} &= L_2 S_2 e^{-CD} \end{aligned}$$

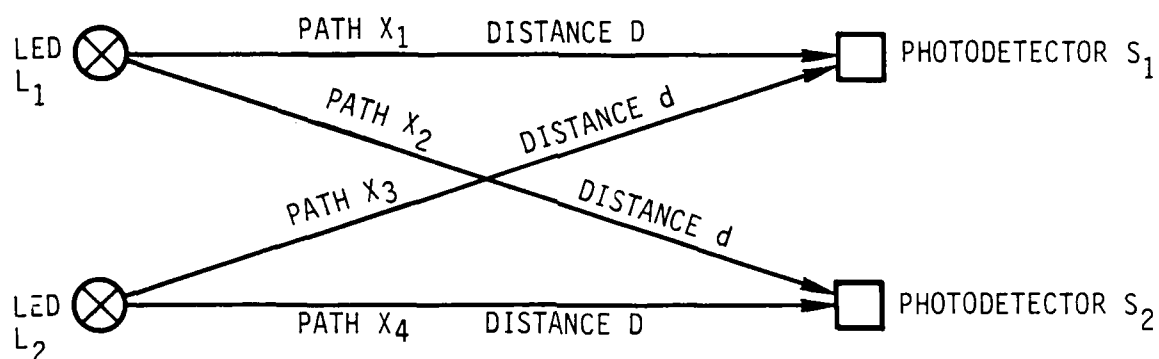


Figure 4-8. Four Beam Turbidity Sensor
(Arrangement of Elements)

These four discrete measurements are obtained by cycling the light sources and photoelectric diodes in an appropriate sequence.

To eliminate the characteristics of the light sources, $I_{1,1}$ is divided by $I_{1,2}$ and $I_{2,1}$ is divided by $I_{2,2}$:

$$\frac{I_{1,1}}{I_{1,2}} = \frac{L_1 S_1 e^{-CD}}{L_1 S_2 e^{-Cd}} = \frac{S_1 e^{-CD}}{S_2 e^{-Cd}}$$

$$\frac{I_{2,1}}{I_{2,2}} = \frac{L_2 S_1 e^{-Cd}}{L_2 S_2 e^{-CD}} = \frac{S_1 e^{-Cd}}{S_2 e^{-CD}}$$

The detector sensitivity is eliminated by rearranging the last two equations as shown

$$\frac{I_{1,1}/I_{1,2}}{I_{2,1}/I_{2,2}} = \frac{S_1 e^{-CD}}{S_2 e^{-Cd}} \times \frac{S_2 e^{-Cd}}{S_1 e^{-CD}} = \frac{e^{-2CD}}{e^{-2Cd}}$$

Taking the logarithm of the above equation

$$2C(d-D) = \ln \left[\frac{I_{1,1} I_{1,2}}{I_{2,1} I_{2,2}} \right]$$

Since d and D are constants, water turbidity (C) can be calculated from the four light transmission values measured by the photoelectric diodes.

Ambient light is also eliminated from the measurement process by monitoring the light that is picked up by the photoelectric diodes when the light sources are off. The influence of fluid color is also eliminated as the probe LEDs (light sources) use a near infrared light which is not absorbed by common organic or inorganic compounds.

Foster-Miller conducted a detailed laboratory analysis of the selected turbidity sensor. Five NTU samples were monitored for turbidity over a fluid temperature range of 40 to 120°F. The results of this analysis are graphically displayed in Figure 4-9. Although the turbidity readings are influenced by the sample temperature, it appears that the dependence is independent of sample turbidity. The characteristic slope of the turbidity sensor remains constant at approximately 10 NTU/80°F. This relationship was incorporated into the WQAU-P microprocessor as a corrective algorithm to provide a ±2 NTU accuracy over a turbidity range of 0 to 150 NTU and a temperature range of 32 to 120°F.

4.2.4 Temperature

The selected temperature sensor (Figure 4-10) is a dual precision thermistor. The probe's outer housing is fabricated from a rugged plastic epoxy. Performance specifications for this probe are:

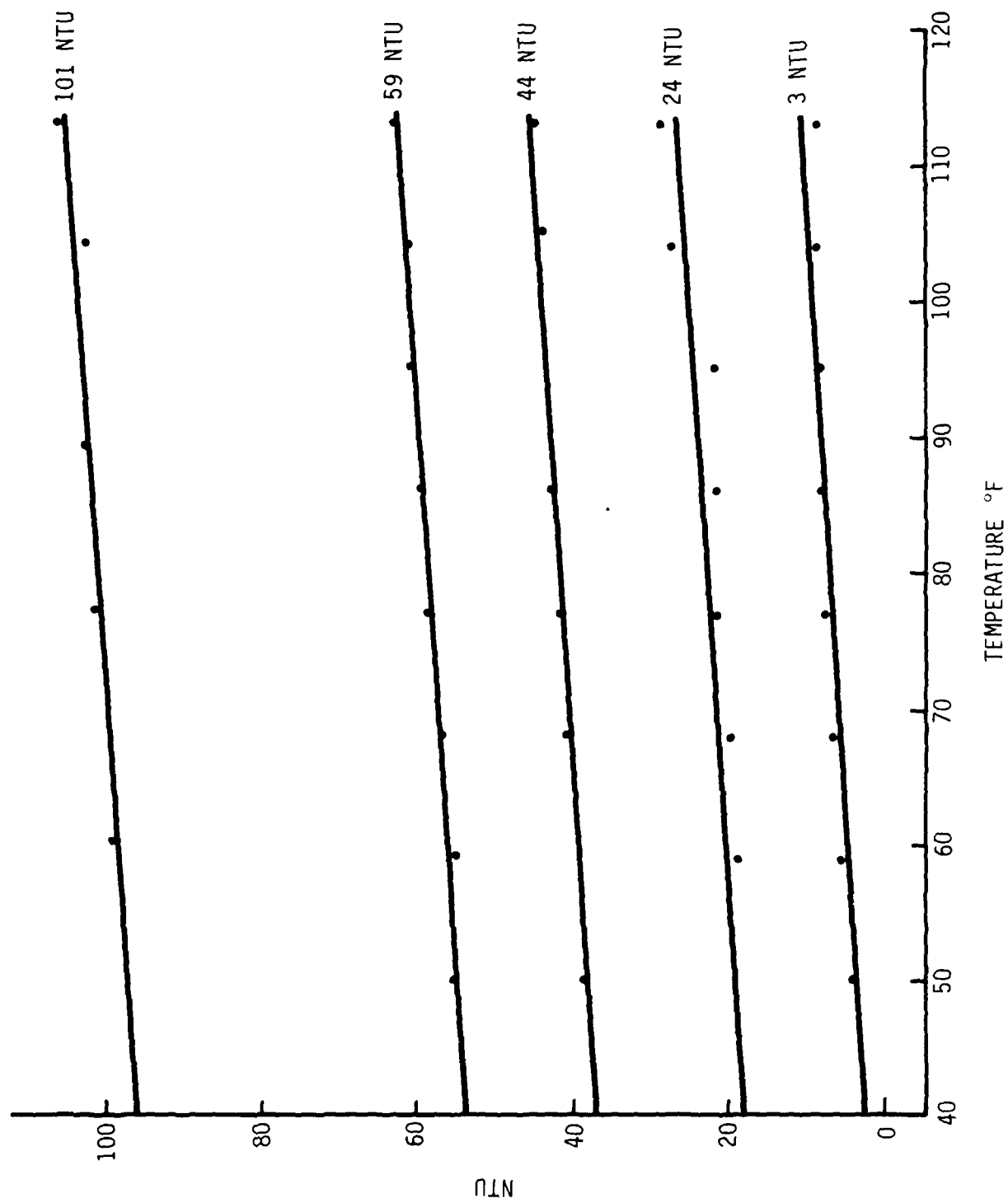


Figure 4-9. Influence of Fluid Temperature on Turbidity



Figure 4-10. Temperature Sensor

- Operating range - 5 to 180°F
- Accuracy - ± 0.3 °F
- Length - 6 in.
- Diameter - 0.25 in.

When testing fluids the maximum response time should not exceed 10 seconds. Response time when measuring air should not exceed 30 seconds.

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5. WQAU-P DESIGN

The WQAU-P is an assembly of specialized water measurement sensors that have been combined with a state-of-the-art micro-processor to form a simple-to-operate water monitoring instrument. Personnel experienced in the operation of the WQAU-P can typically perform a complete calibration and measurement sequence in less than 5 min.

The WQAU-P measures five parameters critical to establishing the effectiveness of a reverse osmosis water purification system or determining the treatability of a raw water source. These process parameters include temperature, pH, total dissolved solids (TDS), turbidity and free available residual chlorine.

The following subsections detail the WQAU-P's parametric and design specifications, mechanical design, electrical design and programming algorithms used for temperature and/or pH corrections. A detailed listing of the WQAU-P software is presented in the Appendix.

5.1 WQAU-P Specifications

Specification for the WQAU-P have been divided into two categories:

- Parametric Specifications
- Design Criteria.

5.1.1 Parametric Specifications

The parametric specifications for the WQAU-P in terms of range and sensitivity are presented in Table 5-1. These

Table 5-1. Specifications for WQAU-P Parameters

Parameter	Range	Sensitivity
Air Temperature	0-160	$\pm 2^{\circ}\text{F}$
Fluid Temperature	32-120	$\pm 2^{\circ}\text{F}$
pH	2-12	± 0.5 pH units
TDS	0-500 mg/l	± 25 mg/l
	500-5,000 mg/l	± 250 mg/l
	5,000-50,000 mg/l	± 2500 mg/l
Turbidity	0-50 NTU	± 5 NTU
	50-150 NTU	± 10 NTU
Free Available Residual Chlorine	0-15 mg/l	± 1 mg/l (at pH less than 9)

ranges/ sensitivities reflect the expressed needs of the user community for adequately measuring raw and processed water.

5.1.2 Design Criteria

To accommodate simplicity of operation and the need for a rugged field portable instrument, there were a number of physical constraints placed on the WQAU-P design. The design goals (criteria) for the WQAU-P are listed in Table 5-2.

5.2 Mechanical Design

The WQAU-P is housed in an aluminum carrying case as shown in Figure 5-1. Manufactured by Zero Corporation, the basic

Table 5-2. WQAU-P Design Criteria

Physical Constraints
Moisture proof design Parameter selector switch to coincide with logical sequence of parametric measurements Five digit display Battery can be replaced without opening the electrical compartment Main system fuses accessible from front control panel Battery recharge can be accomplished while unit is in its storage configuration Survive an EMP while in the closed configuration Survive shock effects from aerial landing and 4 ft drop Survive NBC decontamination while in the closed configuration Protected from emitting a distinctive electronic signature or interfering with electrical communication as per MIL STD 461A Protected from damaging effects of nuclear, biological and chemical contamination Operational in climatic categories basic and hot (AR 70-38)
Electrical Constraints
Powered by internal battery (4 to 8 hr continuous operation) Rechargeable from 110 and 220V, 50-60 Hz ac, and 12 and 24V dc Safety feature to prevent battery overcharge Internal autoranger for TDS ranges Error trapping routine to eliminate stray readings Provide a trickle charge to chlorine sensor while in the storage configuration

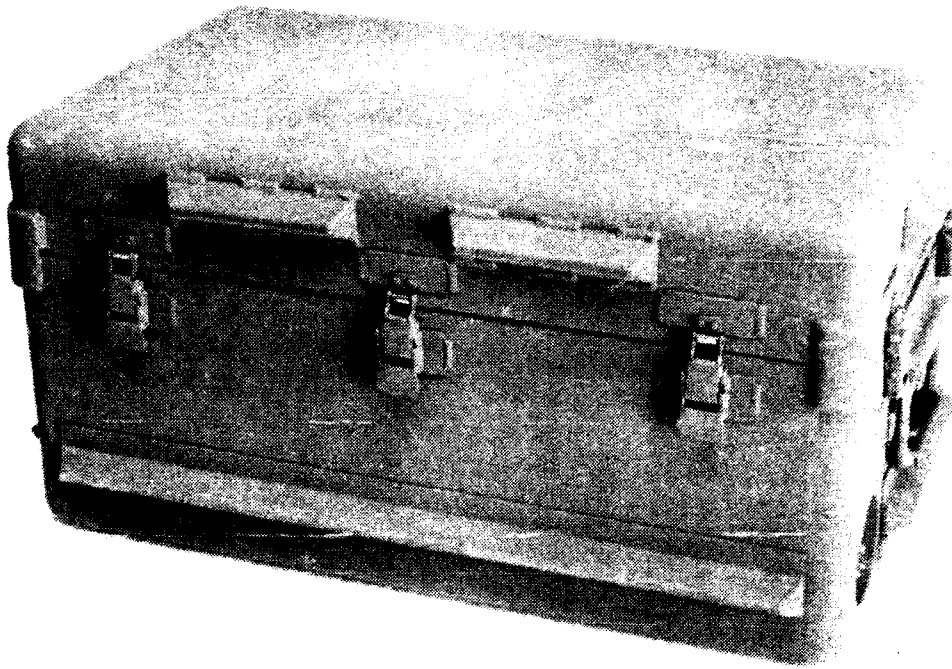


Figure 5-1. WQAU-P in Closed Configuration

outer case features high strength, relatively lightweight and clean outer lines with seamless construction. The upper lid (cover) is sealed by a fully gasketed tongue and groove closure providing EMP protection (when equipped with the appropriate gasket) and is secured by positive locking latches on the front, sides and rear. This 13 in. wide by 22.5 in. long by 12 in. high case occupies 2.0 ft³ and weighs 44 lb.

The outer case was modified during this contract to provide better transit drops (4 ft) protection. Outer case modifications included:

- Adding one case latch at the center of the front and back side, and adding two latches on each end (short length)

- Adding guard rails to all sides of the lower case (Figure 5-2)
- Adding modified guard rails to all sides of the cover
- Replacing case handles with militarized handles as shown in Figure 5-3. Handles lock at 90 deg for ease in carrying and are spring tensioned to lie flush with the side wall of the case when not in use
- Adding corner shearlocks on all four corners to keep cover from moving during impact.

The inner case was also modified during this contract to provide better EMP protection, water leakage protection and EMI protection. These modifications included:

- Replacing the existing EMP case gasket, a wire mesh covered hollow tube, with a solid core circular cross section gasket that is impregnated with silver

PERFORMANCE DATA: Provides protection per MIL-T-21200 and MIL-T-28800.

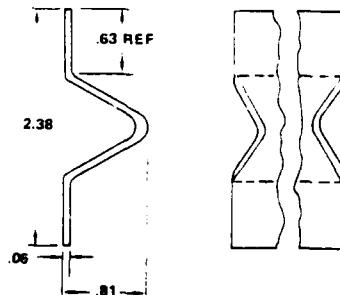


Figure 5-2. Case Guard Rails

PERFORMANCE DATA: provides protection for handle per MIL-T-21200 and MIL-T-28800. Self-contained protection reduces case weight and provides easier fabrication.

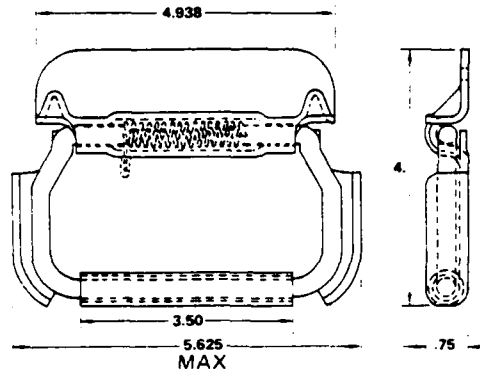


Figure 5-3. Case Handles

- Replacing the existing rubber control panel gasket with a combination foam and EMI wire mesh gasket
- Adding 16 hold down screws to the control panel.

The WQAU-P is divided into two compartments:

- Sensor/Accessory
- Electrical.

When the WQAU-P cover is removed, the control panel and accessory compartment are exposed (Figure 5-4).

5.2.1 Sensor/Accessory (S/A) Compartment

The S/A compartment houses both measurement sensor (multi-parameter and residual chlorine), power cords (ac and dc), battery, sensor connectors and an assortment of field calibration and field maintenance accessories. S/A components are shown in Figure 5-5.

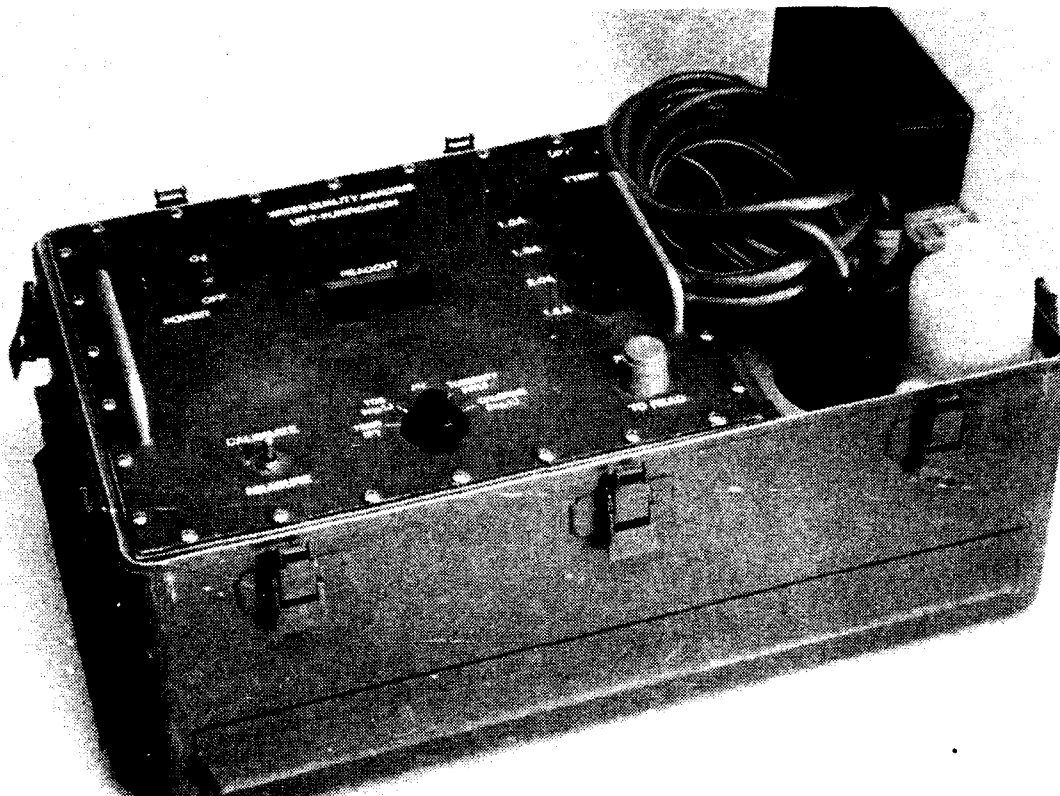


Figure 5-4. WQAU-P with Top Cover Removed

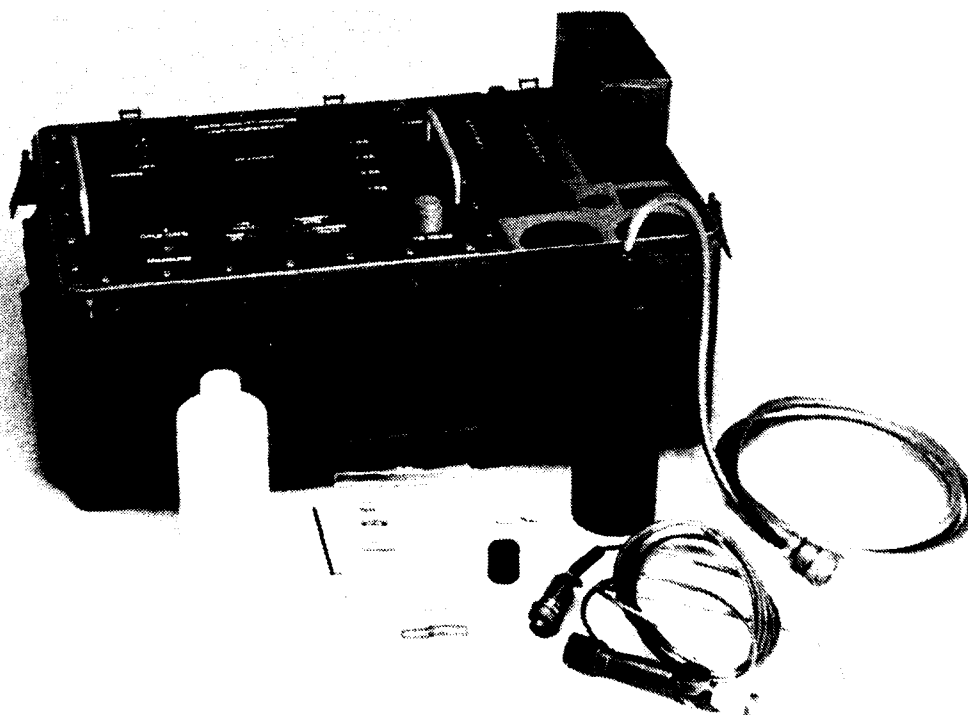


Figure 5-5. WQAU-P Sensors/Accessories

5.2.1.1 Sensors

The multiparameter sensor has been described in detail in Section 4.

