

WATER TREATMENT FOR SMALL PUBLIC SUPPLIES

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TITLE: Water Treatment for Small Public Supplies

SCOPE: On June 23, 1977 a new era began in the supply of the nation's most widely used and essential commodity, drinking water. For the first time the purity of drinking water, and other aspects of the operation of 240,000 water systems came under supervision of the Federal Government. The regulations, adopted by the U.S. Environmental Protection Agency under the Safe Drinking Water Act, set limits on the amounts of various substances found in water which may adversely affect public health. These substances include bacteria, trace metals, fluorides, nitrates, pesticides, total dissolved solids, and radioactive chemicals. Each public water supply in the country serving 15 or more connections or 25 or more people must make sure its water meets these minimum standards for purity.

In New Mexico approximately 800 community-type public water supplies are initially affected according to the State of New Mexico Environmental Improvement Division. These water systems encompass cities, towns, rural water districts, trailer parks, subdivisions, institutions such as hospitals, and company towns that serve water on a year-round basis. Regulations will be extended at a later date to include non-community-type systems, such as campgrounds, motels, road-side parks and service stations serving the traveling public. The range of problems in achieving drinking water supplies which meet current regulations range from a single solute exceeding the limit to waters which fail to meet multiple regulations, e.g., TDS, radio activity and several cations all in excess of the regulations.

ABSTRACT

The Chemical Engineering Department, through the Water Resources

Research Institute and with the cooperation of the New Mexico Environmental Improvement Division has designed, constructed and is operating a water treatment system for improving small community drinking water supplies to meet existing regulations. The technology utilized has been primarily developed under the auspices of the Office of Water Research and Technology of the Department of Interior.

General desalination of water can proceed by one of two methods - phase transition or solute separation. The latter methods are being used in the demonstration project and in the accompanying laboratory studies. The specific project objectives are:

1. to develop operating conditions and information for an engineering evaluation of the two primary treating methods i.e., reverse osmosis and electrodialysis, and their associated secondary support processes;
2. to develop specific cost data;
3. to extend available water treatment technology in the area of single solute removal from drinking water containing a large number of ionic and dissolved species;
4. to provide the necessary material for assimilation of this unit or comparable equipment into the educational activities of water supply and water treating, specifically for engineering and technology students and operator training;
5. to evaluate brine disposal methods in compliance with New Mexico groundwater regulations.

This report covers the selection, design construction and operating procedures for the demonstration unit. The operating experiences at the selected communities will be documented as supplements.

TABLE OF CONTENTS

Scope	i
Abstract	ii
Table of Contents	iii
List of Tables	iv
List of Figures	v
I. INTRODUCTION	1
A. General Desalting Technology	2
B. Reverse Osmosis	5
C. Ion Exchange	8
D. Electrodialysis	12
E. Economic Evaluation	15
II. SYSTEM DESIGN	22
A. Reverse Osmosis Specifications	22
B. Reverse Osmosis System Equipment and Cost	27
C. Electrodialysis Equipment and System Cost	28
D. Reverse Osmosis Membranes	28
III. OPERATING PROCEDURES - WATER TREATMENT UNIT	29
A. Start-up and Running Procedure	30
B. Clean-out Procedure	48
C. Shut-down Procedure	48
D. Safety Precautions	49
IV. PROGRAM SCHEDULE	51
V. REFERENCES	52
Appendix A - New Mexico Drinking Water Regulations	54
Appendix B - Analytical Method, Detection Limits, Sensitivity	55

LIST OF TABLES

	Page
1. Classification of Saline Water Conversion Processes	4
2. Energy Requirements for Six Desalination Processes	5
3. Ion Exchange Active Functional Groups	10
4. Projected Demineralization Costs for 15 Candidate Communities	17
5. Summary of Demineralization Research - Typical Effluent Quality	18
6. Estimated Costs of Water-Reclamation Processes	18
7. Monthly Operating Costs for Minitonas System	20
8. Orange County Water District 5 Mgd RO Plant Cost	21
9. Feed Water Solute Limits	26
10. Major Components List	27
11. Aquamate V Components	28
12. Membrane Suppliers	28
13. Community Water Supplies to be Utilized	51

LIST OF FIGURES

	Page
1. Basic Flow Diagram for a Single-Stage Reverse Osmosis Plant	7
2. Typical Single Column Ion Exchanger Flow Diagrams	11
3. Electrodialysis Cell	13
4. 1978 CE Plant Cost Index	16
5. Van Logos	29
6. Flow Diagram for Water Purification System	31
7. RO System Equipment in Van	32
8. ED System Equipment in Van	33
9. Inlet Piping and Sand Trap	34
10. Chemical Feed Tanks and Pumps	35
11. Manganese Green Sand Filters and 4-way Control Valves	36
12. Holding Tank Feed Pump	38
13. Cartridge Filters	39
14. Pump Surge Vessel and Feed Control Valves	40
15. RO Inlet Valves	41
16. RO Outlet Valves	42
17. Flow Control Manifold	43
18. R.O. Skid	44
19. Electrodialysis Control Panel	46
20. Electrodialysis Stack	47

INTRODUCTION

Although the Safe Drinking Water Act has been law for several years, it has only been recently, as implementation neared, that an awareness of what is involved has developed. The Act required the Administrator (of the EPA) to arrange for the National Academy of Science to determine, among other things, "the maximum contaminant levels in drinking water which should be recommended ... in order to protect the health of persons from any known or anticipated adverse effects" [1]. While the NAS Committee report clearly delineates that awareness of contaminants in water has increased rapidly because of increasingly sensitive analytical techniques and now exceeds the slowly acquired understanding of effects of chronic ingestion at low levels, the report emphasized that the results currently available on which the Safe Drinking Water regulations are based must be considered as the first contribution of an effort that should be continued.

The standards that have gone into effect are: [2]

1. Inorganic chemicals, maximum in milligrams per liter of water: arsenic, 0.5; barium, 1.0; cadmium, .01; chromium, .05; lead, .05; mercury, .002; nitrate, 10.0; selenium, .01; silver, .05; fluoride, 1.4 to 2.4 depending on local temperature.
2. Six persistent pesticides: limits of 0.0002 to 0.1 milligrams per liter for endrin, lindane, methoxychlor, toxaphene, 2,4-D and 2,4,5 TP Silvex.
3. Coliform bacteria: a basic limit of four organisms per 100 milliliters;
4. Radioactivity: 5 picocuries per liter of water for natural radioactivity, such as the mineral radium 226; for man-made radioactive material, a consumer exposure limit of 4 milliroentgens per year.

5. Turbidity: one standard turbidity unit.

Chlorine, the commonest water purifier, has been discussed as a possible hazard since it is a potential constituent of cancer causing compounds; However, the EPA so far has indicated that restrictions on its use may do more harm than good.

Under the Safe Drinking Water Act the EPA has also published secondary water quality standards covering esthetic characteristics such as odor, color, alkalinity and staining tendencies. Adoption of these standards is optional with the states and is not federally enforceable.

In circumstances where a community's drinking water does not meet the standards and alternate acceptable drinking water supplies are not economically available, water treating is the required solution. Appropriate treating methods are generally classified as desalination processes. These processes will be examined as to applicability for treating small community public water supplies.

A. GENERAL DESALTING TECHNOLOGY

In 1952 the U.S. Congress passed the Saline Water Act (Public Law 448 - 82nd Congress) to provide for research into the development of practical means for the economical production, from sea and other saline waters, of water suitable for agricultural, industrial, municipal and other beneficial consumptive uses, and for other purposes. A comprehensive act in 1971 replaced the prior legislation and amendments and extended the program (Saline Water Conversion Act of 1971 - Public Law 92-60).

Progress has been made. Early desalting costs were \$5 per thousand gallons for small applications and \$1-2 per thousand gallons for large (6 MGD) operations.

Today a few processing brackish water provide water for around \$.50 per thousand gallons (3).

Technology developed to date provides substantial evidence of the feasibility of future large-scale applications. It is now necessary to bridge the gap to the future when practical, wide-spread applications of desalting are contributing significantly to the water supply; that is, when desalting plants, in sizes of the order of 50 to 500 million gallons per day, will become a reality. At the same time, a series of desalting plants in the size range of .5 to 20 million gallons per day are necessary to meet the increasing needs of small municipal and industrial uses. With the implementation of the Safe Drinking Water Act this technology needs to be extended down to the 10,000 to 15,000 gallons per day range. At the lower end of the scale, hardware is available; however, it does not at present meet the goals of \$.25 to \$.30 per thousand gallons which is projected for the year 2000. Further, the current available technology must be demonstrated for selective control of single solutes.

The most developed process for sea water conversion is distillation, which includes multistage flash, vertical-tube multieffect, vapor compression and combinations of these. Other processes being developed which are applicable to sea water include freezing methods (crystallization) and the membrane processes. For desalting of brackish waters the preferred processes are membrane processes, including electrodialysis and reverse osmosis and applications of ion exchange technology. In brackish water considerations, combinations of processes show opportunities for economical advantage in some applications. A second method of characterizing desalting technology is: 1) processes which separate water from solution and 2) processes which separate dissolved species from solution. Table 1 lists these processes (4).

Table 1. Classification of Saline Water Conversion Processes

- A. Processes that separate water from the solution
 - 1. Distillation
 - a. Multistage flash
 - b. Multiple-effect long-tube vertical
 - c. Vapor compression
 - d. Humidification (solar)
 - 2. Crystallization or freezing
 - a. Direct freezing
 - b. Indirect freezing
 - c. Hydrates
 - 3. Reverse osmosis
 - 4. Solvent extraction
- B. Processes that separate salt from the solution
 - 1. Electrodialysis
 - 2. Osmionisis
 - 3. Adsorption
 - 4. Liquid extraction
 - 5. Ion exchange
 - 6. Controlled diffusion
 - 7. Biological systems

Those processes involving phase changes have relatively large energy requirements as shown in Table 2. With increasing energy costs and considering the scale of operation for small public water supplies, reverse osmosis, electrodialysis and ion exchange appear to be the technologies most suitable for the proposed use. Ion exchange is used quite extensively for water softening and both electrodialysis and reverse osmosis

Table 2. Energy Requirements for Six Desalination Processes (4)

	Energy per 1000 gallons product water			
	1964 Technology		1980 Technology (a)	
	BTU* 10 ⁻³	Kw-hr	BTU* 10 ⁻³	Kw-hr
Processes Using Heat				
Multistage flash distillation	1020	300	610	180
Long-tube vertical distillation (LTV)	1020	300	610	180
Processes using electricity (b)				
Electrodialysis (brackish water only)	250	25	150	15
Vapor-Compression distillation	610	60	360	35
Reverse Osmosis	510	50	310	30

(a) The estimated 1980 energy requirements are for high-efficiency processes and are not applicable to processes using low-cost energy.

(b) The energy values given for the "electrical" processes are the thermal energies for the appropriate electrical power generation at 33% efficiency.

have been evaluated extensively for desalination applications under federal programs. All systems are available commercially. All systems produce a reject brine which requires controlled disposal. Reverse osmosis has the advantage that it produces a product water essentially free of dissolved organic material and microbial species. All systems, in practice, will be a combination of unit operations of pretreatment, post-treatment and/or polishing.

B. REVERSE OSMOSIS

Reverse osmosis is a membrane separation technique in which a semi-permeable membrane allows water permeation while acting as a highly selective barrier to the passage of dissolved, colloidal, and particulate matter (5,6,7). Inorganic, organic, and microbial species are all included in the membrane rejection. Natural permeation is reversed by applying external pressure (pumping) on the saline solution side of the membrane and "fresh" water is recovered while concentrating the saline solution.

The nature of the membrane material and the structural design required to achieve large transfer surfaces in compact units requires controlled pretreatment of the feed solution. For cellulose acetate membranes basic operational limitations are:

1. feed water pH must be on the acid side to prevent membrane hydrolysis; For best operation, the pH should be between 5 and 7;
2. microbial populations must be limited to prevent microbial degradation of the membrane;
3. process temperatures should not exceed 75 to 80 degrees F if long membrane life is expected;
4. projected membrane life is two to three years of continuous service.

In operation the following general observations have been reported:

1. multivalent ions are more effectively rejected than univalent ions;
2. undissociated or partially dissociated substances are poorly rejected;
3. acids and bases are rejected to a lesser extent than their salts;
4. co-ions affect the rejection of a particular ion; for example, sodium is better rejected as the sulfate than as the chloride;
5. undissociated low molecular weight organic acids are poorly rejected while their salts are well rejected;
6. trace quantities of univalent ions are in general poorly rejected.

A second commercially important membrane material is a polyamide (nylon) material. It has high chemical and physical stability leading to long life expectancies. Polyamide membranes have lower water permeation coefficients than the cellulose acetate membranes and, therefore, to maximize the transfer surface area these membranes are usually formed into hollow, fine fibers having outer and inner diameters of approximately 50 and 25 microns respectively. The feed water is fed external to the fibers and the fresh water permeates into the center (hollow) of the fiber. Suspended solids must be controlled to prevent fouling of the fiber bundles. Scaling and chemical precipitation must also be carefully controlled because of the large potential for plugging the mass of fiber.

A water treatment operation based on reverse osmosis as the primary desalination technology is shown in Figure 1. The unit operations involved

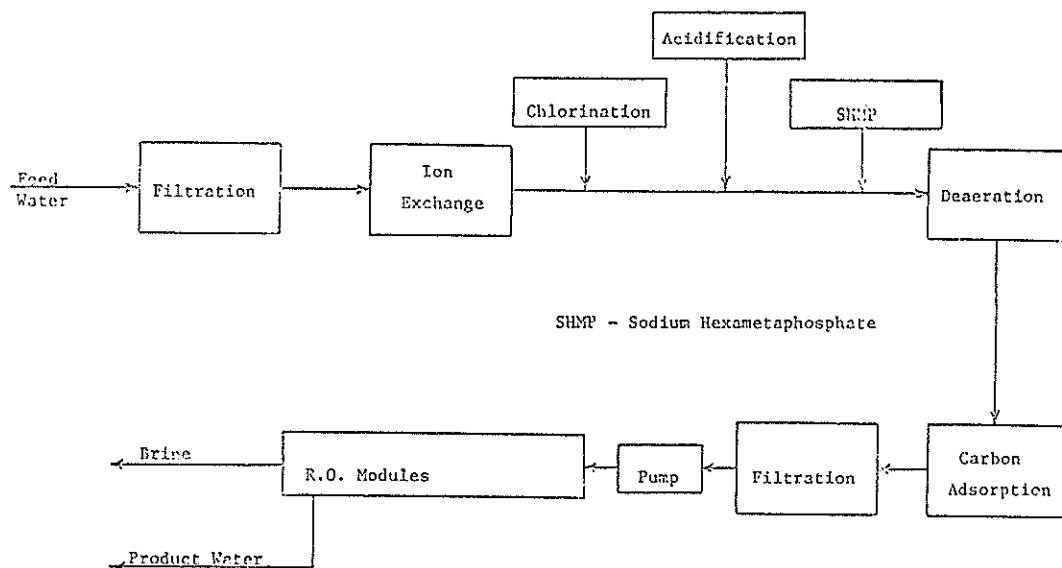


Figure 1. Basic Flow Diagram for a Single-Stage Reverse Osmosis Plant

may include permanganate or ion exchange removal of iron and manganese, sand filters for suspended solids, pH control by acid addition, sodium hexametaphosphate retardation of sulfate deposition, chlorine control of microorganisms, and carbon adsorption to reduce residual chlorine. Pretreatment needs will depend upon the chemical nature of the feed water, the product water to reject brine ratio, type and configuration of membrane being used.

During operation of the reverse osmosis unit flux maintenance procedures have to be performed. Flux maintenance is periodic chemical cleaning of the membrane to remove adhering scale.

