EPA-660/2-75-006
May 1975

Environmental Protection Technology Series

# Plant Scale Studies of the Magnesium Carbonate Water Treatment Process

National Environmental Research Center
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U.S. Environmental Protection Agency

Corvallis, Oregon 97330

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# PLANT SCALE STUDIES OF THE MAGNESIUM CARBONATE WATER TREATMENT PROCESS

By

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&
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Project #12120 HMZ
Program Element 1BB036
ROAP/Task No. 21BAE/18

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# ABSTRACT

The Magnesium Carbonate Process of water treatment has replaced alum in a portion of two (2) water plants in full scale studies conducted over the past two and one-half years. This new water treatment technology was compared to the presently used alum process in parallel treatment using identical units in Montgomery, Alabama and Melbourne, Florida.

The results of these studies indicate that this new process offers a number of significant advantages over the alum process. The primary advantage is that the existing problem of sludge disposal in Melbourne's case is completely eliminated and at Montgomery is greatly reduced. All water is recycled within the process along with the three (3) basic water treatment chemicals - lime, magnesium bicarbonate, and carbon dioxide. Other advantages found were increased floc settling rates, simplicity of operation and control, reduced costs when sludge treatment and disposal costs are considered, and more complete disinfection. In Melbourne's case, considerable energy would be conserved by on-site lime recovery.

In addition to the two full scale studies a number of special studies were conducted in Montgomery using a 50 gpm pilot plant. These studies showed almost complete removal of added cadmium by the highly adsorptive $Mg(OH)_2$ flocs and that it was not released during sludge carbonation and magnesium recycling.

This report was submitted in fulfillment of Project Number 12120 HMZ, by the Montgomery Water and Sanitary Sewer Board, under the partial sponsorship of the Environmental Protection Agency. Work was completed as of June 1973.

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# ACKNOWLEDGEMENTS

Acknowledgement is extended to the following personnel of the Montgomery Water and Sanitary Sewer Board for their assistance, advice and counsel which contributed in carrying out this study:

Mr. Nat P. Wiley, Manager
Mr. Joe L. Coleman, Chairman
Mr. M. L. French, Chief of Maintenance

In the Melbourne phase of the project, special recognition is extended to Smith and Gillespie Engineers, Inc., Melbourne's consulting engineers, for their foresightedness in seeking a new and novel approach to an old problem. The planning and assistance of Messrs. John H. Grantham and John M. Colyer were responsible for the inception and direction of this phase of the project.

Acknowledgement is also extended to the following personnel of the City of Melbourne:

Mr. Richard V. Donahue, Mayor
Mr. John C. Watkins, City Manager
Mr. Cal Yeary, Plant Superintendent

Special acknowledgement is extended to the water plant operators at both Melbourne and Montgomery whose effort and cooperation made this project possible.

Acknowledgement is extended to the American Water Works Research Foundation for their financial assistance to this project.

Mr. Edmond P. Lomasney, Project Officer is extended acknowledgements for his guidance and counsel throughout this project.

# SECTION I

# CONCLUSIONS

1. The use of magnesium carbonate as a recycled coagulant has been found to equal or exceed the results obtained by the use of alum in every aspect of water treatment including: water quality produced, operational characteristics, economy, and adaptability over a wide range of raw water qualities.
2. The Montgomery raw water is too soft to consider lime recovery; however, in Melbourne's case, where lime recovery is economically attractive, no solid or liquid discharge will result. The coagulated color will be converted to carbon dioxide on calcination and the three primary water treatment chemicals (magnesium, carbon dioxide and lime) recycled within the process.
3. In Montgomery, the easily dewatered filter cake will be available for use as a soil pH stabilizer. Considerable quantities of limestone are presently purchased in Alabama for this purpose each year.
4. The increased floc density produced by the magnesium process will allow higher clarifier loading rates. In Melbourne the present loading rates were doubled without a deterioration in the quality of the clarifier effluent.
5. Reduced treatment costs were found when sludge dewatering and ultimate disposal costs were considered. In Melbourne this cost savings would be in excess of $100,000 per year for a water production of 10 MGD. In evaluating the results of these studies, it should be kept in mind that from the standpoint of treatment costs, they represent the most unfavorable conditions

for this process. The greatest benefits from the new technology will be obtained by major cities treating hard waters containing sufficient lime to recalcine.

6. The chemical quality of the treated water was improved in both the Melbourne and Montgomery studies. In Montgomery the increase in finished water alkalinity using the Magnesium Process reduced the corrosion rate to one-half the value found for the extremely soft alum treated water. In Melbourne a considerably softer water would be produced during the winter months.
7. Plant personnel demonstrated their proficiency in the operation of the process under difficult conditions. The nature of the process is such that pH control at three (3) critical points is the primary method of insuring adequate treatment, producing excellent quality over a wide range of influent quality. The process was found to be easily automated and controlled.
8. The full scale use of this new process is compatible with most existing water treatment plants requiring a minimum of land area and capital cost. The conversion of most existing alum treatment plants to this new technology involves few internal process changes and only minor piping changes to add the necessary recovery and recycling units.

# SECTION II

# RECOMMENDATIONS

E.P.A. Project 12120 HMZ recently completed in Montgomery and Melbourne has shown that this process is practical for soft, turbid waters and moderately hard waters high in organic color. Magnesium recovery and recycle has been shown to be practical and economically feasible. This project has provided design criteria which are applicable to many water plants utilizing the types of raw water investigated in this project. The need for extensive pilot studies by each of these type plants is eliminated.

Hard turbid water presents the most serious problems in sludge disposal due primarily to the large quantity of sludge to be treated. While these sludges generally dewater more readily than soft water sludges, high disposal costs can result due to the quantity to be hauled to a suitable landfill. Lime recovery from the precipitated calcium carbonate has been to date considered unfeasible due to the high silt content; however, the use of flotation separation of the calcium carbonate now makes lime recovery possible. All of the unit processes have been demonstrated in the laboratory; however, pilot or full scale studies have been conducted in only limited areas. In the application of new technology, considerable caution must be exercised. In the case of this process the use of pilot and/or demonstration plants are required before considering such a drastic process change to a full scale plant operation.

Work completed at Dayton, Ohio is directly applicable to only a very few cities treating clear ground water. The magnesium carbonate production studies carried out to date have been conducted on a batch basis with little attention given to obtaining design information. The influence of raw water impurities on the magnesium compounds has not been evaluated nor the various means of removing these impurities prior to magnesium carbonate precipitation.

At the present time, there have been three E.P.A. funded projects related to the overall magnesium process. The first project was a laboratory study conducted at Gainesville, Florida, Project 11060 ESW, and concluded in May of 1971. The second was the Demonstration Project 12120 HMZ reported on here. The initial objectives of this project were concerned with the treatment of a very soft, low magnesium water at Montgomery, Alabama with no consideration given for magnesium production. The extension of this project in Melbourne, Florida, studied the application of the process for treatment of a much harder, highly colored, low turbidity water. The third project, in Gainesville, Florida, 12130 HRA, was for the treatment of municipal and industrial wastes. This latter project has been completed, and a final report submitted.

A comprehensive research project, 802800, has also been initiated to study the application of the lime and magnesium recovery aspects of this process on a hard, high magnesium, turbid surface water at Johnson County, Kansas. The specific objectives of the proposed research are:

1. Determine the technical feasibility of separating calcium carbonate from the clay turbidity by froth flotation. This must be accomplished during wide variations in raw water quality. The seasonal effects on both the sludge character and the flotation process should be evaluated.
2. A study of the production of magnesium compounds from a relatively poor quality raw water in continuous flow, pilot scale studies.
3. Development of design information for all required unit operations where recovery is found to be technically feasible.
4. Conduction of a economic analysis for full scale application of lime and magnesium recovery. A

projection as to the cost effectiveness of these recovery processes as a function of plant size and raw water quality will be made.

The studies in Melbourne have shown the process to be applicable to color removal at moderately high levels. A sample of the total effluent from an unbleached southern kraft pulp mill was collected for laboratory jar testing. This effluent had received only settling as treatment and had the following characteristics:

| | |
|---|---|
| pH | 8.3 |
| Total Alkalinity (as $CaCO_3$) | 328 mg/l |
| Color (Pt.-Co. Units) | 530 mg/l |

A number of jar tests were run using different dosages of magnesium carbonate, coagulating at a constant pH of 11.3. A summary of these tests is as follows:

Chemical Dosages

| | |
|---|---|
| Magnesium Dosage* (mg/l as $CaCO_3$) | 350 |
| Lime Dosage mg/l as $Ca(OH)_2$ | 430 |

Treated Stabilized Waste Characteristics

| | |
|---|---|
| pH | 8.5 |
| Alkalinity as $CaCO_3$ | 213 |
| Color (Pt.-Co. Units) | 53 |
| % Color Removal | 90 |

For comparative purposes a brief study was made of the use of alum for the coagulation of the color present. Three hundred (300) mg/l of alum produced a treated effluent with a COD of 205 mg/l and a color of 93 mg/l. This indicates a COD removal of 64% and a color removal of 83%. At an alum cost of 2.1¢ per pound a chemical cost of greater than $52 per million gallons could be expected. Based on these limited

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*Magnesium dosages are expressed in terms of calcium carbonate equivalents for simplicity. The actual magnesium form used may be magnesium sulfate, magnesium carbonate, magnesium bicarbonate, etc.

studies, the chemical cost for the magnesium process would be approximately $20.00 per million gallons.

Presently, lime treatment of these wastes is considered most often when color removal is required in conjunction with conventional treatment. The use of the magnesium process would appear to offer the following advantages over the Massive or Stoichiometric Lime Processes:

1. The sludge produced should be considerably easier to dewater due to the higher calcium carbonate content.
2. Due to magnesium recycle, a lower coagulation pH is possible generally in the range of 11.2 to 11.4.
3. Chemical costs should be considerably less due to the lower coagulation pH and subsequent reduced lime requirements.
4. Using magnesium hydroxide as a coagulant, a much higher degree of color removal and total organic carbon should be achieved. This is based on a very preliminary study with the data presented earlier.

The discussion concerning the potential for the magnesium process for the treatment of a kraft unbleached pulp mill waste illustrates one possible application for industrial waste treatment which should be studied in detail. Similar discussions could be included for many other colored wastes such as dispersed textile dye wastes, treatment of fluoride wastes, removal of many heavy metal constituents of industrial wastes; and silica removal to meet industrial water treatment requirements. It is important that this new technology be evaluated over a wide range of applications, first in the laboratory and later in pilot or demonstration scale projects if initial results are encouraging.

# SECTION III

# INTRODUCTION

In November, 1972, the City of Montgomery, Alabama, began drinking water produced using a totally new concept in water treatment. This new process utilizes chemical recycle and recovery to eliminate waste discharges and reduce the cost of water treatment. The project at Montgomery was sponsored by the Environmental Protection Agency, the American Water Works Association Research Foundation and the Montgomery Water and Sanitary Sewer Board. The study began in pilot scale and culminated in a successful plant scale application producing five million gallons of water per day.

The development work for this system of water treatment began in the 1950's in Dayton, Ohio. Dr. A. P. Black, working with the City of Dayton to reduce the waste sludge from the water treatment plant, developed a technique for the separation of magnesium hydroxide from the calcium carbonate component of the sludge.[1] Dayton's water supply is obtained from clear well water very high in calcium and magnesium hardness. The softening sludge produced is very high in magnesium hydroxide which had to be separated prior to lime recalcination. Carbon dioxide produced in lime recalcination is used to selectively dissolve the magnesium hydroxide as the soluble bicarbonate. The clear magnesium bicarbonate solution is separated by thickening and discharged to a nearby water course.

Lime recalcination with sludge carbonation, begun in 1957, has been operating very successfully resulting in the elimination of waste sludge discharge and at the same time greatly reducing the chemical cost of water treatment.[2] However, Dayton has been advised by the State of Ohio that this clear magnesium bicarbonate discharge represents a pollution problem, due to the high dissolved solids, that should be eliminated. Dr. Black found after extensive laboratory and pilot scale work that extremely pure magnesium carbonate could be easily and inexpensively precipitated from the magnesium bicarbonate liquor.[3].