The free available residual chlorine sensor is shown in Figure 5-6. The probe is composed of a PVC body, gas permeable membrane, gold cathode and silver anode. The sensor is provided with a screw-on membrane tip for easy maintenance. A red snap-on cap protects the sensor membrane during storage and transportation. This cap must be removed prior to making measurements.

The residual chlorine sensor requires a flow of fresh sample at the probe tip. During measurement operations, this sensor must be moved through the sample at a velocity of 1 ft/sec. A figure "8" motion can be used to meet this requirement.

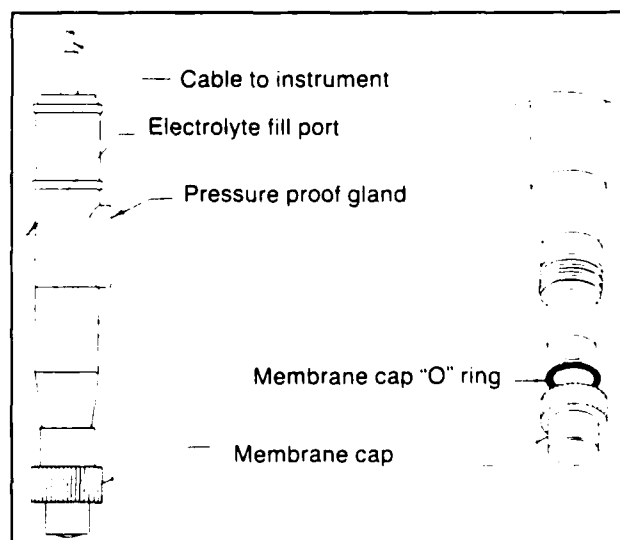
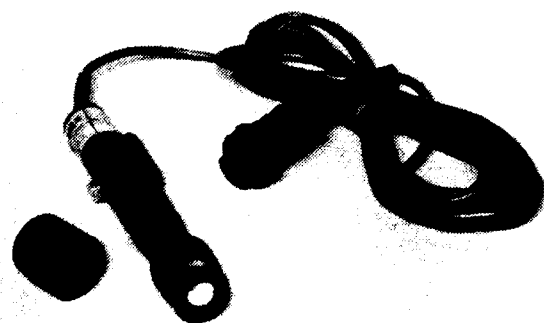


Figure 5-6. Free Available Residual Chlorine Sensor

The chlorine probe is passive-type sensor and must not be removed from its terminal connector. If disconnected or if the battery is removed from the WQAU-P, the sensor must be allowed to stabilize for at least 30 min after it has been reconnected or the battery has been replaced.

5.2.1.2 Main Battery

The WQAU-P's internal power source is a 4.0 Ahr 12V rechargeable nickel cadmium (NiCd) battery (Model No. PAD1252TAL3, manufactured by Adcour Inc., of Sharon, MA). When fully charged this battery will provide approximately 12 hr of continuous operation. A 24 hr recharge period is required to fully charge a battery that has activated the low level battery light. If the low level battery light comes on, the WQAU-P will remain operational for approximately 30 min. The present cycle of measurements can be completed.

The main battery is housed in a water tight compartment positioned within the S/A compartment. The battery can be easily replaced/removed by loosening the two thumb screws and pulling the entire holder up.

5.2.1.3 Accessories

Accessories contained within the WQAU-P include:

- Power cords (110V ac, 220V ac and 12/24V dc)
- 500 ml bottle of buffer solution
- Electrolyte for residual chlorine sensor (R-448)
- Powered buffer packets pH = 7.0
- Control panel fuses.

5.2.1.4 Connectors

Connectors for the multiparameter and residual chlorine sensors are located on the inner side panel of the S/A compartment. Figure 5-7 illustrates the multiparameter sensor connector. The residual chlorine connector is directly below the multiparameter sensor connector. The external power connector is recessed on the outer side of the S/A compartment as shown in Figure 5-8.

5.2.2 Electrical Compartment

The top side of the electrical compartment is the WQAU-P control panel. This control panel as shown in Figure 5-9 houses all operating controls, displays and fuses. Specifically this includes:

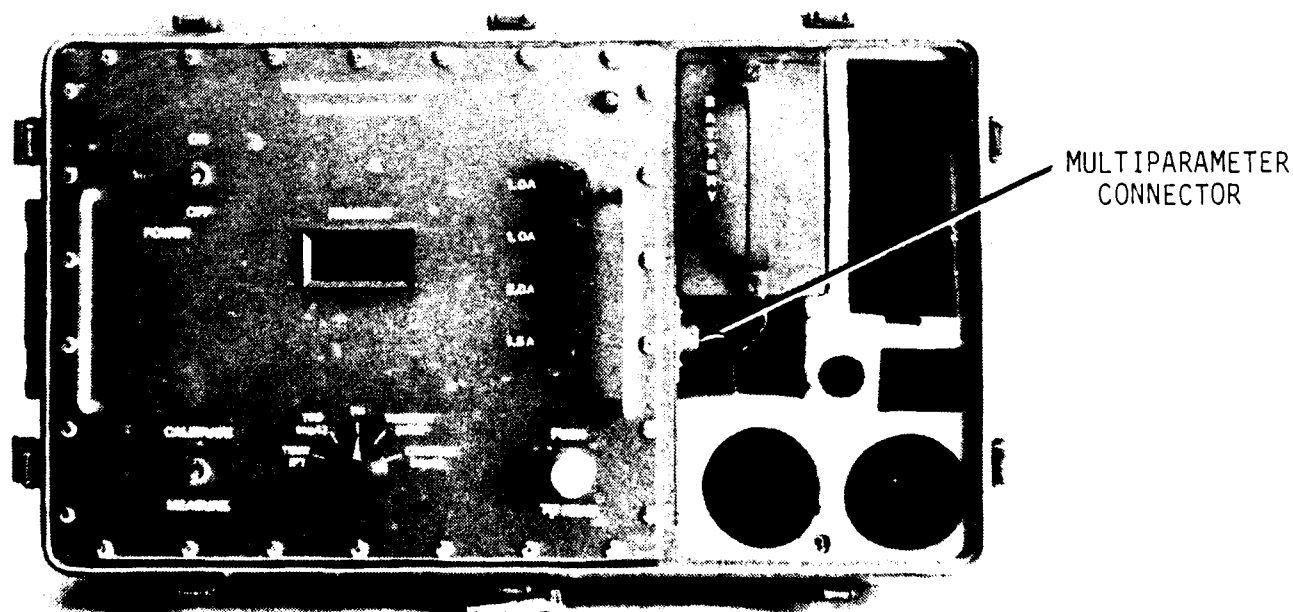


Figure 5-7. Multiparameter Sensor Connector

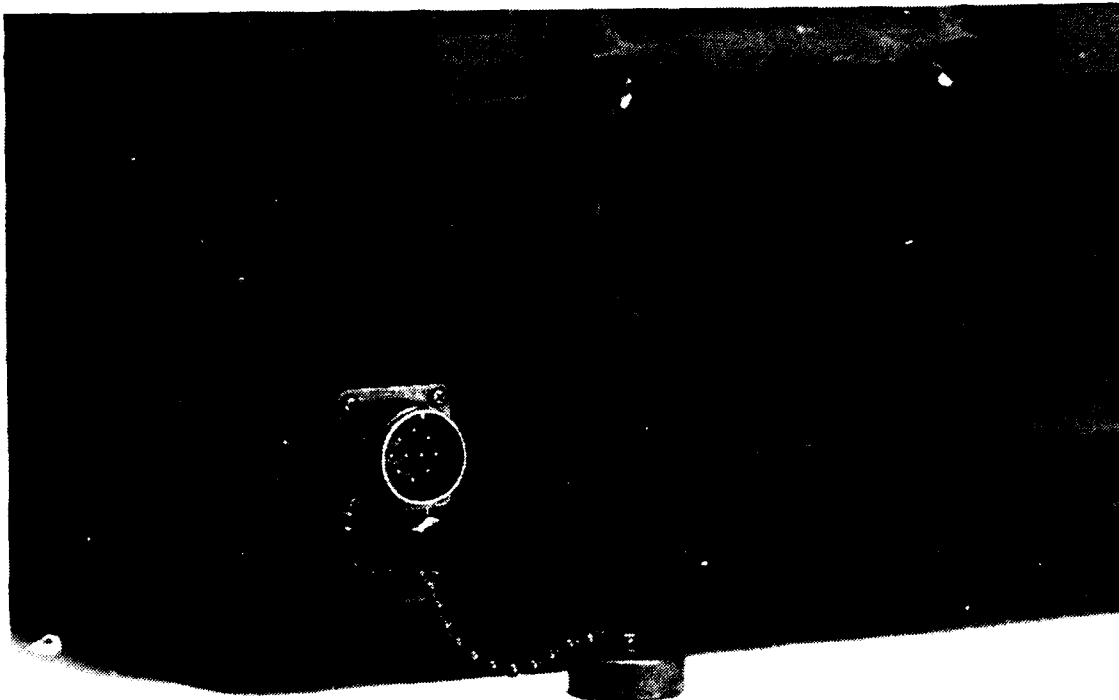


Figure 5-8. WQAU-P Power Connector

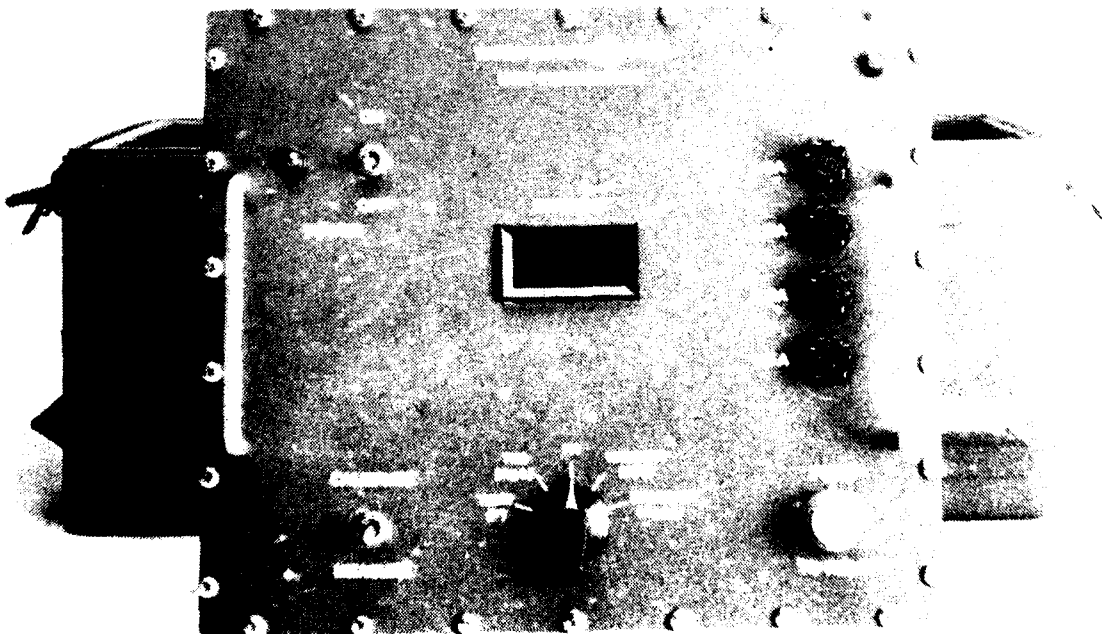


Figure 5-9. Control Panel

Operating controls

- Power switch (on-off)
- Mode switch (calibrate/measure)
- Parameter selector switch
- Push to read button

Displays

- Five digit LED readout
- Power on light
- Low battery light

Fuses

- Two 1.0A ac power fuses
- One 2.0A dc power fuse
- One 1.5A display fuse

The control panel is equipped with two handles for easy removal of the WQAU-P's electronics from the Zero case. When the control panel is removed, all WQAU-P circuitry becomes easily accessible for servicing. All circuit boards requiring adjustments are attached to the outside of the main card cage assembly. This card cage assembly is attached to the control panel with shock mounts for the purpose of protecting all circuitry. The card cage internally houses the CPU board, the I/O board and the memory expansion board. Boards attached to the outside of the card cage assembly include:

- Sensor control circuit board
- Power supply circuit board.

5.3 Electrical Design

The electrical assembly of the WQAU-P consists of several components/subsystems. They are:

- Sensor control circuit board
- Display circuit board
- I/O circuit board
- CPU circuit board
- Memory expansion circuit board
- Power supply circuit board and accessories
- Operator controls.

5.3.1 Sensor Control Circuit Board

The sensor control circuit board provides the signal path between the microprocessor and the measurement systems. It informs the microprocessor which parameter is being monitored and which operating mode is being activated.

The control circuit board contains all the measurement processing circuitry, parametric adjustments and analog to digital conversion circuits that convert the measurement analog voltages to a digital representation for processing by the microprocessor.

All connections to and from the control circuit board are made through ribbon cables and connectors.

The electrical schematic of the control circuit board is shown in Figures 5-10 and 5-11.

The following paragraphs under this subsection describe each of the parametric measurement circuits. Sensor electronics are also discussed when appropriate to provide additional insight as to how each circuit functions.

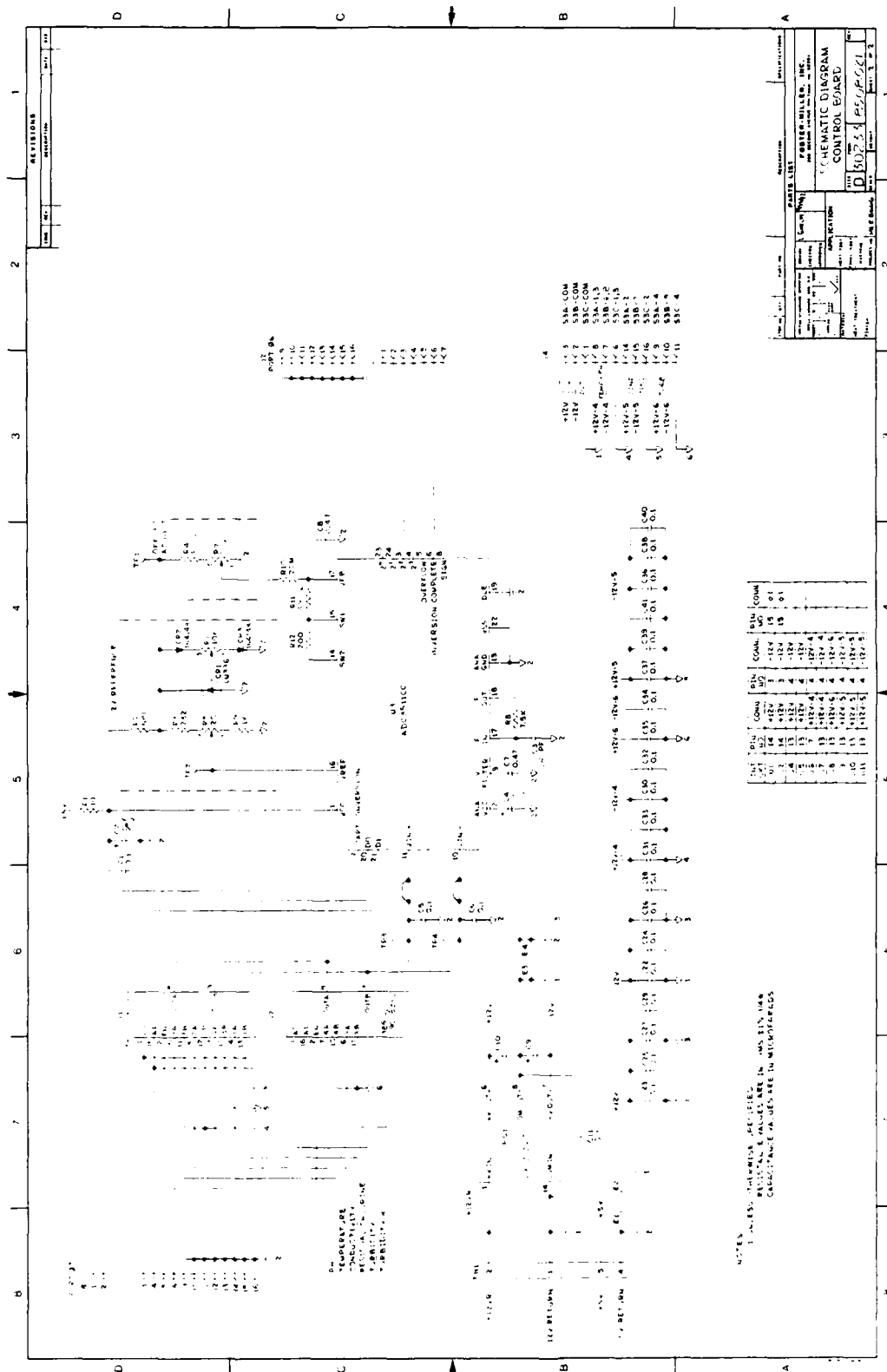


Figure 5-11. Schematic of Sensor Control Circuit Board

5.3.1.1 Temperature

The temperature measuring elements consists of two thermistors and a fixed resistor connected in a series-parallel combination that results in a resistance element that varies linearly as a function of temperature. This resistance element is placed in the feedback loop of an operational amplifier thereby causing the amplifier gain to be a function of temperature. A stable voltage is applied to this amplifier yielding an output voltage proportional to temperature. The output of this viable gain amplifier is fed into another amplifier whose gain is set to scale the output voltage for a 1 mV per 0.1°C sensitivity. Two adjustments are provided for adjusting the 32°F and 120°F endpoints.