Polishing of the product water will depend upon its intended use. For drinking water pH adjustment and disinfection would be required.

The brine created will be concentrated and will require ultimate disposal. Current groundwater quality regulations will limit the possible disposal methods.

C. ION EXCHANGE

Ion exchange is a separation process in which ions held by electrostatic forces to charged functional groups on the surface of an insoluble solid are replaced by ions of like charge in solution. The process involves a phase transfer from a solution to a solid surface phase. Unlike simple physical adsorption phenomena, ion exchange is a stoichiometric process in which every ion removed from solution is replaced by an equivalent amount of another ionic species of the same sign from the solid. Ion exchange is, in general, a reversible process and is selective in the removal of dissolved ionic species. Although many naturally occurring materials exhibit ion exchange properties, synthetic ion exchange resins having a wide range of properties for specific applications have been developed (8,9,10,11).

The characteristic properties of ion exchange materials are due primarily to their structure. These materials consist of solid matrix held together

by chemical bonds. Attached to this framework are soluble ionic functional groups containing ions which are relatively free to move and exchange with similarly charged ions in solution.

Ion exchange materials must possess the following characteristics (11):

1. ion-active sites throughout the entire structure, e.g. very uniform distribution of activity;
2. high total capacity; that is, a high degree of ion substitution or low equivalent weight;
3. good degree of selectivity for ionic species but capable of being regenerated;
4. extremely low solubility;
5. good structural chemical stability;
6. good structural physical stability; and
7. costs competitive with other processes.

Naturally occurring ion exchange materials are soils, cellulose, wool, protein, coal, metallic oxides, and living cells such as algae and bacteria (9). Natural aluminosilicates, zeolites, of crystalline structure are commonly used ion exchangers. These materials have relatively open three-dimensional lattice structures with large and interconnecting pores available for solution to enter.

Synthetic ion exchangers were developed to impart better characteristics into the material than those exhibited by naturally occurring zeolites. Of the synthetic materials, the organic ion exchange resins are most important. They are typical gels consisting of a matrix of irregular, macromolecular, three dimensional network of hydrocarbon chains. The matrix carries replaceable ion groups. Cross linking of the macromolecule is accomplished by carbon-carbon bonding thus giving the resin good chemical, thermal, and

mechanical stability. In synthetic resins the ion selectivity can be controlled by the nature of the fixed ionic groups attached to the matrix.

Ion exchangers are classified by the type of ionic functional group attached to the structure and the charge sign of the exchanging ion. Five major classes of ion exchange resins, categorized according to functional group, are: 1) strongly acidic cationic; 2) weakly acidic cationic; 3) strongly basic anionic; 4) weakly basic anionic; and 5) a broad miscellaneous category of ion-specific structures (9,11). In addition to these classes there exist some intermediate strength acid and base resins (10,11,12,13). Functional groups associated with different classes of resins are shown in Table 3.

Table 3. Ion Exchange Active Functional Groups (10,12,13)

<u>Type</u>	<u>Active Functional Group</u>
Strong Acid	Sulfonate ($-\text{SO}_3^{-1}$)
Intermediate Acid	Phosphonic ($-\text{PO}_3^{-2}$)
	Phosphinic ($-\text{HPO}_2^{-1}$)
	Arsenic ($-\text{AsO}_3^{-2}$)
	Selenic ($-\text{SeO}_3^{-2}$)
Weak Acid	Carboxylic ($-\text{COO}^{-1}$)
	Phosphonous ($-\text{PO}_2^{-2}$)
Weak Base	Primary ammonium ($-\text{NH}_3^{+1}$)
	Secondary ammonium ($=\text{NH}_2^{+1}$)
	Tertiary ammonium ($=\text{NH}^{+1}$)
Intermediate Base	Primary and Quaternary ammonium ($=\text{N}^{+1}$)
Strong Base	Quaternary and Small Amount of Primary Amine
Very Strong Base	Quaternary ammonium ($-\text{N}[\text{CH}_3]_3^{+1}$)
	Quaternary phosphonium ($=\text{P}^{+1}$)
	Tertiary sulfonium ($=\text{S}^{+1}$)

Ion Exchange Process

Purification by ion exchange is a process for removing ionized species from nonionized or slightly ionized solvents, such as water. Most ion exchange operations are carried out in columns, as illustrated in Figure 2. As the solution passes down through the ion exchange bed, its composition changes. Ion exchange processing may be considered batch operation for any single column with the operating cycle consisting of four distinct phases. These are: 1) service period; 2) backwash; 3) regeneration; and 4) rinse. During the service period feed water is passed through the bed with removal of ionized contaminant occurring. As the solution is first fed to the column, it will exchange all of its exchangeable ions in a narrow zone of resin near the feed point. As the capacity of the resin in this zone is approached, the exchange region will move through the column until the entire resin bed is exhausted. In actual operation the service period is ended before complete exhaustion and a fresh column brought into service.

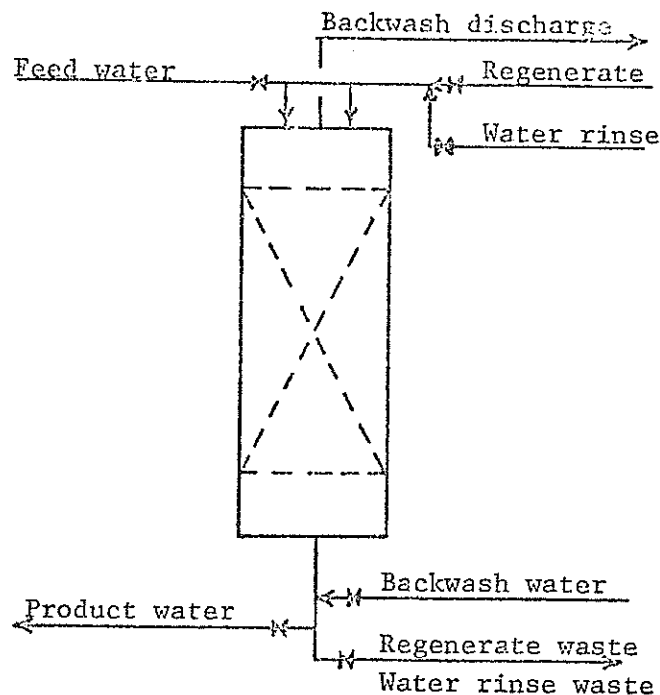


Figure 2. Typical Single Column Ion Exchanger Flow Diagram

The column is placed in a backwash mode in which water is passed up through the column to remove any foreign matter which may have entered and to reclassify the resin particles.

During the regeneration period, regenerant solution is pumped down through the bed displacing undesirable ions from the resin and restoring it to its original condition. In this period a waste stream is generated which requires disposal.

In the rinse period feed water is used to displace spent regenerant remaining in the bed. This water effluent is discarded as long as any contamination with spent regenerant is evident.

Where continuous product water supply is required, an ion exchange processing unit would consist of several columns. The columns would be cycled in different operational phases insuring that at least one column would always be in the service mode.

The economics of ion exchange require high capacity resins, a high degree of column utilization, high selectivity for exchange ions, efficient regeneration, rapid exchange rates, reasonable production rates and inexpensive spent brine disposal methods.

D. ELECTRODIALYSIS (14,15,16)

When most common salts, minerals, acids and alkalis are dissolved in water, each molecule splits into oppositely charged particles called "ions". If a direct current (d.c.) potential is applied across a solution of salt in water by appropriate electrodes in the solution, the cations (positive ions) will move towards the negative electrode (cathode), and the anions (negative ions) will move toward the positive electrode (anode). If proper barriers were available to take advantage of the ion movement and prevent remixing, separation of the ions from the solution would be

achieved. There would be a requirement for two types of membranes;

- 1) Cation membranes which permit the passage of cations only,
- 2) Anion membranes which permit the passage of anions only.

Introduction of a cation membrane and anion membrane into a salt solution to form three water-tight compartments as shown in Figure 3, followed by a direct electric current into the water will result in the demineralization of the central compartment.

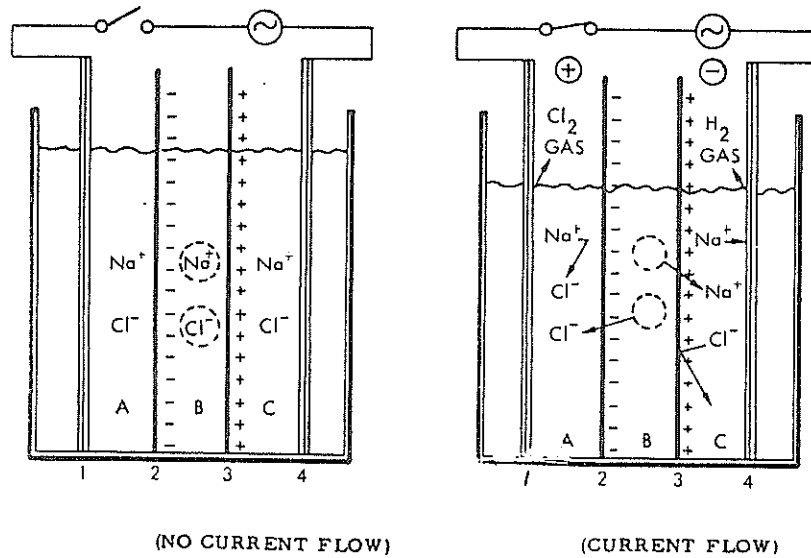


Figure 3A

Figure 3B

Figure 3. Electrodesis Cell

In Figure 3 the anion membrane is (2) and the cation membrane is (3). The cathode is (1) and the anode is (4). As shown in the figure there are reactions which take place at the electrodes, e.g. in the presence of chloride salts, chlorine gas is evolved at the cathode and hydrogen gas is evolved at the anode. Simply by reversing the polarity of the electrodes, the dilute streams become brine streams, and the brine streams become dilute streams. The practical operation of an electrodialysis unit is to operate a "stack of cells," i.e. many units as shown in Figure 3 in parallel.

Generally the rate of production of demineralized water by electro-dialysis is dependent upon water temperature and ionic analysis. A specific ED unit is designed for a given feed. If there is a change in the water analysis of the actual feed there will be a change in the product specifications and/or product capacity. The temperature of the feed water is extremely important to both the efficiency of the operation and to the quality of the product. In general terms, the lower the feed water temperature is, the higher the product total dissolved solids (TDS) will be. The constraints on feed water temperature are that it should be above 45^o F and below 110^o F.

There are several other possible components of a feed water which require special consideration for the operation of an ED unit. Iron in the feed water will cause certain process problems. Above 0.1 ppm certain precautions have to be taken. One of the effects of excess iron in feed water is a deposit of an orange film onto the membrane surface. This in turn has an effect on the product specification and the voltage and current on the stack. This film can be reduced by a "Clean-In-Place" operation. However, excess iron above .3 ppm should be removed by pretreatment of the feed water before the feed water is fed to the ED system. Iron film can develop in the feed water after a few days or weeks of operation. One of the main sources of iron is the

feed pipe and tanks between the water source and the ED. Although water at the source may show little or no iron, periodic checks should be made on the feed water at the ED.

There are several other important considerations concerning the feed water. Primary are:

1. pH
2. Biological
3. Bacteriological

In specific terms, the feed water must be clear of all biological and bacteriological effects. Both of these components can have an adverse effect on the ED as well as other equipment in the system. Also both of these components could cause a health problem if not properly dealt with. The effect of pH is of secondary importance; it has more effect on the equipment in the system in terms of possible corrosion, etc. rather than on the electro dialysis process. In addition the ED unit should not be operated when the feed water contains any of the following:

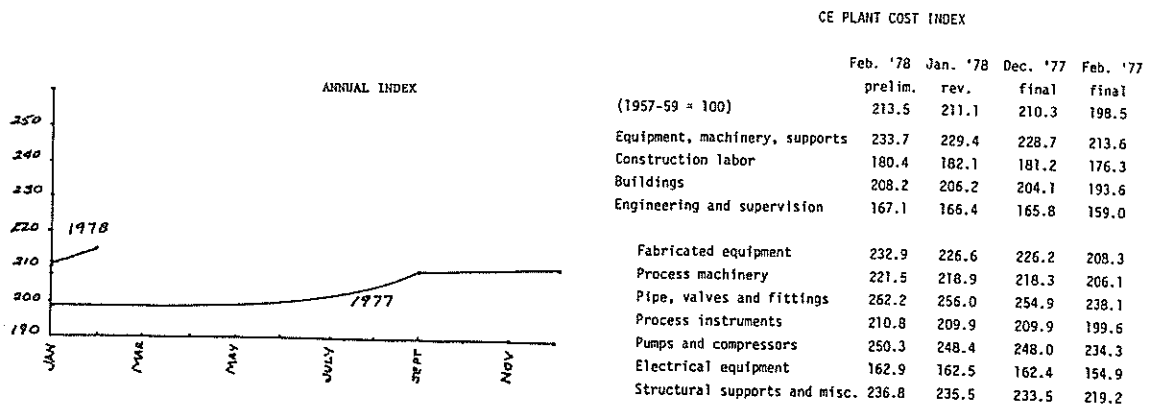
- a) Chlorine-residual of any concentration
- b) Hydrogen sulfide-any concentration
- c) Calgon or other hexametaphosphates in excess of 10 ppm.
- d) Manganese

E. ECONOMIC EVALUATION

The ultimate acceptance of any water treating method is an economic evaluation. The Office of Water Research and Technology and its predecessor, the Office of Saline Water, have expressed goals of 20 to 30 cents per thousand gallons for potable water by the 1980's. Generally these values were keyed to large-scale combined operations of electric power production (nuclear) and available waste-heat for water distillation. Such processes are not and will not have been demonstrated on the scale envisioned

(50 million gallons per day) by 1980. There is currently under construction (and pilot plant operation) the Salt River project in Arizona. This project is designed to use reverse osmosis and will treat 1 million gallons of water per day. Operating data is not available at present. This project is for salinity control and is not primarily directed towards producing a drinking water quality product. Further, the scale of operation would not be transferable to small community water supplies. There are, however many communities currently operating water treating systems that have published economic evaluations.

In June 1971 a report was made to the American Water Works Association on the initial results of state-federal investigations then being conducted on the feasibility and cost of demineralizing candidate brackish ground waters to public health standards (17). These results were extended to other communities over the next several years and in 1977 the projected demineralization costs for fifteen candidate communities were published (18). Table 4 summarizes the results. The original study costs have been adjusted to early (March) 1977 dollars. Figure 4 gives the 1978 CE plant cost index values showing an additional 6-8% increase in the above values.



NOTE: Details and subcomponents of this index are described in Chemical Engineering, Feb. 15, 1963, pp. 143-152. (Reprints are available: No. 132 on the reprint order form in the back of each issue). For recapping and updating, see issues of Apr. 25, 1966, Nov. 13, 1972 and Apr. 26, 1975.

Figure 4. CE Plant Cost Index

A second recent study on demineralization costs was based on the reuse of secondary effluent in water-short Southern California (19). Table 5 summarizes the water quality from the demineralization studies. The estimated costs included additional advanced waste treatment operations which would be required for a waste-water source. These unit costs are shown in Table 6. Again these values are early 1977 dollars.

Further, it should be noted that these operations are conceptual studies and not actual operating plants.

