Field Operations Document for Environmental Technology Verification

of

Kinetico Pressure Filtration System
For The Physical Removal of *Giardia* and *Cryptosporidium* From Drinking Water

Kinetico Incorporated
10845 Kinsman Road
Newbury, Ohio 44065
(216) 564-9111

Prepared by
Cartwright, Olsen and Associates, LLC
19406 East Bethel Blvd.
Cedar, Minnesota 55011
(612) 434-1300

© 1999 COA

FORWARD

The following Field Operations Document (FOD) was prepared for the Environmental Technology Verification of the Kinetico Macrolite® Pressure Filtration System. It was prepared by the Field Testing Organization (FTO) in accordance with the Protocols and Test Plan established by NSF and EPA for the removal of microorganism contaminants.

The ETV program is a cooperative program of the NSF and EPA developed to evaluate in a structured and comprehensive manner new and innovative water treatment technologies. The program was designed with the needs of small systems in mind, although the technologies may be applicable to larger public water supplies as well.

The purpose of this document is to coordinate the understanding of the FTO, the manufacturer of the technology, NSF and EPA, with respect to the objectives and methodologies of the testing. It is intended to serve as an on-site, working document, and subject to some modification as testing proceeds. While it is a public document and is not intended to be proprietary, it is written for the benefit of principal parties and for the convenience of the reviewers of the final verification and performance report and not for the general public. Accordingly, while some background is offered, it is not intended to be a tutorial on the technology. It is expected that future reviewers of the performance report will have at their disposal copies of this document, however, to offer them a background on the testing procedures.

This FOD is based on the Protocol and Test Plan published as Chapters 1 and 6 of the EPA/NSF ETV *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* April 20, 1998, and conforms to those documents.

The Kinetico SW224 System is a backwashable pressure filter system, including two 24 inch diameter filter tanks, each designed for continuous service flows of 30 gpm. The media, called Macrolite®, consists of synthetic ceramic spheres, and is more fully described within the body of the document.

The technology in this FOD is comparatively old; however, the use of a synthetic ceramic media is relatively new, so some adaptation to the common filtration technology is required. The Macrolite® has properties that the manufacturer feels are ideally suited to filtration, and in part, Macrolite® is the substance challenged. In addition, the SW224 Filter System has control and monitoring functions that are exclusive to the design. These functions are also being verified in this study.

TABLE OF CONTENTS

DESCRIPTION	PAGE
FOREWORD	i
TABLE OF CONTENTS	ii
LIST OF ILLUSTRATIONS	v
1.0 INTRODUCTION	1
1.1 Executive Summary	1
1.2 Abbreviations and Acronyms	2
2.0 EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES	4
2.1 Verification Testing Organization And Participants	4
2.2 Organization	6
2.3 Verification Testing Site	7
2.4 Water Quality	7
2.4.1 Raw Water Quality Parameters	7
2.4.2 Treated Water Data From University of Minnesota St. Anthony Falls Hydraulics Laboratory	9
3.0 EQUIPMENT CAPABILITIES & DESCRIPTION	12
3.1 Equipment Capabilities	12
3.2 Equipment Description	13
3.2.1 Design Specifications And Limitations	18
3.2.2 Statement of Performance	19
3.2.3 Installation Requirements	19
4.0 EXPERIMENTAL DESIGN	20
4.1 Purpose	20
4.2 Equipment Characteristics	21
4.2.1 Qualitative Factors	21
4.2.2 Quantitative Factors	21
4.3 Water Quality Considerations	22
4.3.1 Source Water Quality	22
4.3.2 Treated Water Quality	22
4.4 Data Recording	23
4.5 Recording Statistical Uncertainty	23
4.6 Verification Testing Schedule	23
5.0 FIELD OPERATIONS PROCEDURES	25
5.1 Task -A: Characterization of Feed Water	25
5.1.1 Objective	25
5.1.2 Data	25
5.2 Task -B: Initial Test Runs	25
5.2.1 Objective	25
5.2.2 Data	26
5.3 Task 1 - Verification Testing Runs and Routine Equipment Operation	26
5.3.1 Objective	27
5.3.2 Initial Operations	27

TABLE OF CONTENTS (Continued)

DESCRIPTION PAGE

5.3.3 Schedule....27
5.3.4 Verification Period....27
5.4 Task 2 - Feed And Finished Water Quality....28
5.4.1 Objective....28
5.4.2 Initial Test Runs....28
5.4.3 Testing Schedule For Quality Parameters....28
5.5 Task 3 - Documentation of Operation Conditions And Treatment Equipment Performance....30
5.5.1 Objective....30
5.6 Task 4 - Microbiological Contaminant Removal Testing....33
5.6.1 Preparation of Microbial Doses....33
5.6.2 Data Evaluation....35
5.7 Task 5 - Data Management....35
5.7.1 Objective....35
5.7.2 Data Recording....37
5.7.3 Water Quality Data Grab Samples....37
5.8 Task 6 - QA/QC....37
5.8.1 QA/QC Verifications....37
5.8.2 Specific Instrumentation Methods....38
5.8.2.1 pH....38
5.8.2.2 Temperature....38
5.8.2.3 Turbidity....38
5.8.2.4 Particle Counting....39
5.8.2.5 Particle Free Water (PFW)....39
5.8.2.6 Pressure Gauges....40
5.8.3 Procedures for Chemical and Biological Samples Shipped For Off-Site Analysis....40
5.8.3.1 Organic Parameters, Total Organic Carbon and UV Absorbance....40
5.8.3.2 Microbial Samples: Coliform and Algae....40
5.8.3.3 Inorganic Samples....40

6.0 QUALITY ASSURANCE PROJECT PLAN....41
6.1 Objective....41
6.2 Representativeness....41
6.3 Completeness....41
6.4 Accuracy....42
6.5 Precision....43
6.6 Reports....43
6.7 Corrective Action....44

7.0 DATA MANAGEMENT, ANALYSIS AND REPORTING....45
7.1 Data Management and Analysis....45
7.2 Performance Report Draft....45

8.0 SAFETY MEASURES....46

9.0 OPERATIONS AND MAINTENANCE....47

TABLE OF CONTENTS (Continued)

DESCRIPTION	PAGE
10.0 REFERENCES	49
11.0 GLOSSARY	50
APPENDIX A - Installation, Operation and Maintenance Manual	A-1
APPENDIX B - Record Of Data For Mississippi River Water	B-1
APPENDIX C - Time Line Chart	C-1
APPENDIX D - Sample Log Book	D-1
APPENDIX E - Spectrum Laboratory QA/QC Manual	E-1
APPENDIX F - BioVir Laboratories, Inc. QA/QC Manual, Certification & Sample Log	F-1
APPENDIX G - Testing & Calibration	G-1
APPENDIX H - University of Minnesota St. Anthony Falls Hydraulics Laboratory	H-1
APPENDIX I - Approval Letter From The Metropolitan Environmental Industrial Waste Authorities	I-1

LIST OF ILLUSTRATIONS

DESCRIPTION PAGE

Tables:

Table 2-1 - Minneapolis Water Raw Water Parameters..... 8
Table 2-2 - Summary of University of Minnesota St. Anthony Falls Hydraulics Laboratory Treated Water..... 9
Table 3-1 - Kinetico SW224 Maximum And Minimum Influent Conditions.....18
Table 3-2 - Kinetico SW224 System Effluent Characteristics 19
Table 5-1 - Testing Schedule For Quality Parameters.....29
Table 5-2 - Uniformity Of The Macrolite® 70/80 Mesh Media.....31
Table 5-3 - Kinetico Laboratory Analysis of 70 Mesh Media.....31
Table 5-4 - Operating Data 32

Figures:

Figure 2-1 - Organizational Chart 6
Figure 2-2 - Flow Schematic Of Existing Water Treatment Facility And Incorporation Of Pilot Installation.....10
Figure 2-3 - Schematic Of Pilot Installation For Verification Period.....11
Figure 3-1 - Magnification Of Macrolite® Media.....14
Figure 3-2 - Kinetico SW224 - Illustration Of Filter.....15
Figure 3-3 - Process Flow Illustrations & Configuration 17

1.0 INTRODUCTION

1.1 EXECUTIVE SUMMARY

The following is the Field Operations Document (FOD) for the Environmental Technology Verification (ETV) third party field testing of the Kinetico, Inc. (KI) SW224 backwashable Macrolite® Pressure Filtration System. The KI SW224 filter system will be challenged with *Giardia lamblia* cysts and *Cryptosporidium parvum* oocysts seeded into a blend of untreated water from the Mississippi River, and finished water from the University of Minnesota St. Anthony Falls Hydraulic Laboratory.

This FOD was prepared by an NSF approved Field Testing Organization (FTO), Cartwright, Olsen and Associates, LLC, (COA) and is based on the Protocol and Test Plan published as Chapters 1 and 6 of the EPA/NSF ETV *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants,* April 20, 1998.

The purpose of the testing is to verify the performance claims of the manufacturer through a carefully designed study involving rigorous QA/QC controls. Testing is carried out in the field and consists of two phases:

I) An initial operations phase and
II) A testing and verification phase

The initial operations phase consists of two tasks:

A) An evaluation of the source water characteristics for establishing the suitability of the site for the performance study

B) Initial test runs to determine the readiness of the equipment for the second phase

The testing and verification phase consists of six tasks designed to measure the equipment performance against the manufacturer's claims. The six tasks are:

1) Verification testing runs and routine equipment operation
2) Test runs for feed and finished water
3) Documentation of operating conditions and treatment equipment performance
4) Documentation of microbiological contaminant removal
5) Data management
6) Data quality assurance/quality control

Inorganic water analyses will be conducted by Spectrum Labs, Inc., of New Brighton Minnesota, and microbiological laboratory work will be performed by BioVir Laboratories, Inc. of Benicia, California.

These tasks and the testing procedures are more fully described in this document below. Following the testing and verification phase, the data will be reviewed, summarized and a full verification report will be generated by the FTO for submission to the NSF/EPA. EPA will publish the final report for distribution to interested State and Municipal water treatment regulators and engineers.

The purpose of the testing is to verify the performance expectations of the manufacturer through a carefully designed study involving rigorous QA/QC controls. The manufacturer anticipates 2+ log removal of particles of 5 μm or larger at flow rates of 30 gpm and 1.5 log removal of particles of 3-5 μm in size, which includes *C. parvum*. This is the benchmark against which the system will be tested. This test will employ viable microorganisms and thus, the ETV claim is for a 1.5 log removal of *C. parvum*, and a 2 log removal of *G. lamblia*.

The following are the maximum and minimum influent conditions.

Inlet flow rate - maximum	30 gpm
Inlet flow rate - minimum	0 gpm
Maximum static pressure	100 psi
Minimum inlet dynamic pressure	35 psi
Maximum temperature	100° F
Minimum temperature	35 °F
Maximum inlet turbidity	8 NTU

1.2 ACRONYMS, ABBREVIATIONS, FORMULA AND SYMBOLS

APHA
American Public Health Association.

ASTM
American Society for Testing and Materials.

AWWA
American Water Works Association.

COA
Cartwright, Olsen and Associates.

DI
Deionized (demineralized) water.

EPA
US Environmental Protection Agency.

ETV
Environmental Technology Verification.

FOD
Field Operations Document.

FTO
Field Testing Organization.

KI
Kinetico Incorporated.

NIST
National Institute of Standards and Technology.

NSF
NSF International, Formerly National Sanitation Foundation.

(Oo)cyst
Will be used to refer to both cysts and oocysts when used together.

PFW
Particle Free Water.

PLC
Programmable Logic Computer.

SM
Standard Methods for the Examination of Water and Wastewater.

SWTR
Surface Water Treatment Rule.

TOC
Total Organic Carbon.

TSS
Total Suspended Solids

Ten State's Standards
Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, *Recommended Standards for Water Works*.

USEPA
United States Environmental Protection Agency.

WEF
Water Environment Federation.

2.0 EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES

2.1 EQUIPMENT TESTING ORGANIZATION AND PARTICIPANTS

The Field Testing Organization, Cartwright, Olsen and Associates, LLC (COA) will responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, and test data management.

Kinetico Incorporated (KI) will be responsible for the installation and maintenance of the equipment and will provide logistical and technical support during the initial operations period. The FTO will supervise any and all repair and maintenance procedures during the test period for documentation into the final report.

Responsibilities Specific to COA:

- COA will act as coordinator of all communications during the test period and will coordinate all activities.
- COA will ensure that the selected site meets the requirements of the test.
- All data relevant to the data collection, verification studies and analyses will be managed and controlled by COA.
- COA personnel will operate the equipment during the testing period. The equipment will be under the supervision of COA as the Field Testing Organization.
- COA will interpret the data and write the final report for submission to EPA/NSF.

Following is a list of the persons, firms and associates of COA as members of the Field Testing Organization.