5.3.1.2 pH

The combination Ag/AgCl pH probe is connected to a high input impedance amplifier whose gain control is used to set the upper end of the pH slope. The output of this amplifier is connected by means of a relay that is activated by software control to the same amplifier stage used by the temperature probe. This provides the temperature compensation required by the pH probe. The output of the second stage is combined with an adjustable voltage source to set the low pH end point.

5.3.1.3 Conductivity (TDS)

The conductivity probe consists of two electrodes. An oscillating current is passed into the water sample through one of the two electrodes. The resulting current flow between the two electrodes, a function of water conductivity, is measured, manipulated by the microprocessor and displayed in TDS units. TDS levels are established by measuring the conductivity of the

water sample, correcting the conductivity reading for temperature effects and correlating the final result to equate to a specific salt (NaCl). The last two actions are handled by the microprocessor.

The WQAU-P provides three automatically selected (auto-ranging) measurement ranges: 0-500 mg/l, 500-5000 mg/l and 5000-50,000 mg/l. If the measurement is less than the lower value of the tested range, the microprocessor switches the TDS circuit to the next lower range. To accomplish this, the microprocessor switches component values which change the amplitude of the pulsed current. Separate non-interacting adjustments are provided for calibrating the current level injected into the water sample for each measurement range.

5.3.1.4 Turbidity

Turbidity measurements are attained by using a four beam light measurement technique that eliminates errors caused by dirty windows and variations in light level. The turbidity probe consists of two pairs of light emitting diodes (LED), photodetectors, amplifiers and narrow band optical filters. The absorption and scattering effects of suspended particles in the water sample is measured over four optical paths. The output of each LED is measured by each photodiode over fixed optical path lengths through the water sample. The four measurements are processed by the WQAU-P software to cancel out variations in the LED light sources, detectors and temperature. The resulting measurement of attenuated light is a function of water turbidity.

5.3.1.5 Chlorine

The chlorine sensor is an amperometric probe that has a gold cathode at its outer tip and an internal anode that is

made of silver. The body of the sensor is filled with a buffered KCl electrolyte. Channels within the body of the sensor transfer electrolyte from the reservoir to the gold cathode which is covered by a special permeable membrane. As the water being monitored flows past the sensor tip, hypochlorous acid molecules diffuse through the membrane and an electrical current is produced in proportion to the chlorine concentration of the sample.

5.3.2 Display Circuit Board (Figure 5-12)

The display circuit board contains a 5 digit, 0.3 in. high, green, seven segment display for indicating the results of the water quality measurement. The display is blanked after 15 sec to conserve battery power. The display circuit board is driven under software control. Leading zeroes are blanked to eliminate confusion and present concise readouts. Two ports on the I/O circuit board provide the input data and control signals to the display circuit board.

Connections to this circuit board are made by ribbon cables and connectors. The display board is mounted behind the control panel so that the displays can be viewed through a cutout on the panel. A green filter serves the dual purpose of enhancing the display by increasing contrast and serving as a watertight seal for the cutout.

5.3.3 I/O Circuit Board (Figure 5-13)

The CMOS STD BUS I/O Card manufactured by Pro-Log Corporation provides the interface between the STD BUS, the CPU circuit board and the outside world. Eight, eight-bit read/write ports control 64 bidirectional signal lines. The I/O ports are used to drive the display board, control the A/D converter, TDS autoranging and turbidity measurement

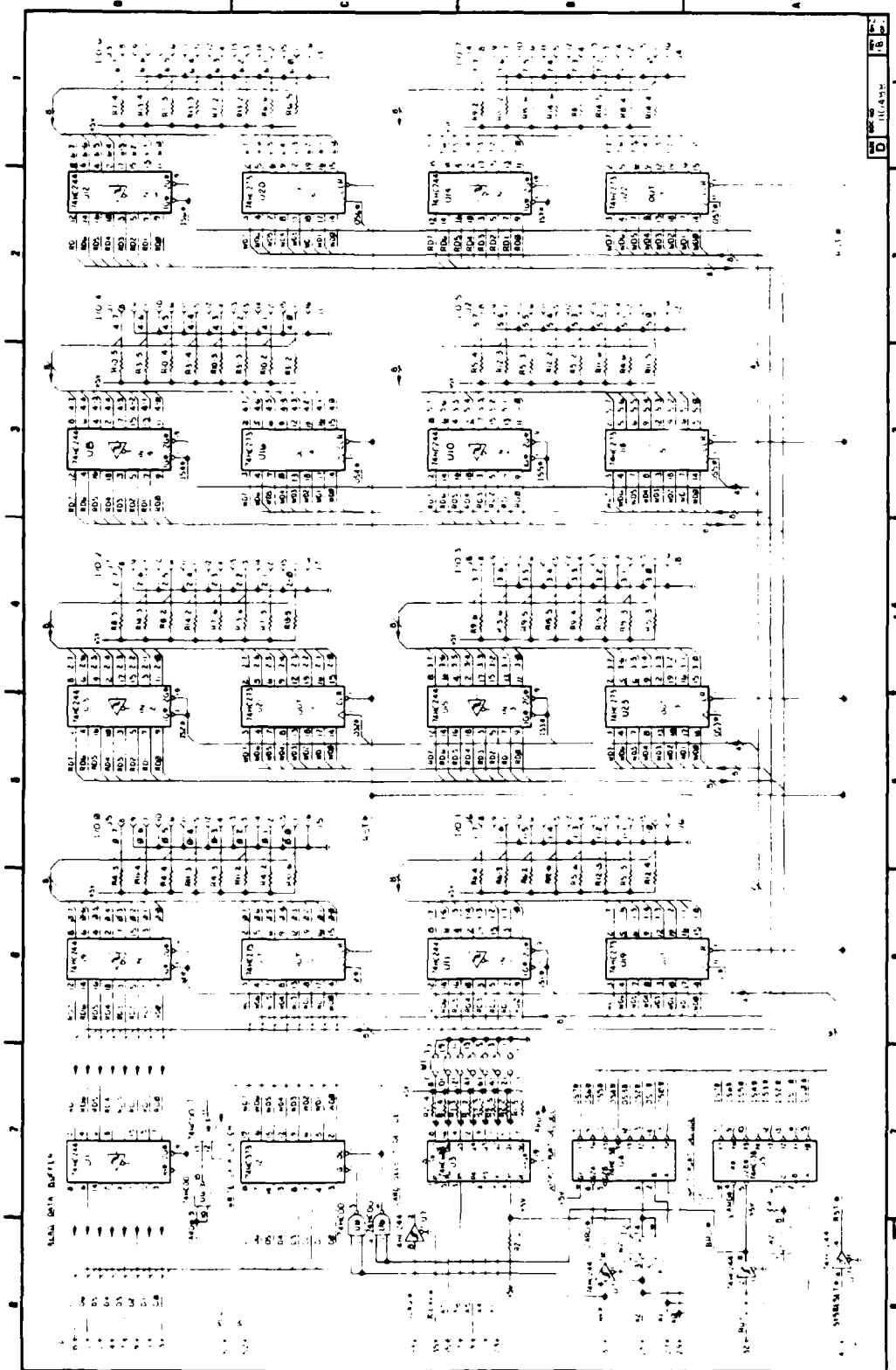


Figure 5-13. Schematic of Pro-Log I/O Circuit Board

sequences. The I/O board also signals the CPU as to which measurement to perform and what operating mode has been selected.

5.3.4 CPU Circuit Board (Figure 5-14)

The CMOS-CPU Card manufactured by Pro-Log Corporation is the microprocessor used in the WQAU-P. The microprocessor is a 80C85A which executes 8080/8085 software. The CPU board also contains sockets for EPROM memory which are not used due to limited on board memory. The WQAU-P software is programmed into 2 CMOS 8K x 8 27C64 Read Only Memory devices, located on the memory expansion board discussed in the next subsection. A 2K x 8 Random Access Memory device is used for temporary memory storage and stack operations. The CPU board also provides three direct restart interrupts. One interrupt is used by the Push to Read Switch to initiate a calibrate or measurement operation. CMOS type CPU, I/O and memory were chosen to minimize power requirements.

5.3.5 Memory Expansion Circuit Board (Figure 5-15 and 5-16)

The 77C08 CMOS 64K-byte Memory Board manufactured by Prolog Corporation is used by the WQAU-P to provide the space for the WQAU-P software contained in two 27C64 EPROMS. A memory expansion board was required because the WQAU-P software exceeded the memory capacity of the existing (GFE) CPU circuit board.

This memory board utilizes high speed CMOS that minimizes power requirements. The board has been configured by jumper selection so that memory is mapped from 0. All unused sockets and options such as segmentation and MEMEX have been disabled. Sockets U10 and U11 (MEM0, MEM1) contain the two EPROMS.

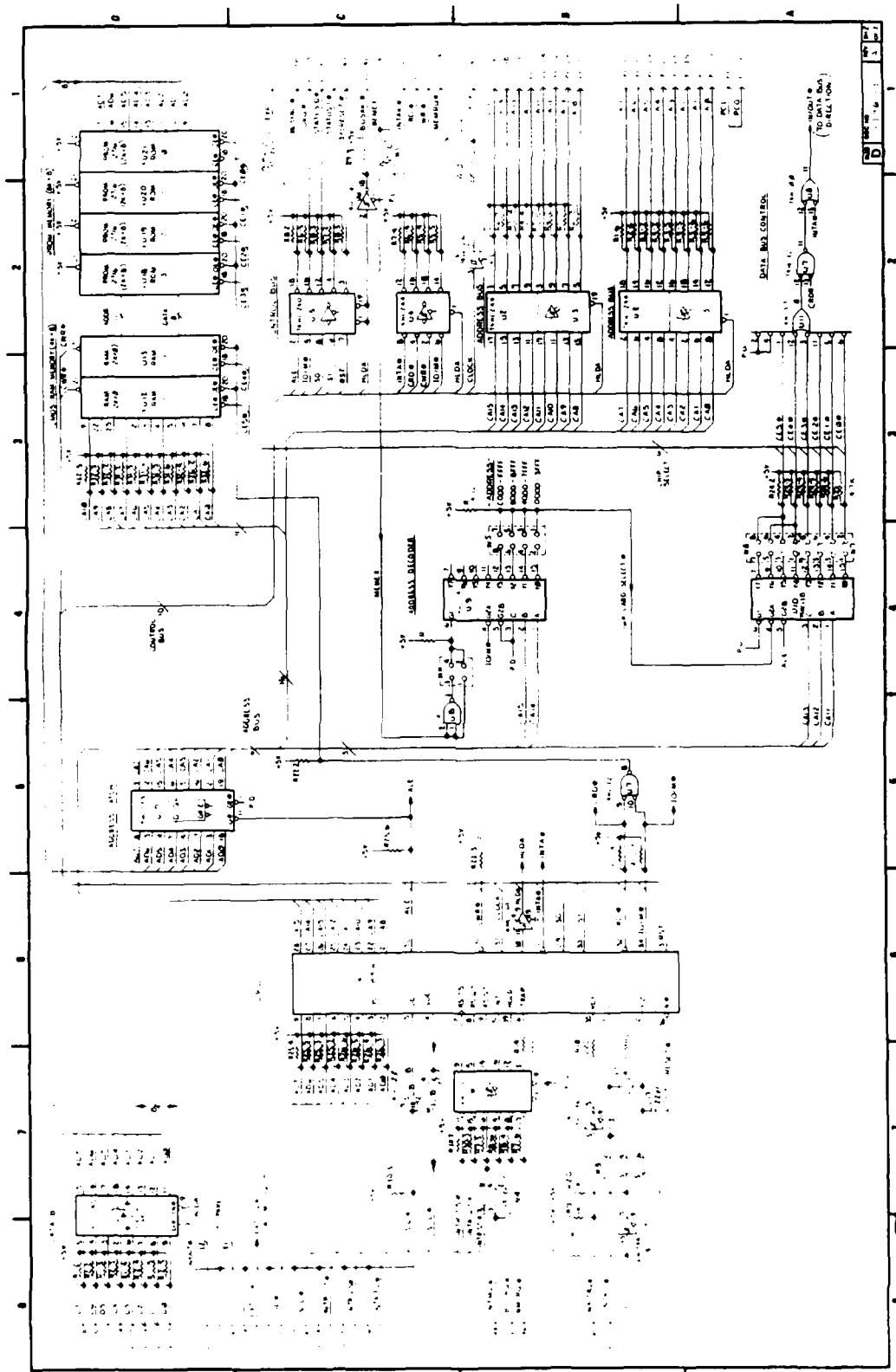


Figure 5-14. Schematic of Pro-Log CPU Circuit Board

Figure 5-15. Schematic of Memory Expansion Circuit Board

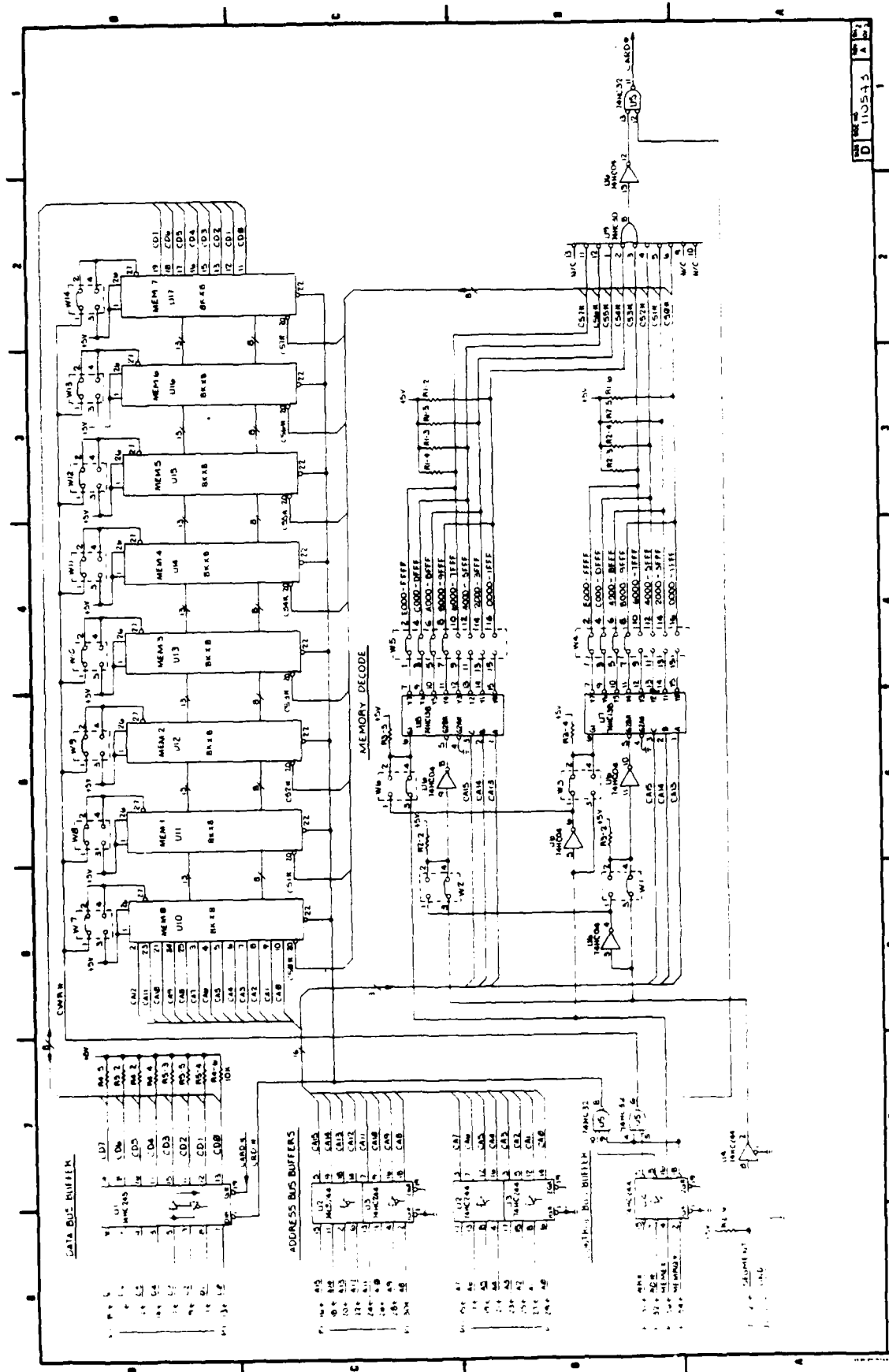


Figure 5-16. Schematic of Memory Expansion Circuit Board (Continued)

5.3.6 Power Supply Circuit Board (Figure 5-17)

The WQAU-P power supply provides power for the operating circuits from an internal battery or external power source. The external power source may be either 115 Vac, 230 Vac, 12 Vdc or 24 Vdc. A linear power supply operated from the power line provides a regulated +12 Vdc. This power supply provides separate primary transformer connections for either 115 Vac or 230 Vac operation. The +12 Vdc output voltage is used to provide trickle charging to the NICAD 12V battery, through a constant current charging circuit. Power is supplied to two dc/dc converters and one, three-terminal voltage regulator from either the +12 Vdc power supply, when operated from the powerline, or from the battery when the WQAU-P is not connected to the powerline.

A dc/dc converter, WF12805/1000Z manufactured by Power Products Inc., supplies +5 Vdc to the sensor control, CPU and I/O circuit boards. The residual chlorine circuitry is activated by the internal battery when the WQAU-P is turned off. When the WQAU-P is turned on, the residual chlorine circuits are powered from the +12 Vdc supply on the sensor control board to provide the floating power supply requirements of A/D converter. A low battery indicator is provided to indicate that the internal battery should be recharged.