During this same time period, Dr. Black discovered that froth flotation provided a highly selective method of separating relatively pure calcium carbonate from clay, silt, or other common raw water contaminants. He found this to be true only if the coagulant used has been removed prior to the flotation process.

Another discovery was that the magnesium carbonate produced from the Dayton plant was an excellent coagulant for water and waste water and that it could be recovered and recycled. Drs. A. P. Black and C. G. Thompson expanded the development of this technology in laboratory studies sponsored by E.P.A. Project 11060 ESW at the University of Florida. It was found that this coagulant compared favorably with alum treatment for a large number of natural waters studied in the laboratory.[4,5,6]

These four basic discoveries -- separation of magnesium hydroxide from calcium carbonate; flotation of calcium carbonate from raw water impurities; the use of magnesium as a recycled coagulant; and the production of magnesium carbonate from the sludges of waters high in magnesium concentration -- meshed together to produce an entirely new system of water treatment. This coagulation system is a unique combination of water softening and conventional coagulation. Sufficient lime slurry is added to a water containing magnesium carbonate or to which magnesium carbonate has been added, precipitating both magnesium hydroxide, which has properties similar to aluminum hydroxide, and calcium carbonate. Carbonation of the sludge selectively dissolves the magnesium hydroxide as magnesium bicarbonate which can be recovered by thickening and vacuum filtration for recycle and reuse. The filter cake, composed of calcium carbonate and clay, is reslurried and the calcium carbonate floated off for recalcination. The carbon dioxide produced in the recalcination is used both for sludge carbonation and finished water stabilization. The flotation underflow, clay, is dewatered and disposed of as landfill.

There are three general applications of the processes involved:

1) The use of magnesium as a coagulant with the recycle of magnesium bicarbonate and sludge dewatering as an integral part of the process. This would be applicable to those waters relatively low in magnesium content with insufficient lime usage to consider lime recovery. The flow diagram is illustrated in Figure 1. Table 1 illustrates a number of cities whose raw water characteristics fall into this category.

2) Magnesium recycle using flotation for calcium carbonate beneficiation prior to lime recovery. The carbon dioxide produced in lime recovery is used for sludge carbonation and finished water stabilization. The impurities separated by flotation would be dewatered and disposed of as landfill. This would be applicable for waters moderately high in hardness with sufficient lime usage to make recalcination economically feasible. This process is illustrated in Figure 2 while Table 2 lists representative cities for this category along with their raw water characteristics.

3) Precipitation of the magnesium present in the hard raw water, use of lime recovery with flotation beneficiation, and magnesium carbonate production. This, of course, would be applicable to waters high in magnesium content with sufficient lime usage to consider lime recovery. The units required are shown in Figure 3. Table 3 illustrates typical cities in this category.

The primary emphasis of this new water treatment process is the elimination of sludge disposal problems by the recovery and reuse of the three (3) water treatment chemicals used - lime, carbon dioxide, and magnesium.

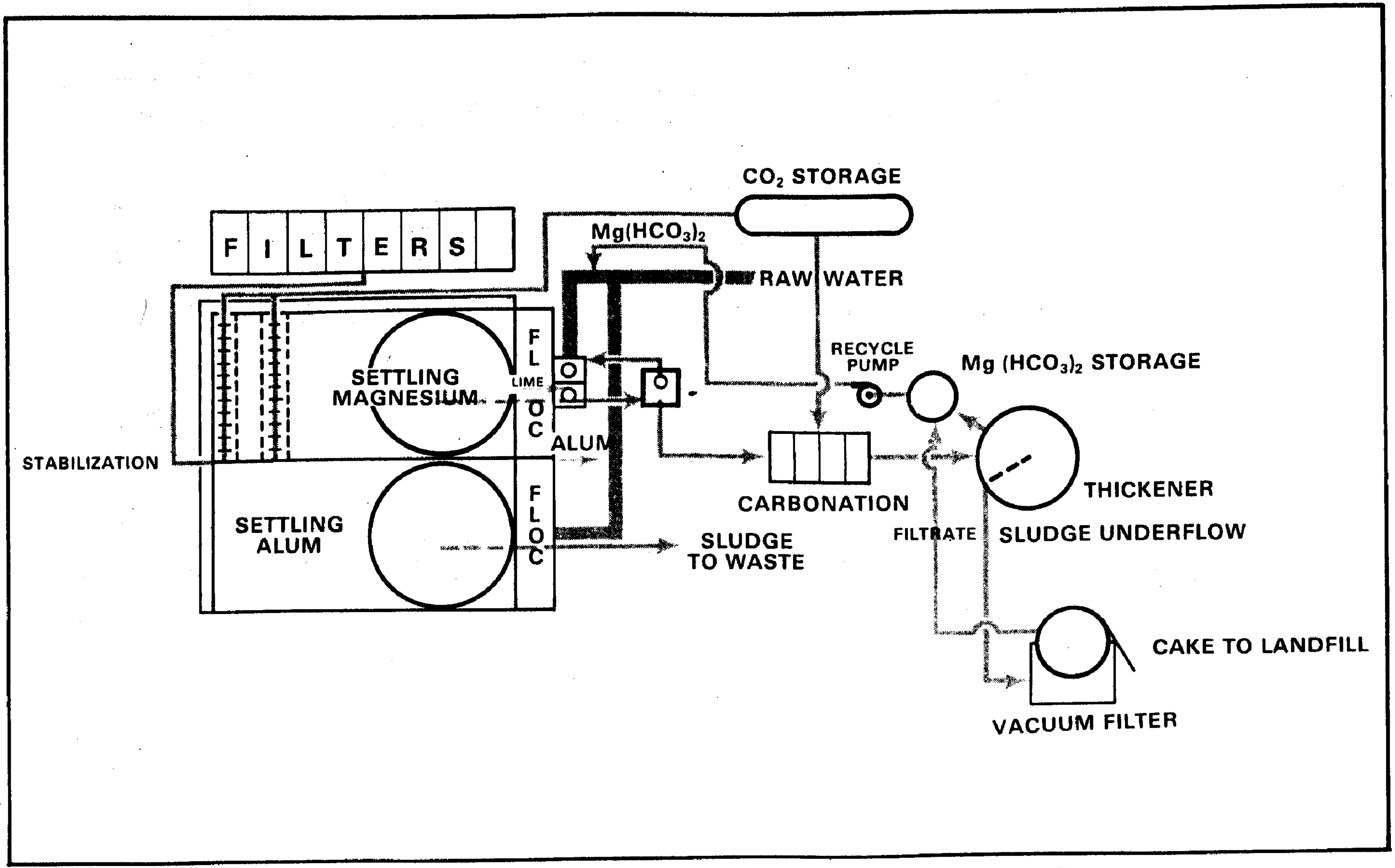

FIGURE 1. MAGNESIUM RECYCLE MAGNESIUM PROCESS FLOW DIAGRAM

## TABLE 1. CITIES TREATING SOFT SURFACE WATERS(a)

### CATEGORY 1

| City | Source of Supply | Chemical Characteristics | | | Turbidity | | |
|---|---|---|---|---|---|---|---|
| | | Mg++ (b) | CH (c) | TH (d) | Avg. | Max. | Min. |
| Baltimore | Three Rivers (Imp.) | 2-3 | 35 | 43 | < 1 | 3 | 0.1 |
| Albany | Imp. Supplies | 3 | 23 | 43 | 5 | 15 | 0 |
| Bridgeport | Imp. Supplies | 1 | 9 | 25 | - | - | - |
| Tulsa | Imp. Supplies | 2 | 86 | 86 | 7 | 13 | 4 |
| Providence | Pawtuxet River | <1 | 5 | 10 | < 1 | < 1 | <1 |
| Newark | Imp. Rivers | 3 | 17 | 19 | - | - | - |
| Lynn, Mass. | | | | | | | |
| Richmond | James River | 2 | 34 | 40 | 44 | 274 | 10 |
| Norfolk | Two Impoundments | 5 | 28 | 52 | 8 | 19 | 3 |
| Atlanta | Chattahoochee River | 1 | 14 | 14 | 27 | 200 | 5 |
| Birmingham | Lake Purdy Imp. | <1 | 7 | 7 | - | - | - |
| Mobile | Big Creek Imp. | <1 | 3 | 6 | 50 | 111 | 32 |
| Montgomery | Tallapoosa River | | | | | | |
| Savannah | Abercorn Creek | 4 | 17 | 18 | 30 | 43 | 21 |
| Shreveport | Cross Lake | 4 | 25 | 42 | 17 | 27 | 8 |
| Jackson | Pearl River | 1 | 16 | 35 | 60 | 1000 | 8 |
| Charlotte | Catawba River | 1 | 16 | 13 | 25 | 142 | 5 |
| Greensboro | Imp. Creeks | 2 | 26 | 30 | 54 | 340 | 3 |