The development and operation of the first municipal reverse osmosis water-treatment plant in Canada has been described and information about

Table 4
Projected Demineralization Costs for 15 Candidate Communities,
1970-1973

Municipality	Population 1970	Feed-water Quality- mg/l		Municipal Water Quality- mg/l		Demineral- ization Process	Demineral- ization Cost			
		TDS	Hard- ness	TDS	Hard- ness		70-73*		1977*	
							c/m ³	c/1000 gal	c/m ³	c/1000 gal
Lakota, N.D.	964	1754	816	195	100	IX-RO	41.5	157	45.2	171
Eureka, S.D.	1547	2163	1248	430	5	Z-RO	20	75	30.1	114
Sibley, Iowa	2747	2720	1547	481	100	IX-ED	38.3	145	50.4	191
Freer, Tex.	3000	1242	77	500	49	ED	15	56	27.7	105
Towanda, Kan.	1242	2417	1033	246	125	RO	36.2	137	55.2	209
Roundup, Tex.	2010	1643	725	385	72	RO	20	77	34.3	130
Malta, Mont.	2195	969	332	493	29	IX	11	42	19	71
Las Animas, Colo	3100	3236	1512	981	194	RO	15	57	25	96
Ft. Lupton, Colo.	2500	1423	588	430	200	RO	11	41	18	69
Ft. Stockton, Tex	7500	1796	798	485	150	IX-ED	10	40	20	73
Kihei, Haw.	13500	1100	207	500	90	ED	15	57	20	75
Casa Grande, Ariz.	10500	945	380	500	205	ED	8.2	31	13	50
Midland, Tex. †	63000	1135	503	400	100	IX-RO	6.9	26	11	42
Ark. City, Kan.	14000	1658	565	500	65	ED	9.2	35	14	53
Artesia, N.M.	10315	941	655	490	100	IX	9.0	34	15	57

*1970-1973 costs equated to 1977 dollar values
†For supplement to surface water supply

Table 5 Summary of Demineralization Research-
Typical Effluent Quality

Process	TDS mg/l	Hardness as CaCO ₃ mg/l ³	Total COD mg/l	Turbidity JTU
Feed Water ⁽¹⁾	700	250	9.0	1.2
Reverse Osmosis	60	7	1.0	.1
Electrodialysis	460	120	6.3	.6
Ion Exchange	70	2	3.7	.1

(1) Feed water was carbon treated secondary effluent

Table 6
Estimated Costs of Water-Reclamation Process*

Process	Capital		Operation and Maintenance		Total	
	c/m ³	c/1000 gal	c/m ³	c/1000 gal	c/m ³	c/1000 gal
Direct Filtration	1.1	4.1	0.74	2.8	1.8	6.9
Single stage carbon treatment	1.7	6.5	1.0	3.9	2.75	10.4
Ozonation (10 mg/l)	0.92	3.5	1.1	4.1	2.0	7.6
Chlorination (10 mg/l residual)	0.55	2.1	0.53	2.0	1.1	4.1
Dechlorination	0.02	0.9	0.48	1.8	0.71	2.7
Reverse osmosis	2.99	11.3	10.2	38.7	13.2	50.0
Electrodialysis †	1.4	5.4	4.62	17.5	6.05	22.9
Ion exchange	1.3	5.1	6.66	25.2	8.00	30.3
Nitrification-denitrification	0.90	3.4	1.7	6.6	2.64	10.0
Phosphate removal	‡	‡	2.4	9.0	2.4	9.0

*Assumptions were: Engeg, News Record Cost Indexes, 2500: plant scale, 0.4m³/5 (10 mgd):
amortization for twenty years at 7 per cent interest; power cost, 2.5 c/kWh.

†This process resulted in 30 per cent TDS removal.

‡Removal by chemical addition to existing biological treatment system results in a capital cost
that is negligible.

the process, cost and water quality has been detailed (20). The water treatment plant is designed to produce 20,000 Imp gallons of product water per day. The raw water contains approximately 3500 mg/l dissolved solids. In addition, the water has a high fluoride content ranging from 3.5 to 4.3 mg/l.

The well water is pumped through a prefilter using a granular non-hydrous aluminum silicate. This material has shown about twice the ability of filter sand for suspended solids removal, and therefore, the prefilter can be smaller than conventional straight sand filters. From the prefilter the water passes through one of two zeolite softeners in the sodium cycle to reduce the hardness from 50 mg/l to less than 5 mg/l. This softening is done to prevent any possibility of calcium carbonate precipitation on the membranes.

After softening pH is adjusted to about 7.2. The water next passes through replaceable or rewashable cartridge filters. Suspended particles of greater than 10 micrometers are removed. The RO membrane units are DuPont 139 Permeators operated at 300-400 psi. Water recovery is 66% and salt rejection is 96% giving 15,000 Imp gallons of 140 mg/l TDS water. Table 7 shows a monthly operating cost for the water treating system. Capital cost is not given and depreciation is not apparent in the monthly cost.

The availability of the Minitonas study is significant for our project for it is this size range unit that is being developed.

A recent demineralization installation for secondary effluent is reported in "Municipal Wastewater Reuse News" (21). Secondary effluent from the Orange County Sanitation District is the feedwater. The TDS range from 1200 to 1400 mg/l. Total flow is 5 million gallons per day. The source is primarily industrial wastes (25% of raw sewage flow). New

imported sources and government regulations on industrial discharges to sewers will lessen the TDS increment in the future but demineralization with RO will still be required prior to injection to meet blending limitations.

The RO plant design includes prechlorination, cartridge filtration and the addition of sodium hexametaphosphate for scale control. The cartridge filters are 25 microns effective size. High pressure feed pumps energize the water to approximately 550 psi, after which sulfuric acid injection adjusts the pH to 5.5 before the water reaches the RO membranes. Post-treatment consists of decarbonation before the water is pumped to a blending tank prior to injection.

Design specifications required a minimum product water recovery of 85%, a salt rejection of 90%, energy consumption of 1108 kilowatt

Table 7 Monthly Operating Costs for Minitonas System

Chemicals	
Salt for softener regeneration	46.00
Sulphuric acid for pH control	10.56
Chlorine for disinfection	8.44
Maintenance	
Operator for 3 hr/day at \$4.20/hr	378.00
Filter-cartridge replacement	15.00
Power cost	320.00
Permeator cost (1)	155.00
Pump replacement (2)	125.00
Miscellaneous	25.00
Total Monthly operating cost	1083.00
Cost per 1000 Imp gallons	3.60

(1) Expected life of membranes is five years

(2) Expected life of pumps is ten years with replacement of seals every six months.

hours (Kwh) per ton of salt removed, and minimum consumption of sodium hexametaphosphate and sulfuric acid. During the 5-day performance and start-up tests, all criteria were met. Average product water recovery was 85.4% (at 5.2 million gallons per day) with a 95% salt rejection. Energy consumption was 1088 Kwh per ton of salt and chemical usage was close to one-half of the specifications. Calcium, chlorides, sodium and sulfate removals were 99%, 94% and 96% respectively. COD was consistently reduced to 2-3 mg/l with a feed water range of 5-65 mg/l. Rejection of the low molecular weight, volatile organic chloroform was considered poor and in fact, increased across the RO unit because of prechlorination. Total costs are detailed in Table 8. These costs indicate the RO system is producing product water at a rate of \$.715/thousand gallons.

Table 8 Orange County Water District
5 Million Gallon Per Day Reverse Osmosis Plant Cost

5 MGD RO Plant		
Reversis Osmosis	\$2,500,000	141
TO Building & Site Work	<u>500,000</u>	<u>29</u>
	3,000,000	170
5 MGD RO Plant		
Personnel	144,000	86
Chemicals	124,000	74
Utilities		
Electricity	370,000	220
Maint. Equip-Struct.	28,000	16
Maint. Contract	250,000	149
(includes cartridge filter and membrane replacement)		
RO TOTAL	<u>\$916,000</u>	<u>545</u>
TOTAL COSTS		715

*Assumptions: 92 percent plant factor, 20-year life, 7 percent interest.

II. SYSTEM DESIGN

The original design was to use reverse osmosis and ion exchange as the primary demineralization operations. Through the auspices of the Office of Water Research Technology, Ionics, Inc. notified the project that they would make available an Ionics Aquamate V to be used for the duration of the project. The project design was changed to use RO and ED as primary demineralization operations and to concentrate on selective solute removal via ion exchange or other chemical methods on a laboratory scale.

A. REVERSE OSMOSIS SPECIFICATIONS

Subsequently the following "Request For Bids" was released through the New Mexico State University Purchasing Office to known reverse osmosis system suppliers.

REQUEST FOR BIDS

Purpose: to equip and construct a reverse osmosis system for the grant,
Water Treatment for Small Public Supplies.

Specifications:

System capacity: ~15 gpm

Feed Water Quality: See Table 9

Product Water Quality: to meet National Safe Drinking Water
Standards.

Pretreatment:

A. Pretreatment will consist of:

- (1) 2-manganese green sand filters in parallel with potassium permanganate chemical feed system and storage. Include backwash system.
- (2) disinfection consisting of a sodium hypochlorite chemical feed system and 30 minute retention tank.
- (3) pH adjustment chemical feed system with acid feed direct from acid shipment carboy.
- (4) scale inhibitor chemical feed system.
- (5) a booster pump for feed water.
- (6) strainer for sand, etc. ahead of pretreatment system.
- (7) 2-cartridge filters in parallel.
- (8) a sodium sulfite chemical feed system for residual chlorine removal.
- (9) a carbon adsorption system.
- (10) instrumentation to include (a) pressure gauges around zeolite filters, around cartridge filters, and at inlet to system; (b) thermometers at inlet to system, ahead and after high pressure pumps; (c) in line conductivity cell with conductivity bridge indicator or monitor and recorder; (d) in line pH cell, indicator, controller, and recorder; and (e) residual chlorine meter, indicator, and recorder.

-2-

(11) bypass around each piece of equipment.

B. Reverse osmosis section will be constructed to provide for 4 reverse osmosis systems:

1. 2-4 inch HFF systems in parallel of 3,000-4,000 gpd capacity each.
2. 2-4 inch spiral wound systems in parallel of approximately 7,000 gpd capacity each.
3. the HFF system and spiral wound system will have separate high pressure feed pumps with flow controllers on each separate reverse osmosis unit.
4. Automatic back pressure controllers will be provided.
5. In line conductivity cell, monitor, and recorder on product water.
6. flow meters on all product and brine streams.

C. Post Treatment shall include

1. pH adjustment
2. sodium hypochlorite disinfection

NOTE: Include post treatment as a separate bid.

D. Automatic shut down shall include:

- (1) Low pressure switch on high pressure pump feed.
- (2) High pressure switch on high pressure pump discharge.
- (3) High-low pH shutdown.
- (4) Manual reset relays.

E. General

- (1) A 50 gallon automatic shutdown flush system for the reverse osmosis modules should be included.
- (2) Electrical system should be self contained within unit, i.e., junction box, meter, etc.
- (3) Provisions for fresh air circulation, cooling, and heating are necessary. These may be external to the box.
- (4) System must fit into an 8 X 8 X 25 ft box (If this is found to be impossible, indicate the size box needed but not to exceed width and height dimensions of 8 X 8 ft.

-3-

F. Bid Proposal shall include:

- (1) Up to two weeks of instruction and operation in Las Cruces.
- (2) Proposed design layout for approval.
- (3) Equipment specifications.
- (4) transportation of box from New Mexico State University and return.

G. Equipment currently in hand to be used in construction includes:

1. Goulds multistage centrifugal pump (rated at 10,700 gpd with 9 ROGA 41603 membrane modules).
2. sufficient pressure vessels (4 in X 10 ft. including end caps) for two complete systems.
3. cartridge type filter housing.
4. Balsbaugh conductivity monitor.
5. L & N pH controller/monitor.
6. 2-rotometer type flow meters.
7. framework for mounting above equipment.
8. 8 X 8 X 25 ft. box with end doors that fully open and 3' wide side door (opens out) located in center of right side.
9. all reverse osmosis elements.

Bids are to be returned on or by May 2, 1977.

Construction of system to be completed within 45 days of contract award.

Table 9 Feed Water Solute Limits

	<u>Limits</u>
Sodium	46.00-697.90
Potassium	0.78-25.35
Calcium	31.00-385.00
Magnesium	11.60-229.40
Iron-Total	0.10-22.5
Manganese	<0.05-0.40
Chloride	26.10-608.00
Fluoride	0-29-4.25
Nitrate	<0.10-16.30
Bicarbonage	209.00-515.60
Carbonate	None
Sulfate	6.30-1,700.00
Phosphate	-
Total Hardness	165.00-1,410.00
Alkalinity	171.00-422.60
Total Dissolved Residue	663.00-4,065.00
Surfactants	0.02-0.06
pH	7.60-8.25
Odor	None
Color	None
Turbidity	0.03-92.00
Conductance Micromhos/cm 25°C	540.00-4,644.00
Arsenic	<0.010-0.08
Barium	Negative-<1,000
Boron	Negative-2.21
Cadmium	Negative-<0.010
Chromium	Negative-0.050
Copper	Negative-0.200
Cyanide	-
Lead	0.010-0.130
Mercury	0.005-0.032
Molybdenum	-
Nickel	Negative-<0.10
Silver	Negative-<0.050
Selenium	Negative-<0.010
Zinc	Negative-0.350

Three bids were received from the following firms:

SALTECH, INC.
9930 Carnegie Avenue
P. O. Box 26872
El Paso, Texas 79926

CONTINENTAL WATER CORP.
12400 Darrington Road
P. O. Box 20018
El Paso, Texas 79998

ENVIRONMENTAL SYSTEMS
123 N. Concepcion
P. O. Box 10751
El Paso, Texas 7997

B. REVERSE OSMOSIS SYSTEM EQUIPMENT AND COST

In accordance with New Mexico State University purchasing policy, the low bidder was selected and SALTECH, INC. commenced construction of the unit in an 8 x 40 foot van supplied by NMSU-Chem. Engr. Table 10 lists the major components of the reverse osmosis system plus the van and its associated environmental control equipment.

Table 10 Major Components List

1. Manufactured by: Saltech, Inc. \$30,000.00
 - Air Injection System
 - Flocculant Injection System
 - Sand Separator System
 - KM_nO₄ Removal System
 - 1000 gal. Feed Tank
 - Feed pH Control System
 - Feed Water Pressure System (see pump below)
 - Sodium Hexametaphosphate Injection System
 - Sodium Hypochlorite Injection System
 - Cartridge Filter System
 - Pressure Maintenance System (see osmo pumps below)
 - 4 Spiral Wound R. O. Systems
 - 2 Hollow Fine Fiber R. O. Systems
 - Conductivity Instrumentation Measurement
 - Electrical Control System
 - Electrical Power System
 - Permeate Flush System
 - Product pH Control System
 - Product Iodination System
 - Product Storage Vessel 750 gal
2. Pumps:
 - 2 - OSMO (R.O) 18H2312 -8771031, 8771032

- 1 - Price (feed) 100100 B - Mod 5Kc39126431X Stock No. C321
 1 - Tee1 (flush) 1P778
3. Feed Pumps: LMi Liquid Metronix
 Feed Acid B51192 1 ea.
 Others A111191 4 ea.
4. Austic Pump: Precision Control
 Model No. 12781-11
 Serial No. 77070287
 water pump W. W. Grainger \$200.00
 Supplied by NMSU Flowcontroller James & Cooke Engineers 65.00
5. Heating and Cooling: W. W. Grainger
 1 heating & cooling unit 600.00
 1 heating unit 30.00
- C. ELECTRODIALYSIS EQUIPMENT & SYSTEM COST

The Aquamate V electro dialysis unit was installed in the van under the supervision of Ionics, Inc.. Table 11 lists the major components of the system and shows the installed cost supplied by Ionics, Inc.

Table 11 Aquamate V Components

Basic V - Ours	\$34,000	Regular V	#37,000
Short Stack			
modified pumps			
repair equipment	2,000		
required pipe			
TOTAL	\$36,000		

These are prices F.O.B. Water Town, Mass.

D. REVERSE OSMOSIS MEMBRANES

Reverse osmosis membrane modules have been supplied without charge by commercial manufacturers. Table 12 lists the corporations which have supplied membranes.