5.4 Software

The software that performs the WQAU-P functions is written in 8080/8085 assembly language code and FORTRAN'.

The assembly language code performs the WQAU-P control functions. These are measurement selection determination, calibrate/measure determination, TDS range determination, the push to read function, the turbidity measurement sequence and

Figure 5-17. Schematic of Power Supply Circuit Board

the WQAU-P startup initiation. The assembly language sub-routines also perform the data gathering and display control functions.

The FORTRAN subroutines do the numerical calculations for subtracting the offset, gathered during the calibrate mode, from the data obtained during the measure cycle. The FORTRAN subroutines perform the calculations that compensate the TDS readings for temperature effects, perform the turbidity calculations and compensate the residual chlorine readings for pH and temperature. The FORTRAN subroutines also manipulate the data passed to it from the assembly language code to be compatible with FORTRAN number formats and then again to be compatible with the display requirements. The data is passed to the FORTRAN code as four separate BCD digits that must be packed into one number for calculation purposes.

The resulting calculations must be unpacked into five separate BCD digits that are passed to the assembly language code for display. Leading zeroes are blanked.

The assembly language code and FORTRAN code subroutines are compiled into binary code which is stored in two CMOS EPROMS that reside on the memory expansion board.

A complete listing of the WQAU-P software is included in Appendix A.

5.5 Processing Algorithms

Turbidity, TDS and residual chlorine measurements utilize FORTRAN algorithms to process and manipulate sensor input data and to correct these readings for pH and/or temperature. Specifics of each algorithm are outlined in the following paragraphs.

5.5.1 Turbidity

The turbidity algorithm performs two distinct functions. The first function is performed independently of the WQAU-P mode of operation (i.e. calibrate or measure) and results in the generation of a calculated logarithmic value that is related to the suspended solids concentration of the water sample. The second function corrects the calculated logarithmic value generated during the measurement operation for shift in the zero (calibrate) turbidity reading and for changes in the water temperature from the calibration fluid temperature.

During the calibrate sequence the turbidity probe is placed in zero turbidity water. Each of the sensor's photodiode outputs (two) are initially measured while both of the sensor's LEDs are off. The output from each photodiode is then measured while the LEDs are individually turned on and off. The photodiode dark readings are then subtracted from the appropriate light induced photodiode readings. The resulting four measurements are manipulated to cancel the affects of LED intensity and photodiode sensitivity, and produce a logarithmic value that is proportional to water turbidity. This numerical procedure is detailed in subsection 4.2.3. The calculated logarithmic value and the temperature of the zero turbidity water sample are stored in the WQAU-P microprocessor for use in the measurement aglorithm.

During the measurement sequence the same type of individual sensor readings are obtained as described in the previous paragraph. The resulting calculated logarithmic value is then adjusted to compensate for temperature, to compensate for shift in zero turbidity calibration value and to convert into Nephelometric Turbidity Units (NTU). The algorithm which performs this corrective action is described by the following equation:

$$\text{Turbidity (NTU)} = \left\{ C_m - \left[C_o - \left[K_s (T_o - T_m) \right] \right] \right\} / K_t$$

where

C_m = logarithmic value of sensor output generated during measurement sequence

C_o = logarithmic value of sensor output generated during calibration sequence

K_s = Correction factor for shift in temperature

T_o = temperature of fluid used during calibration

T_m = temperature of water sample being measured

K_t = conversion factor for NTV output

5.5.2 TDS

The TDS probe selected for the multiparameter sensor measures the actual fluid conductivity in terms of millimhos per centimeter. Since the conductivity of a salt solution varies considerably with temperature, the conductivity reading must be adjusted to a standard temperature and then converted to a concentration based on a particular salt. The WQAU-P TDS readings are expressed in terms of equivalent parts of NaCl.

Curves illustrating the temperature correlation between NaCl conductivity readings in micromhos per centimeter and salt concentration were obtained from Beckman Instruments.

Using these curves, an equation was developed which adjusts the conductivity readings to a standard temperature and converts the adjusted conductivity into an equivalent NaCl concentration. This conversion equation is:

$$\text{NaCl (ppm)} = 217754.8 T^{-0.8354} K^{1.00398 T^{0.01995}}$$

where

T = temperature in degrees Fahrenheit

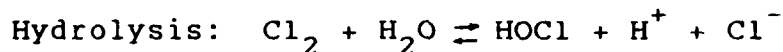
K = conductivity in millimhos per centimeter

Z = temperature related correction factor

$T < 40^{\circ}\text{F}$	$Z = 0.0055 (44 - T) + 1$
$40 \leq T < 60$	$Z = 0.00005 (T - 60)^2 + 1$
$60 \leq T < 70$	$Z = 1.000$
$70 \leq T \leq 120$	$Z = 0.0024 (T - 70) + 1$

5.5.3 Free Available Chlorine

When elemental chlorine is dissolved in water two reactions take place:



Hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) are referred to as the free available chlorine.

The sample pH, and to a lesser degree its temperature, controls the proportions of each of these chlorine species.

Figure 5-18 illustrates this relationship. Since the Xertex sensor measures only the hypochlorous acid a corrective factor must be used to adjust the sensor readings for changes in pH and temperature. Corrective factors are expressed as percentages and are divided into the sensor readings to provide the actual free available chlorine concentration. A correction table has been included in the microprocessor of the WQAU-P.

Figure 5-18 also illustrates that any free available chlorine determinations of water with a pH in excess of 9-9.5 will be relatively meaningless. This should present little if any difficulties since the product water from the RO system is rarely if ever above a pH of 9. In fact, input waters to the RO system with a pH above 9 will degrade or destroy the RO membranes.

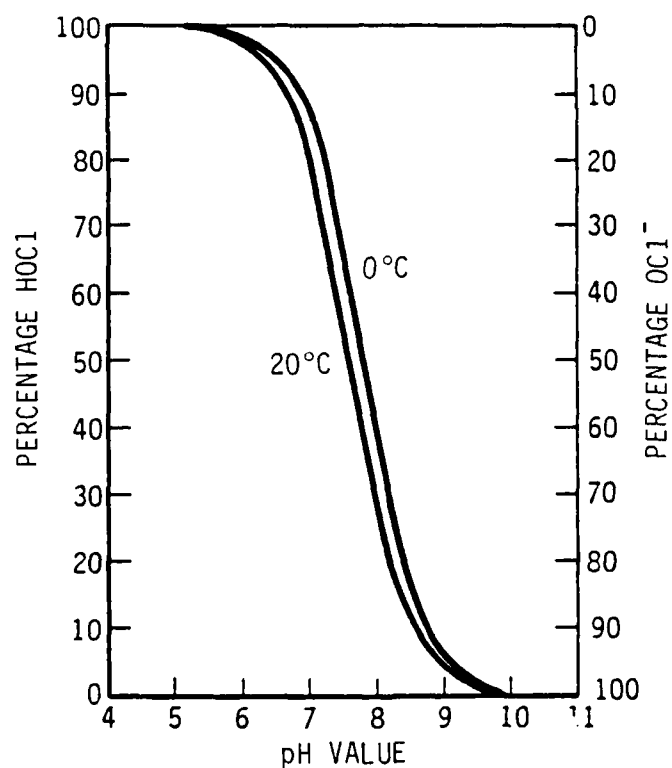


Figure 5-18. Distribution of Hypochlorous Acid and Hypochlorite Ion in Water at Different pH Values and Temperatures

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6. WQAU-P OPERATIONS

WQAU-P operations have been divided into six basic categories. They are:

- Preparation for use
- Field calibration
- Measurement
- Field maintenance
- Laboratory calibration
- Laboratory maintenance.

Preparation for use covers the basic operations needed to ensure that the WQAU-P is totally functional and that all required components and accessories are assembled prior to placing the WQAU-P into field use.

Field calibration operations are performed by the user in the field. This is a very simple procedure which makes adjustments for electrical shifts in the zero or standardized readings of each parameter.

Measurement operations describe the procedures for obtaining instrument readings.

Field Maintenance operations are general procedures that can be performed by the user in the field. This would include cleaning sensor heads, replacing electrolytic fluids and replacing certain sensors.

Laboratory calibration operations must be performed by a qualified laboratory technician. This level of calibration sets the zero value and span value for each parameter.

Laboratory maintenance operations must be performed by a qualified laboratory technician. This would include replacing electrical boards and/or sensors.

Details are available in the commercial grade manual prepared in accordance with CDRL A0005 and titled "Operating and Service Instructions for Water Quality Analysis Unit-Purification" March 1987.

7. RESULTS OF WQAU-P VALIDATION TESTING

Six WQAU-Ps with individual multiparameter sensors were subjected to an extended matrix of tests. This test matrix is detailed in Table 7-1.

Table 7-1. Parametric Test Matrix

Parameter	Measurement Level	Fluid Operating Range	Measurements	Measurements per Sample	Total Measurements
pH	4, 7, 10 pH units	36°F, 68°F, 100°F, 120°F	12	10	120
TDS	50, 100, 500, 1,500, 3,000, 30,000, 50,000 mg/l	36°F, 68°F, 100°F, 120°F	28	10	280
Turbidity	3, 10, 50, 100, 150 NTU	36°F, 68°F, 100°F, 120°F	20	10	200
Residual Chlorine	1, 7, 15	36°F, 68°F, 90°F and 5.5, 7.5 pH units	18	10	180
Temperature (Air)	10°F, 20°F, 140°F, 160°F	N/A	4	10	40

More than 5,400 individual measurements were taken/recorded with the Phase III WQAU-P/multiparameter sensors. Over 95 percent of the readings fell within the accuracy requirements for the parametric measurements. The multiparameter sensor provided over a 97 percent accuracy rate. Residual chlorine was less impressive, logging an 89 percent accuracy rate.

The cumulative percentage of correct readings for each parameter is listed in Table 7-2.

Table 7-2. Cumulative Test Results

Parameter	Total Number of Tests	Percent Correct Readings
Temperature (Fluid)	493	97
Extreme Temperature (Air)	240	85
Total Dissolved Solids	1,680	98
pH	720	100
Turbidity	1,200	95
Residual Chlorine	1,080	89

On an individual WQAU-P basis, the percentage of correct parametric measurements ranged as follows:

- Temperature (fluid) - 94 to 99 percent
- Extreme temperature (air) - 60 to 98 percent
- Total dissolved solids - 93 to 100 percent
- pH - 100 percent (no failures)
- Turbidity - 89 to 99 percent
- Residual chlorine - 78 to 97 percent.

Individual WQAU-P results are summarized in Table 7-3.

Over 55 percent of the TDS errors occurred when measuring salt concentrations of 50,000 mg/l (upper level of measurement). Turbidity errors were evenly distributed over all ranges. Approximately 60 percent of the residual chlorine errors occurred at the upper limit of 15 mg/l. Approximately 75 percent of the temperatures errors occurred below 40°F when measuring fluids between 32°F and 120°F. At extreme temperatures (10°F to 20°F and 140°F to 160°F), 95 percent of the errors occurred at the high range.

Details of test procedures, test results and data analysis are available in the demonstration and test report prepared in accordance with CDRL A013 and titled "Demonstration and Test Report of the WQAU-P Validation Testing" June 1987.

Table 7-3. Test Results for Individual WQAU-Ps

WQAU-P/Multiparameter Sensor	1/1	3/8	6/5	7/4	5/3	4/6
Parameter	Percent Correct Readings					
Temperature (Fluid)	94	99	96	96	98	99
Extreme Temperature (Air)	98	75	85	95	60	98
Total Dissolved Solids	100	98	98	93	100	100
pH	100	100	100	100	100	100
Turbidity	99	99	98	89	97	90
Residual Chlorine	78	85	93	92	97	88

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8. CONCLUSIONS

The Phase II WQAU-P developed during 1985-1986 was retrofitted to include a newly developed multiparameter sensor and modified mechanically to improve the unit's ability to survive rough handling and harsh environments. This improved Phase III WQAU-P occupies 2.0 ft³ and weighs 46 lb. The WQAU-P's simplified calibration and measurement routines can be easily completed in less than 5 min. Only one liquid standard (a mixture of DI water and a sealed packet of pH buffer powder) is required for field calibration. Trained personnel, experienced with the WQAU-P's operation, have performed a complete calibration and measurement sequence in less than 3 min.

All conclusions are based on Foster-Miller's direct experience with the fabrication, assembly, validation testing and field service of the WQAU-Ps.

- The revised WQAU-P with the newly developed multiparameter sensor was able to meet the parametric accuracy requirements for temperature, pH, TDS and turbidity on an average of 97 percent
- Residual chlorine measurements were less impressive, logging only an 89 percent accuracy rate
- The modified WQAU-P case with the improved EMP gasket successfully passed the EMP testing at White Sands
- EMI, drop, decontamination and shock testing by the Government was not completed as of the writing of this Final Report

- The electrical connector for the temperature probe and the TDS probe should be changed to provide easier assembly and a watertight connection at the electrical end
- The spanner nut/gasket design for the three replaceable multiparameter probes did not provide a quality seal against water leakage into the probe socket
- Dead space inside the TDS probe above the sensing elements provides a fluid trap that can contaminate future water samples and produce slightly inaccurate results
- The pH probe requires further protection to minimize breakage due to rough handling
- Residual chlorine measurement techniques/sensor needs to be improved.

9. RECOMMENDATIONS

Recommendations generated from the outcome of this program are directed at two specific goals.

- Improving the WQAU-P's accuracy/repeatability, survivability and maintainability
- Reducing the WQAU-P's size and weight.

The recommendations for reducing the WQAU-P's size/weight are detailed in our weight reduction feasibility report prepared in accordance with CDRL A0009 and titled "Feasibility Study for WQAU-P Weight Reduction." The recommendations listed below are directed at improving the WQAU-P's accuracy, survivability and maintainability.

- Conduct a state-of-the-art survey to see if any new or innovative residual chlorine measurement techniques have been developed since the conception of this program
- Determine if the existing chlorine sensor or measurement technique can be improved to provide more repeatability measurements
- Design a protective cage that will protect the glass bulb of the pH electrode from breakage
- Eliminate the dead space in the TDS probe by filling this void with epoxy
- Continue testing the Phase III WQAU-P to determine the unit's ability to meet EMI, transit drop, decontamination and shock requirements

- Replace the pin type connectors of the temperature probe and TDS probe with coaxial and triaxial connectors, respectively
- The spanner nut used to secure the probes into the multiparameter sensor assembly should be changed into a hex nut design
- Redesign the probe gasket and seating arrangement associated with the spanner nut.

APPENDIX A
WQAU-P Software

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.1

NTRY1 PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3	NAME NTRY1 ;2/16/87
		4	
		5	
		6	
		7	;;
		8	
		9	EXTRN EOD, TYPBR, BLNKAL
		10	PUBLIC D1, D2, D3, D4, D5, DELAY, LDLY
		11	
		12	;;
		13	
		14	
		15	DSEG
		16	
0000		17	FLASH: DS 1 ;STRG FOR PARAM PASS FROM FORTRAN
0001		18	D1: DS 1 ;LSB DISPLAY
0002		19	D2: DS 1 ;LSB+1 DISPLAY
0003		20	D3: DS 1 ;LSB+2 DISPLAY
0004		21	D4: DS 1 ;LSB+3 DISPLAY
0005		22	D5: DS 1 ;MSB DISPLAY
		23	
		24	
		25	;;
		26	
		27	ASEG
		28	
0000		29	ORG 0H
		30	
0000		31	BEGIN: LXI SP, 0E7F0H ;SET STACK POINTER
0003		32	MVI A, 0FFH
0005		33	OUT 01H ;BLANK DISPLAY
0007		34	MVI A, 1EH ;BIT PATTERN FOR INTERRUPT MASK
0009		35	SIM ;SET INTRPT MASK
		36	
		37	
000A		38	DSP8: MVI B, 08H ;SET TO DISPLAY 88888
000C	E	39	CALL EOD
000F	E	40	JMP BLNKAL
		41	
0012		42	DELAY: LXI H, 0CB73H ;.5 SEC. DELAY CONSTANT
0015		43	DLY: DCX H ;DECREMENT LOOP CTR
0016		44	MOV A, H ;GET READY FOR H=L=0=LOOP DONE
0017		45	ORA L ;H & L=0 (COUNTER ZERO)
0018		46	JNZ DLY ;COUNTER NOT =0 (.5 SEC.)
001E		47	RET
		48	
		49	
001C		50	LDLY: CALL DELAY ;LONG DELAY CONSTANT IN P
001F		51	DCR B
0020		52	JNZ LDLY ;LOOP SOME MORE
0023		53	RET ;BACK
		54	

LOC	OBJ	LINE	SOURCE STATEMENT
0024	00	55	NOP
0025	00	56	NOP
0026	00	57	NOP
0027	00	58	NOP
0028	00	59	NOP
0029	00	60	NOP
002A	00	61	NOP
002B	00	62	NOP
		63	
002C	C30000 E	64	DOITV: JMP TYPBR ;GO TO /CAL MEAS & TYPE SUBROUTINE
		65	END

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3 ;	PORT 02
		4	
		5 ;	7 6 5 4 3 2 1 0
		6 ;	- - - - - 0 TEMP
		7 ;	- - - - - 0 TDS
		8 ;	- - - - - 0 PH
		9 ;	- - - - 0 - - - - TURB
		10 ;	- - - 0 - - - - RCHL
		11 ;	- - X - - - - - /CAL-MEAS
		12	
		13	NAME TYP01 ;2/16/87
		14	
		15	
		16	;;;
		17	
		18	
		19	EXTRN PHOF, PHM, TEMPER, RCLOFS, RCLM, TDSOF, TDSMB, TURBOF, TURBM
		20	
		21	PUBLIC TYPBR
		22	
		23	;;;
		24	
		25	
		26	
		27	CSEG
		28	
		29	
0000	31F0E7	30	TYPBR: LXI SP, 0E7F0H ;RESET STACK POINTER
		31	
0003	3EFF	32	MVI A, 0FFH ;BLANK DISPLAY
0005	D301	33	OUT 01
0007	DB02	34	IN 02H ;SET TYPE BITS
0009	E63F	35	ANI 3FH ;CAL/MEAS/& TYPE
000B	FE1B	36	CPI 1BH ;(CAL) . (PH) ?
000D	CA0000 E	37	JZ PHOF ;YES CALCULATE OFFSET
0010	FE3B	38	CPI 3BH ;(MEAS) . (PH) ?
0012	CA0000 E	39	JZ PHM ;MEASURE PH
		40	
		41	
0015	FE1E	42	CPI 1EH ;(CAL) . (TEMP) ?
0017	CA0000 E	43	JZ TEMPER ;SETS ITEM=N
001A	FE3E	44	CPI 3EH ;(MEAS) . (TEMP)
001C	CA0000 E	45	JZ TEMPER
		46	
		47	
001F	FE0F	48	CPI 0FH ;(CAL) . (RESID CHLORINE) ?
0021	CA0000 E	49	JZ RCLOFS ;OFFSET FOR R CL
0024	FE2F	50	CPI 2FH ;(MEAS) . (R CL) ?
0026	CA0000 E	51	JZ RCLM ;MEASURE R CL
		52	
		53	
		54	