(a)All data compiled from annual reports and/or U.S.G.S. Water Supply Paper 1812

(b)Magnesium as Magnesium

(c)Calcium Hardness

(d)Total Hardness

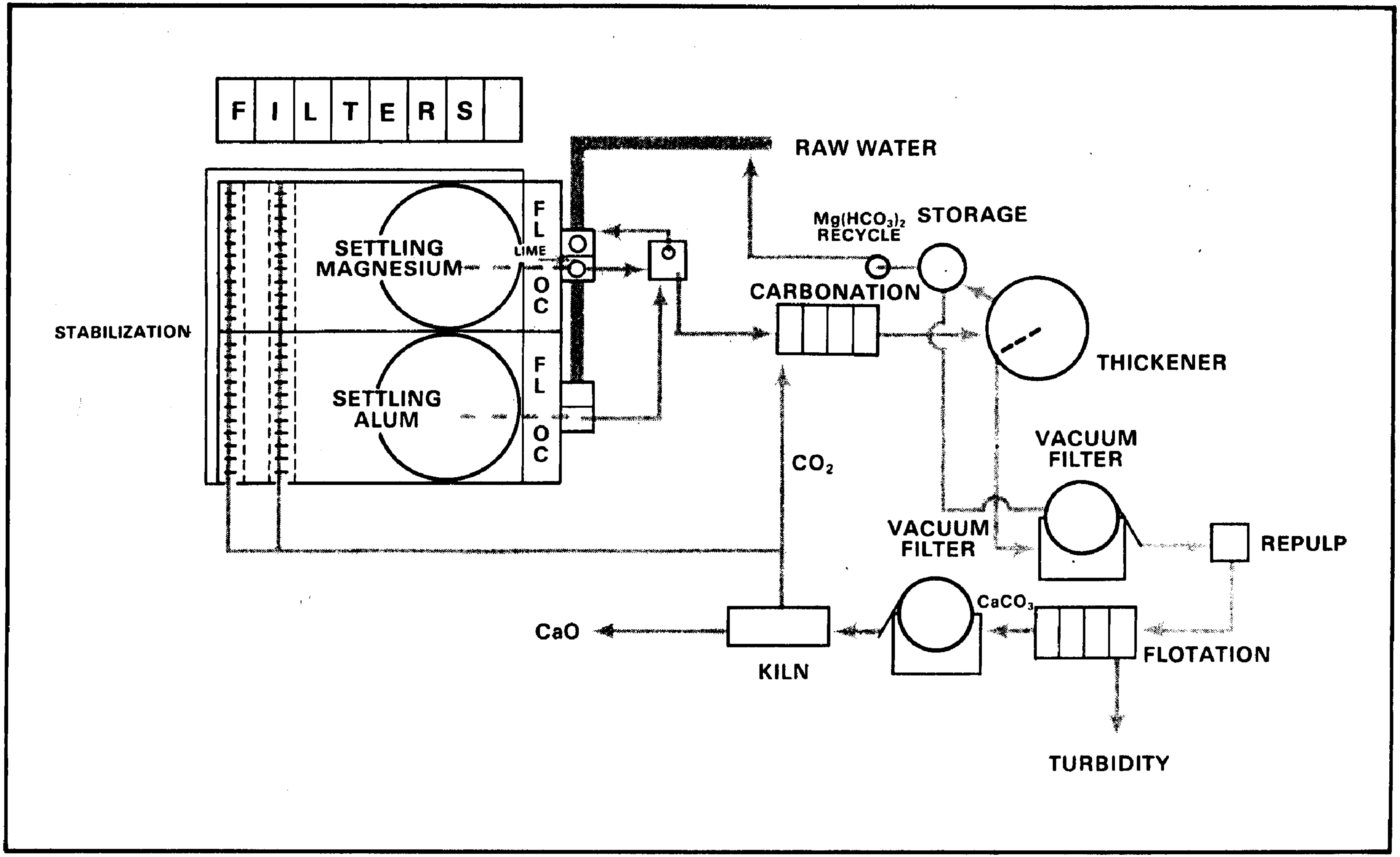

FIGURE 2. LIME RECOVERY MAGNESIUM PROCESS FLOW DIAGRAM

# TABLE 2. CITIES TREATING MODERATELY HARD, TURBID SURFACE WATERS[(a)]

## CATEGORY 2

| City | Source of Supply | Chemical Characteristics |  |  | Turbidity |  |  |
|---|---|---|---|---|---|---|---|
|  |  | Mg++ (b) | CH (c) | TH (d) | Avg. | Max. | Min. |
| Chicago | Lake Michigan | 11 | 108 | 128 | 15 | 160 | 1 |
| Cleveland | Lake Erie | 7 | 94 | 127 | 9 | 140 | 1 |
| Detroit | Detroit River | 7 | 80 | 100 | 11 | 20 | 2 |
| Milwaukee | Lake Michigan | 10 | 108 | 131 | 4 | 38 | 1 |
| Toledo | Lake Erie | 8 | 89 | 186 |  |  |  |
| Erie, Pa. | Lake Erie | 10 | 92 | 121 | 9 | 40 | 1 |
| Buffalo | Lake Erie | 9 | 95 | 131 | 12 | 200 | 1 |
| Philadelphia | Delaware River | 6 | 34 | 67 | 22 | 36 | 13 |
| Philadelphia | Schuylkill River | 15 | 65 | 153 | 27 | 85 | 9 |
| Washington, D.C. | Potomac River | 8 | 70 | 101 | 49 | 600 | 6 |
| Pittsburg, Pa. | Allegheny River | 10 | 6 | 120 | 139 | 25 | - |
| Pittsburg, Pa. | Monongehela River | 5 | 4 | 112 | - | - | - |
| Louisville, Ky. | Ohio River | 10 | 74 | 131 | 101 | 800 | 4 |
| Paterson, N.J. | Several Streams | 6 | 51 | 69 | 10 | 13 | 7 |
| Grand Rapids | Lake Michigan | 11 | 109 | 130 | 6 | 20 | 1 |
| Rochester, N.Y. | Lake Ontario | 10 | 92 | 127 | 6 | 40 | 1 |
| Evansville, Ind. | Ohio River | 10 | 70 | 136 | 102 | 620 | 6 |
| Akron, Ohio | Cuyahoga River | 7 | 74 | 107 | 5 | 36 | 1 |
| Chattanooga | Tennessee River | 5 | 52 | 73 | 25 | 340 | 15 |
| Nashville | Cumberland River | 8 | 65 | 81 | 29 | 60 | 13 |
| Youngstown | Meander Creek (Imp.) | 6 | 36 | 86 | - | - | - |
| Dallas, Texas | Impounded | 6 | 119 | 164 | 62 | 732 | 15 |
| Dallas, Texas | Lakes | 7 | 110 | 152 | 49 | 1120 | 13 |
| Ft. Worth | Imp. Lakes | 8 | 128 | 139 | 22 | 40 | 5 |
| Cincinnati | Ohio River | 9 | 40 | 137 | 70 | 1100 | 1 |
| Corpus Christi | Nueces River | 6 | 119 | 164 | 62 | 732 | 15 |
| Tampa | Hillsboro River | 6 | 106 | 125 | Seasonal organic color |  |  |
| Gary | Lake Michigan | 11 | 108 | 128 | 5 | 160 | 1 |

(a)All data compiled from annual reports and/or U.S.G.S. Water Supply Paper 1812

(b)Magnesium as Magnesium

(c)Calcium Hardness

(d)Total Hardness

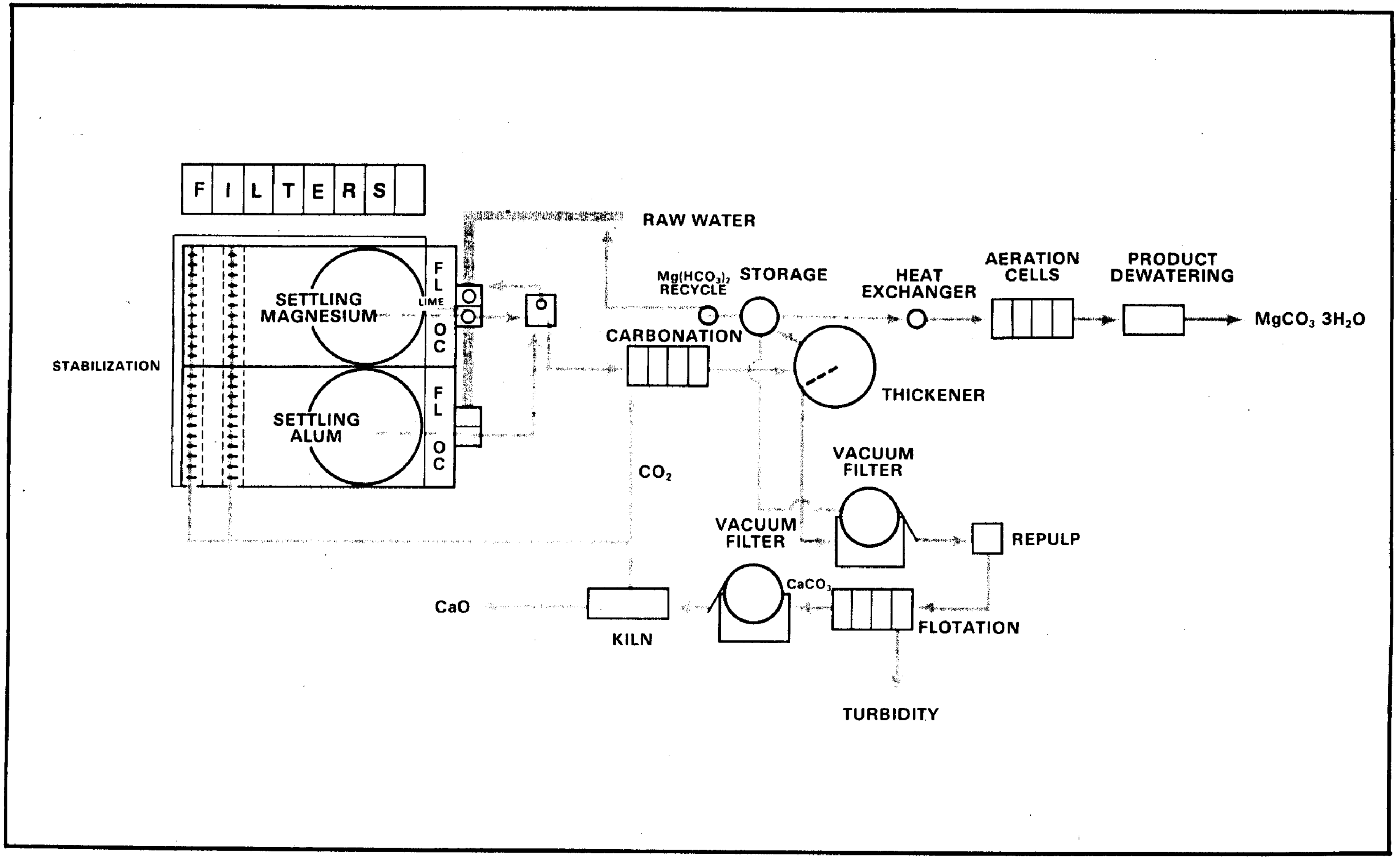

FIGURE 3. LIME AND MAGNESIUM RECOVERY MAGNESIUM PROCESS FLOW DIAGRAM

## TABLE 3. CITIES TREATING HARD TURBID SURFACE WATER(a)

### CATEGORY 3

| City | Source of Supply | Chemical Characteristics | | | Turbidity | | |
|---|---|---|---|---|---|---|---|
| | | Mg++ (b) | CH (c) | TH (d) | Avg. | Max. | Min. |
| Des Moines | Racoon River | 33 | 244 | 331 | 50 | 1330 | 1 |
| Kansas City, Mo. | Missouri River | 16 | 163 | 218 | 800 | 1800 | 70 |
| Kansas City, Ka. | Missouri River | 13 | 172 | 231 | 810 | 4800 | 10 |
| Flint, Mich. | Flint River | 24 | 208 | 276 | 15 | 23 | 4 |
| Minneapolis | Mississippi River | 16 | 158 | 185 | 7 | 60 | 1 |
| St. Paul | Mississippi River | 10 | 164 | 178 | 1 | 2 | 0 |
| Omaha | Missouri River | 23 | 172 | 245 | 280 | 780 | 15 |
| Columbus | Scioto River | 26 | 159 | 272 | 40 | 110 | 15 |
| Columbus | Big Walnut Creek | 15 | 92 | 152 | 13 | 28 | 3 |
| St. Louis | Missouri River | 17 | 153 | 208 | 350 | 1750 | 20 |
| St. Louis | Missouri River | 17 | 154 | 206 | 383 | 2500 | 20 |
| Oklahoma City | Lake Hefner | 26 | 143 | 246 | 6 | 6 | 6 |
| Fort Wayne, Ind. | St. Joseph River | 20 | 225 | 279 | 75 | 735 | 30 |
| Austin, Texas | Colorado River | 19 | 155 | 187 | 10 | 91 | 6 |
| Phoenix, Ariz. | Salt River | 15 | 122 | 205 | - | - | - |
| Lima, Ohio | Upland Res. | 23 | 136 | 252 | - | - | - |
| Phoenix, Ariz. | Verde River | 14 | 144 | 184 | - | - | - |
| Topeka, Ka. | Kansas River | 23 | 203 | 292 | 912 | 1120 | 375 |
| New Orleans | Mississippi River | 11 | 108 | 128 | 5 | 160 | 1 |
| St. Louis County | Missouri River | 17 | 145 | 208 | 322 | 2195 | 0 |

(a)All data compiled from annual reports and/or U.S.G.S. Water Supply Paper 1812

(b)Magnesium as Magnesium

(c)Calcium Hardness

(d)Total Hardness

## PROJECT ORGANIZATION

The E.P.A. Demonstration Project 12120 HMZ was a natural outgrowth of the laboratory research reported previously, Project 17060 ESW. The Montgomery Water and Sanitary Sewer Board sponsored the project, however, financial support was also obtained from the American Water Works Association Research Foundation. An additional E.P.A. Research Grant award was made to the Montgomery Water and Sanitary Sewer Board to extend the application of this project to Melbourne, Florida. In addition, the City of Melbourne, Florida utilized a considerable portion of the Montgomery equipment which resulted in both an expedited project start-up date as well as financial savings. Smith & Gillespie Consulting Engineers, Inc., Jacksonville, Florida, Melbourne's consultants, were directly involved in planning and carrying out the Melbourne portion of the study and are now in the process of designing a full scale installation for Melbourne.

## PROJECT OBJECTIVES

The objectives were:

1. To evaluate the process in full scale operation as to the technical and operational characteristics in the treatment of both a highly colored, and a soft, highly turbid surface water.
2. To determine if color or other raw water contaminants release on magnesium recovery would prove to be a problem.
3. To develop design information for all unit operations involved.
4. To develop economic information concerning all aspects of the process.
5. To perform selected studies in the areas of taste and odor, heavy metals, dissolved organics and new sources of make-up magnesium.