Table 12 Membrane Suppliers

Spiral Wound
 Roga - Fluid Systems Division of V.O.P.
 Environgenies, Inc.
 Hollow-Fined Fiber, Dow & Dupont @Carrizozo

NEW MEXICO STATE UNIVERSITY
DEPARTMENT OF CHEMICAL ENGINEERING

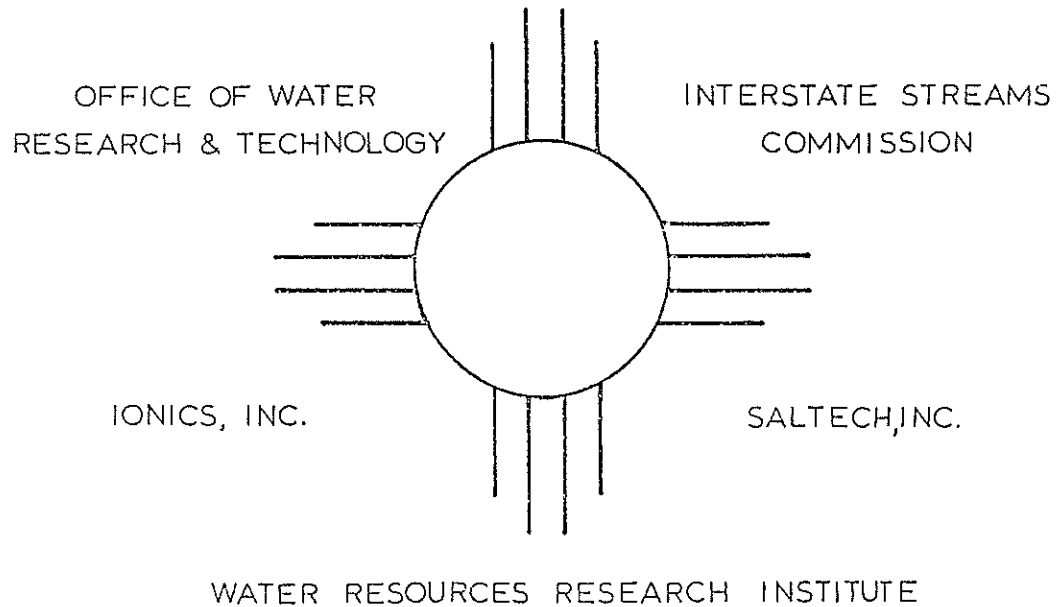


Figure 5 Van Logos

III. OPERATING PROCEDURES - WATER TREATMENT UNIT

The "Water-Treatment" van was received by the Department of Chemical Engineering for checkout on 15 August 1977. Figure 5 is the van logos

showing the participating agencies in the project. Figure 6 is the flow schematic of the system in the van. Figure 7 is an overall view of the RO system in the van. Figure 8 shows the Aquamite V Unit.

The system is designed to be semi-automatically controlled in that it is manually started and shut-down. If an upset occurs during un-attended operation the system shuts down based on pump pressure. Following are descriptions of the system equipment and their operation.

A. START-UP AND RUNNING PROCEDURES

Note: Before turning on any of the equipment, become familiar with the general layout of the system, including process units and their respective parts before attempting operation.

Steps:

1. Check for power (440V-3phase) and water (preferably 20-50 psi line pressure) by inspecting gauges near hose connection.
2. Connect feed and discharge hoses and check water pressure inside (minimum necessary = 25 psi).
3. Place E.D. power meter (5mg) RO power meters A(5mg) in their respective sockets. All boxes, sockets, and meters are appropriately marked: E.D., R.O. S.W., R.O. H.F.F.. Record meter readings on log sheets.
4. Install the fluorescent light bulbs.
5. Fill acid and bleach containers. (Figure 10).
6. Turn switches marked 'main', '220V transformer', and '110V transformer' to 'on' position in 440 breaker box. Check power by turning on the lights located on switch panel above 240 breaker box.
7. Turn valves marked 1,2,3,4 to 'open' position (see Figure 9).

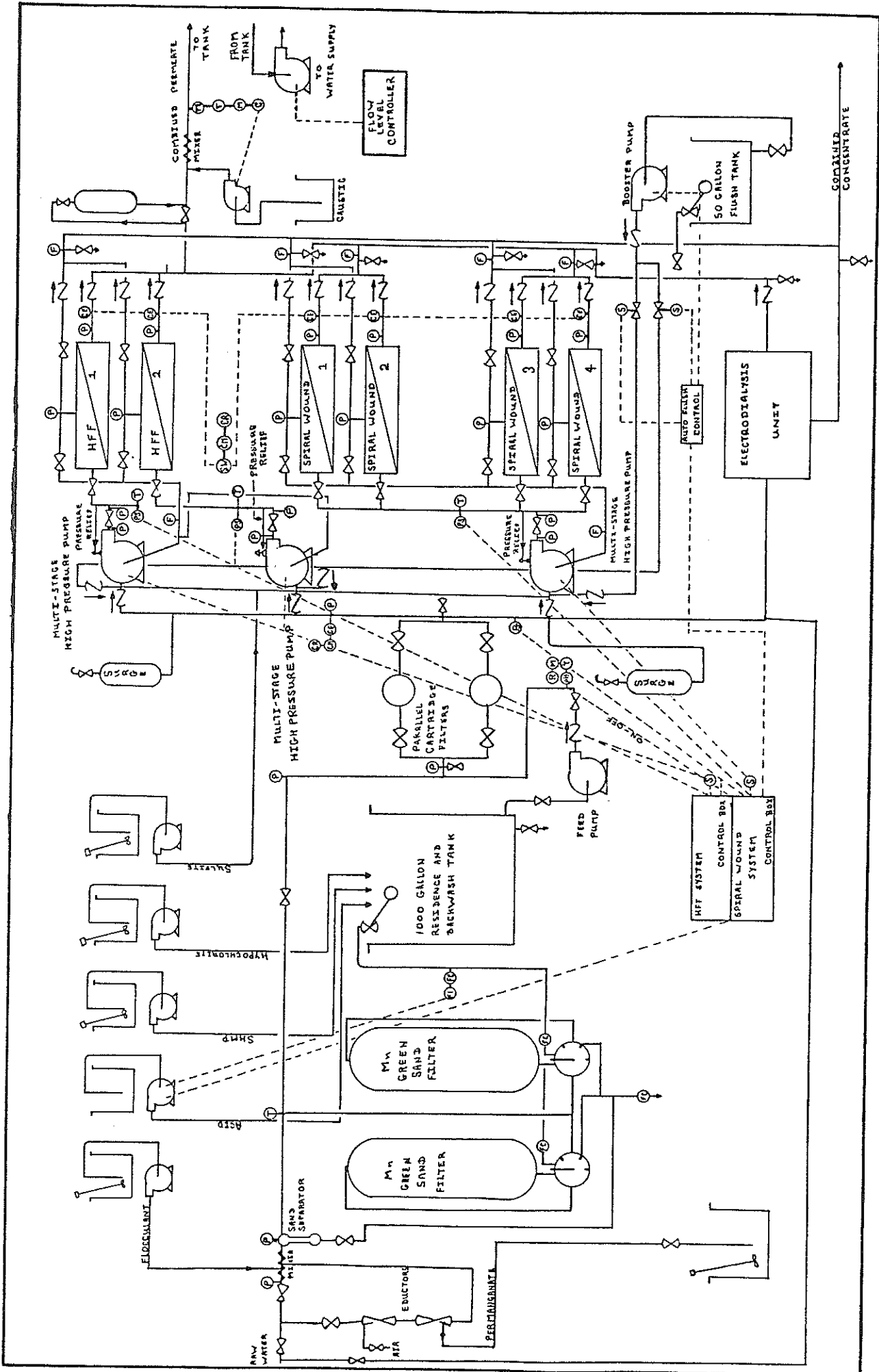


Figure 6. Flow Diagram for Water Purification System

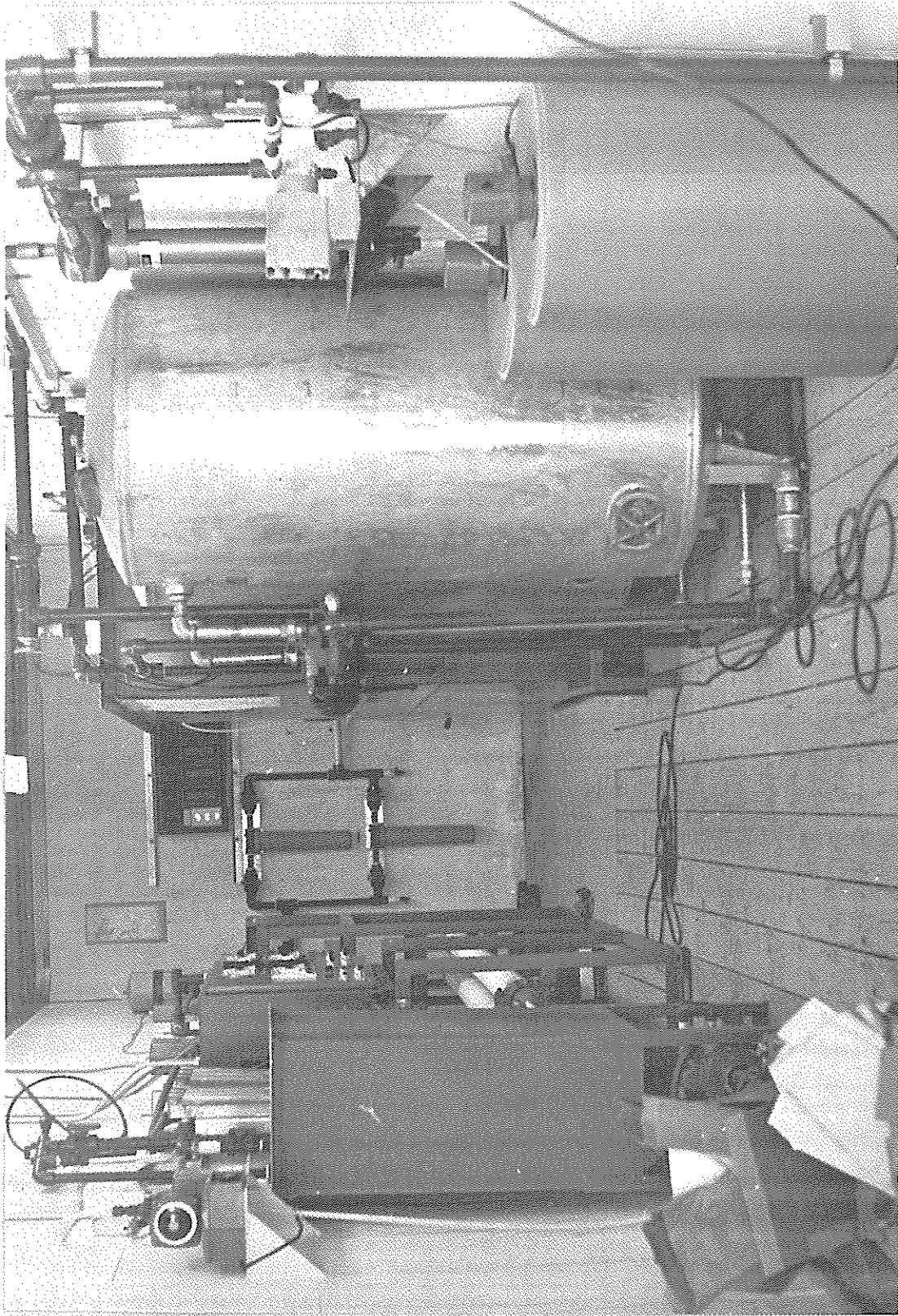


Figure 7. This is an overall view of the reverse osmosis system in the trailer.

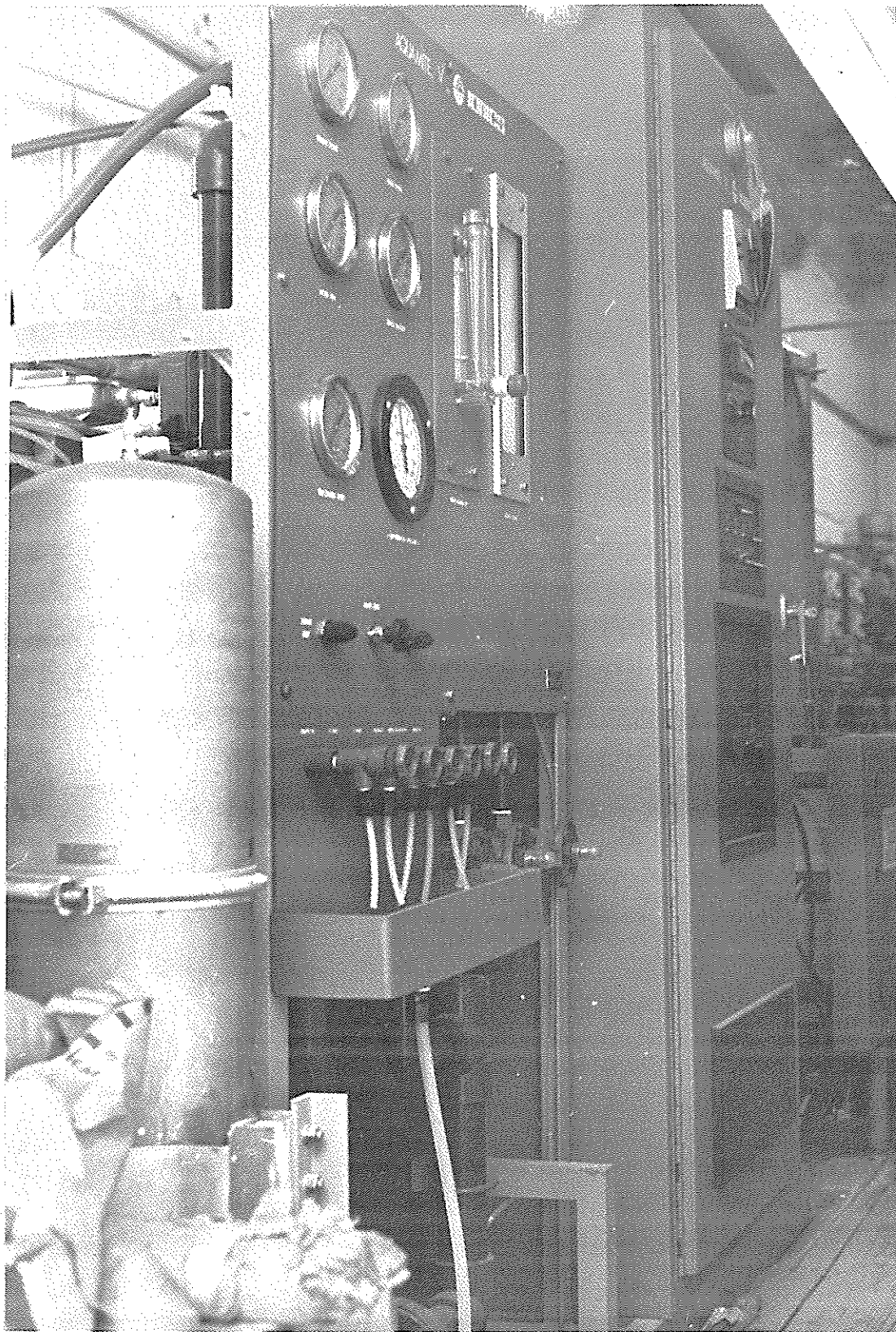


Figure 8. Aquamite V Equipment as Installed in Van.