LOC	OBJ	LINE	SOURCE STATEMENT		
0029	FE1D	55	CPI	1DH	;(CAL) . (CONDUCTIVITY)
002B	CA0000	E 56	JZ	TDSOF	;GET COND OFFSET
002E	FE3D	57	CPI	3DH	;MEAS AND COND?
0030	CA0000	E 58	JZ	TDSMB	;MEASURE COND FOR TDS
		59			
		60			
0033	FE17	61	CPI	17H	;(CAL) . (TURBIDITY)?
0035	CA0000	E 62	JZ	TURBOF	;GET TURB OFFSET
0038	FE37	63	CPI	37H	;MEASURE TURBIDITY
003A	CA0000	E 64	JZ	TURBM	;MEASURE IT
		65			
		66			
		67			
		68			
		69			
			END		

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WDM3
		2	
		3	NAME CAL1 ;2/17/87
		4	
		5 ;	DESCRIPTION: MACRO USED TO PERFORM CALIBRATIONS AND MEASUREMENTS
		6 ;	VARIABLES ARE MEASUREMENT SETTLING TIME CONSTANTS,
		7 ;	(G1), CALIBRATION NAME SUBROUTINES, OR MEASUREMENT
		8 ;	NAME SUBROUTINES (G2).
		9 ;	(G3) IS THE DECIMAL POINT FLAG
		10 ;	(G4) IS PORT 07 BIT SETTINGS
		11 ;	(G5) IS PORT 05 BIT SETTINGS (RELAY CONTROL)
		12	
		13	;;
		14	
		15	EXTRN LDLY, RDSNS, PACK, UNPACK, DISPLA, BLNKAL, ERTRAP
		16	EXTRN PHOFS, RCLO, OFFST
		17	EXTRN F00G0
		18	EXTRN D2
		19	
		20	PUBLIC PHOF, RCLOFS
		21	
		22	;;
		23	
		24	
		25	MCM MACRO G1, G2, G3, G4, G5
		26	
-		27	MVI A, G5 ;SET PORT 05 TO CONTROL RELAYS
-		28	OUT 05H ;SET PORT
-		29	MVI A, G4 ;SET PORT 07 FOR MUX CHANNEL
-		30	OUT 07H ;OUTPUT IT
-		31	MVI B, G1 ;SETTLING TIME CONSTANT
-		32	CALL LDLY ;WAIT FOR RDG TO SETTLE
-		33	CALL RDSNS ;GET BCD DIGITS FROM HORIBA
-		34	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
-		35	CALL G2 ;SUBTRACT OFFSET OR ---
-		36	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
-		37	CALL OFFST ;CHECK FOR EXCESSIVE OFFSET 50mV
-		38	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
-		39	ORI G3 ;0H=NO DEC. POINT--10H=DEC. POINT
-		40	STA D2 ;SAVE DATA
-		41	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
-		42	JMP BLNKAL ;BLANK ALL DIGITS
-		43	
		44	ENDM
		45	
		46	
		47	CSEG
		48	
0000 CD0000	E	49	CALL F00G0 ;INITIALIZE FORTRAN I/O
		50	
		51	PHOF: MCM 05H, PHOFS, 10H, 50H, 00H ;2.5SEC, PH OFFSET, D.P., P 07
		52+	
0003 3E08		53+	MVI A, 00H ;SET PORT 05 TO CONTROL RELAYS

LOC	OBJ	LINE	SOURCE STATEMENT
0009	D307	55+	OUT 07H ;OUTPUT IT
000E	0605	56+	MVI B,05H ;SETTLING TIME CONSTANT
000D	CD0000	E 57+	CALL LDLY ;WAIT FOR RDG TO SETTLE
0010	CD0000	E 58+	CALL RDSENS ;GET BCD DIGITS FROM HORIBA
0013	CD0000	E 59+	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
0016	CD0000	E 60+	CALL TEMPS ;SUBTRACT OFFSET OR ---
0019	CD0000	E 61+	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
001C	3A0000	E 62+	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
001F	F610	63+	ORI 10H ;0H=NO DEC. POINT--10H=DEC. POINT
0021	320000	E 64+	STA D2 ;SAVE DATA
0024	CD0000	E 65+	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
0027	C30000	E 66+	JMP BLNKAL ;BLANK ALL DIGITS
		67+	
		68	
		69	PHM: MCM 05H,PHMC,10H,058H,00H ;2.5SEC,PH MEAS,D.P.,P 06
		70+	
002A	3E08	71+	MVI A,00H ;SET PORT 05 FOR RELAY ENABLE
002C	D305	72+	OUT 05H ;SET PORT
002E	3E58	73+	MVI A,058H ;SET PORT 06 FOR MUX CHANNEL
0030	D307	74+	OUT 07H ;OUTPUT IT
0032	0605	75+	MVI B,05H ;SETTLING TIME CONSTANT
0034	CD0000	E 76+	CALL LDLY ;WAIT FOR RDG TO SETTLE
0037	CD0000	E 77+	CALL RDSENS ;GET BCD DIGITS FROM HORIBA
003A	CD0000	E 78+	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
003D	CD0000	E 79+	CALL PHMC ;SUBTRACT OFFSET OR ---
0040	CD0000	E 80+	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
0043	3A0000	E 81+	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
0046	F610	82+	ORI 10H ;0H=NO DEC. POINT--10H=DEC. POINT
0048	320000	E 83+	STA D2 ;SAVE DATA
004B	CD0000	E 84+	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
004E	C30000	E 85+	JMP BLNKAL ;BLANK ALL DIGITS
		86+	
		87	
		88	RCLM: MCM 05H,RCLMC,10H,50H,00H ;2.5SEC,R CHL MEAS,D.P.,P 06
		89+	
0051	3E00	90+	MVI A,0H ;SET PORT 05 FOR RELAY ENABLE
0053	D305	91+	OUT 05H ;SET PORT
0055	3E50	92+	MVI A,50H ;SET PORT 06 FOR MUX CHANNEL
0057	D307	93+	OUT 07H ;OUTPUT IT
0059	0605	94+	MVI B,05H ;SETTLING TIME CONSTANT
005B	CD0000	E 95+	CALL LDLY ;WAIT FOR RDG TO SETTLE
005E	CD0000	E 96+	CALL RDSENS ;GET BCD DIGITS FROM HORIBA
0061	CD0000	E 97+	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
0064	CD0000	E 98+	CALL RCLMC ;SUBTRACT OFFSET OR ---
0067	CD0000	E 99+	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
006A	3A0000	E 100+	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
006D	F610	101+	ORI 10H ;0H=NO DEC. POINT--10H=DEC. POINT
006F	320000	E 102+	STA D2 ;SAVE DATA
0072	CD0000	E 103+	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
0075	C30000	E 104+	JMP BLNKAL ;BLANK ALL DIGITS
		105+	
		106	
		107	END

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3	NAME MES1 ;2/17/87
		4	
		5 ;	DESCRIPTION: MACRO USED TO PERFORM CALIBRATIONS AND MEASUREMENTS
		6 ;	VARIABLES ARE MEASUREMENT SETTLING TIME CONSTANTS,
		7 ;	(G1), CALIBRATION NAME SUBROUTINES, OR MEASUREMENT
		8 ;	NAME SUBROUTINES (G2).
		9 ;	(G3) IS THE DECIMAL POINT FLAG
		10 ;	(G4) IS PORT 07 BIT SETTINGS
		11	
		12	;;;;;;;;;;;;;
		13	
		14	EXTRN LDLY, RDSNS, PACK, UNPACK, DISPLA, BLNKAL, ERTRAP
		15	EXTRN PHOFS, TEMPS, RCLD, PHMC, RCLMC
		16	EXTRN FQ0G0
		17	EXTRN D2
		18	
		19	PUBLIC TEMPER, PHM, RCLM
		20	
		21	;;;;;;;;;;;;;
		22	
		23	
		24	MCM MACRO G1, G2, G3, G4, G5
		25	
-		26	MVI A, G5 ;SET PORT 05 FOR RELAY ENABLE
-		27	OUT 05H ;SET PORT
-		28	MVI A, G4 ;SET PORT 06 FOR MUX CHANNEL
-		29	OUT 07H ;OUTPUT IT
-		30	MVI B, G1 ;SETTLING TIME CONSTANT
-		31	CALL LDLY ;WAIT FOR RDG TO SETTLE
-		32	CALL RDSNS ;GET BCD DIGITS FROM MORIBA
-		33	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
-		34	CALL G2 ;SUBTRACT OFFSET OR ---
-		35	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
-		36	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
-		37	ORI G3 ;0H=NO DEC. POINT-10H=DEC. POINT
-		38	STA D2 ;SAVE DATA
-		39	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
-		40	JMP BLNKAL ;BLANK ALL DIGITS
-		41	
		42	ENDM
		43	
		44	
		45	CSEG
		46	
0000 CD0000	E	47	CALL FQ0G0 ;INITIALIZE FORTRAN I/O
		48	
		49	
		50	TEMPER: MCM 05H, TEMPS, 10H, 54H, 0H ;2.5SEC, TEMP OFF & MEAS, P 06
		51+	
0003 3E00		52+	MVI A, 0H ;SET PORT 05 FOR RELAY ENABLE
0005 D305		53+	OUT 05H ;SET PORT
0007 7554		54+	MVI A, 54H ;SET PORT 06 FOR MUX CHANNEL

LOC	OBJ	LINE	SOURCE STATEMENT
0007	3E58	55+	MVI A, 58H ;SET PORT 07 FOR MUX CHANNEL
0009	D307	56+	OUT 07H ;OUTPUT IT
000B	0605	57+	MVI B, 05H ;SETTLING TIME CONSTANT
000D	CD0000	E 58+	CALL LDLY ;WAIT FOR RDG TO SETTLE
0010	CD0000	E 59+	CALL RDSNS ;GET BCD DIGITS FROM HORIBA
0013	CD0000	E 60+	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
0016	CD0000	E 61+	CALL PHDFS ;SUBTRACT OFFSET OR ---
0019	CD0000	E 62+	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
001C	CD0000	E 63+	CALL OFFST ;CHECK FOR EXCESSIVE OFFSET 50MV
001F	3A0000	E 64+	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
0022	F610	65+	ORI 10H ;0H=NO DEC. POINT--10H=DEC. POINT
0024	320000	E 66+	STA D2 ;SAVE DATA
0027	CD0000	E 67+	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
002A	C30000	E 68+	JMP BLNKAL ;BLANK ALL DIGITS
		69+	
		70	
		71	
		72	RCLOFS: MCM 05H, RCLO, 10H, 50H, 0H ;2.5 SEC, RCHL OFF, D.P., P 07
		73+	
002D	3E00	74+	MVI A, 0H ;SET PORT 05 TO CONTROL RELAYS
002F	D305	75+	OUT 05H ;SET PORT
0031	3E58	76+	MVI A, 50H ;SET PORT 07 FOR MUX CHANNEL
0033	D307	77+	OUT 07H ;OUTPUT IT
0035	0605	78+	MVI B, 05H ;SETTLING TIME CONSTANT
0037	CD0000	E 79+	CALL LDLY ;WAIT FOR RDG TO SETTLE
003A	CD0000	E 80+	CALL RDSNS ;GET BCD DIGITS FROM HORIBA
003D	CD0000	E 81+	CALL ERTRAP ;ELIMINATE STRAY OUT OF RANGE RDG
0040	CD0000	E 82+	CALL RCLO ;SUBTRACT OFFSET OR ---
0043	CD0000	E 83+	CALL UNPACK ;UNPACK RESULT FOR DISPLAY
0046	CD0000	E 84+	CALL OFFST ;CHECK FOR EXCESSIVE OFFSET 50MV
0049	3A0000	E 85+	LDA D2 ;SECOND DIGIT HAS DECIMAL POINT
004C	F610	86+	ORI 10H ;0H=NO DEC. POINT--10H=DEC. POINT
004E	320000	E 87+	STA D2 ;SAVE DATA
0051	CD0000	E 88+	CALL DISPLA ;PUT UNPACKED DIGITS IN DSP REG
0054	C30000	E 89+	JMP BLNKAL ;BLANK ALL DIGITS
		90+	
		91	
		92	
		93	END

ASSEMBLY COMPLETE, NO ERRORS

```

C                                WQM3

C      THIS SUBROUTINE READS EACH SENSOR 8 TIMES AND STORES EACH
C      READING IN AN ARRAY CALLED STAT. THE 8 READINGS ARE TO BE
C      USED BY SUBROUTINE ERTRAP TO ELIMINATE ANY STRAY BAD READS.

C                                2/25/87

C                                VERSION 1

1      SUBROUTINE      RDSENS

2      INTEGER*1 RC,I,J
3      INTEGER*1 N1,N2,N3,N4,PARAM,SIGN
4      REAL N,STAT(8)

5      COMMON/NUMB/N
6      COMMON/DATA/N1,N2,N3,N4,PARAM,SIGN
7      COMMON/RDAT/STAT
8      COMMON/RDCNT/RC,I,J

9      EXTERNAL      PACK,CONVRT

10     DO 100 RC=1,8

11     CALL      CONVRT
12     CALL      PACK
13     IF(SIGN .EQ. #00H) N=N*(-1)
14     100  STAT(RC)=N
15     110  CONTINUE
16     RETURN

17     END

```

MODULE INFORMATION:

```

CODE AREA SIZE      = 004BH      75D
VARIABLE AREA SIZE = 0000H      0D
MAXIMUM STACK SIZE = 0002H      2D
37 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT RDSENS

0 TOTAL PROGRAM ERROR(S)
 END OF FORTRAN COMPILATION

```

C                               WQM3
C                               2/25/87
C                               VERSION 1
C    THIS SUBROUTINE CHECKS FOR ANY STRAY BAD READS AND RETURNS
C    A SINGLE GOOD VALUE.

1      SUBROUTINE ERTRAP
2      INTEGER*1 RC, I, J
3      REAL N, STAT(8)
4      COMMON/NUMB/N
5      COMMON/RDAT/STAT
6      COMMON/RDCNT/RC, I, J

7      DO 100 J=1,7
8      DO 100 J=I+1,8
9      IF (STAT(I) . LT. STAT(J)) GO TO 100
10     H=STAT(I)
11     STAT(I)=STAT(J)
12     STAT(J)=H
13 100 CONTINUE

14     N=(STAT(4)+STAT(5))/2.0

15     RETURN

16     END

```

MODULE INFORMATION:

```

CODE AREA SIZE    = 0080H    184D
VARIABLE AREA SIZE = 0004H     4D
MAXIMUM STACK SIZE = 0004H     4D
35 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT ERTRAP

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```

C          WQM3

C          THIS SUBROUTINE TAKES 4 BCD DIGITS IN INTEGER*1 FORM
C          AND CONVERTS(PACKS) THEM INTO ONE REAL NUMBER AND
C          STORES IT IN ADDRESS N.

C                               2/25/87
C                               VERSION 1

1          SUBROUTINE      PACK

2          INTEGER*1 N1,N2,N3,N4,PARAM,SIGN
3          REAL N

4          COMMON/DATA/N1,N2,N3,N4,PARAM,SIGN
5          COMMON/NUMB/N

6          N=N4*1000.0+N3*100.0+N2*10.0+N1

7          RETURN
8          END

```

MODULE INFORMATION:

```

CODE AREA SIZE      = 0072H    114D
VARIABLE AREA SIZE = 0000H      0D
MAXIMUM STACK SIZE = 000EH    14D
25 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT PACK

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```

C      THIS SUBROUTINE UNPACKS A REAL NUMBER INTO 5 INTEGER*1
C      NUMBERS FOR EVENTUAL DISPLAY.