# SECTION IV

# DESCRIPTION OF PROJECT PHASES

The project was divided into three distinct phases; a 50 gpm pilot operation in Montgomery, a 5 MGD full scale study in Montgomery, and a 2 MGD full scale study in Melbourne. The Montgomery pilot studies were conducted for the purpose of:

1) Providing design information for subsequent full scale studies.
2) Training plant operators.
3) Evaluating potential process control problems.
4) Performing special studies.

In both the Montgomery and Melbourne full scale studies, parallel treatment with the alum process using essentially identical units was also accomplished. In a practical sense, in each location these studies resulted in the simultaneous operation of two water treatment plants using dramatically different processes. This was accomplished with existing personnel in both applications.

## PILOT PLANT DESCRIPTION
## MONTGOMERY, ALABAMA

The pilot plant operation began in November, 1971 and the studies were concluded in September of 1972. A photograph of the pilot facilities is shown in the Appendix.

The flow sheet for the pilot plant is shown in Figure 4. The major equipment utilized consisted of the following:

- 10 ft. diameter reactor-clarifier
- 5 ft. diameter thickener
- dual cell 15" X 15" carbonator (Galigher #15 flotation cells)

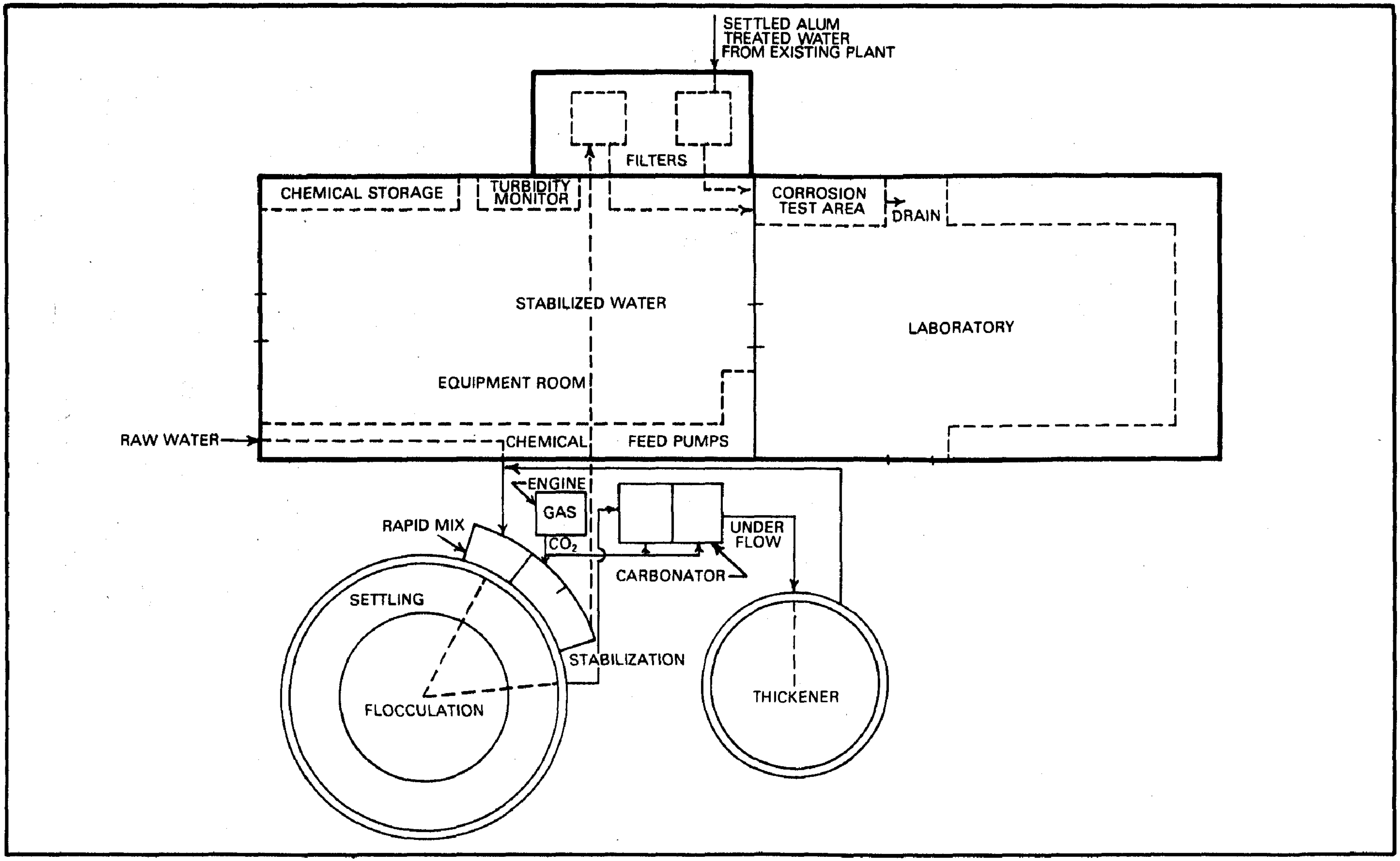

FIGURE 4. MAGNESIUM DEMONSTRATION PILOT PLANT LAYOUT

- Wallace and Tiernan A747 diaphragm solution pumps
- (2) 1-1/2' X 1-1/2' pilot filters using sand and anthracite media
- Continuously recording turbidmeter
- 7.5 horsepower natural gas engine

Raw water was obtained prior to pre-chlorination and regulated by a control valve to maintain the desired flow rate. Recycled magnesium bicarbonate, make-up magnesium sulfate, and lime were added to the raw water in successive order. Recycled sludge from the clarifier underflow was added to the rapid mix. The settled water was stabilized using the exhaust from the natural gas engine. Two stage settled water stabilization was used during a portion of the study by introducing carbon dioxide into the transfer line between the clarifier and filter.

The clarifier underflow was carbonated using pure carbon dioxide, in a Galigher #15 dual cell flotation machine. During periods of the study, exhaust gas was also used for sludge carbonation. The 5 ft. diameter thickener was used for solids-liquid separation, the overflow magnesium bicarbonate recycled to the raw water and the underflow to disposal or special studies.

Recycled sludge was provided for the following purposes:

1) Recycled calcium carbonate increases magnesium precipitation kinetically as well as quantitatively as reported by several early investigators.[7,8,9,10]

2) A portion of the magnesium hydroxide fraction of the sludge reacts with the recycled magnesium bicarbonate as well as the natural bicarbonate alkalinity and carbon dioxide in the raw water. This solubilized magnesium carbonate is effective for coagulation when reprecipitated; however,

some coagulated turbidity is also released. The overall effect is difficult to evaluate but is generally considered to be of some value.

3) The preformed calcium carbonate recycled acts as a seed or nucleus for precipitation preventing a build-up on mechanical equipment.

4) The excess causticity in the sludge water, pH 11.40, reduces the lime requirements slightly. The precipitation reactions occur rapidly and produce small dense flocculent particles. Even at maximum flocculation speeds the floc tends to settle from suspension.

## MONTGOMERY FULL SCALE STUDIES

Figure 1 is the flow diagram of the Montgomery plant as converted for the study. This plant was an excellent facility for this project as only minor alterations were required to produce parallel plants with almost identical treatment units. Rapid mixing could not be provided for the alum process, but jar tests indicated that with the ample time provided in the flocculator, floc formation was not affected. A partial analysis of Montgomery's raw water is shown in Table 4.

TABLE 4. TYPICAL RANGE IN RAW WATER CHARACTERICS
TALLAPOOSA RIVER, MONTGOMERY, ALABAMA

| pH | Alkalinity (mg/l) | Hardness (mg/l) (As $CaCO_3$) | Magnesium (mg/l) | Color (mg/l) (Pt-Co) | Turbidity (mg/l) (JTU) |
|---|---|---|---|---|---|
| 6.6-7.0 | 10/22 | 10-22 | 0-5 | 5-60 | 2-300 |

The description of the plant facilities is in the order of occurrence.

## RAPID MIX AND FLOCCULATOR

Figure 5 illustrates the recycle and chemical feed points using the two rapid mixers in series which provides a total detention time of four minutes at a rate of 5 MGD. Recycled magnesium bicarbonate was added to the raw water immediately prior to rapid mixing while uncarbonated recycled sludge and magnesium sulfate* were added in rapid mixer #1. Lime was added between rapid mixers #1 and #2 adjusting the pH to the desired value.

Lime feed was controlled automatically using a pH probe in rapid mixer #2, coupled to a pH controller and S.C.R. controlled pump as shown in Figure 6. Flocculation was carried out using conventional reel type variable speed flocculators normally operated at the maximum speed.

## SETTLING-CARBONATION

The Montgomery plant utilizes conventional horizontal settling basins with mechanical sludge removal in the first half. Approximately two-thirds of the basin was used for settling with the remaining third used for two stage stabilization. Liquid carbon dioxide was metered manually into the settled water, dispersed through 1" PVC pipe drilled with small holes approximately 2 ft. apart. Baffles of polyethylene film were installed to prevent mixing back to the settling zone.

The purpose of the two stage carbonation is to first convert the hydroxide to carbonate alkalinity, precipitating calcium carbonate. For this reaction, the pH was held at 10.3.

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*Magnesium sulfate was used as a make-up source of magnesium as no magnesium carbonate tri-hydrate was available at this time. The make-up dosage was quite low, less than 5 mg/l, thus, the noncarbonate hardness addition was minimal.