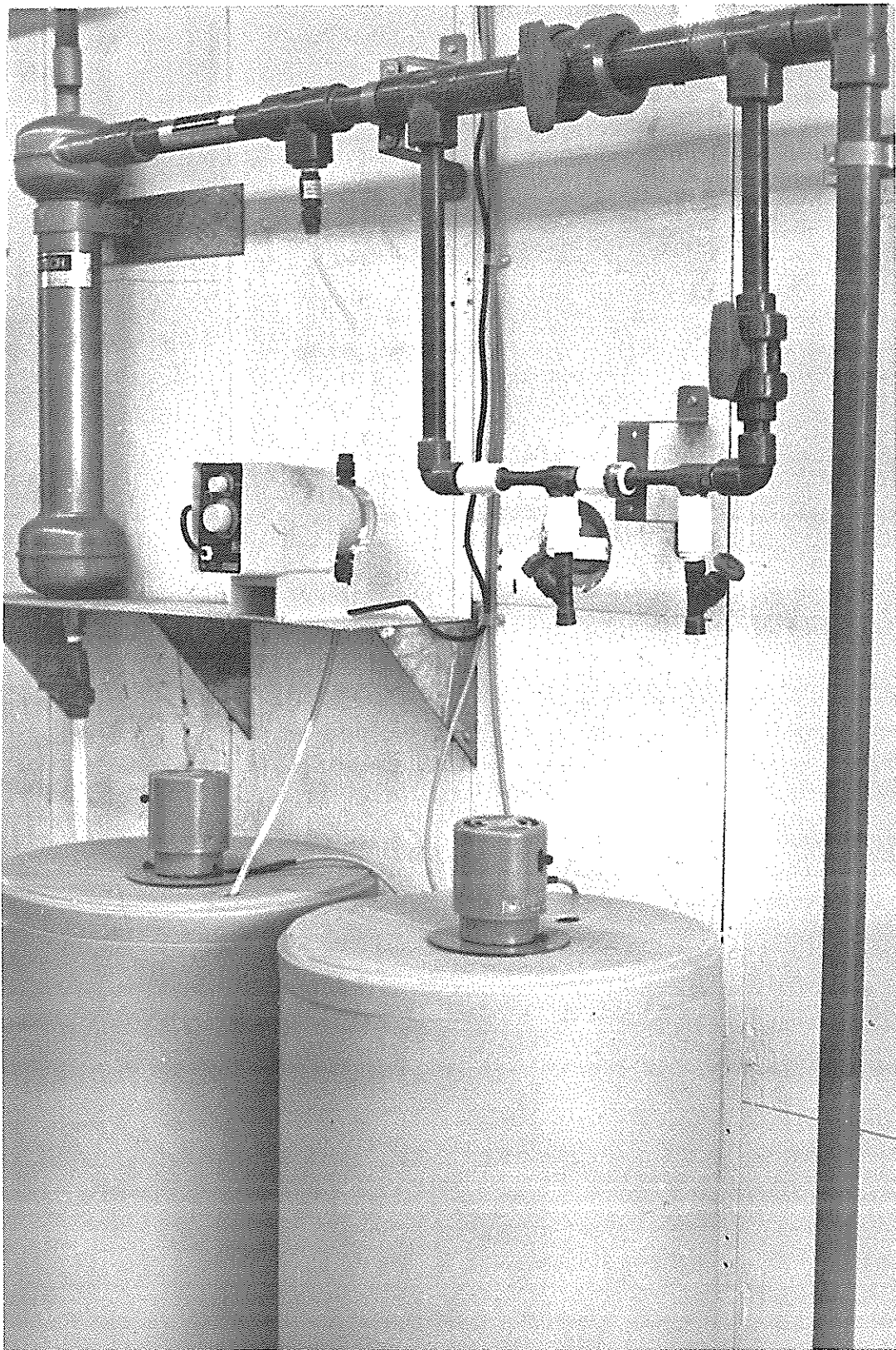
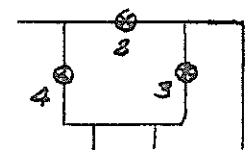


Figure 9. Inlet Piping and Sand Trap

The sand trap (upper left) is used to trap large particles that may be introduced to the system by the well water.

The two tanks below the trap: KMnO_4 feed tank, and polyelectrolyte feed tank.



VALVES



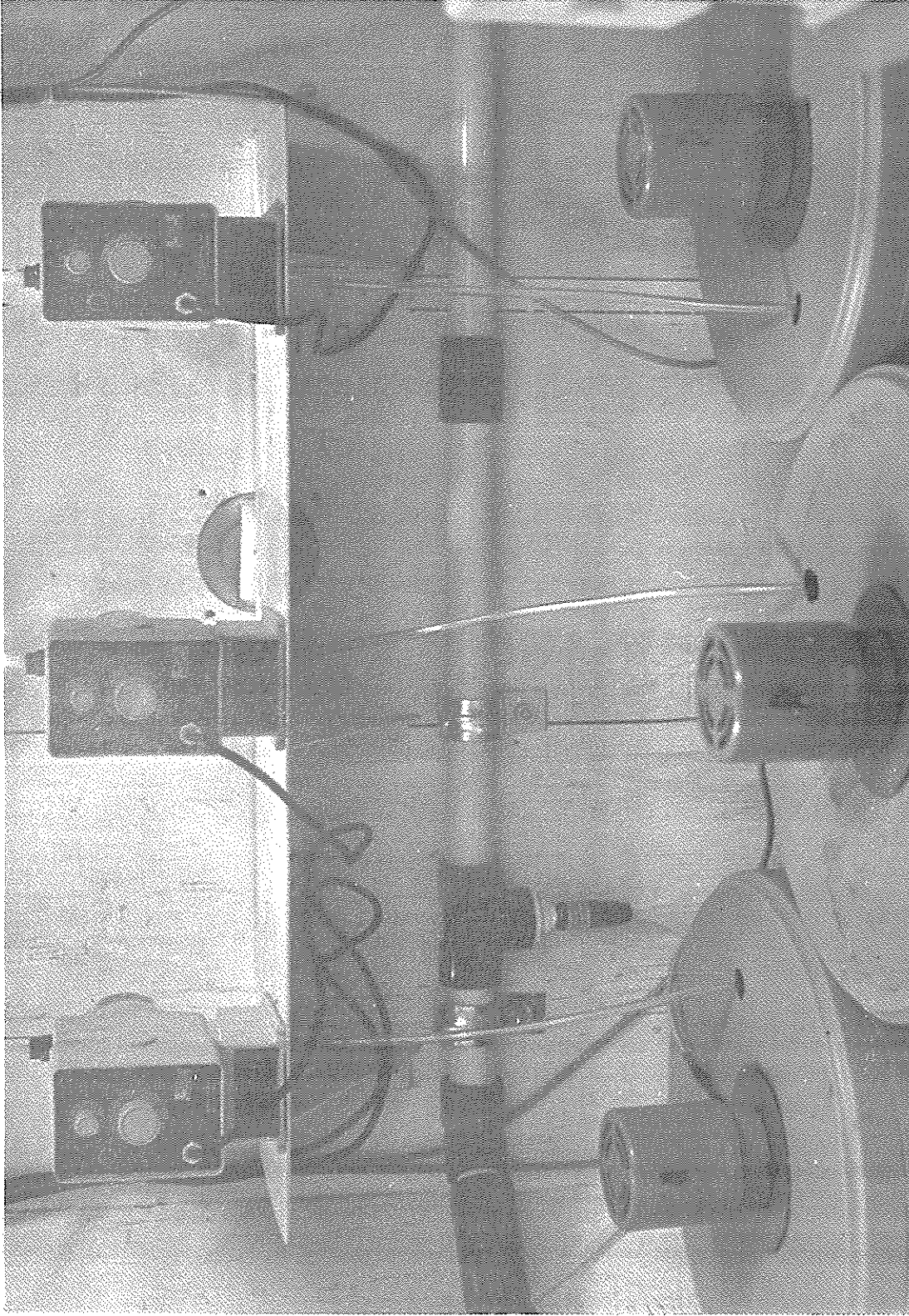


Figure 10. Chemical Feed Tanks and Pumps

Chemical feed tanks and metering pumps are used for adding: acid, sodium hexameta-phosphate, and sodium hypochlorite in the pre-conditioning of water for reverse osmosis treat-ment.

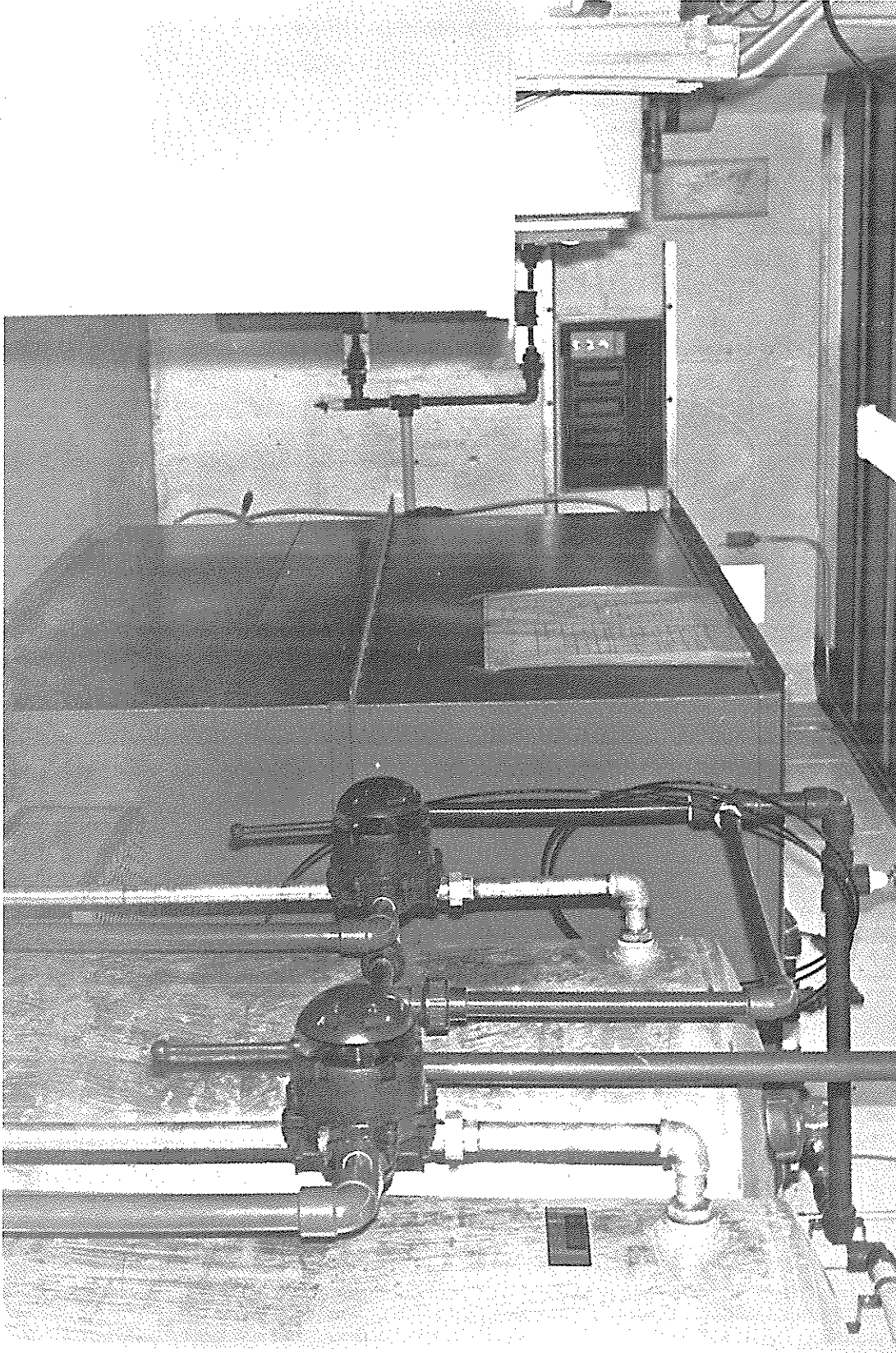


Figure 11. Manganese Greensand Filters

Media filters (center) are designed to remove iron and manganese in feed water and reduce the turbidity associated with the presence of iron and manganese. The four way control valves control service, backflush, recharge operations.

8. Record water meter reading on log sheet.
9. Close drain valve on tank.
10. Turn 4-way valves on media filters, to 'run' (straight down position). (Figure 11).
11. Fill tank...check operation of float level controller on tank.
12. Open valves 5 and 6, and close valve 7 (Figure 12).
13. Turn valves 8,9,10 and 11 to open position (Figure 13).
14. Be sure all lines leading to and from the R.O. modules are open. (Figure 14,15,16, and 17).
15. If there is an excess of Fe, Mn, or Cl₂ in the feed water, be sure the by-pass line (located outside the trailer), is closed and the feed line to the ED from the prefiltration is open.
16. If there is <0.3 ppm of Cl₂ and Fe and less than 0.1 ppm of Mn, close the E.D. feed and open the by-pass for raw feed (located outside of trailer).
17. Return to the 440V breaker box and turn the switches marked: 'ED', 'HFF pump', and 'Spiral Pump' to the 'on' position.
18. Turn to the 240V breaker box and turn the switches marked: 'Control Box' and 'Feed Pump' to the 'on' position.
(An Ionics representative is available to be present when starting up ED the first time in each community).
19. Turn the ED Power lever (located at the top of the control cabinet) to the 'on' position.
20. On the control flip the switches labeled: 'man'-'auto'

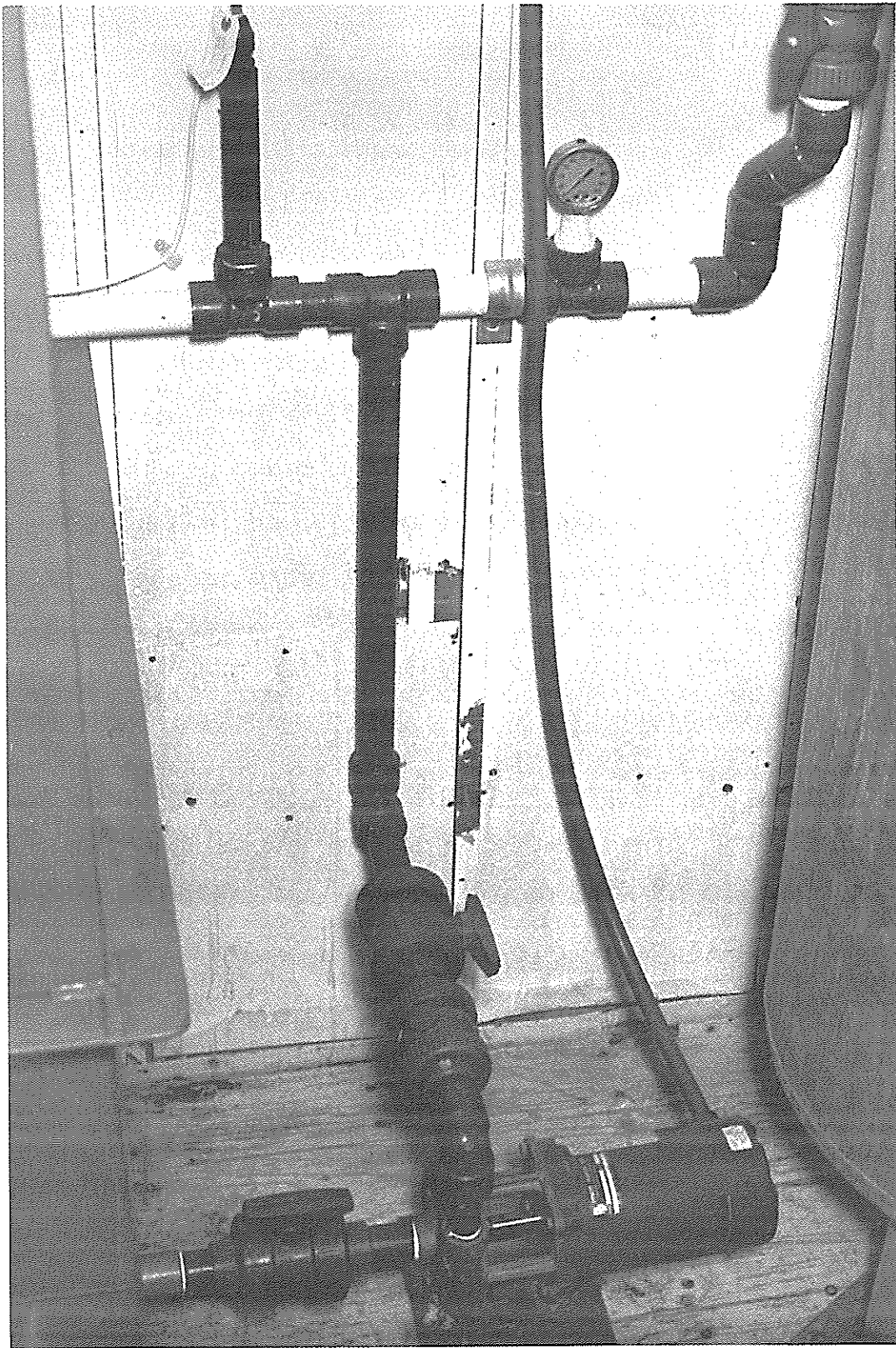
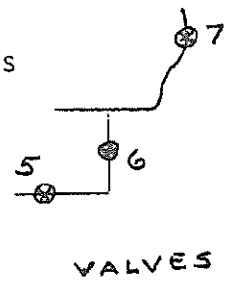