C              2/25/87
C              VERSION 1
1      SUBROUTINE      UNPACK

2      REAL N
3      INTEGER*1 D1, D2, D3, D4, D5

4      COMMON/NUMB/N
5      COMMON/DDATA/D1, D2, D3, D4, D5

6      D5=N/10000.0
7      D4=(N-D5*10000.0)/1000.0
8      D3=(N-(D5*10000.0+D4*1000.0))/100.0
9      D2=(N-(D5*10000.0+D4*1000.0+D3*100.0))/10.0
10     D1=(N-(D5*10000.0+D4*1000.0+D3*100.0+D2*10.0))

11     RETURN

12     END

```

MODULE INFORMATION:

```

CODE AREA SIZE      = 00CFH      207D
VARIABLE AREA SIZE = 0000H       0D
MAXIMUM STACK SIZE = 000EH      14D
22 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT UNPACK

0 TOTAL PROGRAM ERROR(S)
 END OF FORTRAN COMPILATION

```
C          WOM3

C          THIS SUBROUTINE SETS THE PACKED DIGITS INTO MEMORY. NO OFFSET
C          ADJUSTMENT IS REQUIRED. THE SAME ROUTINE IS USED IN THE CAL AND
C          MEASUREMENT MODES. THE VALUE IS RECEIVED IN DEG C.
C          TEMPF= DEG F; TEMPC= DEG C

C                               5/4/87

C                               VERSION 3

1          SUBROUTINE TEMPS

2          REAL N, TEMPF, TEMPC

3          COMMON/NUMB/N
4          COMMON/TEMPV/TEMPF, TEMPC

5          CALL    FQ0G0

6          TEMPF=(N*1.8+320.0)/10.0
7          TEMPC=N/10.0
8          N=ABS(TEMPF*10.0)

9          RETURN

10         END
```

MODULE INFORMATION:

```
CODE AREA SIZE    = 0055H    85D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
30 LINES READ
```

```
0 PROGRAM ERROR(S) IN PROGRAM UNIT TEMPS
```

```
0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION
```

```

C                               WQM3

C      THIS SUBROUTINE CALCULATES THE OFFSET FOR PH MEASUREMENTS.
C      IT IS USED IN THE CALIBRATION MODE. THE STANDARD SOLUTION
C      HAS A PH OF 7
    
```

```

C                               2/25/87
    
```

```

1      SUBROUTINE    PHOFS
2      REAL N,PHO,PH
3      COMMON/NUMB/N
4      COMMON/PHV/PHO,PH

5      N=N-70.0
6      PHO=N
7      IF(PHO .GT. 10.0) N=55555.0
8      IF(PHO .LT. -10.0) N=55555.0

9      N=ABS(N)

10     RETURN
11     END
    
```

MODULE INFORMATION:

```

CODE AREA SIZE    = 0073H    115D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0006H    6D
30 LINES READ
    
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT PHOFS

0 TOTAL PROGRAM ERROR(S)
 END OF FORTRAN COMPILATION

C WQM3
C THIS SUBROUTINE SUBTRACTS THE OFFSET FROM THE MEASURED PRODUCT
C WATER. THE RESULT IS ALSO USED IN THE RESIDUAL CHLORINE
C CORRECTION FACTOR CALCULATION.

C 2/25/87

C VERSION 1

```
1       SUBROUTINE     PHMC
2       REAL N,PHO,PH
3       COMMON/PHV/PHO,PH
4       COMMON/NUMB/N
5       N=N-PHO
6       PH=N
7       N=ABS(N)
8       RETURN
9       END
```

MODULE INFORMATION:

CODE AREA SIZE = 0024H 36D
VARIABLE AREA SIZE = 0000H 0D
MAXIMUM STACK SIZE = 0002H 2D
27 LINES READ

0 PROGRAM ERROR(S) IN PROGRAM UNIT PHMC

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2 ;	
		3 ;	
		4	NAME TDSO1 ;2/18/87
		5 ;	
		6 ;	GETS TDS OFFSET VALUE FOR EACH RANGE
		7 ;	
		8 ;	PORT 05
		9 ;	
		10 ;	7 6 5 4 3 2 1 0
		11 ;	- - - - - 1 TDS RANGE (1)
		12 ;	- - - - - 1 - TDS RANGE (10)
		13 ;	- - - - - 1 - - TDS RANGE (50)
		14 ;	- - - - X - - - /TEMP,PH
		15 ;	- - - 1 - - - - LED 2 "1"
		16 ;	- - 1 - - - - - LED 1 "1"
		17 ;	- X - - - - - /DET 1,DET 2
		18 ;	1 - - - - - UNUSED
		19 ;	;;
		20 ;	
		21 ;	
		22	EXTRN RDSNS,PACK,CONDO,UNPACK,LDLY,DISPLA,BLNKAL,ERTRAP
		23	EXTRN D2,OFFST
		24	
		25	PUBLIC TDSOF,TDSRNG
		26	
		27 ;	;;
		28	
		29	DSEG
		30	
0000		31	TDSRNG: DS 1 ;RANGE INDICATOR STR6
		32	
		33	
		34 ;	;;
		35	
		36	CSEG
		37	
		38	
0000	3E04	39	TDSOF: MVI A,04H ;SET PORT 05 FOR TDS 50 RANGE
0002	320000	D 40	STA TDSRNG ;RANGE INDICATOR
0005	CD1B00	C 41	CALL TDS1 ;DO TDS OFFSET FORTRAN ROUTINE
0008	3E02	42	MVI A,02H ;SET PORT 05 FOR TDS 10 RANGE
000A	320000	D 43	STA TDSRNG
000D	CD1B00	C 44	CALL TDS1
0010	3E01	45	MVI A,01H ;SET PORT 05 FOR TDS 1 RANGE
0012	320000	D 46	STA TDSRNG
0015	CD1B00	C 47	CALL TDS1
0018	C30000	E 48	JMP BLNKAL ;BLANK ALL DIGITS; SAVE BATTERY
		49	
		50 ;	WAIT FOR NEXT DO IT (INTERRUPT) STACK RESET BY TYPBR
		51	
		52	
001B	3EFF	53	TDS1: MVI A,0FFH ;BLANK DISPLAY CONTROL BITS
001D	D301	54	OUT 01H ;OUTPUT BITS - BLANK DISPLAY

LOC	OBJ	LINE	SOURCE STATEMENT
001F	3A0000	D 55	LDA TDSRNG ;GET RANGE INDICATOR BITS AGAIN
0022	D305	56	OUT 05H ;OUTPUT RELAY SELECT BITS
0024	060A	57	MVI B,0AH ;10 LOOPS FOR 5 SEC SETTLE TIME
0026	CD0000	E 58	CALL LDLY ;.5 SEC DELAY LOOP
0029	3E5C	59	MVI A,5CH ;MUX CHANNEL & ENABLE BITS
002B	D307	60	OUT 07H ;SET MUX
002D	CD0000	E 61	CALL RDSENS ;SAMPLE THE TDS CKT OUTPUT
0030	CD0000	E 62	CALL ERTRAP ;TEST FOR STRAY BAD READ
0032	CD0000	E 63	CALL PACK ;PACK DIGITS INTO SINGLE INTEGER
0036	CD0000	E 64	CALL CONDO ;SAVE RESULT FOR LATER CALCULATION
0039	CD0000	E 65	CALL UNPACK ;UNPACK DATA FOR DISPLAY
003C	CD0000	E 66	CALL OFFST ;CHECK FOR EXCESSIVE OFFSET >50MV
003F	3A0000	E 67	LDA D2 ;GET DIGIT 2 DATA FOR D.P. ADDITION
0042	F610	68	ORI 10H ;4TH BIT HIGH FOR D.P.
0044	320000	E 69	STA D2 ;PUT DATA BACK WITH D.P.
0047	CD0000	E 70	CALL DISPLA ;DISPLA RESULT FOR 15 SEC.
004A	C9	71	RET
		72	
		73	END

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3	NAME TDSM1 ;2/18/87
		4	
		5	
		6 ;	TDS MEASUREMENT SUBROUTINE- SUBTRACTS OFFSET, COMPENSATES FOR
		7 ;	TEMPERATURE, AND CHECKS RANGE. CALLS FORTRAN ROUTINE TDS## FOR
		8 ;	RANGE TEST. IF OUT OF RANGE AUTOMATICALLY SETS NEXT LOWER RANGE.
		9	
		10	
		11 ;	PORT 05
		12 ;	
		13 ;	7 6 5 4 3 2 1 0
		14 ;	- - - - - 1 TDS RANGE (1)
		15 ;	- - - - - 1 - TDS RANGE (10)
		16 ;	- - - - - 1 - TDS RANGE (50)
		17 ;	- - - - X - - - /TEMP, PH
		18 ;	- - - 1 - - - - LED 2 "1"
		19 ;	- - 1 - - - - - LED 1 "1"
		20 ;	- X - - - - - /DET 1, DET2
		21 ;	1 - - - - - UNUSED
		22 ;	
		23 ;	;;
		24	
		25	EXTRN RDSNS,PACK,UNPACK,CONDC,LDLY,DISPLA,BLNKAL,ERTRAP
		26	EXTRN TDS50,TDS10,TDS1
		27	EXTRN D1,D2,D3,D4,D5
		28	EXTRN TDSRNG
		29	EXTRN EOD
		30	
		31	
		32	PUBLIC TDSMB
		33	
		34 ;	;;
		35	
		36	
		37	DSEG
		38	
0000		39	RANGE: DS 1
		40	
		41 ;	;;
		42	
		43	CSEG
		44	
0000	3E04	45	TDSMB: MVI A,04H ;SET PORT 05 FOR TDS 50 RANGE
0002	320000	E 46	STA TDSRNG ;TDS50 RANGE INDICATOR
0005	D305	47	OUT 05H ;OUTPUT TO PORT;
0007	CD4700	C 48	CALL TDSMC ;GET READING
000A	CD0000	E 49	CALL TDS50 ;CHECK IN RANGE 5000-50000 MG/L
000D	3A0000	D 50	LDA RANGE ;GET RANGE STATUS CODE
0010	FE55	51	CPI 55H ;IN RANGE?
0012	CA5A00	C 52	JZ TDSMD ;YES, DISPLAY RESULT
		53	
0015	3E02	54	MVI A,02H ;SET PORT FOR TDS10 500-5000 MG/L

LOC	OBJ	LINE	SOURCE STATEMENT
0017	320000	E 55	STA TDSRNG
001A	D305	56	OUT 05H
001C	CD4700	C 57	CALL TDSMC
001F	CD0000	E 58	CALL TDS10 ;CHECK IN RANGE 500-5000 MG/L
0022	3A0000	D 59	LDA RANGE
0025	FE55	60	CPI 55H
0027	CA5A00	C 61	JZ TDSMD
		62	
002A	3E01	63	MVI A,01H ;SET PORT 05 FOR TDS1 0-500 MG/L
002C	320000	E 64	STA TDSRNG
002F	D305	65	OUT 05H
0031	CD4700	C 66	CALL TDSMC
0034	CD0000	E 67	CALL TDS1 ;CHECK IN RANGE 0-500 MG/L
0037	3A0000	D 68	LDA RANGE
003A	FE55	69	CPI 55H
003C	CA5A00	C 70	JZ TDSMD
003F	060E	71	MVI B,0EH ;OUT OF RANGE (0 DISPLAY EEEEE
0041	CD0000	E 72	CALL EOD ;DISPLAY E'S
0044	C30000	E 73	JMP BLNKAL
		74	
0047	060A	75	TDSMC: MVI B,0AH ;5 SEC DELAY CONSTANT
0049	CD0000	E 76	CALL LDLY ;WAIT 5 SEC FOR THINGS TO SETTLE
004C	3E5C	77	MVI A,5CH ;MUX CHANNEL & ENABLE BITS
004E	D307	78	OUT 07H ;SET MUX
0050	CD0000	E 79	CALL RDSENS ;READ CONDUCTIVITY SENSOR, PACK DIGITS
0053	CD0000	E 80	CALL ERTRAP ;CHECK FOR STRAY BAD READ
0056	CD0000	E 81	CALL CONDC ;SUBTRACT OFFSET AND CALCULATE
		82	;FOR TEMPERATURE COMPENSATION.
0059	C9	83	RET
		84	
005A	CD0000	E 85	TDSMD: CALL UNPACK ;UNPACK RESULT INTO INDIVIDUAL DIGITS
005D	CD0000	E 86	CALL DISPLA ;DISPLAY RESULT
0060	C30000	E 87	JMP BLNKAL ;BLANK ALL DIGITS; SAVE BATTERY
		88	
		89	END

ASSEMBLY COMPLETE, NO ERRORS

```

C                WQM3

C      THIS SUBROUTINE HANDLES THE CONDUCTIVITY OFFSET FACTOR.
C      THE STANDARD SOLUTION HAS 0 CONDUCTIVITY. CONDUCTIVITY IS
C      USED AS A MEASUREMENT OF TOTAL DISSOLVED SOLIDS (TDS).

```

```

C                2/25/87
C                VERSION 1

```

```

1      SUBROUTINE      CONDO

2      INTEGER*1 N1,N2,N3,N4,PARAM,SIGN
3      INTEGER*1 TDSRNG
4      REAL N,CONOS,CONOT,CONO1,UC

5      COMMON/DATA/N1,N2,N3,N4,PARAM,SIGN
6      COMMON/NUMB/N
7      COMMON/TDS/CONOS,CONOT,CONO1,UC
8      COMMON/TDSR/TDSRNG

9      CALL      F0060

10     IF(TDSRNG .EQ. #04H) GO TO 10
11     IF(TDSRNG .EQ. #02H) GO TO 20
12     IF(TDSRNG .EQ. #01H) GO TO 30

13     10  CONOS=N
14         N=ABS(N)
15         RETURN

16     20  CONOT=N
17         N=ABS(N)
18         RETURN

19     30  CONO1=N
20         N=ABS(N)
21         RETURN

22     END

```

MODULE INFORMATION:

```

CODE AREA SIZE      = 0063H      99D
VARIABLE AREA SIZE = 0000H      0D
MAXIMUM STACK SIZE = 0002H      2D
43 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT CONDO

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

C THIS SUBROUTINE TESTS FOR IN RANGE TDS READING ON 5000-50000 MG/L
C RANGE. THE ROUTINE RETURNS TO THE CALLING PROGRAM, TDSM, A HEX
C 55 IF THE READING IS IN RANGE; OTHERWISE IT RETURNS A HEX AA.

C 3/16/87

C VERSION 2

```
1      SUBROUTINE    TDS50
2
3      INTEGER*1 RANGE
4      REAL N
5
6      COMMON/NUMB/N
7      COMMON/RNGE/RANGE
8
9      IF (N .GE. 6000.0) GO TO 10
10     RANGE=#00AH
11     RETURN
12
13     10  RANGE=#55H
14     RETURN
15
16     END
```

MODULE INFORMATION:

CODE AREA SIZE = 0022H 34D
VARIABLE AREA SIZE = 0000H 00
MAXIMUM STACK SIZE = 0002H 2D
26 LINES READ

0 PROGRAM ERROR(S) IN PROGRAM UNIT TDS50

0 TOTAL PROGRAM ERROR(S)

END OF FORTRAN COMPILATION

```
C                                WQM3

C      THIS SUBROUTINE TESTS FOR IN RANGE TDS READING ON 500-5000 MG/L
C      RANGE. THE ROUTINE RETURNS TO THE CALLING PROGRAM, TDSM, A HEX
C      55 IF THE READING IS IN RANGE; OTHERWISE IT RETURNS A HEX AA.

C                                3/16/87

C                                VERSION 2

1      SUBROUTINE      TDS10
2
3      INTEGER*1 RANGE
4      REAL N
5
6      COMMON/NUMB/N
7      COMMON/RNGE/RANGE
8
9      IF (N .GE. 600.0) GO TO 10
10     RANGE=#00AH
11     RETURN

10     RANGE=#55H
11     RETURN

11     END
```

MODULE INFORMATION:

```
CODE AREA SIZE      = 0022H      34D
VARIABLE AREA SIZE = 0000H      0D
MAXIMUM STACK SIZE = 0002H      2D
26 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TDS10

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C                               WQM3

C      THIS SUBROUTINE TESTS FOR IN RANGE TDS READING ON 0-500 MG/L
C      RANGE. THE ROUTINE RETURNS TO THE CALLING PROGRAM, TDSM, A HEX
C      55 IF THE READING IS IN RANGE; OTHERWISE IT RETURNS A HEX AA.

C                               2/26/87

C                               VERSION 1

1      SUBROUTINE      TDS1

2      INTEGER*1 RANGE
3      REAL N

4      COMMON/NUMB/N
5      COMMON/RNGE/RANGE

6      IF (N .LT. 0.0) GO TO 10
7      RANGE=#55H
8      RETURN

9      10      RANGE=#00AH
10     RETURN

11     END
```

MODULE INFORMATION:

```
CODE AREA SIZE   = 0022H    34D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
26 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TDS1

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WDM3

C          THIS SUBROUTINE SUBTRACTS THE OFFSET AND CALCULATES THE
C          TOTAL DISSOLVED SOLIDS AS A FUNCTION OF TEMPERATURE.

C          4/8/87

C          VERSION 3

1          SUBROUTINE    CONDC

2          REAL    TEMPF,Y,Q
3          REAL    N,CONOS,CONOT,CONO1,UC

4          INTEGER*1 N1,N2,N3,N4,PARAM,SIGN
5          INTEGER*1 TDSRNG

6          COMMON/DATA/N1,N2,N3,N4,PARAM,SIGN
7          COMMON/NUMB/N
8          COMMON/TEMPV/TEMPF,TEMPC

9          COMMON/TDS/CONOS,CONOT,CONO1,UC
10         COMMON/TDSR/TDSRNG

C          CHECK CONDUCTIVITY RANGE

11         CALL    F0060

12         IF(TDSRNG .EQ. #01H) GO TO 10
13         IF(TDSRNG .EQ. #02H) GO TO 100
14         IF(TDSRNG .EQ. #04H) GO TO 500

C          SUBTRACT OFFSET AND PUT IN REAL FORM:

15         10    UC=(N-CONO1)/1000.0
16              GO TO 1000

17         100    UC=(N-CONOT)/100.0
18              GO TO 1000

19         500    UC=(N-CONOS)/10.0

20              IF(UC .GE. 88.0) GOTO 800
21              GO TO 1000

22         800    Q=.00387*TEMPF+.702

23              UC=UC*Q

24         1000   N=17754.8/TEMPF**.8354*UC**(.00398*TEMPF**.01195)

C          FURTHER CORRECTIONS IN BECKMAN CURVES FOR TEMPERATURE

25              IF((TEMPF .LE. 30.0) .OR. (TEMPF .LT. 56.0)) GO TO 2010

26              IF((TEMPF .LE. 56.0) .OR. (TEMPF .LT. 64.0)) GO TO 2030
```

```
27          GO TO 2040

28      2010  Y=.00346*(TEMPF-30.0)+.972
29          GO TO 3000

30      2030  Y=1.062
31          GO TO 3000

32      2040  Y=.00172*(64.0-TEMPF)+1.062

          C      CORRECTED TDS IN MG/LITER

33      3000  N=N*Y
34          N=ABS(N)

35          RETURN

36          END
```

MODULE INFORMATION:

```
CODE AREA SIZE    = 01EDH    493D
VARIABLE AREA SIZE = 0000H     8D
MAXIMUM STACK SIZE = 000CH    12D
76 LINES READ
```

```
0 PROGRAM ERROR(S) IN PROGRAM UNIT CONDC
```

```
0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION
```

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WDM3
		2	
		3	
		4	NAME TURBO2 ;3/9/87
		5	
		6	
		7	;;;;;;;;;;;;;
		8	
		9	;DESCRIPTION: SUBROUTINE TO CONTROL THE TURBIDITY SENSOR ELEMENTS
		10	; AND TO INVOKE OTHER SUBROUTINES TO CALCULATE THE
		11	; TURBIDITY VALUE. THE OFFSET VALUE IS STORED FOR
		12	; LATER USE BY THE TURBIDITY CALCULATION ROUTINE.
		13	;
		14	;;;;;;;;;;;;;
		15	
		16	EXTRN TBCTRL, TURBO, UNPACK, OFFST, DISPLA, BLNKAL
		17	EXTRN D2, TURLN, TEMPTD, RDSNS, ERTRAP, LDLY
		18	
		19	PUBLIC TURBOF
		20	
		21	;;;;;;;;;;;;;
		22	
		23	CSEG
		24	
0000	CD0000	E 25	TURBOF: CALL TBCTRL ;READ TURBIDITY HEAD AND STORE DATA
0003	3E54	26	MVI A,54H ;GET TEMPERATURE PORT 7 MUX CHANNEL
0005	D307	27	OUT 07H ; SET PORT
0007	0605	28	MVI B,05H ; SETTLING TIME CONSTANT
0009	CD0000	E 29	CALL LDLY ; WAIT FOR RD6 TO SETTLE
000C	CD0000	E 30	CALL RDSNS ; DO A/D READ TEMP
000F	CD0000	E 31	CALL ERTRAP ; ELIMINATE BAD READ
0012	CD0000	E 32	CALL TEMPTD ; CONVERT TEMP AND STORE
0015	CD0000	E 33	CALL TURLN ;CALCULATE LNC
0018	CD0000	E 34	CALL TURBO ;ROUTINE TO PROCESSED DATA OFFSET
001B	CD0000	E 35	CALL UNPACK ;UNPACK DIGITS FOR DISPLAY
001E	CD0000	E 36	CALL OFFST ;CHECK FOR EXCESSIVE OFFSET
0021	3A0000	E 37	LDA D2 ;SECOND DIGIT DECIMAL POINT
0024	F610	38	ORI 10H ;0H NO DEC PT. 10H DEC PT.
0026	320000	E 39	STA D2 ;STORE IT HERE
0029	CD0000	E 40	CALL DISPLA ;PUT UNPACKED DIGITS IN DISP REG
002C	C30000	E 41	JMP BLNKAL ;BLANK ALL DIGITS
		42	
		43	END