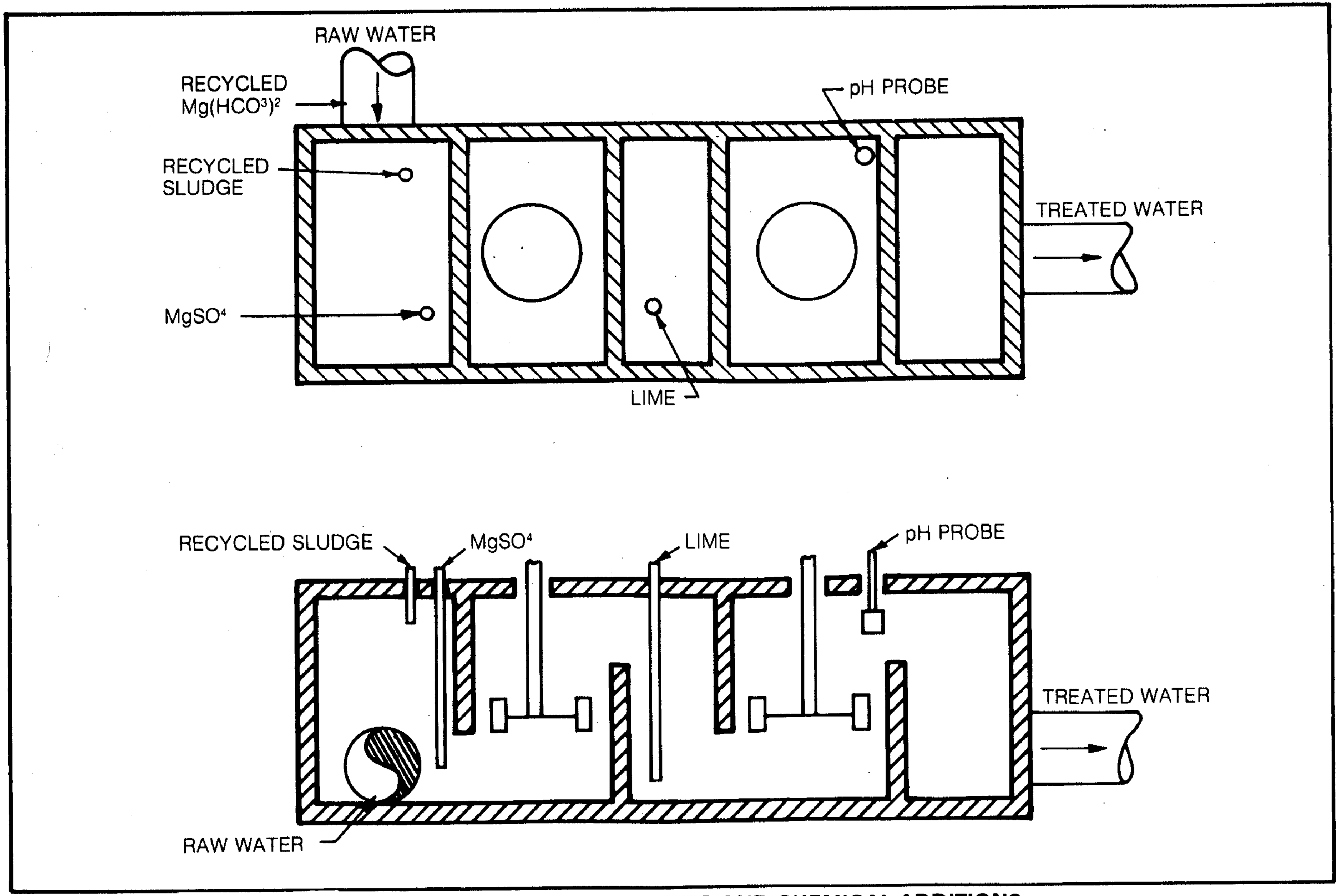

FIGURE 5. DETAILS OF RAPID MIX UNITS AND CHEMICAL ADDITIONS
MONTGOMERY, ALABAMA

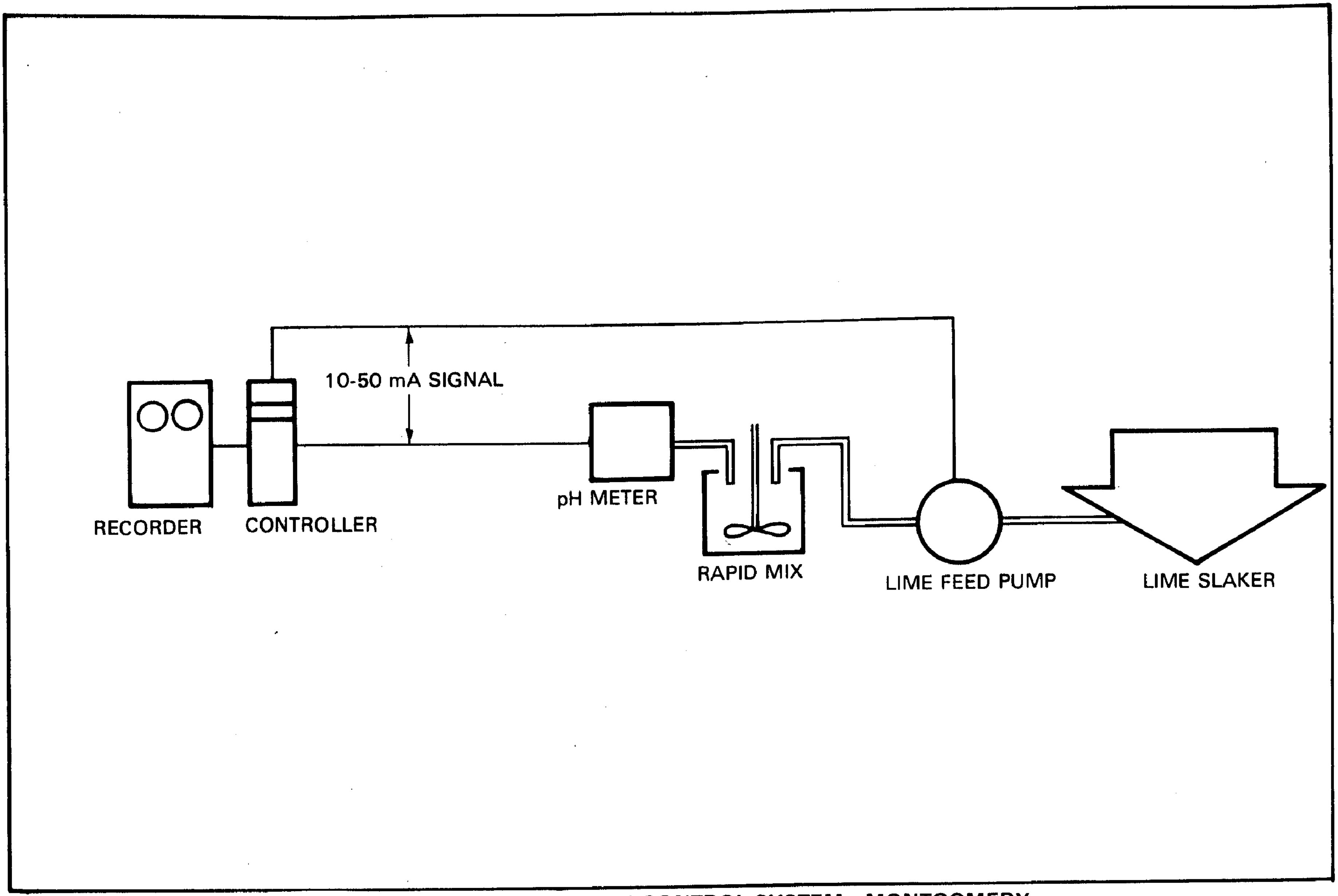

FIGURE 6. FLOCCULATION pH CONTROL SYSTEM - MONTGOMERY

Very little of the calcium carbonate formed settled, however, the solid phase is relatively stable and does not redissolve upon final pH stabilization just prior to filtration. The carryover of calcium carbonate onto the filter does not shorten the length of filter run and does not pass through the filter. Proper adjustment of the settled water pH prevents calcium carbonate from precipitating on the sand in the filter. Precipitated calcium carbonate carried onto the filter was easily removed on backwashing.

## FILTRATION

Settled, stabilized waters from the alum and magnesium processes were separated and filtered in identical sand filters, generally at a rate of 1 to 2.5 gallons per square foot per minute. One of the four filters used on the magnesium process was converted to a dual media filter, replacing three inches of sand with anthracite having an effective size of 1.2 mm.

## MAGNESIUM RECOVERY AND SLUDGE HANDLING

Figure 7 illustrates the units comprising the sludge recovery system. Sludge was pumped at a controlled rate into the carbonation cells using a variable speed Moyno pump. Four 10 cubic feet flotation cells were used for sludge carbonation. Again pure carbon dioxide was used, the feed being automated as shown in Figure 8. Carbonated sludge was pumped into a 10 feet diameter thickener with the overflow returned to the raw water using an intermediate 1800 gallon storage tank. The recycled magnesium bicarbonate was pumped at a controlled rate to give the desired coagulant dosage. The thickener underflow was vacuum filtered with a 3' X 3' drum filter* The filtrate

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*Envirotech Corporation, Salt Lake City, Utah