Cartwright, Olsen & Associates, LLC
19406 East Bethel Blvd.
Cedar, Minnesota 55011
(612) 434-1300
Fax (612) 434-8450
e-mail: p.olsen@ix.netcom.com

– Peter S. Cartwright, P.E., Principal Investigator, QA/QC.
– Philip C. Olsen, Managing Partner.
– Debra E. Huffman, Ph.D., Principal Investigator (Microbiology).
– Lawrence Henke, Associate, Documentation, Field Technician.
– Russell G. Olsen, Field Engineer, Technician.
– Julie A. Tank, Jr. Engineer, University of Minnesota.
– Scott Morgan, M.S., P.E. Research Fellow, University of Minnesota
– Richard L. Voight, P.E. Research Fellow, University of Minnesota

The laboratory selected for microbiological analysis is:

BioVir Laboratories, Inc.
685 Stone Road
Benicia, CA 94510
(707) 747-5906 or (800) 442-7342
Fax (707) 747-1751

– John L. Riggs, Ph.D., President
– Robert C. Cooper, Ph.D., Vice President, Research

Staff that will be affiliated with this project:

– Richard E. Danielson, Ph.D., Quality Assurance Officer, Principal Analyst/Supervisor
– Koichi Nakamura, Principal Analyst/Supervisor
– Mark D. Wallin, Principal Analyst/Supervisor
– Steven J. Mullaney, Analyst
– Mary P. Philbrook, Analyst
– Dennis Catanyag, Technician
– Christine Willits, Technician

A Quality Assurance Program Plan, sample data sheet/chain of custody form, the EPA ICR Approval notification, and the State of California Environmental Laboratory Certification are attached as Appendix F.

Additional, off-site analytical work will be performed by:

Spectrum Labs Inc.
301 West County Road E2
St. Paul, MN 55112
(651) 633-0101
Fax (651) 633-1402

– Duane Nowlin, PhD, President
– Tom Halverson, Laboratory Manager
– Wayne Mattsfield, Microbiologist

The Spectrum Labs, Inc. Quality Assurance Plan/Manual, along with appropriate chain of custody and other recording and lab forms are included as Appendix E.

The Manufacturer of the Equipment is:

Kinetico Incorporated
10845 Kinsman Road
Newbury, Ohio 44065
(440) 564-9111 or (800) 432-1166
Fax (440) 564-9541

– Bill Prior, President
– Glen Latimer, Operations Manager

KI staff associated with the ETV Project include:

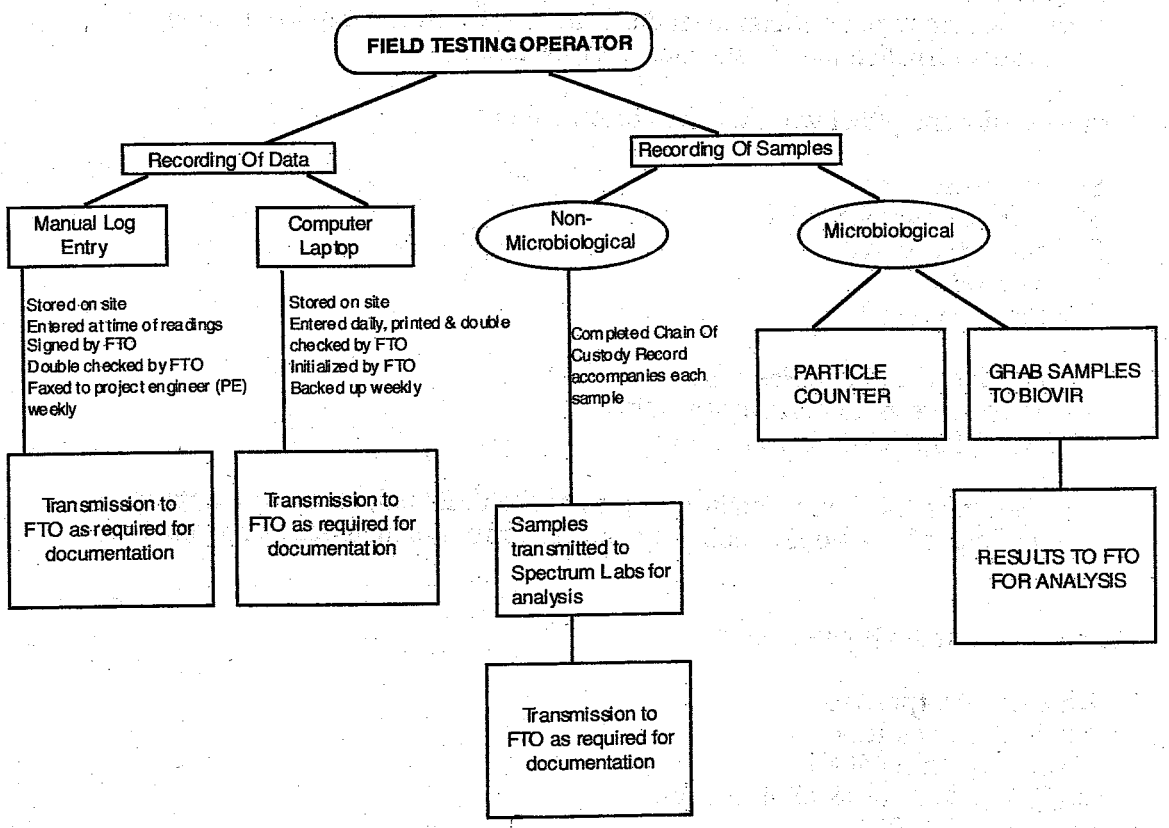
- Skip Wolfe, Project Manager, Engineer
- Chip Fatheringham, Engineering Technician
- Jeremy Litz, Electrical Engineer
- Wilfreid Schott, Engineer
- Dan Combs, Accountant
- Vicky Zbozein, Administrator
- Holly Nickita, Secretary

2.2 ORGANIZATION

An organizational chart illustrating communication is shown in Figure 2-1.

FIGURE 2-1

ORGANIZATIONAL CHART



2.3 VERIFICATION TESTING SITE

The site selected for challenge testing of the Kinetico Filtration System is the University of Minnesota, St. Anthony Falls Hydraulic Laboratory located at the University of Minnesota campus, Minneapolis, MN (Appendix H). The St. Anthony Falls Hydraulics Laboratory is not a water treatment plant, therefore no historical data is available. The Minneapolis Water Treatment Plant however is located on the Mississippi River in close proximity to the Hydraulic Laboratory, thus the historical data below is from the Minneapolis Water Treatment Plant.

This site was selected because of the need to supply flow rates of 30 gpm, the ability to blend treated and raw water to meet water quality matrix requirements, and because of the proximity to FTO offices for test period staffing. The test site makes available a wide range of water quality matrices, and thereby offers a wide variety of challenge opportunities.

The University of Minnesota St. Anthony Falls Hydraulic Laboratory takes water directly from the Mississippi River. Typical water quality of Mississippi River water at the intake location is summarized in Table 2–1. The Metropolitan Environmental Industrial Waste Authorities have approved the use of the site, including the introduction of viable microorganisms for the challenge. The St. Anthony Falls Hydraulic Laboratory understands and accepts that live (oo)cysts will be used during the verification seeding study (letter attached as part of Appendix H).

The effluent from the pilot plant will be directed to sanitary sewer. The Metropolitan Environmental Authority, which encompasses the Twin Cities Metro Area, maintains a primary sewage treatment plant that discharges to the Mississippi River downstream of the Hydraulic Laboratory. The addition of this volume of water and particulate matter from this test is minuscule with respect to the 235,000,000 gallons processed daily. Metropolitan Environmental Industrial Waste Authorities have given written approval to disposal of the effluent (letter attached as Appendix I).

River water at the University of Minnesota St. Anthony Falls Hydraulics Laboratory will be fully compiled as a function of Task A in initial operations and described in the final report. Water Quality Data for 1997 are included as Appendix B, and are briefly summarized below.

2.4 WATER QUALITY

2.4.1 Raw Water Quality Parameters

Typical water quality of the Mississippi River Water is represented by the data from 1997, which is summarized in Table 2-1. Printouts of water quality parameters are attached as Appendix B.

TABLE 2-1
MISSISSIPPI RIVER WATER
RAW WATER QUALITY PARAMETERS

PARAMETER	AVERAGE	MAXIMUM	MINIMUM
Temperature (C)	12.00	26.00	1.00
Turbidity (NTU)	8.60	27.00	2.20
Order Threshold	37.00	80.00	3.00
Color	42.00	81.00	23.00
pH	8.31	8.70	7.84
Tot. Hardness (ppm)	201.00	265.00	142.00
Alkalinity (ppm)	172.00	226.50	127.50
HCO3 (ppm)	162.00	219.00	113.00
Calcium Hardness (ppm)	135.00	170.00	92.00
Fluoride (ppm)	0.18	0.28	0.10
TOC (ppm)	9.10	12.00	7.25

2.4.2 Treated Water Data From The University of Minnesota St. Anthony Falls Hydraulics Laboratory

Summary of the effluent water at the University of Minnesota St. Anthony Falls Hydraulics Laboratory is summarized in Table 2-2. Additional parameters will be collected during Task A and included as a part of the final report.

TABLE 2-2
SUMMARY OF UNIVERSITY OF MINNESOTA ST. ANTHONY FALLS HYDRAULICS LABORATORY TREATED WATER
(ALL IN PPM)

PARAMETER	AVERAGE	MAXIMUM	MINIMUM
Silica	7.10	9.30	3.80
Aluminum	0.07	0.12	<0.01
Calcium	23.80	28.80	18.80
Magnesium	4.30	5.40	2.20
Sulfate	22.00	25.30	18.70
Chloride	20.70	25.00	17.00
Iron	<0.02	0.02	<0.01
Manganese	<0.01	<0.01	<0.01
Fluoride	1.04	1.30	0.14
Total Alkalinity	39.00	53.00	22.00
Total Hardness	76.00	102.00	61.00
Total Residue	145.00	169.00	106.00
pH	8.49	9.27	7.74
Chlorine/-amine	4.00	4.40	3.60
Phosphate	0.49	0.56	0.21
Nitrate-Nitrogen	0.10	0.16	0.02