ASSEMBLY COMPLETE, NO ERRORS

```
C          WQM3

C          THIS SUBROUTINE SETS THE PACKED DIGITS INTO MEMORY. NO OFFSET
C          ADJUSTMENT IS REQUIRED. THE SAME ROUTINE IS USED IN THE CAL AND
C          MEASUREMENT MODES. THE VALUE IS RECEIVED IN DEG C.
C          TEMPF= DEG F; TEMPC= DEG C

C                      5/4/87

C                      VERSION 3

1          SUBROUTINE TEMPTO

2          REAL N, TTEMPO

3          COMMON/NUMB/N
4          COMMON/TURSOL/UCTUR, TTEMPO, TTEMPM

5          CALL      FQ06D

6          TTEMPO=(N*1.8+320.0)/10.0

7          RETURN

8          END
```

MODULE INFORMATION:

```
CODE AREA SIZE   = 002EH   46D
VARIABLE AREA SIZE = 0000H   0D
MAXIMUM STACK SIZE = 0002H   2D
27 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TEMPTO

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```

      C                      WQM3

      C      CALCULATES FOUR BEAM MEASUREMENTS AFTER SUBTRACTING DARK
      C      CURRENT AND AMPLIFIER OFFSET COMPONENTS.  THE RESULT IS
      C      A NATURAL LOG

      C                      3/9/87

      C                      VERSION 1

1      SUBROUTINE      TURLN

2      REAL      N, UCTUR
3      REAL      DKD1, DKD2, E1D1, E1D2, E2D1, E2D2, KF

4      COMMON/NUMB/N
5      COMMON/TURDTA/DKD1, DKD2, E1D1, E1D2, E2D1, E2D2, KF
6      COMMON/TURSOL/UCTUR, TTEMPO, TTEMPM
7      CALL      F00G0

8      UCTUR=ALOG(((E1D1-DKD1)/(E1D2-DKD2))*((E2D2-DKD2)/(E2D1-DKD1)))

9      RETURN

10     END

```

MODULE INFORMATION:

```

CODE AREA SIZE      = 0074H      116D
VARIABLE AREA SIZE = 0008H       8D
MAXIMUM STACK SIZE = 000EH      14D
25 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TURLN

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3	NAME TCTRL4 ;4/7/87
		4	
		5 ;	THIS SUBROUTINE CONTROLS THE TURBIDITY HEAD. IT READS
		6 ;	AND STORES THE HEAD DATA AND THE K FACTOR.
		7	
		8	
		9	;;
		10	
		11	EXTRN LDLY, TURDK1, TURDK2, TE1D1, TE1D2, TE2D1, TE2D2, TKF
		12	EXTRN DATDSP, DBLANK
		13	
		14	PUBLIC TBCTRL
		15	
		16	;;
		17	
		18	CSEG
		19	
0000	FB	20	TBCTRL: EI ;ENABLE INTERRUPT
0001	3EBF	21	MVI A, 0BFH ;D2-D5 BLANK
0003	320000	22	STA DBLANK ;BLANK DATA STRG
0006	3E6C	23	MVI A, 6CH ;TURB MUX2 CH4
0008	D307	24	OUT 07H ;SET MUX
000A	3E80	25	MVI A, 80H ;D1 DARK
000C	D305	26	OUT 05H ;SET HEAD
000E	0604	27	MVI B, 04H ;2 SEC DELAY
0010	CD0000	28	CALL LDLY ;WAIT FOR CKT SETTLE
0013	CD0000	29	CALL TURDK1 ;READ D1 DARK VALUE
0016	3E0A	30	MVI A, 0AH
0018	CD0000	31	CALL DATDSP
		32	
001B	3ED0	33	MVI A, 0C0H ;D2 DARK
001D	D305	34	OUT 05H ;SET HEAD
001F	0604	35	MVI B, 04H ;2 SEC DELAY
0021	CD0000	36	CALL LDLY ;WAIT FOR CKTS TO STABILIZE
0024	CD0000	37	CALL TURDK2 ;READ D2 DARK VALUE
0027	3E0B	38	MVI A, 0BH
0029	CD0000	39	CALL DATDSP
		40	
002C	3EA0	41	MVI A, 0A0H ;E1D1
002E	D305	42	OUT 05H ;SET HEAD
0030	0604	43	MVI B, 04H ;DELAY FACTOR
0032	CD0000	44	CALL LDLY ;SETTLE TIME
0035	CD0000	45	CALL TE1D1 ;READ LED1 WITH DIODE 1
0038	3E0C	46	MVI A, 0CH
003A	CD0000	47	CALL DATDSP
		48	
003D	3E90	49	MVI A, 90H ;E2D1
003F	D305	50	OUT 05H ;
0041	0604	51	MVI B, 04H ;
0043	CD0000	52	CALL LDLY ;SETTLE TIME
0046	CD0000	53	CALL TE2D1 ;READ LED 2 WITH DIODE 1
0049	3E0D	54	MVI A, 0DH

LOC	OBJ	LINE	SOURCE STATEMENT
004B	CD0000	E 55	CALL DATDSP
		56	
004E	3EE0	57	MVI A, 0E0H ;E1D2
0050	D305	58	OUT 05H ;
0052	0604	59	MVI B, 04H ;
0054	CD0000	E 60	CALL LDLY ;
0057	CD0000	E 61	CALL TE1D2 ;READ LED 1 WITH DIODE 2
005A	3E0E	62	MVI A, 0EH
005C	CD0000	E 63	CALL DATDSP
		64	
005F	3ED0	65	MVI A, 0D0H ;E2D2
0061	D305	66	OUT 05H ;
0063	0604	67	MVI B, 04H ;
0065	CD0000	E 68	CALL LDLY ;
0068	CD0000	E 69	CALL TE2D2 ;READ LED 2 WITH DIODE 2
006B	3E0F	70	MVI A, 0FH
006D	CD0000	E 71	CALL DATDSP
		72	
0070	3E68	73	MVI A, 68H ;K FACTOR MUX 2, CHANNEL 3
0072	D307	74	OUT 07H ;SET MUX
0074	0604	75	MVI B, 04H ;LET MUX SETTLE
0076	CD0000	E 76	CALL LDLY ;
0079	CD0000	E 77	CALL TKF ;READ K FACTOR ANALOG FROM CKT BOARD
		78	
007C	C9	79	RET
		80	
		81	END

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3	
		4	NAME TURBM2 ;3/9/87
		5	
		6	
		7	;;;
		8	
		9	;DESCRIPTION: SUBROUTINE TO CONTROL THE TURBIDITY SENSOR ELEMENTS
		10	AND TO INVOKE OTHER SUBROUTINES TO CALCULATE THE
		11	TURBIDITY VALUE. THE OFFSET VALUE IS STORED FOR
		12	LATER USE BY THE TURBIDITY CALCULATION ROUTINE.
		13	
		14	;;;
		15	
		16	EXTRN TBCTRL, TURBC, UNPACK, OFFST, DISPLA, BLNKAL
		17	EXTRN D2, TURLN, TEMPTM, RDSENS, ERTRAP, LDLY
		18	
		19	PUBLIC TURBM
		20	
		21	;;;
		22	
		23	CSEG
		24	
0000	CD0000	E 25	TURBM: CALL TBCTRL ;GET TEMPERATURE HEAD AND STORE DATA
0003	3E54	26	MVI A,54H ; PORT 7 MUX CHANNEL
0005	D307	27	OUT 07H ; SET PORT
0007	0605	28	MVI B,05H ; SETTLING TIME CONSTANT
0009	CD0000	E 29	CALL LDLY ; WAIT FOR RD6 TO SETTLE
000C	CD0000	E 30	CALL RDSENS ; DO A/D READ TEMP
000F	CD0000	E 31	CALL ERTRAP ; ELIMINATE BAD READ
0012	CD0000	E 32	CALL TEMPTM ; CONVERT TEMP AND STORE
0015	CD0000	E 33	CALL TURLN ;CALCULATE LNC
0018	CD0000	E 34	CALL TURBC ;CALCULATE NTU
001B	CD0000	E 35	CALL UNPACK ;UNPACK DIGITS FOR DISPLAY
001E	3A0000	E 36	LDA D2 ;SECOND DIGIT DECIMAL POINT
0021	E6EF	37	ANI 0EFH ;0H NO DEC PT. 10H DEC PT.
0023	320000	E 38	STA D2 ;STORE IT HERE
0026	CD0000	E 39	CALL DISPLA ;PUT UNPACKED DIGITS IN DISP REG
0029	C30000	E 40	JMP BLNKAL ;BLANK ALL DIGITS
		41	
		42	END

ASSEMBLY COMPLETE, NO ERRORS

```
C          WQM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS TURBIDITY DATA FROM
C          THE TURB. HEAD. DATA IS THEN SAVED FOR LATER CALCULATION
C          OF TURBIDITY.

1          SUBROUTINE      TURDK1
2          REAL N
3          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
4          COMMON/NUMB/N
5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
6          EXTERNAL RDSENS,ERTRAP

7          CALL  RDSENS
8          CALL  ERTRAP
9          DKD1=N

10         RETURN

11         END
```

MODULE INFORMATION:

```
CODE AREA SIZE   = 0010H    16D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
28 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TURDK1

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WQM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS TURBIDITY DATA FROM
C          THE TURB. HEAD. DATA IS THEN SAVED FOR LATER CALCULATION
C          OF TURBIDITY.

1          SUBROUTINE    TURDK2

2          REAL N
3          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

4          COMMON/NUMB/N
5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

6          EXTERNAL RDSENS,ERTRAP

7          CALL    RDSENS
8          CALL    ERTRAP
9          DKD2=N

10         RETURN

11         END
```

MODULE INFORMATION:

```
CODE AREA SIZE    = 0010H    16D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
28 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TURDK2

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WQM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS TURBIDITY DATA FROM
C          THE TURB. HEAD. DATA IS THEN SAVED FOR LATER CALCULATION
C          OF TURBIDITY.
```

```
1          SUBROUTINE    TE1D1
2          REAL N
3          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
4          COMMON/NUMB/N
5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
6          EXTERNAL RDSENS,ERTRAP
7          CALL    RDSENS
8          CALL    ERTRAP
9          E1D1=N
10         RETURN
11         END
```

MODULE INFORMATION:

```
CODE AREA SIZE    = 0010H    16D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
27 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TE1D1

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WQM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS TURBIDITY DATA FROM
C          THE TURB. HEAD. DATA IS THEN SAVED FOR LATER CALCULATION
C          OF TURBIDITY.

1          SUBROUTINE      TE2D1

2          REAL N
3          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

4          COMMON/NUMB/N
5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

6          EXTERNAL RDSENS,ERTRAP

7          CALL  RDSENS
8          CALL  ERTRAP
9          E2D1=N

10         RETURN

11        END
```

MODULE INFORMATION:

```
CODE AREA SIZE   = 0010H    16D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
27 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TE2D1

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WQM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS TURBIDITY DATA FROM
C          THE TURB. HEAD. DATA IS THEN SAVED FOR LATER CALCULATION
C          OF TURBIDITY.

1          SUBROUTINE    TE1D2
2
3          REAL N
3          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
4
5          COMMON/NUMB/N
5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
6
7          EXTERNAL RDSENS,ERTRAP
8
9          CALL    RDSENS
9          CALL    ERTRAP
9          E1D2=N
10
11         RETURN
11
11         END
```

MODULE INFORMATION:

```
CODE AREA SIZE    = 0010H    16D
VARIABLE AREA SIZE = 0000H    0D
MAXIMUM STACK SIZE = 0002H    2D
27 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TE1D2

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WOM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS TURBIDITY DATA FROM
C          THE TURB. HEAD. DATA IS THEN SAVED FOR LATER CALCULATION
C          OF TURBIDITY.

1          SUBROUTINE      TE2D2

2          REAL N
3          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

4          COMMON/NUMB/N
5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

6          EXTERNAL RDSENS,ERTRAP

7          CALL  RDSENS
8          CALL  ERTRAP
9          E2D2=N

10         RETURN

11         END
```

MODULE INFORMATION:

```
CODE AREA SIZE      = 0010H      16D
VARIABLE AREA SIZE  = 0000H       0D
MAXIMUM STACK SIZE  = 0002H       2D
27 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TE2D2

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WQM3
C          3/3/87
C          VERSION 1
C          THIS SUBROUTINE READS AND CHECKS K FACTOR DATA
C          DATA IS THEN SAVED FOR LATER TURBIDITY CALCULATION
C
```

```
1      SUBROUTINE      TKF
2
3      REAL N
4      REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
5
6      COMMON/NUMB/N
7      COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
8
9      EXTERNAL RDSENS,ERTRAP
10
11     CALL  RDSENS
12     CALL  ERTRAP
13     KF=N
14
15     RETURN
16
17     END
```

MODULE INFORMATION:

```
CODE AREA SIZE   = 0010H   16D
VARIABLE AREA SIZE = 0000H   0D
MAXIMUM STACK SIZE = 0002H   2D
27 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TKF

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```

C          WQM3
C      THIS SUBROUTINE CALCULATES THE OFFSET FOR TURBIDITY
C      MEASUREMENTS. IT IS USED IN THE CALIBRATE MODE.
C      THE STANDARD SOLUTION HAS ZERO TURBIDITY.

C          3/3/87

C          VERSION 1

1      SUBROUTINE      TURBO

2          INTEGER*1 D1,D2,D3,D4,D5

3          REAL N,TURBF,TURB,UCTUR
4          REAL DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF

5          COMMON/TURDTA/DKD1,DKD2,E1D1,E1D2,E2D1,E2D2,KF
6          COMMON/DDATA/D1,D2,D3,D4,D5
7          COMMON/NUMB/N
8          COMMON/TUR/TURBF,TURB
9          COMMON/TURSOL/UCTUR,TTEMPO,TTEMPM

10         CALL      F0060

11         TURBF=UCTUR

12         IF(TURBF .LT. 5.0) GO TO 100
13         IF(TURBF .GT. 8.0) GO TO 100
14         N=0

15         GO TO 1000

C      MAKE D5,D4 GREATER THAN ZERO TO FORCE UNACCEPTABLE OFFSET DISPLAY (F'S)

16         100      N=55555.0

17         1000     RETURN

18         END

```

MODULE INFORMATION:

```

CODE AREA SIZE      = 0054H      84D
VARIABLE AREA SIZE = 0000H      0D
MAXIMUM STACK SIZE = 0002H      2D
43 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TURBO

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```

      C                      WQMS

      C      THIS SUBROUTINE SUBTRACTS THE OFFSET FROM THE TURBIDITY
      C      MEASUREMENT. THE TEST SOLUTION TURBIDITY IS ZERO.

      C                      3/23/87
      C                      VERSION 3

1      SUBROUTINE      TURBC

2      REAL N, TURBF, TURB, UCTUR, TTEMPO, TTEMPM, NTU
3      REAL DKD1, DKD2, E1D1, E1D2, E2D1, E2D2, KF

4      COMMON/TUR/TURBF, TURB
5      COMMON/NUMB/N
6      COMMON/TURSOL/UCTUR, TTEMPO, TTEMPM
7      COMMON/TURDTA/DKD1, DKD2, E1D1, E1D2, E2D1, E2D2, KF

8      CALL      F0060

      C      CALCULATE NTU VALUE - CORRECTED FOR TEMPERATURE

9      KF=KF/100000.0

10     TURB=(UCTUR-(TURBF-(.00175*(TTEMPO-TTEMPM))))/KF

      C      SET N EQUAL TO NTU VALUE FOR DISPLAY

11     N=ABS(TURB)

12     RETURN
13     END

```

MODULE INFORMATION:

```

CODE AREA SIZE   = 0054H    84D
VARIABLE AREA SIZE = 0004H    4D
MAXIMUM STACK SIZE = 0002H    2D
37 LINES READ

```

0 PROGRAM ERROR(S) IN PROGRAM UNIT TURBC

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

C WQM3

C THIS SUBROUTINE SETS THE PACKED DIGITS INTO MEMORY. NO OFFSET
C ADJUSTMENT IS REQUIRED. THE SAME ROUTINE IS USED IN THE CAL AND
C MEASUREMENT MODES. THE VALUE IS RECEIVED IN DEG C.
C TEMPF= DEG F; TEMPC= DEG C

C 5/4/87

C VERSION 3

```
1        SUBROUTINE TEMPTM  
  
2        REAL N, TTEMPM  
  
3        COMMON/NUMB/N  
4        COMMON/TURSOL/UCTUR, TTEMPO, TTEMPM  
  
5        CALL    FQ060  
  
6        TTEMPM=(N*1.8+320.0)/10.0  
  
7        RETURN  
  
8        END
```

MODULE INFORMATION:

CODE AREA SIZE = 002EH 46D
VARIABLE AREA SIZE = 0000H 0D
MAXIMUM STACK SIZE = 0002H 2D
27 LINES READ

0 PROGRAM ERROR(S) IN PROGRAM UNIT TEMPTM

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

```
C          WQM3
C      THIS SUBROUTINE SUBTRACTS THE OFFSET. IT ALSO CHECKS FOR FURTHER
C      NEEDED CORRECTION. IF THE PH IS EQUAL TO OR GREATER THAN FIVE
C      IT MUST BE CORRECTED.

C          4/9/87
C
C          VERSION 2

1      SUBROUTINE      RCLMC

2          INTEGER*1 N1,N2,N3,N4,PARAM,SIGN

3          REAL N,PHO,PH,RCLOF,RCLU,FICF,TEMPC,P,TC,KT

4          COMMON/DATA/N1,N2,N3,N4,PARAM,SIGN
5          COMMON/NUMB/N
6          COMMON/PHV/PHO,PH
7          COMMON/RCL/RCLOF,RCLU,FICF,P,TC
8          COMMON/TEMPV/TEMPF,TEMPC
9          COMMON/RCVA/A1,A2,A3,A4,A5

C      SUBTRACT OFFSET

10         CALL      FQ060

11         RCLU=N-RCLOF

C      PH ( 5?