Figure 12. Holding Tank Feed Pump and Control Valves



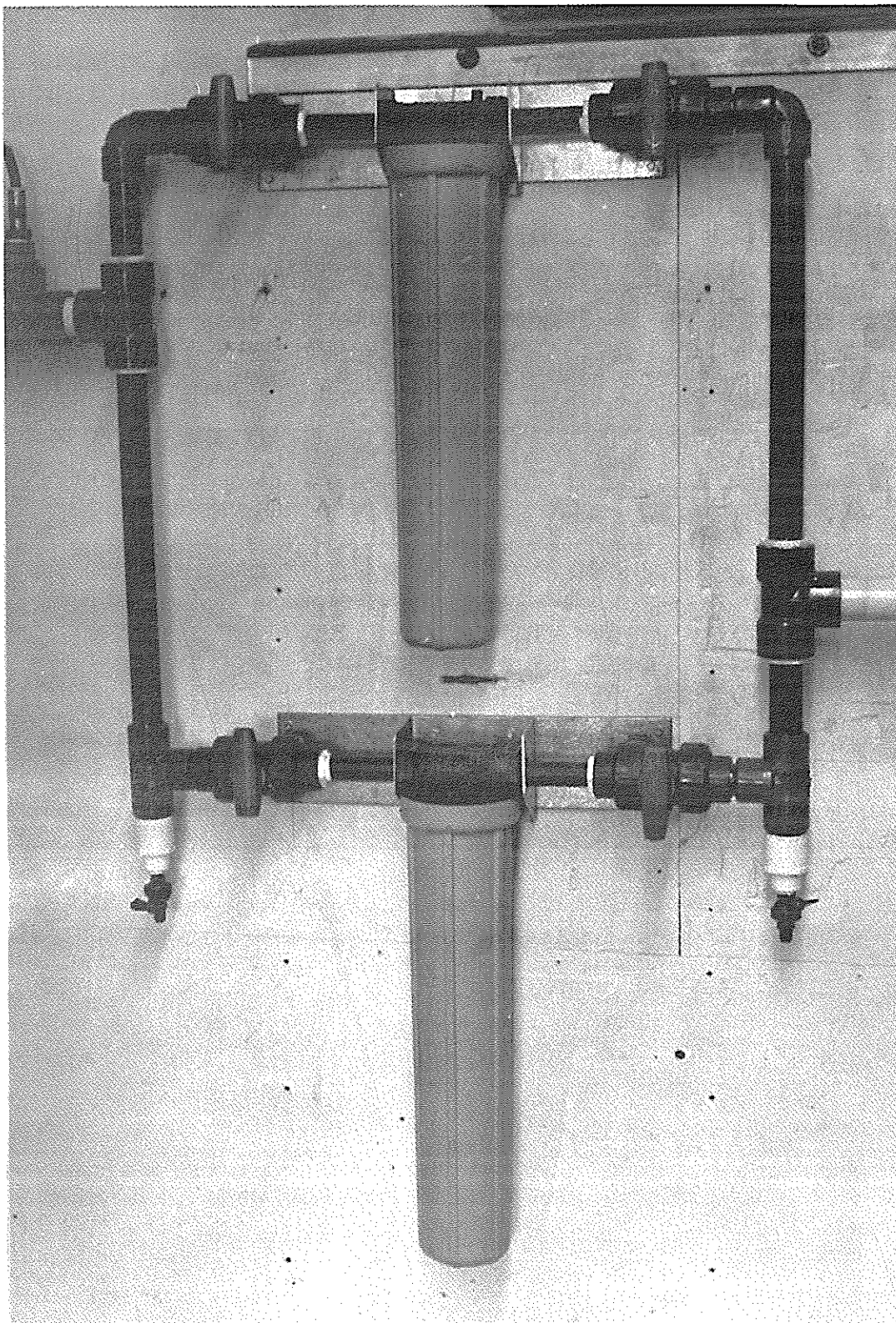
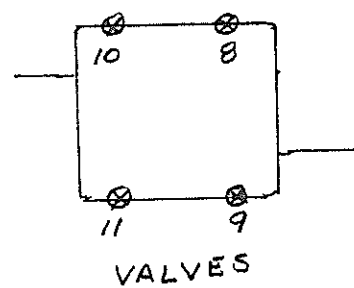


Figure 13 Cartridge Filters

These are cartridge filters that are designed to remove suspended solids, that haven't been removed by the media filters and that may pass through the residence tank.