FIGURE 2-2

FLOW SCHEMATIC OF EXISTING WATER TREATMENT FACILITY AND INCORPORATION OF PILOT INSTALLATION

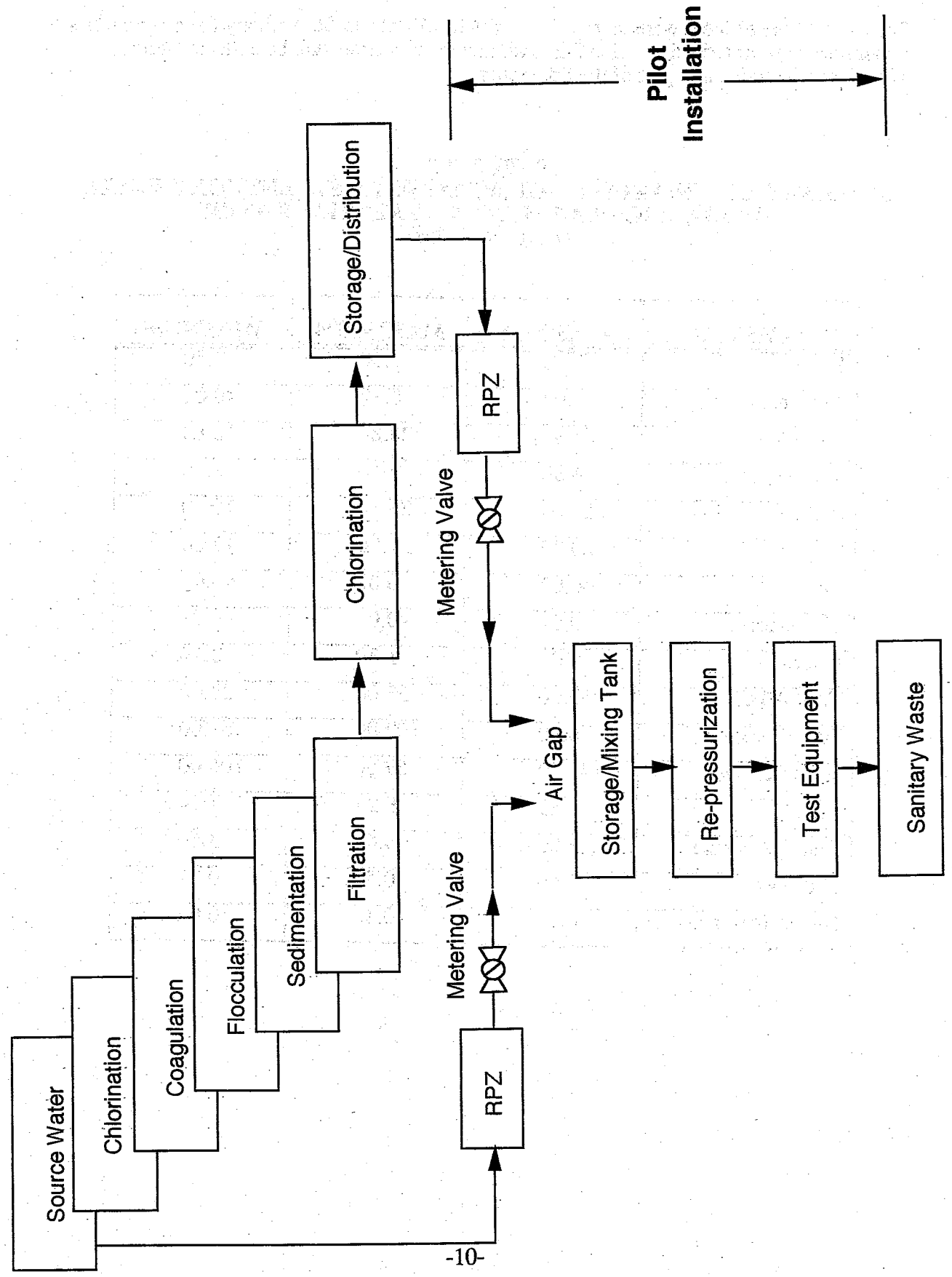
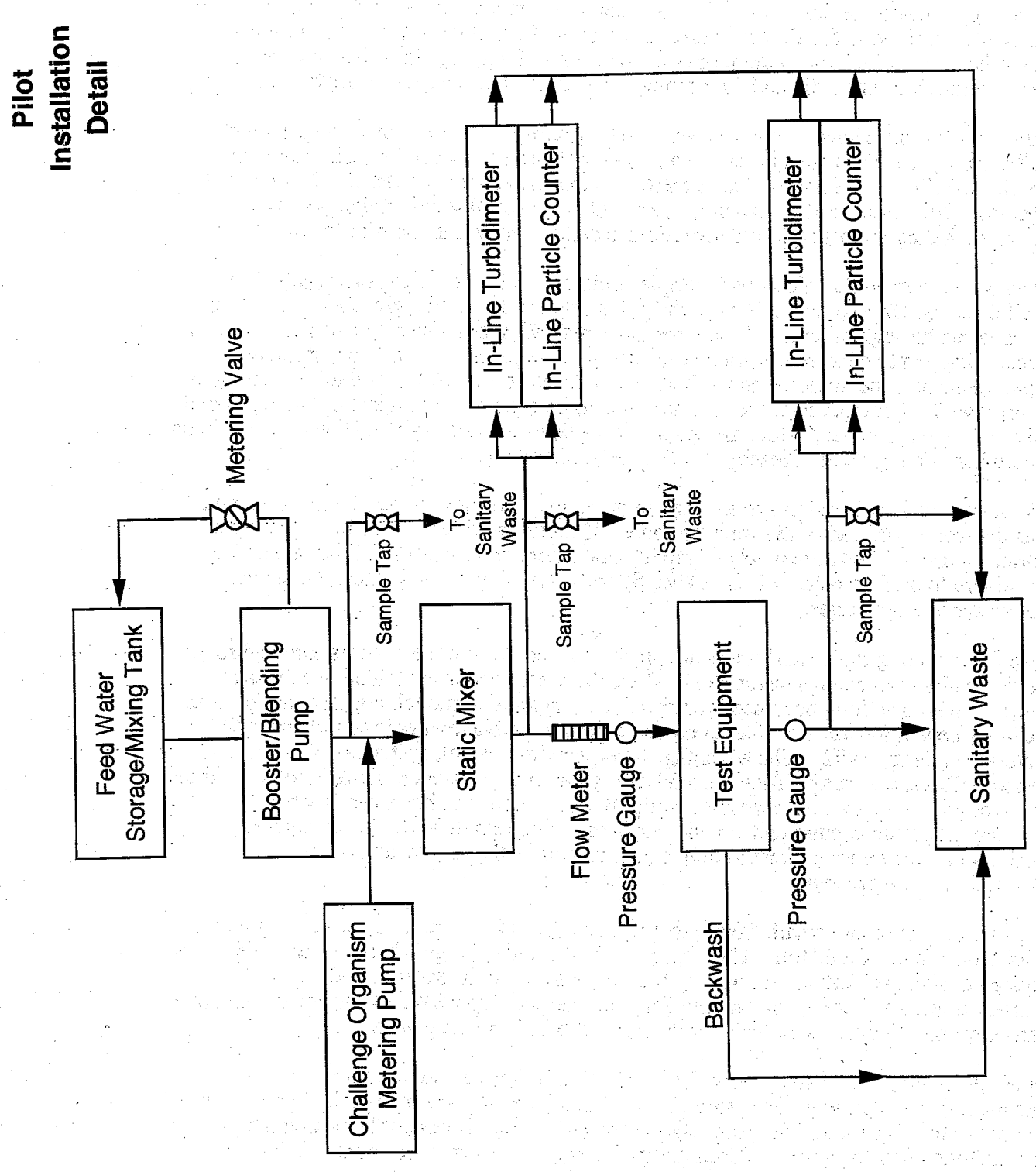


FIGURE 2-3

SCHEMATIC OF PILOT INSTALLATION FOR VERIFICATION PERIOD



3.0 EQUIPMENT CAPABILITIES AND DESCRIPTION

3.1 INTRODUCTION

Filtration is the most ancient of all water treatment methods. The slow movement of water through granulated media, commonly sand, coal or charcoal, has been employed as a civil engineering technique for almost as long as water has been distributed in communities. Water that is muddied, discolored, or contains debris of varying sizes, has long been poured through filter media and the accumulated debris then scraped or backwashed away.

Only in recent times have scientists been able to quantify the collection of material within the filter bed, especially the particulate matter—including microbes—that lie below our visual capabilities. We now know that particles that we cannot see can also be removed by filtration. Still under study, however, are the mechanisms through which particulate matter, including microscopic life forms, are accumulated within the filter media.

It has been assumed that along with simple straining, which is the physical capture of a small mass too large to move through the pores between the media granules, small particles are captured through other attachment mechanisms. Most of those mechanisms involve a surface charge attraction of the granulated media to the particle and as a result many experiments have been performed to both better describe the process and to seek methods to improve it. Some particles are also assumed to be collected by impact on the surface of the filter media granules; while the actual mechanisms are not clearly understood, straining is certainly among them (Cleasby, 1963, 1990, Amirtharajah, 1988).

The most common filtration system used in municipal treatment is the gravity filter, which uses the weight or head of the water to force it through the filter at very low flow rates. Normal, gravity filters, often called "rapid" sand filters, have a normal flow rate of 3 gpm per square foot of surface, or less. Other filters, such as slow sand filters, have even slower service flow rates.

Also listed among rapid sand filters are pressure filters, where the water is forced through a media bed by high head pressures, and where the media bed is contained in a pressure vessel. They have long been used for iron and manganese removal, but have not been as readily accepted for surface water treatment where microbial matter is of concern. (Ten State's Standards, 1992). The advantages—especially to small systems—of rapid sand pressure filters, are many. They are a relatively passive treatment system, involve minimal operator attention, are low in cost and long lived. Of concern, however, is whether pressure filters can capture and contain particles that are small, and more importantly, particles that may pose a threat to public health, such as the protozoan oocyst *Cryptosporidium parvum.*

C. parvum oocysts are small, from 3 to 5 microns (μm) in diameter, relatively round in shape, and somewhat pliable. They have a slight anionic charge which serves to keep them separated from each other; that is, they behave as a colloid in water suspensions. The primary issue then here is whether the Kinetico pressure filter SW224 can act as a suitable barrier for these particles, preventing their passage into drinking water.

Operator training for small systems filter operation is limited and offered by the manufacturer on delivery of a system. The manufacturer requires no special license beyond that required by the state of local public health authorities. It has not been an issue in prior installations of the equipment. Community water supplies have requirements that vary

from state to state. In Minnesota, there are four levels of community water plant operator qualification: A, B, C and D, depending on the size of the community. At this time there is no requirement for non-community, non-transient public supplies, however the state is considering enacting such a requirement. There is also no requirement for licensing for operators of transient, non-community public water supplies, and there is little likelihood of such a requirement due to the nature of the owner/operator status of most such facilities. Other states may have requirements beyond those noted here, although it is expected that designers of public health water treatment installations will be familiar with any requirements specific to their state or municipality. There may be possible Federal requirements concurrent with the enactment of the ESWTR, but those are not yet in effect.

3.2 EQUIPMENT DESCRIPTION

This environmental technology verification (ETV) test is designed to challenge the Kinetico, Inc. SW224 filter to capture and contain 5 µm particles at flow rates of 30 gpm. Prior field and pilot testing has demonstrated that pressure filters containing Macrolite® can achieve a 1-2 log removal of *C. parvum* (Clancy et al. 1993). Kinetico, Inc. anticipates that the SW224 filter system will achieve 2 log or greater removal of *C. parvum* oocysts at a flow rate of 30 gpm filter bed surface area.

The filter media is Macrolite®, a ceramic, stable substance synthesized into small, slightly elongated spheres. The mesh size for this test will be 70 mesh (US Standard Sieve). In this mesh size 70, the individual grains have a diameter of 0.008 inches (210 microns). A magnified view of Macrolite® is provided in Figure 3-1.

The equipment under test will be two identical filters vessels operating alternately. Each filter vessel will be 24 inches in diameter and 72 inches high, constructed of carbon steel, and pressure rated to 100 psi. The vessels have access ports at the top and bottom and a viewing port along the sideshell. The vessel interior and exteriors are protected with epoxy based coatings. The distributor is a stainless steel hub and lateral, with 0.005 inch slot sizes.

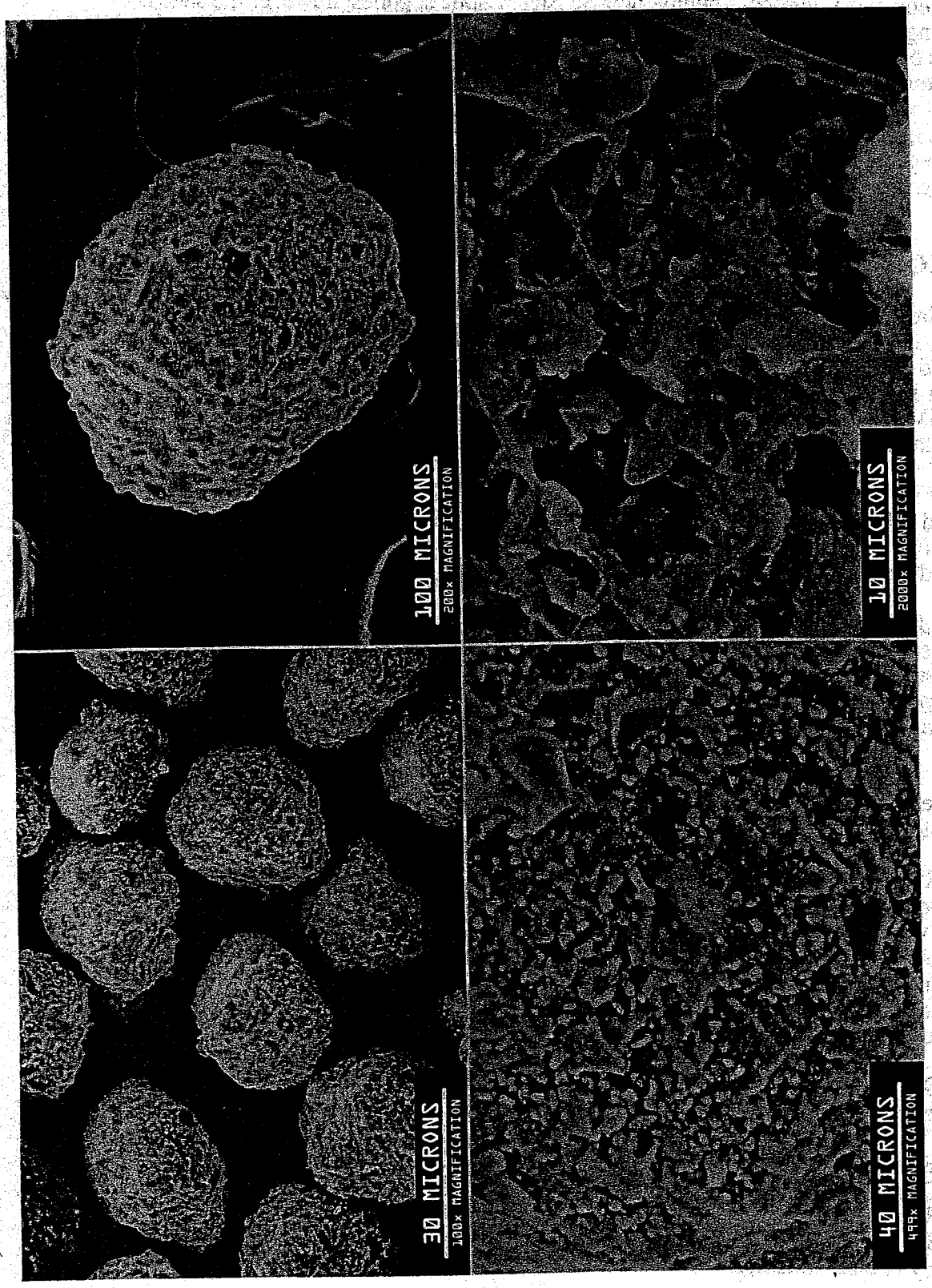
The system, along with controls and a backwash pump is mounted on an epoxy coated, welded steel frame.