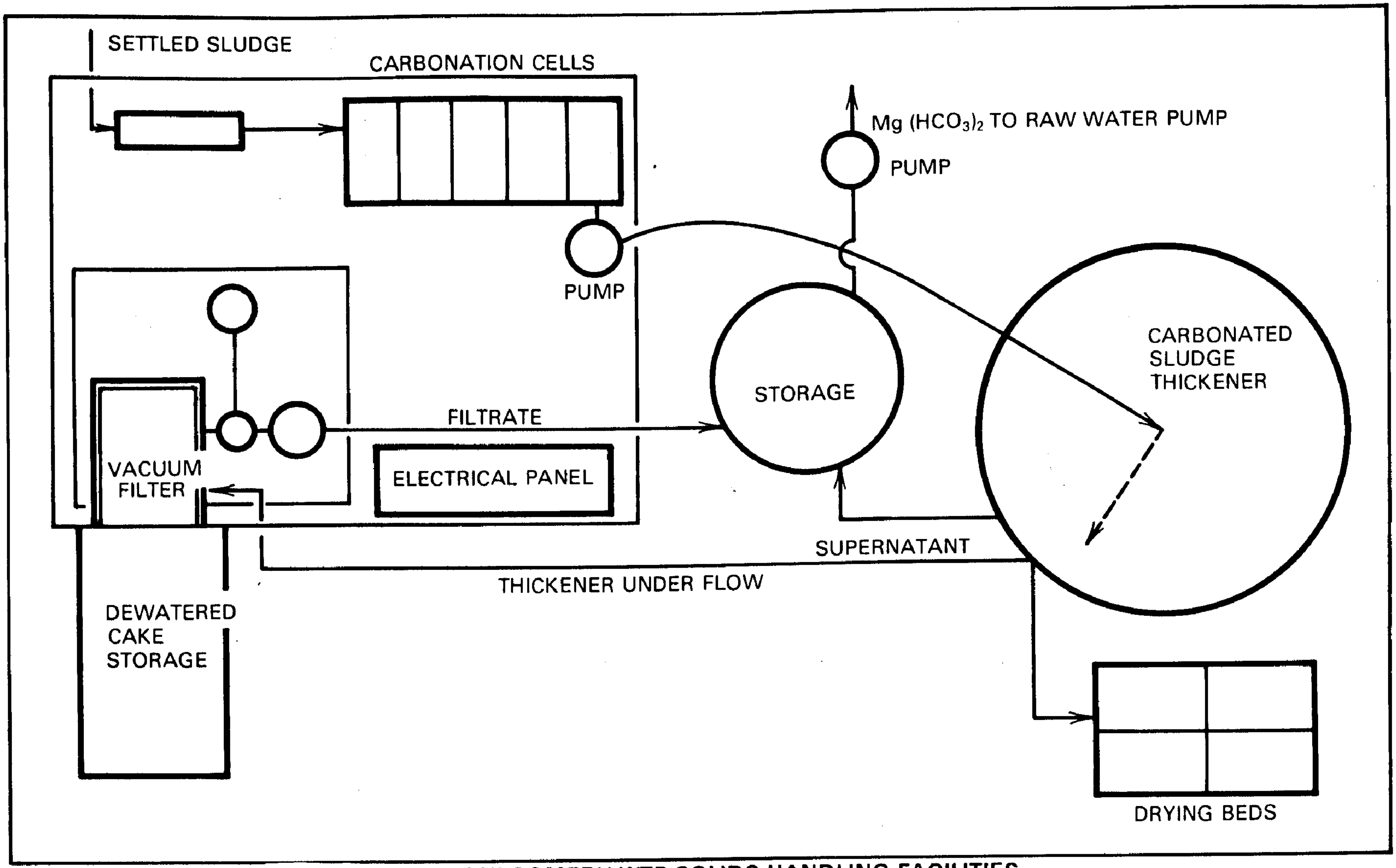


**FIGURE 7. MONTGOMERY WTP SOLIDS HANDLING FACILITIES**

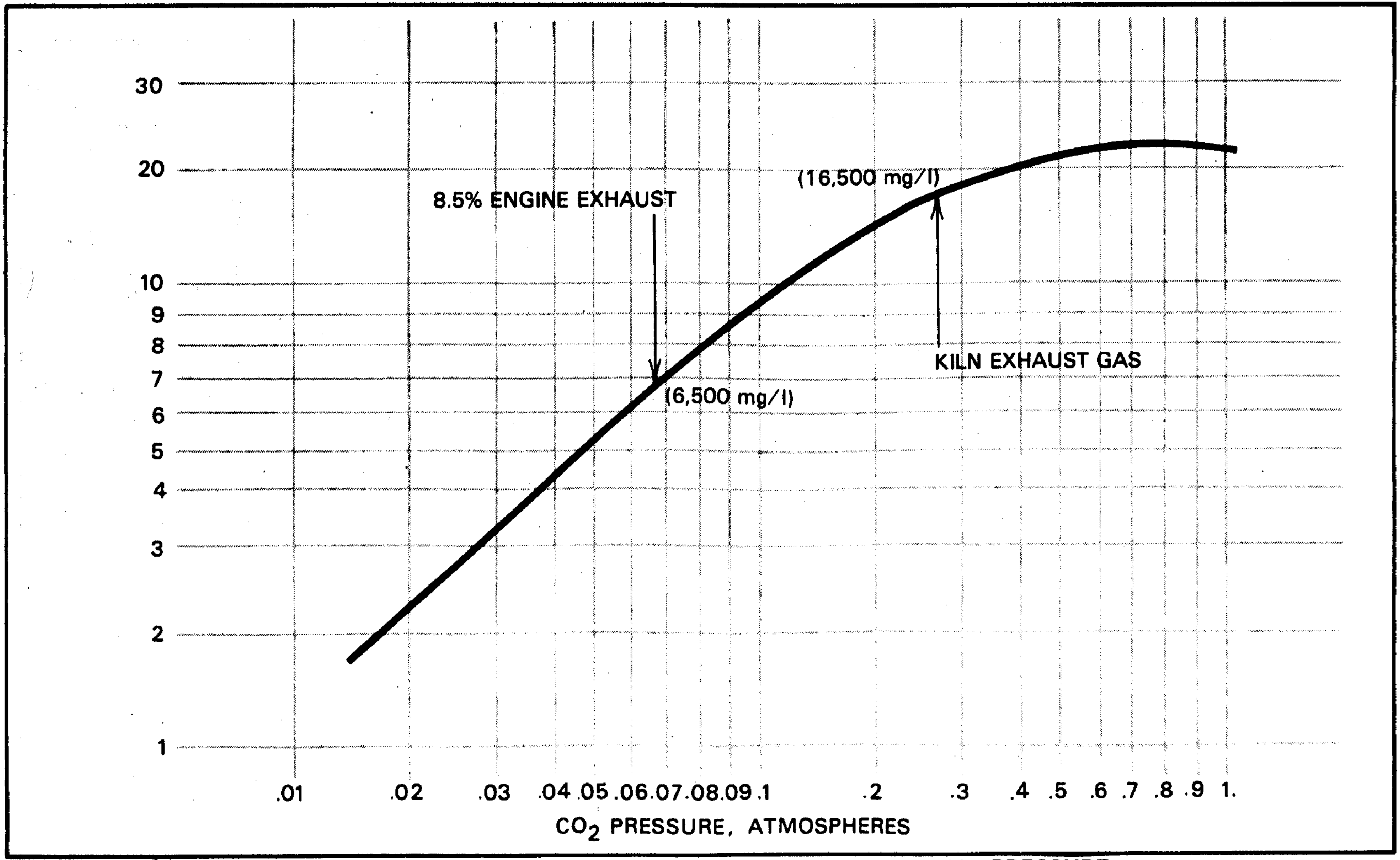


FIGURE 8. SOLUBILITY OF MAGNESIUM AS A FUNCTION OF $CO_2$ PARTIAL PRESSURE

was pumped to the magnesium bicarbonate storage tank and the filter cake hauled to a landfill.

There are several reasons why pure carbon dioxide should be considered for use in the smaller plants not recovering lime. The rate at which carbon dioxide solubilizes magnesium has been found to be first order with respect to the partial pressure of the carbon dioxide.[11] In addition, pure carbon dioxide will dissolve approximately 25,000 mg/l of magnesium bicarbonate, as shown in Figure 8, considerably more than the lower percentage carbon dioxide produced from on-site generation. The feed of liquid carbon dioxide is simpler, more flexible and easier to automate.

Carbon dioxide feed was automatically controlled to achieve a pH of 7.3, as shown in Figure 9. Near 100% efficiency is possible due to the very fine bubbles produced and the high driving force between the caustic sludge and the carbonic acid. At pH values below 7.3 the reaction has essentially gone to completion resulting in the loss of carbon dioxide to the atmosphere. The carbon dioxide bubbles cause foaming which is greatly accentuated by the slightly surface active organic color released from the sludge on carbonation. This foaming serves as a good indicator of excess carbonation and can be used for visual pH control of the process.

## MELBOURNE FULL SCALE STUDIES

Both Montgomery and Melbourne presently use the conventional alum water treatment process; however, the raw waters treated vary drastically in chemical and physical characteristics. Table 5 illustrates typical ranges in raw water characteristics for Melbourne's Lake Washington water.

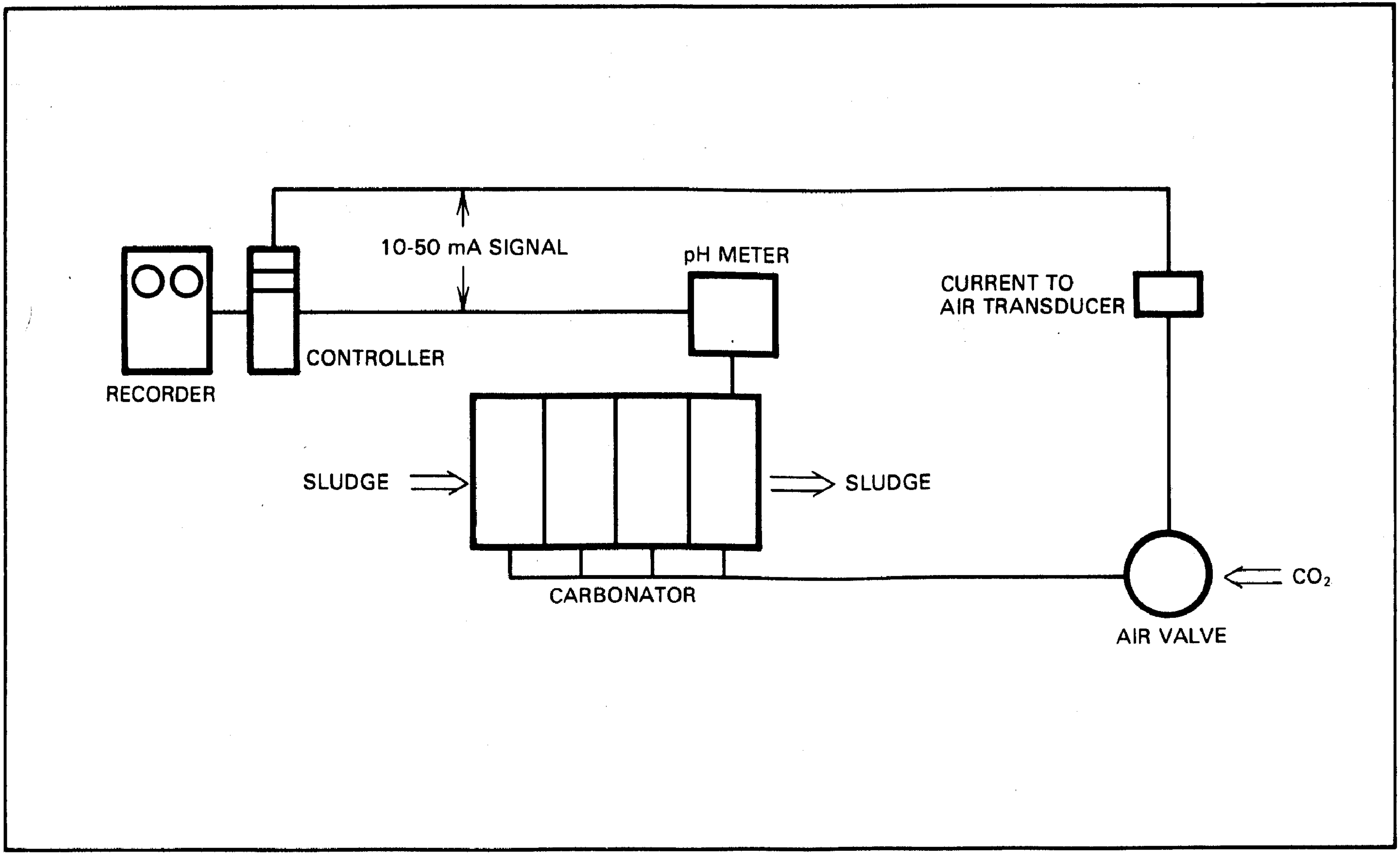


FIGURE 9. SLUDGE CARBONATION pH CONTROL SYSTEM - MONTGOMERY

## TABLE 5. TYPICAL RANGE IN RAW WATER CHARACTERISTICS LAKE WASHINGTON, MELBOURNE, FLORIDA

| pH | Alkalinity (mg/l) | Hardness (mg/l) (As $CaCO_3$) | Magnesium (mg/l) | Color (mg/l) (Pt-Co) | Turbidity (mg/l) (JTU) |
|---|---|---|---|---|---|
| 6.8-7.8 | 25-100 | 40-200 | 6-50 | 60-300 | [a] |

[a] Normally zero, but under severe storm conditions can increase to 30-50 JTU.

The chemical and physical characteristics of Lake Washington water are consistent on a daily basis. The water during the seasonal "dry" period is much harder and lower in organic color than during the "wet" season.

Montgomery typically uses from 20 to 30 mg/l of alum, coagulating in the pH range of 6.0 to 7.0. Melbourne uses as much as 130 mg/l of alum with coagulation in the pH range of 5.1 to 5.3. In addition, due to the high dissolved organics in the Melbourne water, high dosages of activated carbon are required along with large dosages of chlorine added to the finished water. Thus, while both plants would be termed "alum treatment plants", they represent different types of raw waters and treatment considerations.

## PLANT PHYSICAL FACILITIES

Figure 10 is a layout of the Melbourne water plant converted to include the magnesium process in half of the plant. The Melbourne plant facilities differed from the Montgomery facilities primarily in that:

1. Vertical flocculators were used versus the Montgomery horizontal flocculators.
2. Upflow clarifiers designed for an overflow rate of .5 gallons/sq.ft./minute versus six (6) hour retention horizontal, settling basins in Montgomery.

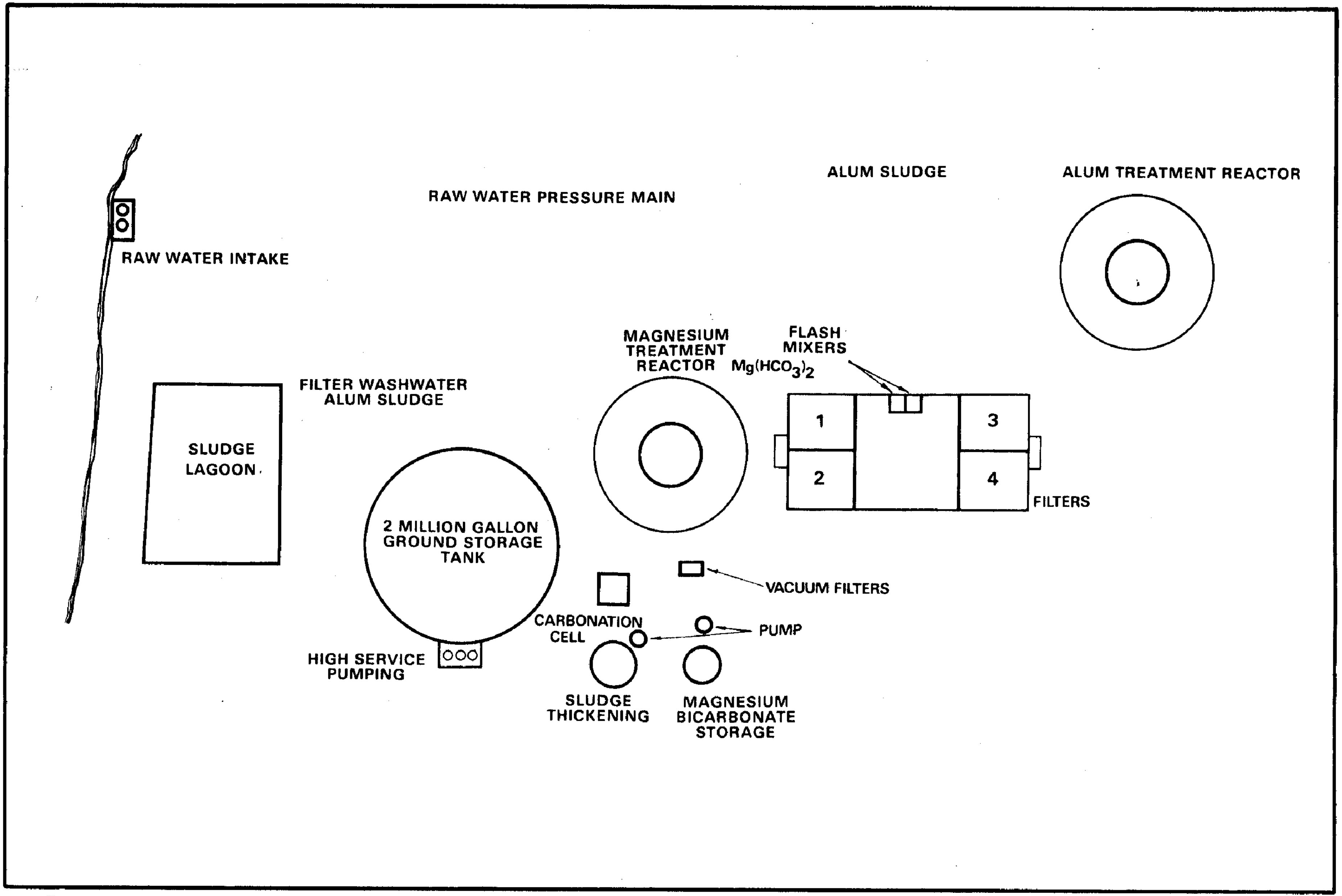


FIGURE 10. LAYOUT OF MELBOURNE WATER PLANT CONVERTED TO INCLUDE THE MAGNESIUM PROCESS

3. Manual feed of carbon dioxide and lime was provided at Melbourne.
4. Melbourne was provided with single stage finished water stabilization versus two stage stabilization at Montgomery.