12         IF (PH .LT. 50.0) GO TO 200
13         GO TO 1000

14     200      N=ABS(RCLU)

15         RETURN

16     1000     P=PH/10.0

17         KT=(.05623*TEMPC+1.486)
18         FICF=100*(1/(1+(KT*10**P*1E-8)))

C          CALCULATE RESID. CHLORINE

19         N=ABS(ANINT(100.0/FICF*RCLU))

20         RETURN

21         END
```

```
C          WQM3

C          THIS SUBROUTINE GETS THE RESIDUAL CHLORINE OFFSET FACTOR.
C          THE SAMPLE SOLUTION PH IS LESS THAN 6.0. THE SOLUTION
C          IS DE-MINERALIZED WATER.

C          2/25/87

C          VERSION 1

1          SUBROUTINE      RCLO

2          INTEGER*1 N1,N2,N3,N4,PARAM,SIGN
3          REAL N,RCLOF,RCLU,FICF,P,TC

4          COMMON/DATA/N1,N2,N3,N4,PARAM,SIGN
5          COMMON/NUMB/N
6          COMMON/RCL/RCLOF,RCLU,FICF,P,TC

7          RCLOF=N

8          N=ABS(N)

9          RETURN

10         END
```

MODULE INFORMATION:

```
CODE AREA SIZE      = 0015H      21D
VARIABLE AREA SIZE = 0000H       0D
MAXIMUM STACK SIZE = 0002H       2D
30 LINES READ
```

0 PROGRAM ERROR(S) IN PROGRAM UNIT RCLO

0 TOTAL PROGRAM ERROR(S)
END OF FORTRAN COMPILATION

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.1

ADC1 PAGE 1

LOC	OBJ	INC	SOURCE STATEMENT
		1 ;	WQM3
		2 ;	
		3 ;	
		4	NAME ADC1 ;2/16/87
		5 ;	
		6 ;	
		7 ;	ANALOG TO DIGITAL DATA CONVERSION SUBROUTINE
		8 ;	
		9 ;	
		10 ;	
		11 ;	PORT 07
		12	
		13 ;	7 6 5 4 3 2 1 0
		14 ;	- - - - - X X A/D DIGIT 0 SELECT
		15 ;	- - - - - X Y A/D DIGIT 1 SELECT
		16 ;	- - - - - X - - MUX A0 (CHANNEL ADDR)
		17 ;	- - - - - X - - MUX A1 (CHANNEL ADDR)
		18 ;	- - - 1 - - - - TEMP, PH, TDS, R.CHLR MUX ENABLE "1"
		19 ;	- - 1 - - - - - TURB MUX ENABLE "1"
		20 ;	- X - - - - - UNUSED
		21 ;	1 - - - - - START CONVERSION
		22	
		23	
		24 ;	PORT 06
		25 ;	
		26 ;	7 6 5 4 3 2 1 0
		27 ;	- - - - - X BCD DATA IN 1
		28 ;	- - - - - X - BCD DATA IN 2
		29 ;	- - - - - X - - BCD DATA IN 4
		30 ;	- - - - - X - - BCD DATA IN 8
		31 ;	- - - X - - - - UNUSED
		32 ;	- - 1 - - - - - CONVERSION COMPLETE "1"
		33 ;	- 1 - - - - - OVERFLOW "1"
		34 ;	X - - - - - SIGN 1=+ 0=-
		35 ;	
		36	
		37	
		38	;;;
		39	
		40	
		41	EXTRN EOD,BLNKAL
		42	
		43	PUBLIC CONVRT,N1,N2,N3,N4
		44	
		45	
		46	;;;
		47	
		48	
		49	DSEG
		50	
0000		51	TRYCTR: DS 1 ;READ OVFL COUNTER
0001		52	N1: DS 1 ;LSD ->
0002		53	N2: DS 1 ;->
0003		54	N3: DS 1 ;->

LOC	OBJ	LINE	SOURCE STATEMENT
0004		55	N4: DS 1 ;*— N4 N3 N2 N1
0005		56	PARAM: DS 1 ;NOT USED
0006		57	SIGN: DS 1 ;RDG POLARITY (SIGN) STRG
		58	
		59	
		60	;;
		61	
		62	CSEG
		63	
		64	
0000	3E00	65	CONVRT: MVI A, 0H ;INITIALIZE OVERFLOW COUNTER
0002	320000	66	STA TRYCTR ;SAVE IT HERE
		67	
0005	DB07	68	ATD: IN 07H ;GET PORT 7 BITS FOR SOC
0007	F680	69	ORI 80H ;RAISE BIT 7 (SOC)
0009	D307	70	OUT 07H ;OUT TO PORT 7 ADC
000B	00	71	NOP ;DELAY A LITTLE
000C	DB07	72	IN 07H ;GET PORT TO LOWER SOC LINE
000E	E6FC	73	ANI 0FCH ;LOWER BIT 7
0010	D307	74	OUT 07H ;LOWER SOC LINE
		75	
0012	DB06	76	CONVDN: IN 06H ;CHECK FOR END OF CONVERSION
0014	E620	77	ANI 20H ;END OF CONVERSION BIT ONLY
0016	FE20	78	CPI 20H ;DONE?
0018	C21200	79	JNZ CONVDN ;NO, TRY AGAIN
001B	DB06	80	IN 06H ;YES, GET OVERFLOW BIT
001D	E640	81	ANI 40H ;OVFLW ONLY
001F	FE40	82	CPI 40H ;OVERFLOW = "1"?
0021	CA5D00	83	JZ OVFL ;YES, GO HANDLE SITUATION
		84	
0024	DB07	85	DIG1: IN 07H ;GET PORT TO SET A/D DIGIT ADDR
0026	E6FC	86	ANI 0FCH ;BITS 0,1="0" DIGIT 1 LSD
0028	D307	87	OUT 07H ;SET ADDR
002A	DB06	88	IN 06H ;GET DATA BYTE
002C	E680	89	POLAR: ANI 80H ;SIGN BIT ONLY
002E	320600	90	STA SIGN ;SAVE IT HERE
0031	DB06	91	IN 06H ;GET BYTE AGAIN FOR DATA
0033	E60F	92	ANI 0FH ;BCD DATA ONLY
0035	320100	93	STA N1 ;SAVE LSD HERE
		94	
0038	DB07	95	DIG2: IN 07H ;BITS TO SET ADDR FOR LSD+1
003A	3C	96	INR A ;ADD 1 TO BYTE TO INCREMENT ADDR
003B	D307	97	OUT 07H ;SET A/D 2ND DIGIT ADDR
003D	DB06	98	IN 06H ;GET SECOND DIG BCD VALUE
003F	E60F	99	ANI 0FH ;BCD DATA ONLY
0041	320200	100	STA N2 ;SAVE 2ND DIGIT VALUE HERE
		101	
0044	DB07	102	DIG3: IN 07H
0046	3C	103	INR A
0047	D307	104	OUT 07H
0049	DB06	105	IN 06H
004B	E60F	106	ANI 0FH
004D	320300	107	STA N3
		108	
0050	DB07	109	DIG4: IN 07H

LOC	OBJ	LINE	SOURCE STATEMENT
0052	3C	110	INR A
0053	D307	111	OUT 07H
0055	DB06	112	IN 06H
0057	E60F	113	ANI 0FH
0059	320400	D 114	STA N4
005C	C9	115	RET ;GO BACK AFTER A/D CONVERSION
		116	
		117	
005D	3A0000	D 118	OVFL: LDA TRYCTR ;GET NUMBER OF TRYS TO READ
0060	3C	119	INR A ;INCREMENT VALUE
0061	320000	D 120	STA TRYCTR ;SAVE NEW VALUE
0064	FE03	121	CPI 03H ;4TH READ?
0066	CA6C00	C 122	JZ ERROR ;YES, DISPLAY ERROR
0069	C30500	C 123	JMP ATD ;NOT 4TH TRY; TRY AGAIN
		124	
006C	060E	125	ERROR: MVI B,0EH ;DISPLAY EEEEE
006E	CD0000	E 126	CALL EDD ;DISPLAY THEM
0071	C30000	E 127	JMP BLNKAL
		128	
		129	END

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2 ;	
		3 ;	PORT 01
		4 ;	
		5 ;	7 6 5 4 3 2 1 0
		6 ;	----- 1 UNUSED
		7 ;	----- X - /WE
		8 ;	----- 1 -- 5TH DIGIT BLANK
		9 ;	----- 1 -- 4TH DIGIT BLANK
		10 ;	--- 1 --- 3RD DIGIT BLANK
		11 ;	-- 1 ---- 2ND DIGIT BLANK
		12 ;	- 1 ----- 1ST DIGIT BLANK
		13 ;	1 ----- UNUSED
		14	
		15 ;	PORT 00
		16 ;	
		17 ;	7 6 5 4 3 2 1 0
		18 ;	----- X LSB BCD DATA
		19 ;	----- X - BCD DATA
		20 ;	----- X -- BCD DATA
		21 ;	----- X --- MSB BCD DATA (DIGIT)
		22 ;	--- X ---- DECIMAL POINT
		23 ;	-- X ----- A1 DIGIT ADDRESS MM74C917
		24 ;	- X ----- A2 DIGIT ADDRESS
		25 ;	X ----- A3 DIGIT ADDRESS
		26	
		27	
		28	
		29	NAME DISPLY2 ;4/7/87
		30	
		31	
		32	
		33	::
		34	
		35	
		36	EXTRN LDLY,D1,D2,D3,D4,D5
		37	
		38	PUBLIC DISPLA,DSPLY,BLNKAL,DATDSP,DBLANK
		39	
		40	
		41	::
		42	
		43	
		44	DSEG
		45	
0000		46	DBLANK: DS 1
		47	
		48	
		49	::
		50	
		51	
		52	CSEG
		53	
		54	

LOC	OBJ	LINE	SOURCE STATEMENT
0000	3E83	55	DISPLA: MVI A, 83H ;SETUP FOR DIGIT BLANKING
0002	320000	D 56	STA DBLANK
		57	
		58	
0005	3A0000	E 59	DBLNK5: LDA D5 ;GET 5TH DIGIT
0008	FE00	60	CPI 0H ;= ZERO?
000A	C24500	C 61	JNZ DSPLY ;NO, DISPLAY ALL DIGITS
000D	3A0000	D 62	LDA DBLANK ;YES, GET DIGIT BLANK INFO
0010	F687	63	ORI 87H ;5TH DIGIT BLANK ADDED
0012	320000	D 64	STA DBLANK ;SAVE IT
		65	
0015	3A0000	E 66	DBLNK4: LDA D4 ;GET 4TH DIGIT VALUE
0018	FE00	67	CPI 0H
001A	C24500	C 68	JNZ DSPLY
001D	3A0000	D 69	LDA DBLANK
0020	F688	70	ORI 88H ;BLANK 4TH DIGIT =0
0022	320000	D 71	STA DBLANK
		72	
0025	3A0000	E 73	DBLNK3: LDA D3 ;GET 3RD DIGIT VALUE
0028	FE00	74	CPI 0H
002A	C24500	C 75	JNZ DSPLY
002D	3A0000	D 76	LDA DBLANK
0030	F690	77	ORI 90H
0032	320000	D 78	STA DBLANK
		79	
0035	3A0000	E 80	DBLNK2: LDA D2
0038	FE00	81	CPI 0H
003A	C24500	C 82	JNZ DSPLY
003D	3A0000	D 83	LDA DBLANK
0040	F6A0	84	ORI 0A0H
0042	320000	D 85	STA DBLANK
		86	
		87	
		88	
0045	3A0000	E 89	DSPLY: LDA D5 ;DISPLAY DATA
0048	E61F	90	ANI 1FH ;ZERO ADDRESS AREA
004A	F680	91	ORI 80H ;INCLUDE DIGIT ADDRESS BITS
004C	CD7A00	C 92	CALL DATDSP ;LIGHT THE LAMPS
		93	
004F	3A0000	E 94	DSPLY4: LDA D4
0052	E61F	95	ANI 1FH
0054	F660	96	ORI 60H
0056	CD7A00	C 97	CALL DATDSP
		98	
0059	3A0000	E 99	DSPLY3: LDA D3
005C	E61F	100	ANI 1FH
005E	F640	101	ORI 40H
0060	CD7A00	C 102	CALL DATDSP
		103	
0063	3A0000	E 104	DSPLY2: LDA D2
0066	E61F	105	ANI 1FH
0068	F620	106	ORI 20H
006A	CD7A00	C 107	CALL DATDSP
		108	
006D	3A0000	E 109	DSPLY1: LDA D1

LOC	OBJ	LINE	SOURCE STATEMENT
0070	E61F	110	ANI 1FH
0072	F600	111	ORI 00H
0074	CD7A00	C 112	CALL DATDSP
0077	CD8800	C 113	CALL DSPTMR
		114	;DISPLAY FOR 15 SECONDS
		115	;THEN BLANK ALL DIGITS
		116	
007A	D300	117	DATDSP: OUT 00H ;LOAD MM74C917 REGISTERS
007C	3A0000	D 118	LDA DBLANK ;LEADING 0 BLANK INFO
007F	E6FD	119	ANI 0FDH ;LOWER WE/ LINE MM74C917 WRT EN.
0081	D301	120	OUT 01H ;OUTPUT BLNKG & WRT ENABLE
0083	F602	121	ORI 02H ;RAISE WE/ LINE
0085	D301	122	OUT 01H ;OUTPUT IT
0087	C9	123	RET ;GO BACK
		124	
		125	
0088	FB	126	DSPTMR: EI ;RE-ENABLE INTERRUPTS
0089	DB02	127	IN 02H ;GET MEAS TYPE BITS
008B	E63F	128	ANI 3FH ;CAL MEAS TYPE BITS
008D	FE1D	129	CPI 1DH ;TDS OFFSET ?
008F	CA9000	C 130	JZ SHORTD ;YES, 5 SEC DISPLAY
0092	0618	131	MVI B,18H ;24 LOOPS
0094	CD0000	E 132	CALL LDLY ;.5 SEC DELAY LOOP
0097	C9	133	RET
0098	0608	134	SHORTD: MVI B,08H ;5 SEC DISPLAY LOOP CONSTANT
009A	CD0000	E 135	CALL LDLY ;DELAY
009D	C9	136	RET
		137	
		138	
		139	
009E	3EFF	140	BLNKAL: MVI A,0FFH ;CONTROL TO BLANK ALL DIGITS
00A0	D301	141	OUT 01H
00A2	C39E00	C 142	JMP BLNKAL ;WAIT HERE FOR NEXT DO IT
		143	
		144	
		145 ;	BLANK 5TH DIGIT DBLANK=87H
		146 ;	5TH,4TH DIGITS =8FH
		147 ;	5TH,4TH,3RD DIGITS =9FH
		148 ;	5TH,4TH,3RD,2ND DIGITS =BFH
		149	
		150	
		151	END

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.1

OFTST1 PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3	NAME OFTST1 ;2/17/87
		4	
		5 ;	SUBROUTINE CHECKS FOR OFFSET MEASUREMENTS GREATER THAN
		6 ;	50 MILLIVOLTS. IF > 50MV FFFF IS DISPLAYED BUT ERROR
		7 ;	IS NOT FATAL. VALUE CAN BE USED FOR MEASUREMENT CYCLE.
		8	
		9	;;
		10	
		11	
		12	EXTRN D5,D4,D3,D2,D1
		13	EXTRN EDD
		14	
		15	PUBLIC OFFST
		16	
		17	;;
		18	
		19	CSEG
		20	
		21	
0000	3A0000	E 22	OFFST: LDA D5 ;GET 5TH DIGIT
0003	FE00	23	CPI 0H ;= 0 ?
0005	C22A00	C 24	JNZ HI ;NO > 0 OFFSET HIGH
0008	3A0000	E 25	LDA D4 ;YES GET 4TH DIGIT
000B	FE00	26	CPI 0H ;= 0 ?
000D	C22A00	C 27	JNZ HI
0010	3A0000	E 28	LDA D3
0013	FE00	29	CPI 0H
0015	C22A00	C 30	JNZ HI
0018	3A0000	E 31	LDA D2
001B	07	32	RLC
001C	07	33	RLC
001D	07	34	RLC
001E	07	35	RLC
001F	47	36	MOV B,A
0020	3A0000	E 37	LDA D1
0023	B0	38	ORA B
0024	FE50	39	CPI 50H
0026	D22A00	C 40	JNC HI ;YES
0029	C9	41	RET ;NO
		42	
002A	060F	43	HI: MVI B,0FH
002C	CD0000	E 44	CALL EDD
002F	C9	45	RET
		46	
		47	
		48	END

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.1

EROVF PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	
		2 ;	WQM3
		3	
		4	
		5	NAME EROVF ;2/17/87
		6	
		7	
		8 ;	SUBROUTINE USED TO DISPLAY ERROR MESSAGES
		9 ;	E=ERRORS
		10 ;	F=OFFSET MEASUREMENTS TOO LARGE - NOT FATAL
		11 ;	B=INITIAL DISPLAY SEGMENT CHECK
		12	
		13	;;
		14	
		15	EXTRN DISPLA,BLNKAL
		16	EXTRN D1,D2,D3,D4,D5
		17	
		18	PUBLIC EDD
		19	
		20	;;
		21	
		22	
		23	CSEG
		24	
0000	78	25	EDD: MOV A,R
0001	320000 E	26	STA D1
0004	320000 E	27	STA D2
0007	320000 E	28	STA D3
000A	320000 E	29	STA D4
000D	320000 E	30	STA D5
0010	CD0000 E	31	CALL DISPLA
0013	C9	32	RET
		33	END

ASSEMBLY COMPLETE, NO ERRORS

LOC	OBJ	LINE	SOURCE STATEMENT
		1 ;	WQM3
		2	
		3 ;	TRANSFERS DATA FROM ARRAY TO A VARIABLE
		4	
		5	
		6	NAME TRANSFR1
		7	
		8 ;	DATE: 2/17/87
		9	
		10 ;	ITPTR OR IARY ADDR. IN DE
		11 ;	ITEMP OR ICF ADDR. IN BC
		12 ;	
		13	;;
		14	
		15	PUBLIC TFR
		16	
		17	;;
		18	
		19	CSEG
		20	
0000	1A	21	TFR: LDAX D ;GET LOW ADDR NIBBLE
0001	6F	22	MOV L,A ;STORE IN L
0002	13	23	INX D ;BUMP FOR HIGH NIBBLE ADDR.
0003	1A	24	LDAX D ;GET HIGH NIBBLE ADDR
0004	67	25	MOV H,A ;PUT IT IN H
0005	7E	26	MOV A,M ;GET DATA FROM ARRAY
0006	02	27	STAX B ;STORE IT IN ITEMP OR ICF
0007	03	28	INX B ;BUMP FOR HIGH ADDR NIBBLE
0008	AF	29	XRA A ;ZERO A
0009	02	30	STAX B ;ZERO HIGH NIBBLE
		31	;HIGHEST AOH—INT*2 POSITIVE
000A	C9	32	RET ;GO BACK
		33	
		34	
		35	END

ASSEMBLY COMPLETE, NO ERRORS