The KI SW224 is an automated, 100% redundant system with electronic monitoring and electronic controls designed to steer a filter vessel through the on line, backwash and rinse (filter to waste) cycles. The automation is performed by a programmable industrial computer with a touch screen monitor and interface control. Connection to remote monitoring is readily available. Turbidimeters, flow meters and particle counting serves a monitoring and control function, although in the instance of the ETV test, monitoring will be subjected to more rigorous QA/QC.

The KI SW224 Filter System is designed to backwash upon any of the following conditions:

Effluent Turbidity	0.5 NTU
Differential pressure	12 psid or greater
Run Time	24 hours
Standby Time	48 hours
By Manual Initiation	

FIGURE 3-1
MAGNIFICATION OF MACROLITE® MEDIA



MACROLITE®
Scanning Electron Microscope Photos

KINETICO®

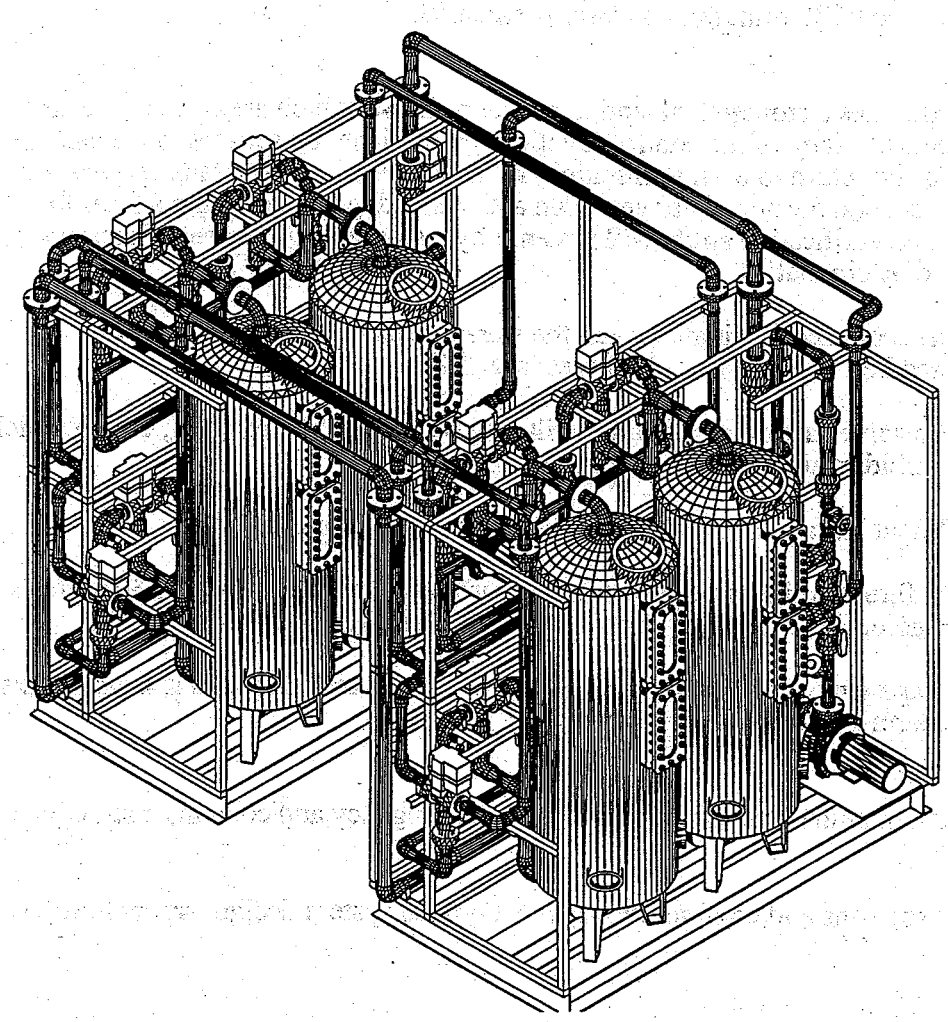
FIGURE 3-2
KINETICO SW224 - ILLUSTRATION OF FILTER

Macrolite® Pressure Filtration System

Standard Design

60 GPM (100% Redundant) or 90 GPM (50% Redundant)

(2 Skids - Each 3' 9" x 7' 2" Long x 7' 1" Tall)



The KI SW224 is designed to backwash until a minimum turbidity of 5 NTU is reached. Built in are several controls to allow repeated backwash if the initial sequence is insufficient. In addition, controls to signal an alarm in the event of backwash failure are incorporated into the system. The usual backwash sequence is as follows:

1. The off-line (backwashing) vessel is drained of approximately 12 inches of water;

2. The system is air sparged for 2 minutes with air at 70 cubic feet per hour per square foot;

3. The motorized valve moves to the backwash position and the vessel is backwashed with water from a backwash pump for 15 minutes;

4a. If the turbidity is 5 NTU (or less) that tank returns to a standby position;

4b. If *not,* the vessel continues to backwash for an additional 30 minutes.

5. During that period, if the NTU reaches 5 or less, the vessel is placed on standby; if not, at the end of 30 minutes, an alarm is signaled.

The KI SW224 assumes a storage tank and intermittent flows, which are common to small system requirements. Many of the control functions are initiated by sensors in the storage tank. One such is the return to on-line filtration, initiated when a storage tank reaches a low level. When that occurs, the next filter vessel on active standby is placed into a filter to waste position. The verification study will not employ a storage tank so these functions will be challenged by simulation.

The filter to waste sequence is initiated when the storage tank calls for water and the standby filter is readied to go on line. It proceeds as follows:

1. Automatic valves are opened to allow filter to waste for three minutes, during which time the turbidimeter monitors the effluent;

2a. If the effluent has an NTU of 0.5 or less, the filter goes on line;

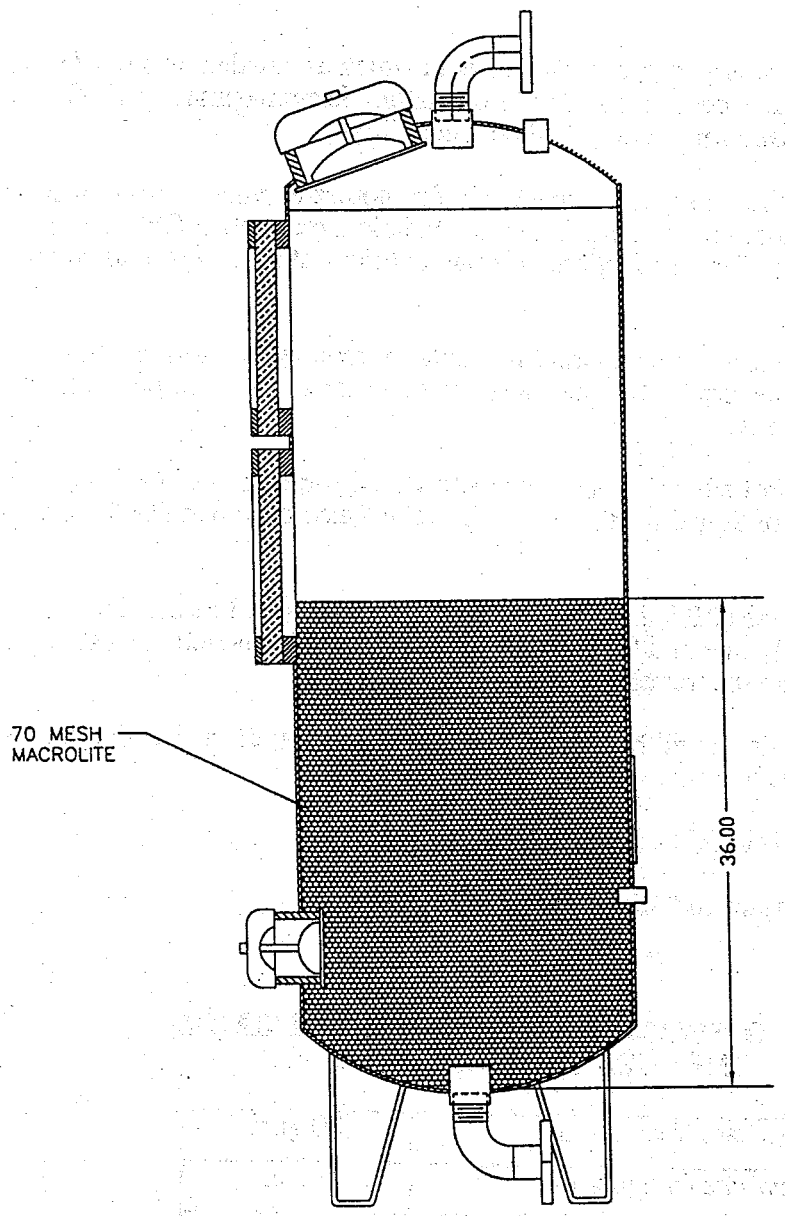
2b. If not, the filter continues to rinse until the turbidity limit is reached, or 30 minutes expire, where, if the turbidity is not 0.5, an alarm is signaled.

3. If the storage tank again calls for water, the process is repeated, and if it again fails, a major alarm is signaled.

The operations and maintenance manual covers this contingency and contains instructions for the operator.

Process flow illustrations and configurations, and a typical system design are included as Figures 3-3.

FIGURE 3-3
PROCESS FLOW ILLUSTRATIONS & CONFIGURATION



MACROLITE® MEDIA

3.2.1 Design Specifications And Limitations

The Kinetico SW224 is designed for small system applications. The tanks can be made of fiberglass or steel. Steel tanks will be used for this ETV test. The piping is Schedule 80 PVC.

The filters are shipped skid mounted, but without media which are loaded on site. The total weight of the system without accessories and instrumentation is approximately 1700 pounds. Steel vessels are used for strength and dependability.

Filters require little power; electricity is required only for motorized valves, a backwashing pump, air compressor and instrumentation. The only chemical required is Chlorine (as sodium hypochlorite, bleach) for disinfection. Media are long lasting and should be less than 2%/year attrition.

The equipment contains electronic connections available for remote monitoring. While limited operator experience is required, some states may require a water treatment plant license for public water supply.

The water flow will be controlled with electrically activated George Fischer valves mounted on face piping constructed of Schedule 80 PVC. The valves also have handles for manual activation.

Watts Reduced Pressure Zone (RPZ) backflow prevention devices will be plumbed between both the raw supply line and finished water supply line to ensure (oo)cysts are not inadvertently introduced into the treatment plant water streams.

At the inlet of the filter manifold will be a Ross motionless mixer with an injection probe for inoculation of challenge oocysts.

An illustration of the filter is attached at Figure 3-2.

Table 3-1 shows the maximum and minimum influent conditions.

TABLE 3-1
KINETICO SW224 MAXIMUM AND MINIMUM INFLUENT CONDITIONS

Inlet flow rate (maximum)	30 gpm
Inlet flow rate (minimum)	0 gpm
Maximum static pressure	100 psi
Minimum inlet dynamic pressure	35 psi
Maximum temperature	100°F
Minimum temperature	35°F
Maximum inlet turbidity	8 NTU

The purpose of the testing is to verify the performance expectations of the manufacturer through a carefully designed study involving rigorous QA/QC controls. The manufacturer anticipates 2+ log removal of particles of 5 µm or larger at flow rates of 30 gpm and 1.5 log removal of particles 3-5 µm in size, which includes *C. parvum*. This is the benchmark against which the system will be tested. This test will employ viable microorganisms and thus, the ETV claim is for a 1.5 log removal of *C. parvum*, and a 2 log removal of *G. lamblia*.

3.2.2 Statement Of Performance.

The Kinetico SW224 System will produce the following effluent characteristics as shown in Table 3-2:

TABLE 3-2
KINETICO SW224 SYSTEM EFFLUENT CHARACTERISTICS

Inlet flow rate (maximum)	30 gpm
Inlet flow rate (minimum)	0 gpm
Expected pressure drop	15/30 psi
Minimum outlet pressure	10 psi
High pH	pH 8
Low pH	pH 3
Maximum temperature	100° F
Minimum temperature	35° F
Normal effluent turbidity	0.10 NTU
Maximum allowable effluent turbidity	0.50 NTU

The Kinetico SW224 Pressure Filtration System is expected to produce a 95% (1.5 log) removal of particles of 3 µm and a 2 log removal of particles of 5 µm or larger at 30 gpm, and with a pressure differential of less than 15 psi.

3.2.3 Installation Requirements

Room temperature range	50-120° F
Voltage/frequency/amperage	120,220,480 v/60 Hz/ 30 amps
Ceiling height	9 feet
Phone service for instrumentation	2 lines

4.0 EXPERIMENTAL DESIGN

4.1 PURPOSE

The purpose of this test is to verify the performance of the Kinetico backwashable depth filtration system in a formal and comprehensive manner to offer state and local public health professionals an opportunity to evaluate the system for specific applications. Accordingly, the test will:

1) Verify performance claims of the manufacturer of the Kinetico filter with respect to particle reduction in the size range of *C. parvum*, (3-5 microns). Since *G. lamblia* cysts are larger (5-15 microns) it is assumed that if the smaller oocysts are contained, the larger cysts will be contained at least at the same level; however, challenging with *G. lamblia* cysts will confirm removal;

2) Correlate particle reduction to SWTR requirements (minimum 2 log reduction);

3) Compare the performance with the performance recommendations for the "Partnership for Safe Water";

4) Determine the effects of variations in water quality on performance;

5) Measure the operational costs for the system;

6) Determine reliability and underscore other operational parameters.