The carbonation cells, thickener, recycle pumps, vacuum filter, and other miscellaneous equipment were shipped from Montgomery to Melbourne, so that little change was made in the magnesium recovery and recycle system. Melbourne's North Water Treatment Plant is constructed on a small hill. This elevation differential was used advantageously in the study to minimize pumping and to utilize gravity flow where possible.

A coagulant aid, either Dow AP30 or American Cyanamid 845A, both high molecular weight anionic polymers was added to the flocculator in very dilute solution. Typical dosages ranged from 0.1 to 0.3 mg/l.

## PROJECT LIMITATIONS

The conversion of both plants was accomplished with a very limited budget on a temporary basis. This resulted in excessive mechanical down-time, particularly in Montgomery, and excessive labor requirements, generally in the early project stages.

In Melbourne, an unavoidable limitation was that 1973 was a "wet" year and the raw water hardness did not increase in the Fall as expected. Past records indicated that both a very soft, high-colored water and a hard, moderately-colored water would be treated during the project period. The "soft", highly-colored water treated during the entire project proved, as expected from previous laboratory studies, to be both the most challenging and expensive to treat. This as important to the overall evaluation program since during dry years, such as 1971, the water is hard most of the year.

# SECTION V

# RESULTS AND DISCUSSIONS

## PILOT PLANT STUDIES

Pilot studies were conducted in Montgomery, Alabama from November, 1971 until October 1972 using the facilities discussed in Section IV. Initial operation evaluated the use of liquid alum as a coagulant to compare the pilot plant performance with the full scale plant operation. It was found that only 10 gpm of raw water could be treated with alum without excessive floc carryover to the filters. These studies were conducted over a two week period.

The pilot plant system was thoroughly flushed and the magnesium process placed into operation. Operation was conducted initially on an intermittant daily basis; however, continuous operation was soon undertaken. Studies were initially undertaken for each of the various operations or processes involved, such as sludge carbonation, clarification, finished water stabilization, etc. Although all units were operating, data collection and special attention were given only to the specific process under study.

After each portion of the water treatment system had been studied and adjustments made as required, the pilot plant was operated as an integral system.

## PILOT PLANT OPERATION

The pilot plant was typically operated treating raw water at the rate of 25 to 50 gpm. During normal daylight hours supervision was continuous. At night, water plant operators would hourly inspect the mechanical equipment, perform the necessary analyses and make the necessary chemical feed adjustments.

The sources and sinks of magnesium are extremely important in determining optimum process operating conditions. The sources of magnesium include the magnesium present in the raw water as well as any magnesium added. The sinks include magnesium losses in the dewatered sludge and magnesium present in the treated water. The magnesium loss in the finished water is largely affected by the pH of coagulation although finely divided magnesium hydroxide floc present as clarifier carry-over will be dissolved on stabilization. The relationship between magnesium solubility as a function of pH is illustrated in Figure 11 for theoretical, jar test, and pilot plant conditions.

Table 6 illustrates typical data collected and operating conditions. Calcium carbonate turbidity, either carryover from clarification or formed during pH adjustment, was found to be completely removed by filtration without causing unduly short filter runs. In order to better evaluate process performance it was desirable to distinguish between true turbidity, the type found in the raw water, and calcium carbonate turbidity. This is referred to as acidified turbidity. Levels of less than 1.0 FTU were commonly experienced.

Table 7 illustrates the effect of drastically changed raw water quality on both the alum and magnesium process. At a constant magnesium dosage of 50 mg/l and coagulation pH of 11.3, the pilot plant produced a high quality product with almost no supervision. The alum process was upset by the change in raw water quality, even with constant supervision.

## DISINFECTION STUDIES

The effect of high pH on bacterial and virus survival has been well documented by other investigations.[12,13,14] Limited studies were conducted to verify the effect of high pH

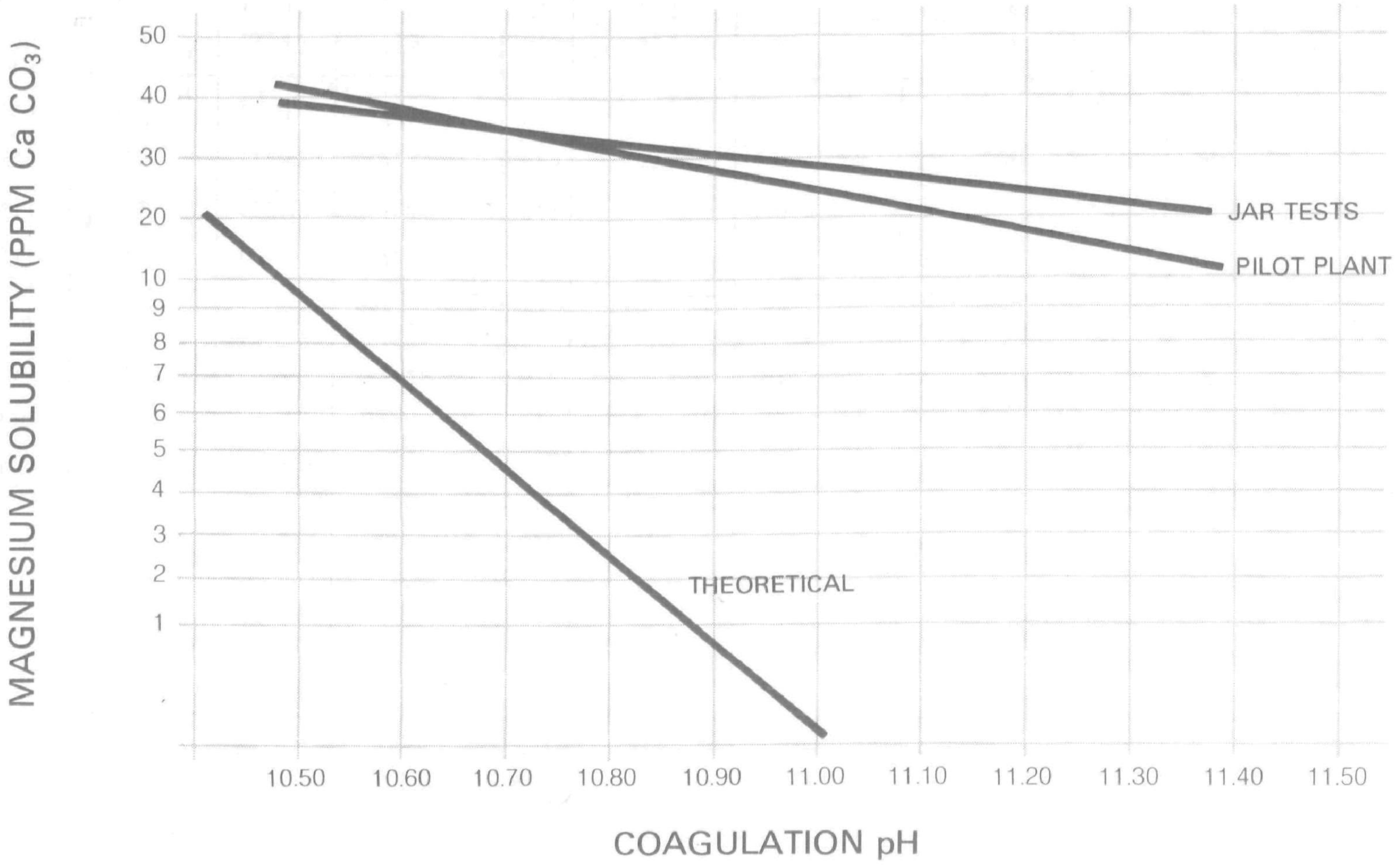


**FIGURE 11. COMPARISON OF THEORETICAL SOLUBILITY OF Mg $(OH)_2$ WITH OBSERVED JAR TEST AND PILOT PLANT VALUES**

TABLE 6. TYPICAL PILOT PLANT RESULTS

(Analyses performed each hour, averages shown)

| Date/ Time | Raw Turbidity (FTU) | Coagulation pH | Carbonated Sludge pH | Stabilized Water |  |  |  |  | Filtered Magnesium |  |  | Filtered Alum Water Turbidity (FTU) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | pH | Turbidity (FTU) | Acid Turb. (FTU) | Alkalinity $CO_3^=$ | $HCO_3^-$ | Turb. (FTU) | Alkalinity $CO_3^=$ | $HCO_3^-$ |  |
| 8/14<br>1200 |  | 11.4 |  | 7.1 | 0.6 | 0.4 | 0 | 144 |  |  |  |  |
| 1800 | 5.1 | 11.3 | 7.38 | 8.2 | 0.5 | 0.3 | 32 | 118 | .08 | 0 | 121 | .30 |
| 8/15<br>0030 | 4.7 | 11.3 | 7.16 | 7.9 | 0.6 | 0.4 | 0 | 107 | .06 | 0 | 108 | .24 |
| 0630 | 5.3 | 11.3 | 7.05 | 7.9 | 1.9 | 0.2 | 0 | 109 | .05 | 0 | 101 | .17 |
| 1200 | 3.5 | 11.3 | 7.10 | 9.0 | 0.8 | 0.5 | 32 | 117 | .05 | 0 | 117 | .05 |
| 1800 | 5.6 | 11.2 | 7.21 | 8.5 | 1.0 | 0.3 | 26 | 112 | .05 | 0 | 110 | .05 |
| 8/16<br>0000 | 4.7 | 11.3 | 7.91 | 7.9 | 0.6 | 0.3 | 0 | 92 | .05 | 0 | 90 | .07 |
| 0630 | 5.4 | 11.2 | 7.20 | 7.9 | 0.9 | 0.6 | 0 | 87 | .06 | 0 | 85 | .08 |
| 1200 | 4.9 | 11.3 | 7.28 | 8.2 | -- | 1.0 | 56 | 87 | -- | 0 | 97 | .07 |
| 1800 | 4.3 | 11.1 | 6.21 | 8.4 | -- | 2.3 | 20 | 89 | -- | 12 | 94 | .09 |
| 8/17<br>0000 | 4.6 | 11.0 | 7.5 | 7.5 | -- | 1.3 | 0 | 77 | -- | 0 | 82 | .12 |
| 0600 | 5.2 | 11.1 | 7.4 | 7.7 | -- | 0.8 | 16 | 66 | .07 | 0 | 82 | .09 |
| 1200 | 4.6 | 11.3 | 7.3 | 8.5 | 3.3 | -- | 0 | 61 | .08 | 0 | 60 | .06 |
| 1800 | 5.0 | 11.3 | 7.2 | 8.8 | 5.8 | -- | 19 | 63 | .07 | 0 | 75 | .06 |
| 8/18<br>0000 | 5.2 | 11.4 | 7.2 | 8.3 | 5.5 | -- | 20 | 74 | .06 | 0 | 81 | .12 |
| 0630 | 3.9 | 11.4 | 7.4 | 7.7 | 6.5 | -- | 0 | 81 | .06 | 0 | 95 | .05 |