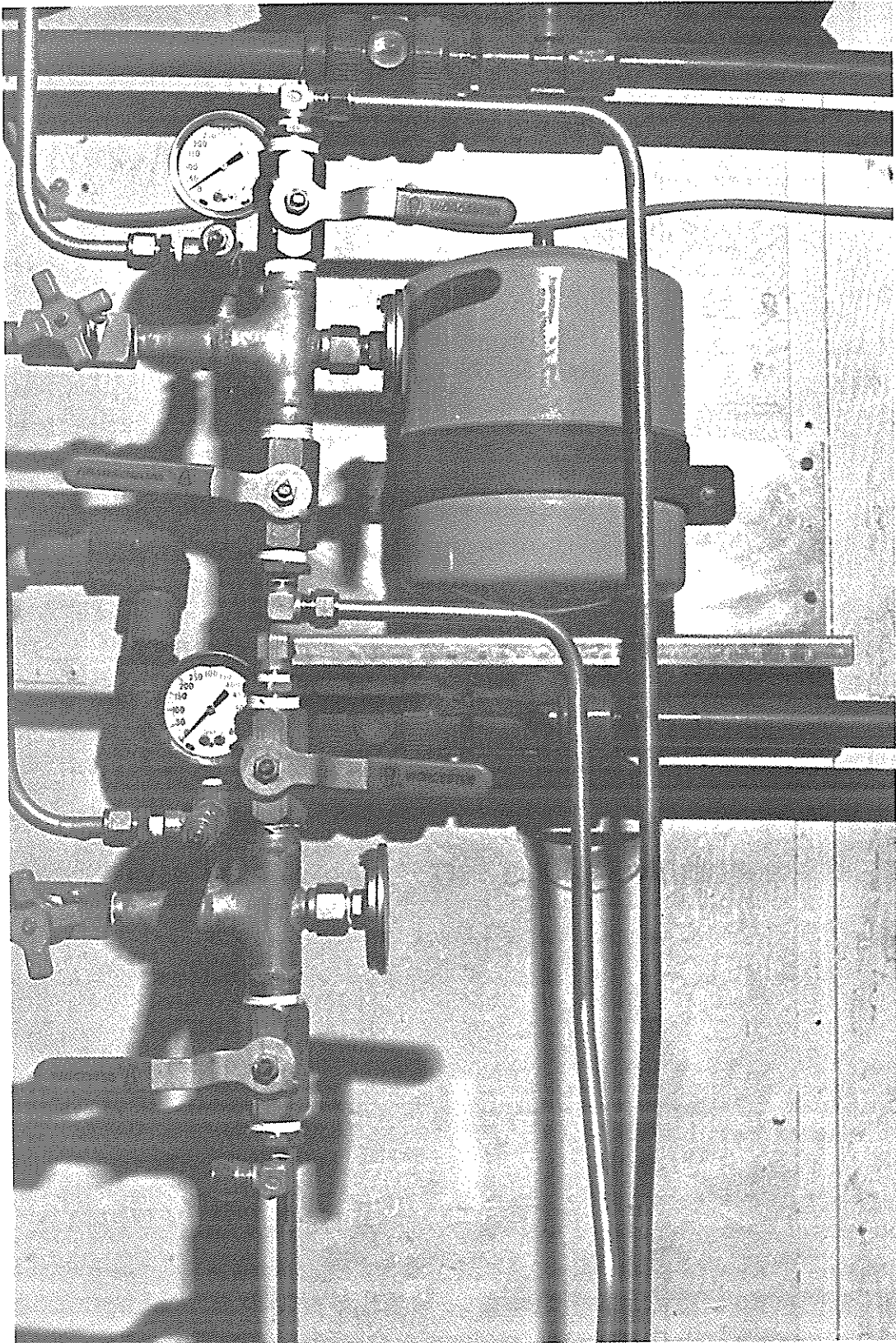


Figure 14. Pump Surge Vessel and Feed Control Valves

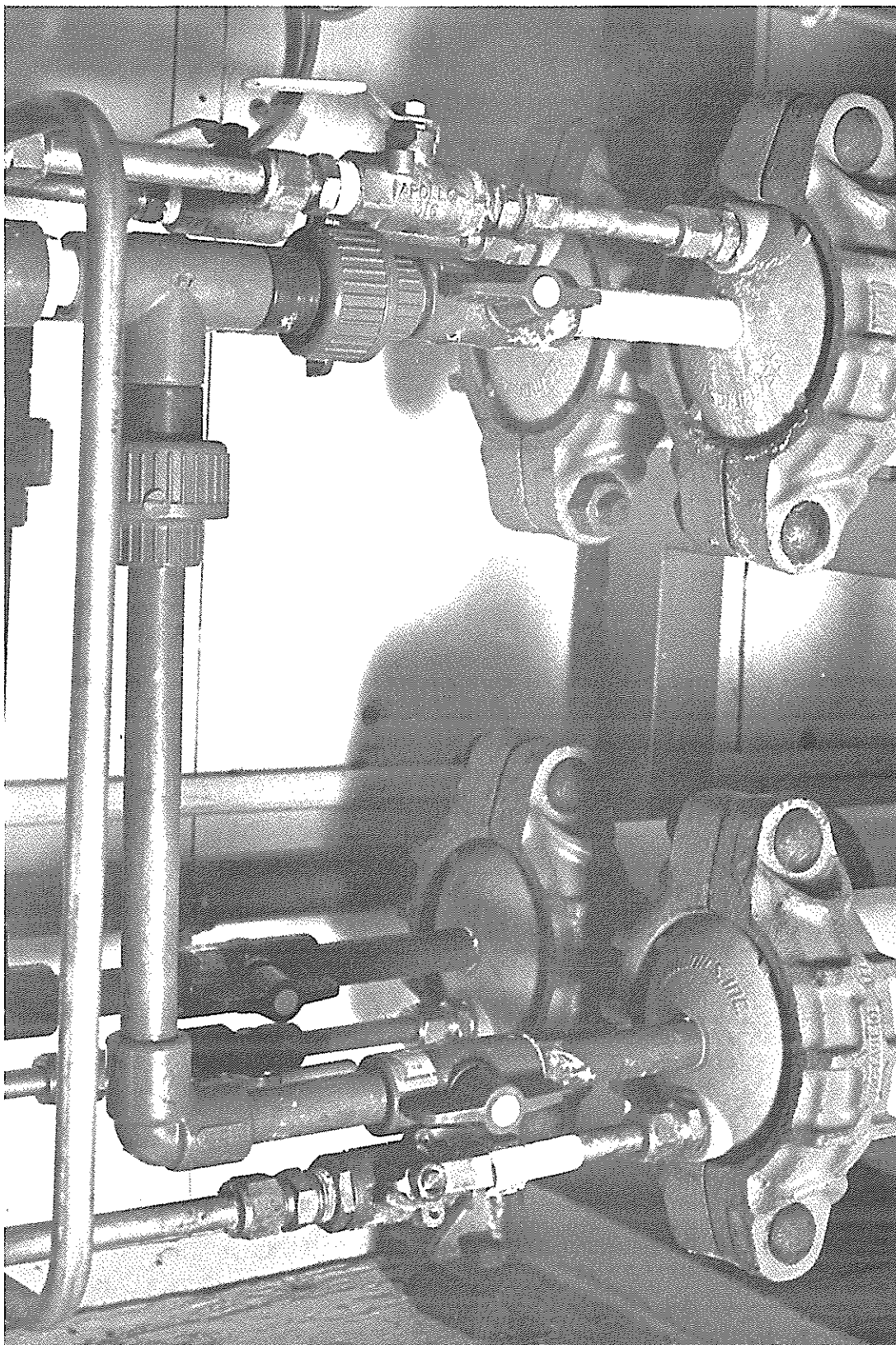


Figure 15. RO Inlet Valves

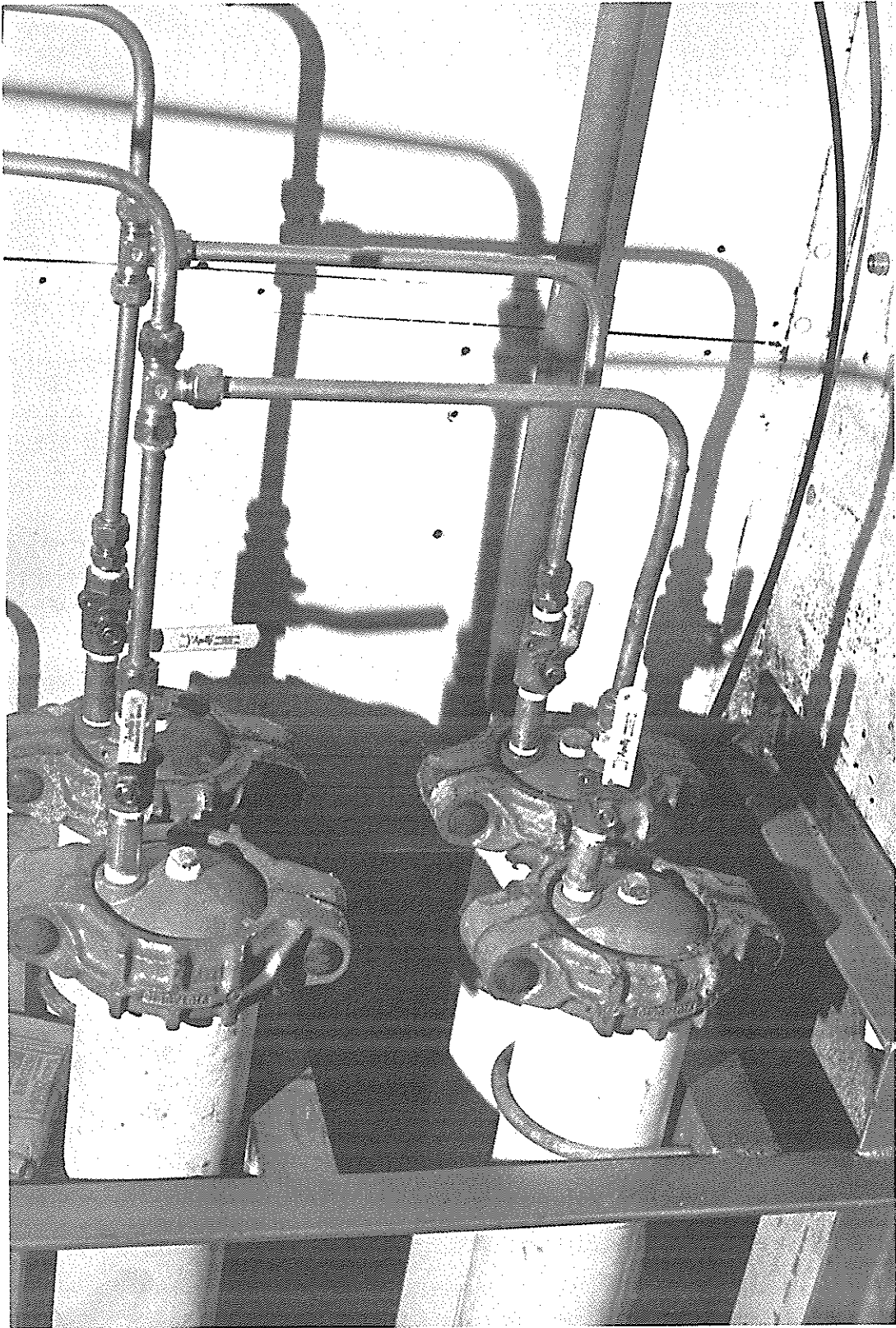


Figure 16. RO Outlet Valves

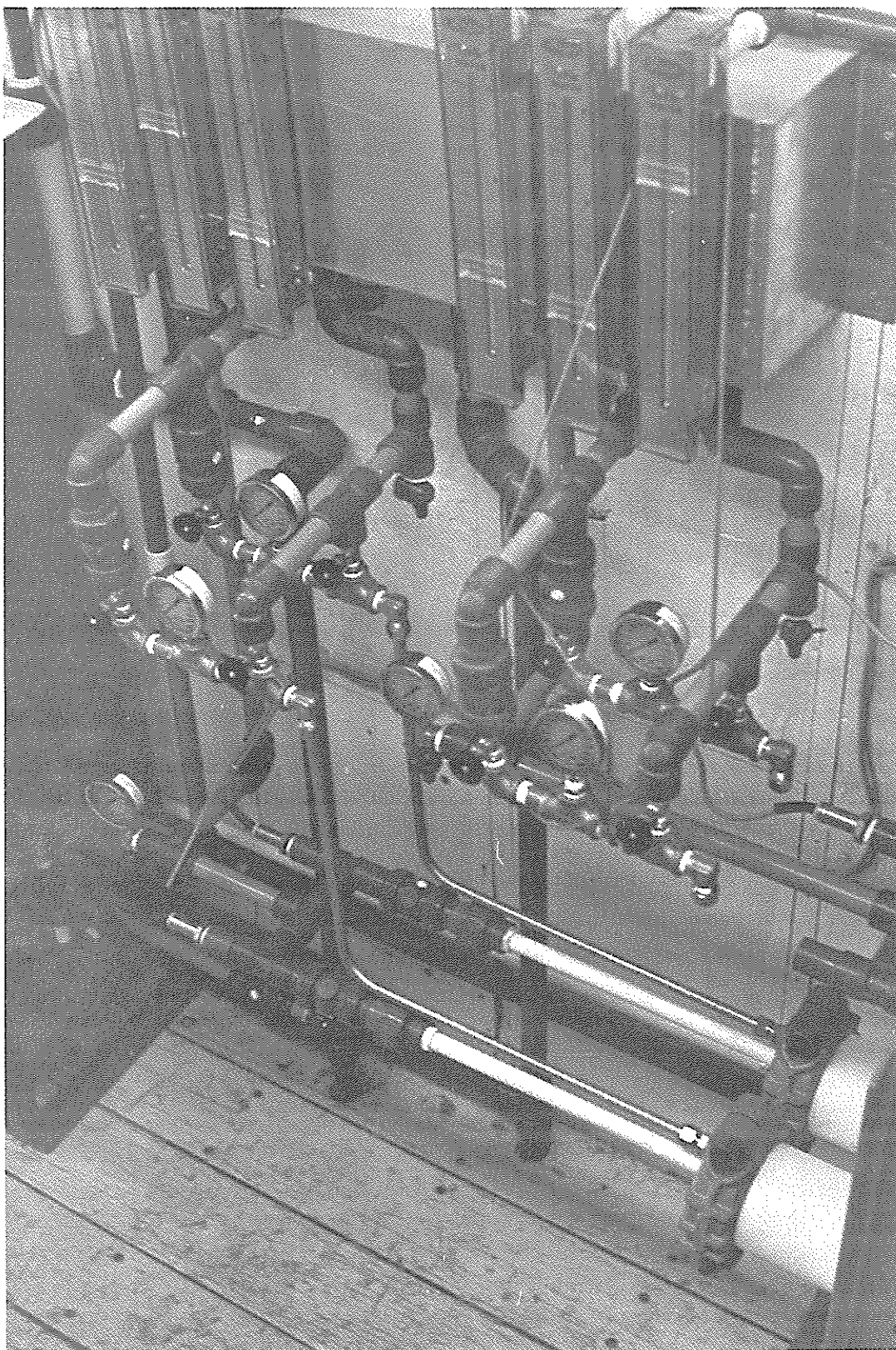


Figure 17. Flow Piping

An overall view of the outlet piping, pressure gauges and flow meters.

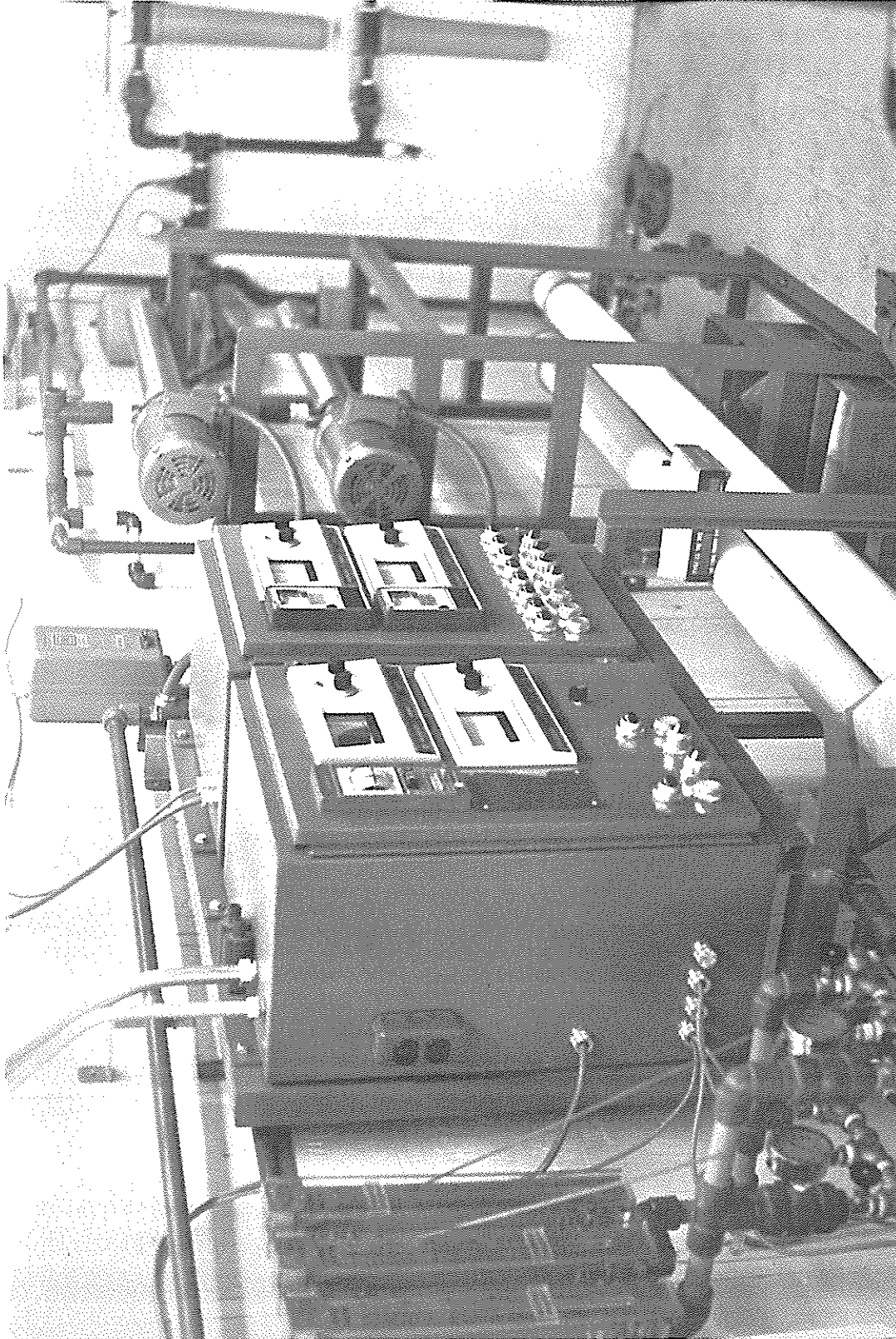


Figure 18. RO Skid

Here is a picture of the complete reverse osmosis (RO) skid with control panel in the foreground, high speed pumps located immediately behind that and the RO pressure vessels on the bottom.

- to "man" position; 'start'-'stop' to 'start' position.
21. Step to the rear of the trailer and watch to make sure MOV-1 moves to the open position.
 22. Regulate Dilute and Brine flows to desired amount range (max-min dilute-5.0 gpm brine make-up 1.5 gen. running conditions).
 23. Turn rectifier switch to 'on'.
 24. RO, turn the RO switch (located on the right hand control box) marked 6 'Feed' to the 'on' position and the chemical pumps switch to 'on'.
 25. Once water is flowing through the membranes, turn the switches marked: RO #1 to 'man' RO #2.
 26. Set flows to desired flow rates.
 27. After 30 min. of running fill the nalgene containers marked 'SULFITE' and 'PHOSPHATE' with permeate. Use Cl bleach-measure at input point of 1000 gal. tank. Add 942 gms of Sodium Sulfite and Sodium Heametaphosphate to the correct containers. Stir constantly until all solids dissolve. Set to desired ppm (1-2 Cl, 1-2 Sulfite, 5 SHMP).



Figure 19. Electrodialysis Control Panel

Controls fluid flow to the stack, stack pressure, brine and product stream. All sample collections are made at this locality.

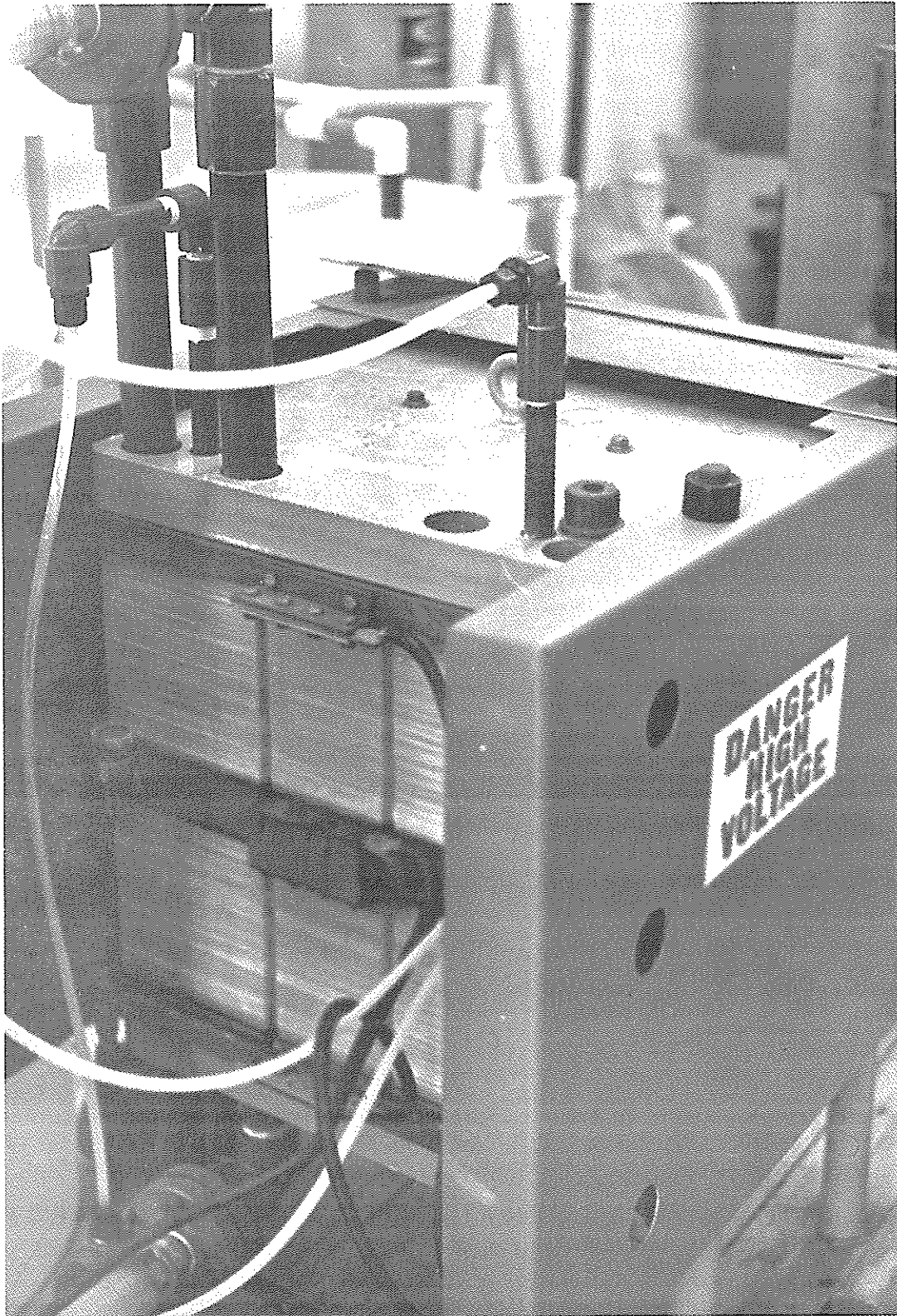


Figure 20. Electro dialysis Stack

Raw water is fed into the top of the unit and as it passes through, the stack is charged with electrical current. The brine and product pass out the bottom. The small lines are electrode feed and waste lines.

B. Clean-Out Procedure

1. Before shut-down, fill flush tank and CIP tank with 45 gal of RO permeate each.
2. Fill the 1000 gal. tank with about 800 gal.
3. Add 200# of HTH (commercial calcium hypochlorite) to the 1000 gal tank. Stir well until dissolved.
4. Disconnect product line from city mains; and locate product line in brine pond.
5. Flush 500 gal. of the Cl solution through the media filters and the feed piping with the feed pump (set valves on filters to 'flush' position, and check to make sure operating properly).
6. Turn off rectifier on ED. Turn off all other pumps.
7. Flush 250 gal. of the Cl solution through the remaining RO and ED systems using the feed pump only (30 psi pressure).
8. Follow the CIP directions given in the IONICS manual (7 gal. HC) + 45 gal. H₂O).
9. Add 7.5# of Citric Acid (dry), plus 2500 ml of formaldehyde plus gms. of Triton X-100 (if available) to the flush tank. Flush solution through all RO modules. Secure system.
10. Drain piping and filters.

C. SHUT-DOWN PROCEDURE

For other than Relocation:

1. Determine the problem area; RO or ED
2. Isolate the area;
ED
 1. Shut off unit at control box (lever at top).
 2. Turn rectifier switch to off.
 3. Turn 'Stop-Start' switch to stop.
 4. Turn main breaker 'ED' switch to off.