This testing and verification period is designed to challenge the Kinetico, Inc. SW224 Pressure Filtration System, which employs Macrolite® ceramic media—fully described below—as a backwashable granulated bed and its ability to remove *G. lamblia* cysts and *C. parvum* oocysts from water. The purpose of the test is to offer state public health regulators an evaluation of the system for applicability to specific small system needs.

Cysts and oocysts will be injected into a water stream through the filters. A portion of the filter effluent will be collected and analyzed to enumerate the level of (oo)cysts present post filtration. In addition, other conditions such as start/stop, backwash, filter ripening and (oo)cyst removal from the bed will also be evaluated.

Turbidity measurements, as well as particle counts in the size range of 3 to 15 microns will be studied to offer evaluators a comprehensive overview of performance under anticipated water conditions.

Important to the overall evaluation of performance is a characterization of the raw water quality matrix. Water quality considerations are intended to challenge the filters in typical application, not necessarily applications of extreme conditions which would not commonly be encountered. The ability of the filters to react to modest changes in water quality is important, however.

All testing will be performed in accordance with the procedures and protocols established in *Standard Methods*. All on-site testing instruments will be calibrated and/or standardized daily by FTO staff.

The analyses of water quality data from grab samples will be analyzed for 95% confidence interval by the FTO. The confidence formula is that noted in Chapter 1 of the EPA/NSF ETV Protocol and repeated in section 4.5 below.

4.2 EQUIPMENT CHARACTERISTICS

The equipment is designed to be used in water as a final barrier to the cysts and oocysts *G. lamblia* and *C. parvum* respectively.

The performance of the Kinetico filter system will be challenged by seeding *G. lamblia* cysts and *C. parvum* oocysts at a known concentration, passing them through the filter system at the design flow rate, and then measuring the effluent concentration of those particles. One filter of the two will be selected as the seeding filter, and that filter will be challenged with microorganisms. Operating performance and the control and monitoring conditions will be based on both filters, however.

The influent/effluent particle counts will be done with an electronic particle counter, a Met One Particle Counter with PCC Display and PCX counting sensors, and will be confirmed by grab evaluation of effluent samples suing a Gelman Capsule filter following the EPA 1622 procedure.

Small systems are particularly vulnerable to changes in process flow, and assurance that particles will not detach or be driven through the media during these episodes is of considerable concern by small system operators and purveyors. Tests to verify performance under these conditions are included as part of the test plan, by stopping the flow in the middle of a run following a challenge seeding, and then measuring particle counts after restarting without backwashing.

4.2.1 Qualitative Factors

Under test also are operational aspects of the Kinetico filter (for example, the measurement of head loss) as well as other factors that might impact performance. Hands-on operation of the system by FTO staff will be instrumental in determining the skill level required to maintain and service the filter system.

The KI SW224 Filter System can be controlled either automatically or through a manual over-ride. During initial operations, certain functions will be manually controlled. During the operational phase of the verification period, the automatic controller will be employed to verify performance of that aspect of the system.

4.2.2 Quantitative Factors

Among the relevant factors in the verification process are costs associated with the filter system. The operating conditions will be recorded to allow reasonable prediction of performance under other, similar conditions. The specific parameters to be measured are discussed below and their impact on filter run length will be addressed and noted for inclusion in the final report. Also to be noted and reported are any occasional, anomalous conditions that might require operator response such as high levels of algae growth, excessive turbidity spikes or frequent filter clogging.

4.3 WATER QUALITY CONSIDERATIONS

The Kinetico System is designed for application to small systems where the source might be surface water or well water under the influence of surface water. Along with the challenge microbial contaminants *C. parvum* and *G. lamblia,* the filter system will remove other particulate matter and the filter load of those materials—along with their possible origin—will be studied. Specifically, the water quality characteristics to be recorded and analyzed are:

- Turbidity and Particle concentrations (especially in the range of 3-15 microns).
- Temperature
- pH
- Total Alkalinity
- Total Hardness
- Total Organic Carbon
- UV Absorption
- True Color
- Total Coliform
- Algae
- Iron
- Manganese
- Free and Total Chlorine

4.3.1 Source Water Quality

The University of Minnesota St. Anthony Falls Hydraulics Laboratory source water historical data is attached as Appendix B. Finished and raw water will be blended as necessary to provide turbidity levels and other water conditions appropriate to the study.

4.3.2 Treated Water Quality

The Kinetico Filtration System is designed to remove particles in the 3-5 micron size range which include *C. parvum*; however, bacteria and viruses are smaller and not within the capture range of the filters. It is expected that disinfection procedures will be employed in addition to filtration to achieve EPA log removal/inactivation specifications under either the SWTR or the ESWTR. It is assumed that with a 2 log reduction in *C. parvum* concentration, equal or greater log removal of *G. lamblia* will result. Disinfection residual levels will be recorded to allow correlations with other removal factors.

The presence of iron, manganese, silica or clay particulate will impact on filter performance and will likely shorten filter runs. Moreover, high levels of bacteria such as heterotrophic or iron bacteria may produce biological growth on the filter grains. Disinfection will therefore be assured by introducing a chlorine residual of 0.5 mg/L through a chemical feed pump upstream of the filtration systems. The chemical feed pump for this ETV test is a ProMinet Gamma G14B.

Chlorine will be fed into the water stream before the seeding injection point and in from of the filters. Because of the blending of finished and raw water for the study some chlorine residual may be present. During the seedings however, the addition of chlorine will be suspended, and sodium thiosulfate will be added to destroy any residual.

Although the filters are not impacted by the viability of the organisms, and it is their capture, not their inactivation that is being evaluated, chlorine may influence the filtration characteristics by altering the surface charge conditions of the microorganisms.

In all field applications of the Kinetico SW224 filtration system, the filters are backwashed with chlorinated, finished water, again to limit biological growth.

4.4 DATA RECORDING

The chemical parameters and operator read operating data will be maintained in a bound log book and transferred to computer spread sheets. The control system for the KI SW224 includes automatic data recording access and automatic systems will be employed where possible. Other readings will be manually logged.

In addition to the items noted in the data sheets (contained in Appendix D), any variations in the treatment plant regimen will be noted. Among the changes possible are changes in chemical coagulant aids, disinfection levels to respond to varying biological contamination and unusual source water episodes, such as weather related incidents (ice outs, storms), unusual river traffic or contaminant spills. The source water will be a blend of finished and raw water.

4.5 RECORDING STATISTICAL UNCERTAINTY

Statistical 95% confidence calculations shall be performed for water quality data: Each of the water quality parameters will be analyzed, and confidence intervals determined by taking three discrete samples for each of the parameters at one operating set during the testing period. Sampling requirements are noted in the work plan below.

$$\textit{confidence interval} = \overline{X} \pm t_{n-1,\,1-\frac{a}{2}} \left(S / \sqrt{n}\right)$$

S = standard deviation
n = number of measurements in data set
t = distribution value with n-1 degrees of freedom
α = the significance level defined for 95% confidence as: 1- 0.95 = 0.05.

$$\textit{95\% confidence interval} = \overline{X} \pm t_{n-1,0.975} \left(S / \sqrt{n}\right)$$

4.6 VERIFICATION TESTING SCHEDULE

The verification testing will be conducted during a single period.

Following initial operations the verification period will continue until the tasks are completed according to the work plan, but for at least thirty days. Once begun, the Testing and Verification phase will not be stopped and restarted.

An anticipated Timeline is shown in Appendix C.

5.0 FIELD OPERATIONS PROCEDURES

This section of the FOD describes the testing procedures to be performed for the verification of the Kinetico filtration system.

5.1 TASK A: CHARACTERIZATION OF FEED WATER

5.1.1 Objective

The objective of this task is to determine the suitability of the feed water to the application of the technology.

5.1.2 Data

Data from past years from local and regional sources will be compiled and analyzed with respect to the biological, physical and chemical characteristics of the water. Parameters to be studied at each site include (but are not limited to) the following:

- Turbidity,
- Temperature and temperature variations within a season,
- pH,
- Total Coliform,
- Total Alkalinity,
- Hardness,
- True Color,
- Algae,
- Total Suspended Solids (TSS),
- Iron and manganese
- Total Organic Carbon (TOC)

Data from third party sources will be subjected to QA/QC evaluation as to method, sampling technique and confidence calculations.

Factors that could influence water chemistry, such as weather, boat traffic, in and out-flows, and bottom composition will be included where appropriate. Also included will be a discussion of the human impact upon the source; for example, whether the source is used for other activities, or whether it accepts waste water of any description.

5.2 TASK B: INITIAL TEST RUNS

5.2.1 Objective

The objective of this task is to establish operational data such as filter run times and backwashing schedules, and to qualify the equipment for performance with the selected source water.

5.2.2 Data

Initial test runs will be performed to both terminal headloss and to turbidity breakthrough. Flow rate variations and the character of finished water will also be studied to determine optimum operational conditions. Backwashing will be initiated manually, when either a terminal headloss is reached or when turbidity breakthrough occurs. Filters will be backwashed until the waste stream runs clear, as determined by a turbidity of 5 NTU or less. Filters will be run to waste for a minimum of two bed volumes of the filter and the time to clear noted in the logbook. Terminal headloss will be considered to be when the filter experiences a 12 psi pressure drop.

Upon return to service, the filter ripening period will be monitored and timed. These data will be used to determine the benchmarks for automatic backwash, rinse and run cycles during the testing and verification period.

During initial operations, tracer tests using sodium chloride will be used to time the residence period of the filter and the side stream through the testing ports. This is done by injecting salt water into the influent stream through the metering pump injection probe ahead of the static mixer. The flow can be timed by using a stopwatch and a TDS meter. The use of salt water over tracer dye in this application is preferable because it can be conveniently measured at small increments, thereby demonstrating both initial and final concentrations; it dissolves readily and hence is not impeded by the filter; and after it is rinsed clean it leaves no residual on the filter media.

Data from this test will be used to establish test runs using polystyrene microspheres for seeding and recovery studies. These studies will be used to calibrate side stream flows and capture and recovery parameters for the challenge tests using *G. lamblia* cysts and *C. parvum* oocysts.

5.3 TASK 1: VERIFICATION TESTING RUNS AND ROUTINE EQUIPMENT OPERATION

All testing will be performed in accordance with the procedures and protocols established in Standard Methods. All on-site testing instrumentation and procedures will be calibrated and/or standardized daily by FTO staff.

Turbidity and particle counters will be both continuous and on line. The turbidity meter will be checked daily against a bench turbidimeter which is checked against turbidity standards.

Turbidity will be evaluated, as noted above, in 15, 30 and 60 minute intervals, as well as at any spikes. The percentage of turbidity at <0.5, 0.51-1.0, 1.1-5.0 and >5.0 NTU will be enumerated. In addition the turbidity levels will be time correlated to particle counts.

The turbidity instruments for this study are Great Lakes, Model 95T/8220 (bench) and Great Lakes Model 95T/SS4 (on-line). The particle counter is a MetOne PCX. Operations and maintenance manuals for these instruments are included in the KI equipment O&M Manual.

5.3.1 Objective

The objective of this task is to operate the equipment for the prescribed period of thirty days, to monitor and register run lengths, backwash frequencies and ripening periods, and to evaluate equipment control features.

5.3.2 Initial Operations

The verification test period operating conditions will be defined in initial operations. The equipment is to be operated continuously during this period, under varying conditions. A minimum of a single season of testing is required. Varying water quality parameters and other conditions may impact performance, and these shall be recorded.

Factors that may affect treatment performance, and which shall be recorded and measured where appropriate include:

- High turbidity due to ice out or snow melt, rainfall, excessive traffic or construction activities;
- Algal blooms;
- Diurnal pH changes;
- Elevated natural organic matter from runoff;
- Changes in feed (blended) water disinfection.

5.3.3 Schedule

The schedule requires the equipment be run continuously for 30 days. The KI SW224 has control functions that allow for differing conditions to initiate backwash. The control functions that allow backwash initiation due to headloss will be verified as well as the controls that initiate backwash on turbidity breakthrough. The system will be operated to turbidity breakthrough or terminal headloss even if the 30 day test period is exceeded.

Also tested will be the ability of the filter to resume filtering following an interruption of flow. The KI SW224 is normally configured to follow each interruption with a backwash and filter-to-waste cycle, however, this aspect can be manually over-ridden and the resultant particle distribution evaluated.

Total gallons produced and rates per square foot are among the factors to be recorded.

5.3.4 Verification Period

The verification period includes a 30-day period, with a minimum of two backwash followed by filtration to terminal headloss cycles. The system will be operated to turbidity breakthrough or terminal headloss even if the 30 day test period is exceeded. Data will be collected during the entire period.

5.4 TASK 2: FEED AND FINISHED WATER QUALITY CHARACTERIZATION

5.4.1 Objective

The objective of this test is to evaluate the water quality matrix of the influent water and effluent water and to identify the composition of the removed particulate material, as related to the terminal headloss and/or turbidity breakthrough point. Certain feedwater parameters will be noted and finished water will be examined relative to the level of removal attained.

5.4.2 Initial Test Runs

Based on the initial test runs, the terminal headloss and turbidity breakthrough points will be established, and the performance of the filter will be evaluated relative to the water quality parameters.

5.4.3 Testing Schedule For Quality Parameters

The testing schedule for water quality parameters is indicated in Table 5-1. Samples of both feedwater and filtered water will be analyzed.

TABLE 5-1

TESTING SCHEDULE FOR QUALITY PARAMETERS

PARAMETER	FREQUENCY	WHERE TESTED	METHOD	STD. REF.
Temperature	daily	on-site	instrument	2550B
pH	daily	on-site	instrument	4500H+
Total Alkalinity	weekly	lab		2320B
Total Hardness	weekly	lab		2340C
Total Organic Carbon	weekly	lab		310 C
UV Absorbance(254)	weekly (with TOC)	lab		5910
Turbidity	daily	on-site	instrument	2130B(2)
Continuous Turbidity	15,30,60 minutes for calculations plus spikes	on-site	instrument	2130B and instrument manufacturer
True color	semi-weekly	lab	instrument	Hach SM2120
Total Coliform	semi-weekly	lab		9221 or 9222
Algae (identify number and species)	weekly**	lab		10200F
Iron	weekly*	lab		3113B
Manganese	weekly*	lab		3113B
Particle Count	continuous	on-site		per instrument manufacturer, ASTM 658

Notes:
* More often once found in raw water;
** Bi-weekly if found in raw water.

All testing will be performed in accordance with the procedures and protocols established in *Standard Methods.* All on-site testing instrumentation and procedures will be calibrated and/or standardized daily by FTO staff.

Turbidity and particle counters will be both continuous and on line. The turbidity meter will be checked daily against a bench turbidimeter which is checked against turbidity standards. Particle counter verification procedures are noted in section 5.8.2.4 below.

The turbidity instruments for this study are Great Lakes, Model 95T/8220 (bench) and Great Lakes Model 95T/SS4 (on-line). The particle counter is a MetOne PCX. Operations and maintenance manuals for these instruments are included in the KI equipment O&M Manual.

5.5 TASK 3: DOCUMENTATION OF OPERATING CONDITIONS AND TREATMENT EQUIPMENT PERFORMANCE.

5.5.1 Objective

The objective of this task is to denote the conditions surrounding the performance of the filter system, including the physical instrument measurement of pressure losses at and prior to turbidity breakthrough. Included in the performance parameters will be flow rates (and any variations), pressures of influent and effluent streams, length of filter run, and backwash lengths.

The flowmeter for the equipment is a Data Industrial Corp. Series 2100. Its accuracy will be verified by bucket and stopwatch technique.

The two filter vessels are intended to be operated on an alternating basis at 30 gpm, for a throughput flowrate of 9.55 gpm/ft^2 bed area. When one filter approaches the end of the run, as determined by one of the conditions noted above, the stand-by vessel is brought on line and the first backwashed and placed into a standby mode. This process is automatically controlled by electrically activated, motorized ball valves, with no discernible loss of flow, and controlled automatically by the on-board programmable computer.

The Macrolite® media employed has a US sieve size of 70. That is equivalent to 0.008 inches (0.2 mm or 210 microns) average diameter for each sphere. The pore size for three such spheres that are touching will leave a void that is 15.47% of the diameter of the spheres, or 32.5 microns, considerably larger than the size of *C. parvum* oocysts. Thus, straining alone is not likely the sole mechanism of removal.

Surface attachment mechanisms, none of which are entirely understood, probably play a role in containment. Some of the surface mechanisms have been related to pH and to ionic strengths as well as to surface charges. The performance claim is not for removal of particulate matter only, but also for protozoan (oo)cysts; thus it is of importance to this study to employ viable (oo)cysts in the trials.

Macrolite® media has a surface charge that varies with pH. At pH 2.3 and pH 8 it has no charge. Between those points, the charge is positive, with a maximum positive charge at pH 3-4; outside that range (<pH 2.3 and > pH 8) the charge is negative.

Moreover, the surface of the spherical granules is rough, suggesting that some particles may become trapped on the surface through adhesion as well as through surface charge attraction. The pore area and volume are described below.

Macrolite® —as synthetic filter media—is not covered under AWWA standards for filter media (B100-89). Standard B100-89 is a purchase guide for filter media and is not intended as a design standard; however, many of the testing parameters will be of interest to public health administrators, especially those physical characteristics which may impact on the longevity of the material. Thus, hardness, specific gravity, acid solubility, uniformity coefficients, particle sieve size distributions (within manufacturing lots and from lot to lot) and other similar physical data have been furnished by the manufacturer and are noted below. They will also be discussed in the final verification report presented to NSF.

Macrolite® of the 70/80 mesh size has a bulk density of 0.96 grams/cc. The specific gravity, as measured by ASTM D2840, is 2.23 g/cc. The collapse strength for the media of this size has not been measured, however, for a larger sphere (30/50 mesh) the collapse

strength as measured by ASTM D 3102 is a nominal 7000 psi for 10% and nominal 8000 psi for 20% collapse.

The uniformity of the Macrolite® 70/80 mesh media was analyzed in accordance with AWWA Standard B100-96 by Bowser-Morner, Inc. in December, 1997. The analysis results are summarized in Table 5-2:

TABLE 5-2

UNIFORMITY OF THE MACROLITE® 70/80 MESH MEDIA

Sieve Size, USA Std.	Nominal Diameter, mm	Effective Diameter, mm	Percent Passing
#45	0.355	0.360	100.0
#50	0.300	0.307	99.9
#60	0.250	0.249	79.8
#70	0.212	0.212	28.9
#80	0.180	0.180	7.2
#100	0.150	0.150	0.4

Effective Size: 0.19 mm
Uniformity Coefficient: 1.2

In addition, a Kinetico Inc. internal laboratory analysis of 70 mesh media employing a mercury/penetrometer Micromeritics Autopore II 9220 instrument gave the following results as shown in Table 5-3:

TABLE 5-3

KINETICO LABORATORY ANALYSIS OF 70 MESH MEDIA

Total intrusion volume	0.2098 mL/g
Total pore area	0.18 sq-m/g
Median pore diameter volume	53.7990 µm
Median pore diameter area	52.5351 µm
Median pore diameter 4V/A	46.5685 µm

A Material Safety Data Sheet is included as a part of Appendix A. Macrolite® media meets the requirements of NSF Standard 61 and is NSF listed.

While the primary objective is the verification of particle capture in the 3-6 μm range, additional data regarding the expected expenses related to the technology will be compiled so that regulators can make a reasoned evaluation of filter performance relative to costs.

A part of the operational information will include pumps and other motor driven components associated with the plant and their power consumption which will be related to the filter performance, specifically to gallons produced per service period and consumed during backwash cycles. Operating data to be included are itemized in the following Table 5-4:

TABLE 5-4

OPERATING DATA

OPERATING DATA	ACTION
Feedwater and Filter Flow	Check and record 2 × /day and adjust when flows are off by +/- 10%. Record rates before and after adjustment in log book.
Filter Headloss	Record at beginning of run and at least twice daily, also record at end of run or when breakthrough occurs.
Air Sparging	Record date, time and duration.
Backwashing	Record date, time, feed and filtered water meter reading and calculate filter finished water volume. Note terminal headloss prior to filter backwash. Describe reason for backwash; note backwash rate and volume for each backwash.
Electric Power	Read meter once daily at same time.
Hours of Operation	Record daily at beginning of first shift.
Filtered Water Production	Calculate total per filter run and total for each day per filter.
Watershed Events	Record weather, snow melt, construction, excessive traffic or other events that could impact on source water quality daily at end of shift.

A utility power meter, reading in kilowatt-hours, will be attached to the power connection for the pilot plant.

5.6 TASK 4: MICROBIOLOGICAL CONTAMINANT REMOVAL TESTING

The object of this Task is to measure the ability of the filter to remove seeded microorganisms. This portion of the study is of central importance, as it is the ability of the filters to remove the target microorganisms *C. parvum* and *G. lamblia* that are the primary claim of the manufacturer, and of greatest interest to the public water community.

The ability of the KI SW224, with Macrolite® media, to remove oocysts from water has been demonstrated in prior studies, and the mechanism is *not* under examination here (that is beyond the scope of this ETV study). Here, only the ability to remove 3 and 6 micron particles, to detach them from the media during backwash, and to prevent re-entry into the process stream, will be challenged and verified.

5.6.1 Preparation of Microbial Doses

The (oo)cysts will be purchased from commercial (academic) sources. *Giardia* cysts will be less than four weeks old, and *Cryptosporidium* oocysts will be less than eight weeks old. The (oo)cysts will be stored in water without preservatives. At a field lab near the site they will be divided into the required number of doses, and into the required concentration of 10^9 (oo)cysts for injection into the water stream.

The doses are prepared by removing an aliquot of the enumerated (oo)cyst suspension and diluting with deionized water to a volume containing the target number of oocysts. These doses are again enumerated with a hemocytometer and analyzed with the Fisher Chi-Squared index. If the variance exceeds chance the suspension is re-sampled and re-counted until an acceptable variance for a minimum of five replicate counts is obtained. The hemocytometer counts are then used to calculate the mean number of oocysts per 10 L dose.

Seedings will be performed as follows:

#1—At initial start up
#2—At the mid-point of the filter run
#3—At the end of the filter run, just prior to terminal headloss

These seedings allow determination of filter efficacy at several points in the filter cycle.

In addition, at a point in the middle of the run, the filter flow will be stopped, and then restarted following a brief interruption. The filter will be restarted *without* a backwash sequence. Grab samples (as well as particle counter and turbidity recordings) will be taken immediately (within one bed volume) following the resumption of flow. The object is to determine if interruption of flow allows previously captured organisms to detach and re-enter the water stream. Pressure loss and flow data will also be recorded before and after the interruption.

This sequence will be repeated twice, during two successive runs of the same filter; the second run will follow a run of the alternate, non-seeded filter. Since both filters are identical, only one filter of the two will be employed for seeding studies.

The inoculation point is through an injection probe at the intake of the static mixer. An inert carboy containing a diluted preparation of suspension and stirred by a magnetic stir bar, is connected by tubing to an injection probe that reaches into the axis of the static mixer. Each

challenge test will inject 10^9 (oo)cysts concentrated into 600 milliliters of deionized, particle free water containing 0.01% Tween 20 There will be no detergents, wetting agents or other chemicals added to the suspension. The injection will take place evenly over a period of one hour plus three theoretical detention times, such that slightly more than 1800 gallons (6800 liters) of water will be inoculated. This will be followed by two volumes of particle free sanitized water to void the excess (oo)cysts through the injection stream.

A seeded suspension containing 10^9 (oo)cysts is capable of indicating 3 log reduction as follows: The seeding will introduce 10^9 (oo)cysts concentrated into 6500 mL of water for a density of 1.66×10^6 (oo)cysts/mL into the process stream. The process stream will dilute this concentration evenly into 6800 liters for a concentration of approximately 150 (oo)cysts/mL. Detection of effluent (oo)cysts by particle counter and by Method 1622 enumeration at levels less than 10/mL will indicate 2+ log reduction. Since a 10 liter grab sample is taken through a Gelman capsule filter for Method 1622 evaluation, 10,000 milliliters will be evaluated, potentially capable of measuring a 3+ log reduction if expected Gelman capsule recovery rates are realized.

During the seedings, 10 liter grab samples for microbiological evaluation (identification and enumeration) will be taken on a side stream and filtered through a Gelman capsule filter for enumeration. The 10 liter grab samples filtered through a Gelman capsule filter will be evaluated in accordance with the procedures indicated in EPA Method 1622. This enumeration when compared with the particle counts for the same period will account for indigenous microbes as well as those seeded.

Influent grab samples will be taken as follows:

1) At time zero (after three detention volumes following initiation of seeding)
2) At 0.5 hours
3) At 1.0 hours following seeding

Filter effluent grab samples will be taken as follows:

1) At time zero
2) At 1.0 hours following time zero
3) At 2.0 hours following time zero

Simultaneous with the seeding, on line particle counters located at the raw water intake, at the filter inlet following the static mixer and at the effluent of the filter, will record the particle analyses in the ranges of 3-6 µm, 6-15 µm, and +15 µm. If the particle counter, during initial operations testing, is incapable of the high level of counts, (due to indigenous particulate matter in that range) grab samples will be evaluated through dilution procedures.

The following table reflects the particle counting and challenge testing schedules:

<u>Particle Counting</u>

Feed water	Continuous
Filtered water	Continuous

<u>Analysis of Feed and Filtered Samples for Challenge Microorganisms.</u>

1. Start filter run following backwash - Continuous particle count, Filter (Gelman) after 3 volumes,

2. Midpoint of run (No Seeding) - Sample before filter run stopped, Sample following filter restart with no backwash (No influent sample is required as this point),

3. At 85-95% of run - Sample before filter run stopped.

4. Two samples following full runs, backwash and filter to waste cycle, and after 3 bed volumes (or at filter ripened time).