R.0

1. Turn off high pressure pumps.
2. Turn off feed pump.
3. Turn off chemical pumps.

For relocation purposes:

1. Follow clean out procedure given.
2. Police trailer. Clean up and box all loose tools, pipe, etc.
3. Shut off all switches.
4. Remove KWhr meters & place in respective boxes. Record KWhrs.
5. Remove lights and place in boxes.
6. Police outside area.
7. Disconnect all unions, valves, etc. to prevent stress breakage.
8. Remove stairs and place in rear of trailer.
9. Place landings in rear of trailer.
10. Follow trailer to next location and hook-up.

D. SAFETY PRECAUTIONS

As part of the requirements for operating under safe condition for the duration of this project, a list of potential dangers and the possible affects they may have on the public and maintenance people is listed below. Possible affects are listed as Toxicities of the chemicals, and containers are labeled "Danger-Chemicals."

DANGERS:

- (1) High Voltage - E.D. & incoming wiring
- (2) Chemicals - R.O. Pretreatment

SAFETY PRECAUTIONS:

- (1) a. Sign - DANGER HIGH VOLTAGE
- b. Protective shield around stack.
- c. Closed, fastened down protective boxes

(2) ChemicalsToxicities

a. KMnO_4	orl rat LD50	1090 mg/kg
b. Polyelectrolyte flocculant	-	-
c. HCl	ihl mus LD50	40 mg/kg
d. SHMP	ivn rbt LDLO:	140 mg/kg
e. Na Hypochlorite	-	-
f. Sodium Sulfite	ivn rbt LD50	65 mg/kg
g. Iodine	orl hmn LDLO:	2000 mg/kg
h. Caustic	orl rbt LDLO:	500 mg/kg

ALL LABELED - DANGER CHEMICALS

SAFETY EQUIPMENT:

- (1) Gloves, Rubber and asbestos
- (2) Apron
- (3) Hard hat w/face shield
- (4) Fire extinguishers - CO_2

LEGEND:

rbt - rabbit

orl - oral

rat - rat

ihl - inhalation

hmn - human

ivn - intravenously

mus - mouse

LDLO - lowest published

lethal dose

LDL) - lethal dose

50% kill

IV. PROGRAM SCHEDULE

In cooperation with the Drinking Water Section of the Environmental Improvement Agency, the New Mexico community water supplies listed in Table 13 will be used as the field study part of this project.

Table 13 Community Water Supplies to be Utilized

Cuba	Nature of Contamination
Carrizozo	TDS, Fe, Mn, Turbidity
La Luz	TDS
San Jon	TDS
San Ysidro	TDS, F, Na
Blue Water (Lake)	TDS, F, Se
Moriarity	TDS, Fe

Other New Mexico Communities have expressed interest in participating and if the program is extended they could be included. These communities range from larger cities to very small supplies without adequate electric power available.

REFERENCES

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APPENDIX A
New Mexico Drinking Water Regulations

New Mexico Environmental Improvement Board
Crown Building, P. O. Box 2348
Santa Fe, New Mexico 87503

December 9, 1977

REGULATIONS GOVERNING WATER SUPPLIES

Water Supply Regulations adopted by the Environmental Improvement Board on November 21, 1977, are as follows:

PART I

General Provisions

" 101. DEFINITIONS. -- As used in the Regulations Governing Water Supplies:

- A. "Act" means the Environmental Improvement Act;
- B. "Agency" means the Environmental Improvement Agency;
- C. "Board" means the Environmental Improvement Board;
- D. "Community Water System" means a public water supply system which serves at least fifteen (15) service connections used by year-round residents or regularly serves at least twenty-five (25) year-round residents;
- E. "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water;
- F. "Director" means the director of the New Mexico Environmental Improvement Agency or his authorized representatives;
- G. "Environmental survey" means an on-site review of the water source, facilities, equipment, operation and maintenance of a public water supply system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water;
- H. "Dose equivalent" means the product of the absorbed dose from ionizing radiation and such factors as account for differences in biological effectiveness due to the type of radiation and its distribution in the body as specified by the International Commission on Radiological Units and Measurements (ICRU).
- I. "Exemption" means a waiver which may be granted by the director to a public water supply system:
 - 1. which was in operation on June 24, 1977;
 - 2. when a maximum contaminant level cannot be complied with because of economic or other compelling factors; and
 - 3. if granting the waiver will not result in an unreasonable risk to health.

Such waiver must be conditioned upon a schedule of compliance or implementation with these regulations by the dates specified in Section 105.

J. "Gross alpha particle activity" means the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

K. "Gross beta particle activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

L. "Man-made beta particle and photon emitters" means all radionuclides emitting beta particles or photons listed in Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, NBS Handbook 69, except the daughter products of thorium-232, uranium-235, and uranium-238.

M. "Maximum contaminant level" means permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water supply system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

N. "Non-community water system" means any public water supply system that is not a community water system; including but not limited to: seasonal facilities such as children's camps or recreational camping areas; or year-round facilities which serve more than twenty-five (25) persons who are not residents thereof, such as factories, gasoline service stations, marinas, rest areas, restaurants or schools which are not served by a community water system.

O. "Person" means the state or any agency, institution, or political subdivision thereof, any public or private corporation, individual, partnership, association or other entity, and includes any officer or governing or managing body of any political subdivision or public or private corporation.

P. "Picocurie (pCi)" means that quantity of radioactive material producing 2.22 nuclear transformations per minute.

Q. "Public water supply system" means a system for the provision to the public of piped water for human consumption if such system has at least fifteen (15) service connections or regularly services an average of twenty-five (25) individuals at least sixty (60) days out of the year. A public water supply system is either a 'community water system' or a 'non-community water system'.

R. "Rem" means the unit of dose equivalent from ionizing radiation to the total body or any internal organ or organ system.

S. "Service connection" means a single physical connection from a water service main which provides water to one or more buildings.

T. "Standard sample" means the portion of finished drinking water that is examined for the presence of coliform bacteria.

U. "Supplier of water" means any person who owns or operates a public water supply system.

V. "Variance" means a waiver which may be granted by the Director to a public water supply system:

1. which, due to the raw water quality reasonable available, cannot comply with a maximum contaminant level, despite application of the best technology, treatment techniques or other available means; and

2. if granting the waiver will not result in an unreasonable risk to health.

Such waiver must be conditioned upon a schedule of compliance, which, pursuant to Section 104, may specify an indefinite time period for compliance with the maximum contaminant level.

102. COVERAGE. -- These regulations shall apply to each public water supply system in New Mexico, unless such system meets all of the following conditions:

A. Consists only of distribution and storage facilities and does not have any collection and treatment facilities;

B. Obtains all of its water from, but is not owned or operated by, a public water supply system to which these regulations apply;

C. Does not sell water to any person; and

D. Is not a carrier which conveys passengers in intrastate commerce.

PART II
WATER SUPPLY CONTROL

201. COMPLIANCE WITH WATER SUPPLY REGULATIONS. -- No person shall control, manage or operate a public water supply system unless the system is maintained in compliance with these regulations.

202. MAXIMUM CONTAMINANT LEVELS FOR INORGANIC CHEMICALS. --

A. The maximum contaminant level for nitrate is applicable to both community water systems and non-community water systems. The levels for the other inorganic chemicals apply only to community water systems. Compliance with maximum contaminant levels for inorganic chemicals is calculated pursuant to Section 304.

B. The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

<u>Contaminant</u>	<u>Level, Milligrams per liter</u>
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

C. When the annual average of the maximum daily air temperatures for the location in which the community water system is situated in the following, the maximum contaminant levels for fluoride are:

<u>Degrees Fahrenheit</u>	<u>Degrees Celsius</u>	<u>Level Milligrams per liter</u>
53.7 and below	12.0 and below	2.4
58.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

203. MAXIMUM CONTAMINANT LEVELS FOR ORGANIC CHEMICALS. -- The following are the maximum contaminant levels for organic chemicals. They apply only to community water systems. Compliance with maximum contaminant levels for organic chemicals is calculated pursuant to Section 305.

Level, Milligrams per liter

A. Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa hydro-1,4-endo, endo-5, 8-dimethano naphthalene)	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1-Trichloro-2, 2-bis [p-methoxyphenyl] ethane)	0.1
Toxaphene (C ₁₀ H ₁₀ Cl ₈ - technical chlorinated camphene, 67-69 percent chlorine)	0.005
B. Chlorophenoxy:	
2,4-D, (2,4-Dichlorophenoxyacetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid)	0.01

204. MAXIMUM CONTAMINANT LEVELS FOR TURBIDITY. -- The maximum contaminant levels for turbidity are applicable to both community water systems and non-community water systems using surface water sources, excluding springs and infiltration galleries, in whole or in part. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

A. One turbidity unit (TU) as determined by a monthly average pursuant to Section 303, except that five or fewer turbidity units may be allowed if the supplier or water can demonstrate to the Director that the higher turbidity does not do any of the following:

1. interfere with disinfection;
2. prevent maintenance of an effective disinfectant agent throughout the distribution system; or
3. interfere with microbiological determinations.

B. Five turbidity units based on an average for two consecutive days pursuant to Section 303.

205. MAXIMUM MICROBIOLOGICAL CONTAMINANT LEVELS. -- The maximum contaminant levels for coliform bacteria, applicable to community water systems and non-community water systems, are as follows:

A. When the membrane filter technique pursuant to Section 302(A) is used, the number of coliform bacteria shall not exceed any of the following:

1. one per 100 milliliters as the arithmetic means of all samples examined per month pursuant to Section 302(B) or (C).

2. four per 100 milliliters in more than one sample when less than 20 are examined per month; or

3. four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

B. 1. When the fermentation tube method and 10 milliliter standard portions pursuant to Section 302(A) are used, coliform bacteria shall not be present in any of the following:

a. more than 10 percent of the portions in any month pursuant to 302(B) or (C);

b. three or more portions in more than one sample when less than 20 samples are examined per month; or

c. three or more portions when more than five percent of the samples are examined per month.

2. When the fermentation tube method and 100 milliliter standard portions pursuant to Section 302(A) are used, coliform bacteria shall not be present in any of the following:

a. more than 60 percent of the portions in any month pursuant to 302(B) or (C);

b. five portions in more than one sample when less than five samples are examined per month; or

c. five portions in more than 20 percent of the samples when five or more samples are examined per month.

C. For community or non-community systems that are required to sample at a rate of less than four per month, compliance with Sections 205(A), (B)(1) or (B)(2) shall be based upon sampling during a three month period.

206. MAXIMUM CONTAMINANT LEVELS FOR RADIUM-226, RADIUM-228, AND GROSS ALPHA PARTICLE RADIOACTIVITY.-- The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity in community water systems:

A. combined radium-226 and radium-228 - 5 pCi/l; and

B. gross alpha particle activity (including radium-226 but excluding radon and uranium) --15pCi/l.

207. MAXIMUM CONTAMINANT LEVELS FOR BETA PARTICLE AND PHOTON RADIOACTIVITY FROM MAN-MADE RADIONUCLIDES. -- The following maximum contaminant levels apply only to community water systems.

A. The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than four millirem per year.

B. Except for the radionuclides listed in Table A, the concentration of man-made radionuclides causing 4 millirem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum

Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure," NBS Handbook 69 as amended August 1963, US Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem per year.

TABEL A. -- Average Annual Concentrations Assumed to Produce
a Total Body or Organ Dose of four milliren per year.

<u>Radionuclide</u>	<u>Cirtical Organ</u>	<u>pCi per liter</u>
Tritium	Total Body	20,000
Strontium-90	Bone Marrow	8

Part III

MONITORING AND ANALYTICAL REQUIREMENTS

301. GENERAL REQUIREMENTS. -- Unless otherwise provided in these regulations, samples shall be examined in accordance with the most current edition of Standard Methods for the Analysis of Water and Wastewater, published by the American Public Health Association or the most current edition of Methods for Chemical Analysis of Water and Wastes published by the United States Environmental Protection Agency.

APPENDIX B

Analytical Methods, Detection Limits, Sensitivity



METHODS OF ANALYSIS

Cationic analyses are accomplished using a Perkin-Elmer model 403 atomic absorption spectrophotometer. Elements such as Fe, Cu, Mn, Sb, Zn, Cr, Ag, Co, Ni, Sr and Li are run using undiluted samples by either atomic absorption methods or emission spectroscopy on an air-acetylene flame. Ba, Mo and Al are analyzed on undiluted samples by atomic absorption methods employing a nitrous oxide-acetylene flame. In order to analyze for Ca and Mg, 1500 mg/l strontium must be added to control ionization interferences. Ca, Mg, Na, and K are analyzed from appropriately diluted samples. As and Se are analyzed using the graphite furnace attachment while Hg is run by flameless methods of vaporization with SnCl_2 . Pb must first be extracted into an organic phase and then analyzed according to standard atomic absorption methods.

The pH is analyzed using a dual electrode system and an orion pH meter. EC is measured with a Barnstead digital electrical conductivity bridge.

TDS or TDR is measured by evaporating a premeasured volume of solution in a evaporating dish, and determining weight gain after evaporation.

Total hardness is a measure of the total Ca and Mg (as CaCO_3). An aliquot of sample is titrated with EDTA using Eriochrome Black T indicator.

Total alkalinity is measured by titration with 0.01N H_2SO_4 to a methyl orange end point. Carbonate or "P" alkalinity is determined by titration to phenolphthaleim end point with 0.01N H_2SO_4 or to pH - 8.3.

Nitrate, Silicate, phosphate, and boron are all analyzed on a Technician auto analyzer using the procedures in the accompanying manual of analyses.

Sulfate is measured using the nitrochromeazo titrimetric method of Rasnick and Nakayama.* The pH meter is employed in the expanded mV range to determine F with a specific ion electrode.

Chloride is analyzed with a Buckler-Cotlove chloridometer which utilizes an argentometric titration of the chloride by means of a silver electrode.

*Ref: Comm. Soil Sci. and Plant Analysis, 4:171-174 (1973).

Table 3-1 Detection Limits and Range for Analytical Procedures

<u>Substance</u>	<u>Detection limit, mg/L</u>	<u>Range, mg/L</u>
Ca	0.08	0.01 to 10.0
Mg	0.007	0.001 to 2.0
Ng	0.02	0.004 to 4.0
K	0.04	0.01 to 12.0
Fe	0.10	0.03 to 5.0
Mn	0.05	0.01 to 3.0
Zn	0.02	0.005 to 0.5
Cu	0.10	0.02 to 5.0
Cr	0.10	0.02 to 5.0
Sr	0.02	0.01 to 5.0
Li	0.02	0.002 to 2.0
Mo	0.5	0.10 to 60.0
Al	1.0	0.2 to 50.0
Ba	0.4	0.1 to 25.0
Cd	0.006	0.005 to 2.0
Pb	0.001	0.002 to 0.1
Hg	0.0002	0.0001 to 0.01
Ag	0.06	0.01 to 4.0
Ni	0.15	0.03 to 5.0
As	0.005	0.001 to 0.1
Se	0.002	0.003 to 0.2
Co	0.15	0.03 to 5.0
Sb	0.5	0.10 to 40.0
NO ₃	0.01	0.01 to 1.0
SO ₄	0.01	1.0 to 300.0
PO ₄	----	0.01 to 2.0
CO ₃	0.1	0.1 to 600
HCO ₃	0.1	0.1 to 600
Cl	0.2	0.2 to 350.0
F	0.01	0.01 to 2.0
SiO ₂	0.1	0.05 to 10.0
B	0.01	0.01 to 4.0
CN	----	-----

<u>Substance</u>	<u>Detection limit, mg/L</u>	<u>Range, mg/L</u>
TDR (TDS)	1.0	1.0 up
Alkalinity	0.1	0.1 to 600
Hardness (total)	2.5	2.5 to 250.0
pH	---	----
Turbidity	---	----
Conductance	---	----