5.6.2 Data Evaluation

The performance will be evaluated with respect to the manufacturer's expected performance for inclusion in to the final report to NSF. The data from electronic particle counters shall be analyzed to determine the median log removal as well as the 95th percentile removal for the verification period.

Particle count data will be analyzed at one hour intervals, except during challenge periods where additional particle count data will be correlated to grab sample data times as closely as possible. The particle counter will be continuous, and will record the particle counts in the ranges of 3-6 μm, 6-15 μm, and +15 μm. The data will be presented as time series data to display trends of particle count over time.

Turbidity will be also be evaluated in 15, 30 and 60 minute intervals, as well as at any spikes. The percentage of turbidity at <0.5, 0.51-1.0, 1.1-5.0 and >5.0 NTU will be recorded and correlated to the particle count data.

Microbial densities between feed and filtered water will be analyzed for median log removal and 95th percentile log removal for each of the operating points noted above: startup following backwash, following restart after midpoint interruption, and at 85-95% of terminal head loss.

5.7 TASK 5: DATA MANAGEMENT

5.7.1 Objective

The objective of this task is to tabulate the collection of data for completeness and accuracy, and to permit ready retrieval for analysis and reporting.

COA as the FTO for the project will be responsible for the maintenance of the logbooks and field notebooks. Data will be collected in bound logbooks and on charts from the instrumentation panels and individual testing instruments. There will be a single field logbook containing all on-site operating data which will remain on site and will contain instrument readings, on-site analyses and any comments concerning the test run with respect to either the nature of the feedwater or the operation of the equipment. The particle counter produces a printed copy of the particle count and that tape will be attached to and become a part of the field log book.

Data will be entered into a computer spreadsheet program (Excel) on a daily basis from the logbook and from any analytical reports. A back-up copy of the log book and computer data will be maintained off site. The database for the project will be set up in the form of a custom-designed spreadsheets. All data from the laboratory notebooks and the data

logbook will be entered into the appropriate spreadsheet. Data entry will be conducted on-site by COA operators. All recorded calculations will be checked at this time. Following data entry, the spreadsheet will be printed out and the print-out will be checked against the handwritten data sheet. Any corrections will be noted on the hard-copies and corrected on the screen, and then a corrected version of the spreadsheet will be printed out. Each step of the verification process will be initialized by the COA operator or engineer performing the entry or verification step.

Each page of the logbook will be sequentially numbered and identified as Kinetico ETV Test. Each completed page will be signed by the on-duty FTO staff. Errors will be crossed with a single line and initialed. Deviations from the FOD whether by error or by a change in the conditions of either the test equipment or the water conditions will be noted in the logbook. The logbook will include a carbon copy of each page. The original logbook will be stored on-site, the carbon copy sheets will be forwarded to the project engineer of COA at least once per week. This will not only ease referencing the original data, but offer protection of the original record of results.

Also entered into the logbook will be any photographs of the station, test equipment or the installation. The existence of video tapes or other documentation will be entered. Photographs must be noted as to direction, time, subject and identity of the photographer.

Included in the logbook will be copies of chain of custody, field sheets and laboratory notes. Original chain of custody forms will travel with the samples. Examples of the spreadsheet format, chain of custody and laboratory worksheets are included as Appendix D.

While the use of laptop computers and electronic data recording is encouraged, any use will be documented in the logbook. Laptop computers will be employed in the spreadsheet analysis and the contents of the data spreadsheets will be noted in the logbook.

Computer data can be transferred either electronically or by physical transfer of data discs.

Each challenge test run will numbered for coordination with the on-site data from that run along with the laboratory testing data. The operating conditions for each test run will be entered into the logbooks and onto the spreadsheet. The spreadsheet will consolidate the information from Tasks 2, 3, 4, and the results from any and all off-site laboratory analyses.

Analysis of all water quality data, including that from each of the seeding studies from Task 4 shall be analyzed separately for 95% confidence in accordance with the confidence formula noted in Chapter 1 of the EPA/NSF ETV Protocol:

$$confidence\ interval = \overline{X} \pm t_{n-1,\,1-\frac{a}{2}}\ (S / \sqrt{n})$$

S = standard deviation
n = number of measurements in data set
t = distribution value with n-1 degrees of freedom
α = the significance level defined for 95% confidence as: 1- 0.95 = 0.05.

$$95\%\ confidence\ interval = \overline{X} \pm t_{n-1,0.975}\ (S / \sqrt{n})$$

5.7.2 Data Recording

The filtration instrumentation is controlled by an industrial, programmable computer XYCOM 9460 (attached as Appendix A) readily attachable to data recording devices; manual logbooks will be used to record data not connected to automatic records, such as flow rates, pressure and differential gauge readings and power consumption. All data will be maintained by the FTO and the data entered to the spreadsheet database.

5.7.3 Water Quality Data Grab Samples

The water quality data grab samples shall be analyzed for 95% confidence. Data on the grab samples should be correlated to any pressure losses and the time of the filter run (whether just prior to or following backwash, for example).

5.8 TASK 6: QA/QC

The objective of this task is to control the methods and instrumentation procedures such that the data are not subject to corruption. Adherence to analytical methods as published in *Standard Methods*, will be assured. Moreover, instrumentation and standard reagents will be referenced to the National Institute of Standards and Technology (NIST). Instruments used to gather data will be standardized and calibrated in accordance with the schedules noted below.

5.8.1 QA/QC Verifications

QA/QC verifications to be performed at the beginning of each testing period include instrumentation checks, cleaning and maintenance of the turbidimeters, pressure gauges, tubing and other components. Flow meters shall be tested against "bucket and stopwatch" procedures. Turbidimeters shall be tested for volumetric accuracy and standardized.

The particle counters will be verified using calibrated microspheres in the 2 μm, 5 μm and 15 μm levels.

In addition, daily verification of turbidimeters and particle counters shall be performed.

Daily QA/QC Verifications will include:
In-line turbidimeter flow rates verified (bucket and stopwatch);
In-line turbidimeter readings standardized against a calibrated bench turbidimeter;

Batch and in-line particle counting flow rates verified (bucket and stopwatch).

Bi-weekly QA/QC Verifications will include:

In-line flow meters cleaned and verified (bucket and stopwatch).

QA/QC Verifications at the beginning of each testing period will include:

Cleaning and re-calibration of in-line turbidimeters;
Verification of particle counter calibration with gradated microspheres;
Check differential pressure transmitter signal and pressure gauge readings with pressure meter;
Inspection of particle counter and turbidimeter tubing for unimpeded flow and integrity.

5.8.2 Specific Instrumentation Methods

Specific Instrumentation methods for on-site QA/QC accuracy are as follows:

5.8.2.1 pH

Analysis will be by *SM* 4500-H^+. A two point calibration with NIST traceable pH buffers will be performed daily. Between tests the pH probe shall be kept wet in KCl solution. For on-site determination of pH, field procedures shall be used to limit absorbance of carbon dioxide to avoid skewing results by poorly buffered water.

5.8.2.2 Temperature

Temperatures will be measured in accordance with *SM* 2550, two times daily at times selected to bracket the extremes of water temperature at the site. The thermometer will be in 0.1° C increments, and will be calibrated weekly against an NIST precision thermometer.

5.8.2.3 Turbidity

Although turbidity is not an effective measure of filter performance with respect to the removal of (oo)cysts, it is an important measure of overall filter performance. Moreover, turbidity has been recorded in many prior pilot tests, hence the inclusion of turbidity data, along with particle counts, is an important addition to the data collection. Since the data are only as valuable as the confidence in them allowed by proper testing, *Standard Methods* 2130 protocol will be employed.

The turbidimeters will remain on during the duration of the testing period. On line and bench top turbidimeters will be used, and the bench top turbidimeter will be the calibration standard for the test. The benchtop turbidimeter will be calibrated at the start of testing and then weekly during the testing period, against standards of 0.1, 0.5 and 5.0 NTU. Manufacturers procedures for maintenance will be followed and the schedules for maintenance and cleaning noted in the log book. All glassware will be dedicated and cleaned with lint free tissues to prevent scouring or deposits on the cells.

Turbidity will be evaluated, as noted above, in 15, 30 and 60 minute intervals, as well as at any spikes. The percentage of turbidity at <0.5, 0.51-1.0, 1.1-5.0 and >5.0 NTU will be noted.

A copy of *SM* 2130 is attached to this FOD as part of Appendix G "Testing and Calibration Procedures" for on-site convenience.

5.8.2.4 Particle Counting

Particle counting is a rapid and efficient means of determining with some accuracy the size distribution and enumeration of particles in a sample. While it conveys more information than turbidity, it cannot alone identify the source or nature of any specific particulate matter. Particle counters are generally calibrated against NIST standards by the manufacturer. Calibration shall be verified on-site with calibrated, mono-sized polymer microspheres. The procedure for monosphere verification is that as follows, and as described in the Test Plan.

1) Establish an initial analysis of particle concentration in the dilution water.

2) To that dilution water add a sample of each size of the monospheres (2, 10, and 15 μm) to achieve a close approximation to 50,000 particles in 25 mL, swirl each suspension in turn.

3) Quickly run the particle counter through the testing ranges to determine that the peak concentration lies at the size of the added monospheres.

4) Prepare a suspension that combines all three of the particle sizes in a concentration of 1000 particles of each of the three sizes (3000 total) in 1 mL, swirl the suspension.

5) Quickly run the particle counter range to determine that the particle counter peaks at each of the three particle sizes, and in approximately the proper enumeration.

Maintenance of the particle counters is important. Manufacturer recommended maintenance shall be followed and noted in the log book.

Procedures for particle counting will be those as noted in *Standard Methods* 2560 (and subsections appropriate to the equipment in use).

5.8.2.5 Particle Free Water (PFW)

Particle free water (PFW) is a necessary component of the testing procedure and shall be prepared fresh and as often as storage limitations will allow. Fresh water is necessary to limit biological growth that could affect the particle counts. The water for this study will be commercially available distilled and/or deionized (DI) water that has been additionally filtered through a .22 μm cartridge filter. Field conditions make the production of PFW in accordance with *Standard Methods* difficult. Commercially prepared DI water, filtered on site through a .22 μm filter will be suitable for particle counting and other reagent preparation in this application.

Glassware associated with the particle counters will be dedicated and cleaned with laboratory glassware detergent, then triple rinsed with PFW.

5.8.2.6 Pressure Gauges

While absolute pressure is less important than relative pressure and pressure differentials, differential pressure gauges, or matched gauges with calibration, and accurate to 1 psi, shall be used to measure pressure losses across the vessels.

5.8.3 Procedures for Chemical and Biological Samples Shipped For Off-Site Analysis

No travel blanks are required for this testing. The Quality Assurance Project Plan requires a discussion on the number of duplicates. The protocol indicates that analytical precision is being verified. The off-site laboratory will supply sample bottles sufficient for their analyses Duplicate samples are required for an evaluation of analytical precision, however with the exception of microbial samples (those for coliform bacteria and algae) the volume of water in a single sample is sufficient for duplicate analyses. Duplicate samples are thus not required for inorganic analysis, but will be taken for algae and bacteria.

5.8.3.1 Organic Parameters, Total Organic Carbon and UV Absorbance

Samples for these analysis shall be collected in glass bottles supplied by Spectrum Labs (a State Qualified Laboratory) and will be delivered by courier (the travel time is approximately twenty minutes). Samples will be preserved, held and shipped in accordance with *Standard Methods* 5010B and *SM* 1060.

5.8.3.2 Microbial Samples: Coliform and Algae

Samples will be collected in glass bottles supplied by Spectrum Labs and kept at 4°C in the proper shipping cooler. Coliform samples may be preserved with sodium thiosulfate if chorine is present. Algae samples will be preserved with Lugol's solution.

5.8.3.3 Inorganic Samples

Inorganic samples will be collected, preserved and shipped in accordance with *Standard Methods* 3010B and C and 1060 and EPA § 136.3, 40 CFR Ch 1. Proper bottles and preservative where required (Iron and Manganese for example) will be used. Although the travel time is brief, samples will be shipped in coolers at 4°C.

6.0 QUALITY ASSURANCE PROJECT PLAN

6.1 OBJECTIVE

The purpose of this section is to assure that the data are reliable. The primary responsibility for recording and monitoring the data lies with the FTO, although other individuals, especially those in off-site analytical laboratories, have responsibilities for supplying the data in accessible and reliable formats.

The inorganic laboratory for this project is Spectrum Labs, Inc. A copy of the Spectrum Labs, Inc. QA/QC manual is attached to this FOD as Appendix E.

The microbiological portions of this study will be performed by BioVir Laboratories, Inc. A copy of their QA/QC manual is attached as Appendix F.

6.2 REPRESENTATIVENESS

Water quality parameter samples will be taken as indicated in Table 5-1. Insofar as possible, samples will be taken at the same time of day. Off-site samples will be delivered to the laboratory for analysis. Included in Appendix E are samples of chain of custody forms, sampling protocols, sample volumes required for the different analyses, and holding times. The holding times are those indicated in EPA 40 CFR, Ch. 1, § 136.3 and *Standard Methods* 1060.

The samples will be transported from the test site to the laboratory via courier; the travel time is approximately twenty minutes.

On-site samples will also be taken utilizing *SM* 1060 sampling techniques.

Operating data, such as flow rate, volume measurements and pressure gauges will be recorded and the time noted; they too will be recorded at the same time of day whenever appropriate. Operational parameters shall be recorded and graphed to indicate changes. A +/- 10 percent change in an operating parameter shall be noted.

6.3 COMPLETENESS

Data collection will be considered complete if 85% of the collected data are acceptable. For the operations period, and the measurement of operational parameters such as flow rate and power consumption, data will be acceptable within ±5% of control values. Instrument failure will be rectified by back-up instrument systems, or through redundant measurement. For example, flow rates can be measured by stopwatch; continuous turbidity failure can be corrected by more frequent bench-top measurements. Particle counting data during the operations period can be verified and backed-up by bench top counters as well. Filter measuring data such as particle counts and turbidities will be deemed complete if 85% of the data are acceptable.

Outliers and anomalous data will be evaluated for cause and if more than 15% of data are not accepted, the corrective action as follows: if instrumental errors are introduced, back-up systems can be employed; if the errors or anomalous data have other causes, such as an abrupt and unforeseeable change in raw water quality, the feed water can be adjusted;

beyond adjustment, such as a catastrophic failure of the equipment, that portion of the test may need to be aborted.

Frequent (daily) review of collected data in spread sheet form should quickly identify instrument anomalies.

The microbial seedings are crucial to the performance verification and loss of any single test result will nullify that testing sequence and require repetition.

The completeness goal for this project is 85 percent. This data will be reported, at a minimum, in the verification report.

6.4 ACCURACY

For water quality parameters, the accuracy refers to the difference between the sample result and the true or reference value. Care in sampling, calibration and standardization of instrumentation and consistency in analytical technique will ensure accuracy. Also noted in Appendices E and F are accuracy goals for the off-site laboratories.

For operating parameters such as flow rates and pressures, high levels of accuracy can be ensured by redundant testing with different methods, for example, by confirming flow meters with bucket and stopwatch measurements. Pressure gauges will be verified either by reference to NIST standard gauges, or by changing gauge positions within a process flow.

Performance Evaluation (PE) sample tests will be conducted for on-site water quality parameters; specifically, turbidity and pH measurements. These will be conducted by unknown samples supplied by off-site laboratory personnel, tested by on-site FTO staff, and then verified by the off-site lab.

Accuracy can be measured by spiking a known value to a solute, or by using a standard sample. The spiked (or standard) sample is analyzed and the following equations are used:

For a spiked sample: $$\%R = 100\left[\frac{A - B}{S}\right]$$

For a standard: $$\%R = 100 \times \frac{\text{Observed}}{\text{True}}$$

Where:

%R	=	Recovery percent
A	=	Result of spiked sample
B	=	Result of un-spiked sample
S	=	Spike value

6.5 PRECISION

Precision is a measure of the degree of consistency from test to test, and can be assured by replication. In the case of on-site testing for water quality, precision will be ensured by triplicate tests and averaging; for single reading parameters, such as pressure and flow rate, precision will be ensured by redundant readings from operator to operator.

Travel blanks are not required for this testing.

Matrix and method blanks will be used for turbidity measurements, pH standardization, and for calibration of the particle counter both with respect to enumeration and size distribution.

Samples to be analyzed in duplicate and triplicate include only those on-site parameters consequential to the testing: bench-top turbidity, pH and bench-top particle counts associated with the calibration of the equipment.

Laboratory precision is assured by spiked samples; an explanation of those procedures is included in Appendix E.

The equation employed for precision is:

$$RPD = \frac{D_1 - D_2}{(D_1 + D_2)/2} \times 100$$

RPD	=	Relative percent difference.
D1	=	First sample value
D2	=	Second sample value

6.6 REPORTS

During the verification testing period, periodic reports will be prepared to detail progress, problems and corrective actions. The reports will discuss problems encountered either with the testing procedures or with the equipment, and will include the corrective action taken. The reports will be distributed to all concerned parties, specifically to the project manager at EPA, the project manager at NSF, the manufacturer's representatives and the staff of the FTO. Brief reports shall follow the initial operations, and at thirty day intervals, or more often if warranted. Reports will be in brief memo form and written. If instrumentation is the subject of a corrective action, the manufacturer of the instrument in question will also be copied in the report.

QA reports will also be forwarded to NSF by the FTO.

6.7 CORRECTIVE ACTION

Contingencies are by their nature unpredictable; however, the FTO will document contingency plans for foreseeable problems, to include analytical instrument backup, delays due to weather, equipment malfunction, or to problems associated with the site during the initial operations period and before formal verification begins. These plans will be maintained on site so that on-site operators can quickly respond to problems.

7.0 DATA MANAGEMENT, ANALYSIS AND REPORTING

7.1 DATA MANAGEMENT AND ANALYSIS

Data from daily written logs relating to the operation of the equipment will be tabulated in electronic spreadsheets. In addition, data from laboratory analysis, along with relevant QA/QC data will be entered from hard copy into electronic spreadsheet form. These data will be correlated with data from the challenge testing of microorganisms, and the removal values as determined by particle counter, turbidimeter and other on-line apparatus. In this manner, graphic displays of the data showing relationships between meaningful parameters can be analyzed and conveniently displayed for the final verification report.

Raw data will be furnished in appendices, along with discussion of any anomalies in the testing procedure, raw water source, or operating conditions that may impact the performance of the equipment.

Photographs, drawings, visitors logs, and field notebooks will be permanent and incorporated into the final report.

In summary, data to be compiled include:

- Laboratory Results on Water Quality Parameters
- On-site Water Testing Results
- Challenge In/Out Enumerations and Reports (from Instruments and Laboratories)
- Operations Logs of Flow meters, Pressure Readings, Chemical Consumption, Power Use, Total Water Volumes,
- Photographs, Visitor Logs, Time Lines and Schedules.

7.2 PERFORMANCE REPORT DRAFT

A final report will be prepared by the FTO following the testing period for submission to NSF and EPA. Included in the report will be a consolidation of the data, achieved results as determined by the data presented, a record of all aspects of the testing period and a discussion of all factors concerning the operation and maintenance of the equipment. The basic outline for the report will be:

- Introduction
- Executive Summary
- Description and Identification of the Product Tested
- Procedures and Methods Used in Testing
- Results and Discussion
- References
- Glossary
- Appendices (containing logs, prior report copies, relevant correspondence, and raw data forms)
- FOD
- QA/QC Results and Verifications of Instrument Calibrations

8.0 SAFETY MEASURES

The testing site is the University of Minnesota, St. Anthonly Falls Hydraulic Laboratory. The site safety plan documentation will be forwarded to COA, and be reviewed for applicability to this testing plan.

Manufacturers safety procedures for handling pressure vessels and for the use of on-site hazardous chemicals will be addressed.

For protection against accidental infection by (oo)cysts, strict environmental laboratory procedures will be followed. Protective clothing such as lab coats and gloves will be used, and the Gelman capsules removed will be double wrapped. Handling of all (oo)cysts and (oo)cyst containing materials will be done by laboratory personnel trained in biological safety.

Reduced Pressure Zone (RPZ) backflow prevention devices of appropriate pipe size will be plumbed between both the raw and finished water supplies to ensure (oo)cysts are not inadvertently introduced into the treatment plant water streams.

Safety considerations associated with a portable, skid mounted filtration system with the accompanying weight and stability issues must be addressed; however, these are incident to the test proper, and not to the use of the equipment.

9.0 OPERATIONS AND MAINTENANCE

During the testing and verification period, the FTO will evaluate the manufacturer supplied O&M manual to evaluate the instructions and procedures for their applicability to small system operators.

Maintenance issues will include (but not be limited to) the following components of the system:

- Valves
- Meters
- Pumps
- Motors
- Backwashing apparatus
- Pressure vessel opening mechanism
- Measuring and analytical instrumentation, such as turbidimeters and pressure gauges.

In addition, cleaning and parts replacement shall be addressed to prevent premature aging and rusting of vessels.

The FTO will also evaluate the manufacturer provided operating procedures. Among the issues to be addressed are:

- Filtration rate control through flow controls or valves
- Determination of head loss schedules
- Filter run limits determination
- Backwashing rates and start mechanisms
- Control of backwash rate and duration
- Determination of backwash frequency
- Determination of backwash length
- Return of filter to service, including filter to waste period
- Can filter run be stopped without initiating backwash?
  - Inlet and outlet pressure readings
  - Head loss indication or calculations
  - Raw water turbidity
  - Filtrate turbidity
  - Rate of flow control
  - Procedures for turbidity breakthrough
  - Turbidity levels and turbidity meter calibration procedures

Troubleshooting guides shall include contingency plans for:

- loss of flow
- uncontrolled flow rates
- loss of meter or gauge readings
- leaking vessels
- high turbidity
- no turbidity reading
- too rapid filter head loss

- excessive headloss following backwash
- stuck, broken (won't seal) or leaky valves.

Questions included in the Test Plan addressing operation and maintenance of the package plant —apart from the ETV test set-up itself—will be reviewed by the FTO for inclusion into the verification report. Among the issues are:

- pressure measurement at the vessel,
- rate of flow measurement device, (if volume meter or flow meter),
- on line turbidity measurement and any fail-safe controls and signals,
- ease of media replacement,
- procedure for seal and entrained air release,
- ease of operation relative to other components of the treatment system (additional prefiltration, chemical feed, check valves, etc.),
- efficiency and performance of other treatment equipment.

10 REFERENCES

Adin, Anner and Rebhum, Menahem, A model to predict concentration and headloss profiles in filtration, J. AWWA, Aug. 1977, pp 444-453.

Amirtharajah, Appiah, Some theoretical and conceptual views of filtration, AWWA Seminar Proceedings, AWWA Denver CO 1988, pp. 21-26.

ANSI/AWWA B100-89, AWWA Standard for Filtering Material, AWWA Denver, Colorado, 1989.

APHA/AWWA/WEF, Standard Methods for the Examination of Water and Wastewater, 19th Edition, APHA, Washington D.C., 1995.

Barnes, Ivan, Field Measurement of Alkalinity and pH, Geological Survey Water-Supply Paper 1535-H, 1964.

Clancy, Jennifer L., Gregory McKelvey, Glen Latimer, John Shramko, Performance of the Kinetico Pressure Filtration System in a Pilot Plant Challenge Using *Giardia lamblia* Cysts and *Cryptosporidium* Oocysts, AWWA Annual Conference Presentation, June 1993.

Cleasby, John L., Filtration, in Water Quality and Treatment, AWWA 1990, pp 455-560.

Cleasby, J. L., Williamson, M.M., & Bauman, E.R., Effect of filtration rate changes on quality, J. AWWA, 1963, pp 869-880.

Frey, M.N. et.al., A Synthesis Report of Cryptosporidium, AWWA Annual Conference Presentation, 1997.

Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, *Recommended Standards for Water Works*, (Commonly referred to as the Ten State's Standards) Health Education Services, Albany NY, 1992.

Hancock, C.M., J.V. Ward, K.W. Hancock, P.T. Klonicki and C.D. Sturbaum, Assessing Plant Performance Using MPA, Journal AWWA, 12:88:24-34, 1996.

Kiminski, J.C. Correspondence in New England Jnl. of Med., Vol. 331, No. 22, pp 1529-1530, 1994.

LeChevallier, M.W. et al, Giardia and Cryptosporidium spp. in Filtered Drinking Water Supplies, Applied and Environ. Microbiology, Vol. 57, No. 9, pp 2617-2621, 1991.

MacKenzie, W.R. et al, A Massive Outbreak in Milwaukee of Cryptosporidium Infection Transmitted through the Public Water Supply, New England Jnl. of Med., Vol. 331, No.3, pp 161-167, 1994.

McTigue, N. E., and MacPhee, M.J., Engineering Pilot Plant Studies for Assessing Pathogen Removal Treatment: Design and Operational Considerations, Environmental Engineering and Technology, Inc. Newport News Virginia.

NSF/EPA ETV Protocol: Chapter 1, *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants*, NSF International, Ann Arbor, Michigan, April 20, 1998.

NSF/EPA Test Plan: Chapter 6, *NSF Equipment Verification Testing Plan, Backwashable Depth Filtration for the Removal of Microbiological and Particulate Contaminants*, NSF International, Ann Arbor, Michigan, April 20, 1998.

USEPA, Method 1622, *Cryptosporidium* in water by Filtration/IMS/FA, Draft of December 1997, EPA-821-R-97-023, 1998.

Watanabe, Myrna E., New Cryptosporidium Testing Methods, Environ. Sci. and Technol., Vol. 30, No. 12, pp 532A-535A, 1996.

11.0 GLOSSARY

Backwashable Depth Filter
A bag filter, cartridge filter, or granulated media filter intended to filter uncoagulated water and to be backwashed when terminal headloss is attained or turbidity breakthrough occurs.

Filtration
A process for removing particulate matter from water by passage through porous media.

Granular Media Filter
A deep bed filter containing granular media used to filter water that has not been coagulated. These filters rely on straining particles out of the water, or by attachment of the particles to the media.

Ten State's Standards
A compilation of accepted civil engineering water treatment plant design standards, published as "Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, *Recommended Standards for Water Works*".