## TABLE. 7. PILOT PLANT RESULTS DURING RAPID RAW WATER QUALITY DETERIORATION

(Analyses performed each hour, averages shown)

| Date/ Time | Raw Turbidity (FTU) | Coag-ulated pH | Carbonated Sludge pH | Stabilized Water | | | | | Filtered Magnesium | | | Filtered Alum Water Turbidity (FTU) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | pH | Turbidity (FTU) | Acid Turb. (FTU) | Alkalinity $CO_3^{=}$ | Alkalinity $HCO_3^-$ | Turb. (FTU) | Alkalinity $CO_3^{=}$ | Alkalinity $HCO_3^-$ | |
| 7/31 | | | | | | | | | | | | |
| 1100 | 40 | 11.2 | 7.1 | 9.2 | 1.8 | 0.5 | 16 | 78 | 0.10 | 0 | 84 | 2.00 |
| 1300 | 32 | 11.2 | 7.2 | 9.2 | 1.5 | 0.5 | 24 | 74 | --- | 12 | 74 | --- |
| 1500 | 36 | 11.2 | 7.6 | 9.6 | 3.5 | --- | 44 | 44 | 0.06 | 28 | 32 | >3.00 |
| 1700 | 53 | 11.1 | 7.5 | 9.3 | 2.4 | 0.5 | 24 | 60 | --- | 8 | 52 | --- |
| 1900 | 75 | 11.1 | 7.4 | 8.4 | 1.5 | 0.4 | 8 | 68 | 0.05 | 4 | 68 | > 3.00 |
| 2100 | 200 | 11.1 | 7.5 | 7.5 | 1.4 | --- | 0 | 76 | --- | 0 | 82 | --- |
| 2300 | 245 | 11.1 | 7.5 | 7.2 | 1.4 | 0.6 | 0 | 74 | 0.15 | 0 | 66 | 3.00 |
| 8/1 | | | | | | | | | | | | |
| 100 | -- | 11.2 | 7.5 | 7.3 | 1.3 | --- | 0 | 68 | --- | 0 | 76 | --- |
| 300 | -- | 11.2 | 7.5 | 7.3 | 1.4 | 0.5 | 0 | 76 | --- | 0 | 70 | --- |
| 500 | -- | 11.2 | 7.5 | 9.5 | 3.0 | --- | 45 | 48 | 0.10 | 0 | 72 | 2.80 |
| 700 | 55 | 11.2 | 7.5 | 9.5 | 2.0 | 1.0 | 46 | 48 | --- | 28 | 28 | --- |
| 900 | 55 | 11.3 | 7.4 | 9.8 | 3.2 | --- | 64 | 38 | --- | 28 | 36 | --- |
| 1100 | 50 | 11.0 | 7.4 | 9.7 | 2.8 | --- | 52 | 38 | 0.22 | 32 | 38 | 2.00 |
| 1300 | 45 | 10.7 | 7.3 | 7.7 | 1.4 | 0.3 | 0 | 82 | 0.31 | 10 | 78 | --- |
| 1500 | -- | 10.7 | 7.3 | 7.4 | 1.0 | 1.0 | 0 | 76 | 0.28 | 0 | 85 | 1.00 |
| 1700 | 40 | 10.7 | 7.4 | 7.2 | 1.7 | --- | 0 | 82 | --- | 0 | 92 | --- |
| 1900 | 40 | 10.7 | 7.4 | 7.3 | 3.9 | 1.5 | 0 | 74 | 0.40 | 0 | 84 | --- |
| 2100 | 40 | 10.9 | 9.8 | 7.2 | 2.7 | 1.6 | 0 | 72 | --- | 0 | 78 | --- |
| 2300 | 54 | 11.0 | 10.4 | 7.1 | 3.0 | 1.2 | 0 | 74 | 0.30 | 0 | 78 | 1.00 |

on coliform survival. In general, these studies consisted of adding various $Ca(OH)_2$ dosages to 1 liter jars of raw water to obtain a pH range of 10.5 to 11.7. Samples were collected from each jar at predetermined time intervals and analyzed for total coliform organisms. A summary of these laboratory studies is shown in Figure 12. Table 8 includes all laboratory coliform disinfection experiments.

The raw water source for the pilot plant was obtained prior to pre-chlorination. When operating at 50 gpm a hydraulic retention time of approximately two hours allowed complete disinfection of coliform organisms when coagulation at a pH above 11.0.

It should be pointed out that while the high pH is effective, it is not nearly as effective as free chlorine at the normal pH range of raw water. A pre-chlorine dosage of 1.5 mg/l resulted in complete disinfection with less than a 30 second contact time.

## SOLIDS HANDLING

This section of the report will be limited to sludge thickening and vacuum filtration. The pilot plant was used to generate sufficient solids for a thorough laboratory evaluation to develop design criteria and predict process performance.

Considerable data exists for thickening and filtering pure calcium carbonate slurries; however, data for clay-calcium carbonate slurries are limited. The higher the percentage of calcium carbonate present the more readily the sludge thickens and dewaters. The characteristics of the Montgomery raw water are such that the only calcium carbonate produced results from the recycle of magnesium bicarbonate. The ratio of calcium carbonate to clay will vary from summer to winter months as the turbidity in the raw water changes. The sludge produced in the treatment of Montgomery's water should represent the most difficult situation to be encountered.

TABLE 8. SUMMARY OF COLIFORM SURVIVAL LABORATORY STUDIES

Lab Studies - Montgomery, Alabama
(total coliform per 100 m.l.)

| | pH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Time (min.) | 10.6 | 10.8 | 10.9 | 10.95 | 11.2 | 11.3 | 11.4 | 11.45 | 11.5 |
| 0 | 900 | 400 | 900 | 400 | 400 | 900 | 1100 | 800 | 1100 |
| 3 | | | | | | | | 560 | |
| 5 | | 400 | | | 200 | | 300 | | 700 |
| 6 | | | | | | | | 360 | |
| 10 | | | | | | | 350 | 190 | 100 |
| 11 | | 150 | | 100 | 100 | | | | |
| 13 | 350 | | 100 | | | 50 | | | |
| 15 | | | | | | | 250 | | 150 |
| 20 | 80 | | 60 | 20 | 20 | 20 | 100 | 65 | |
| 30 | | | | | | | | | 20 |
| 40 | 15 | | 5 | 0 | 0 | 0 | | 18 | |
| 60 | | | | | | | 5 | | 0 |
| 80 | 3 | | 0 | | | | | | |

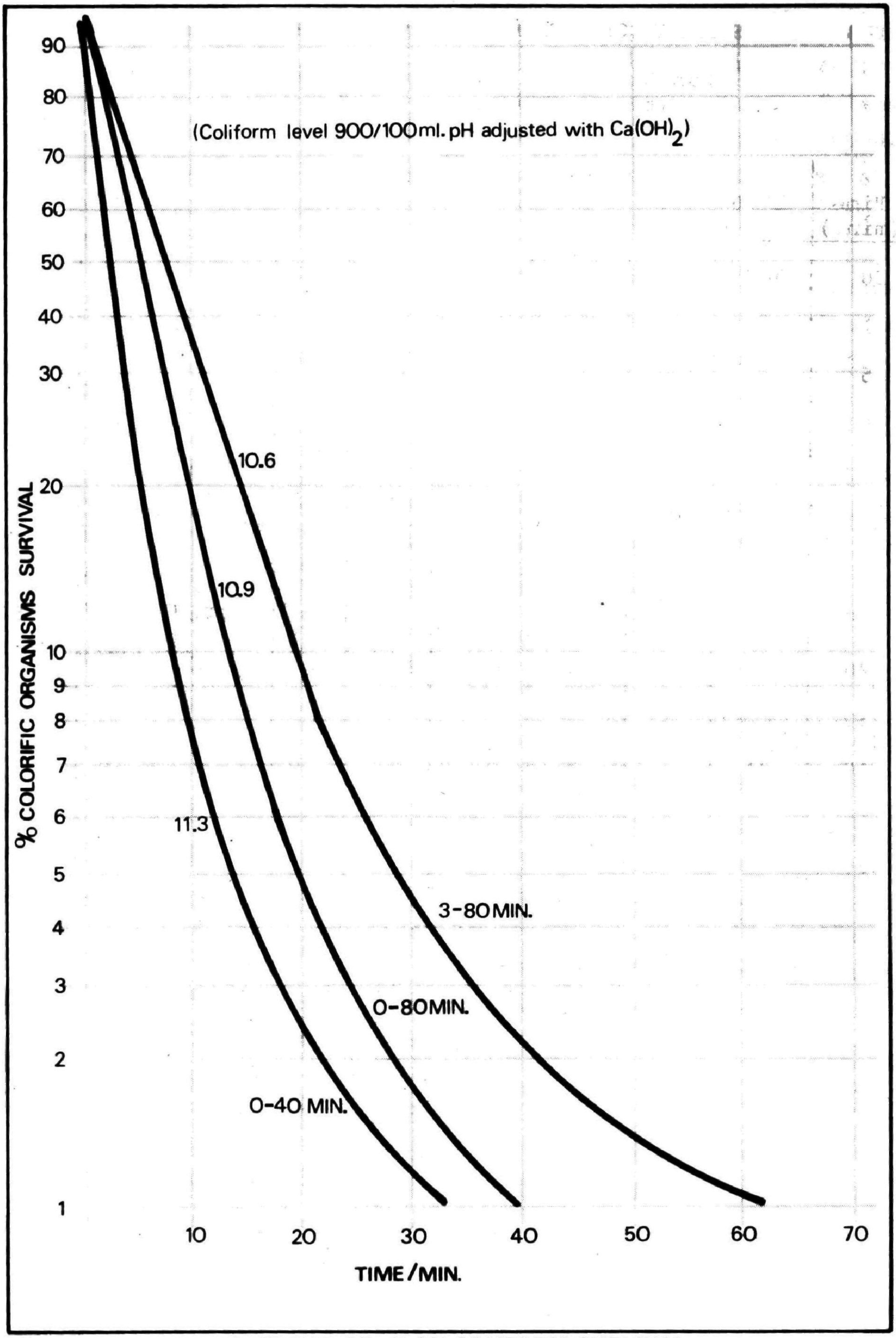


FIGURE 12. EFFECT OF pH ON COLIFORM SURVIVAL LABORATORY STUDIES

A number of bench scale thickening studies were performed during the pilot plant study. Figure 13 illustrates the relative differences between the thickening characteristics of the alum sludge and the carbonated pilot plant sludge.

The uncarbonated sludge thickened to a lesser degree due to the magnesium hydroxide present. The sludge concentration from the clarifier, however, exceeded 15% solids during most of the study period.

Leaf filter tests were run to determine design criteria for the full scale vacuum filter. A number of cloths were evaluated and a multi-filament, polypropylene, high air flow rate cloth was found most effective in producing a clear filtrate, high cake yield, and relatively clean cake discharge. Figure 14 summarizes a number of leaf filter tests and illustrates the effect of feed solids concentration on the filtration rate. During this study period, the sludge was composed of 70% calcium carbonate, 25% clay or inert content, and 5% magnesium hydroxide.

The thickener and vacuum filter design are obviously related. Each situation dictates an optimum design to minimize costs and labor requirements.

## COLOR REMOVAL STUDIES

Organic color release upon carbonation will not present a problem for the application of the magnesium process in Montgomery. However, for the more highly colored waters and in the treatment of certain colored industrial wastes, this could become a significant problem. Water plants treating high magnesium waters, producing magnesium carbonate as a by-product, also present a problem with the coloring of the magnesium carbonate. Thus, color removal prior to magnesium carbonate precipitation would increase the quality of the product. For these reasons, decolor-

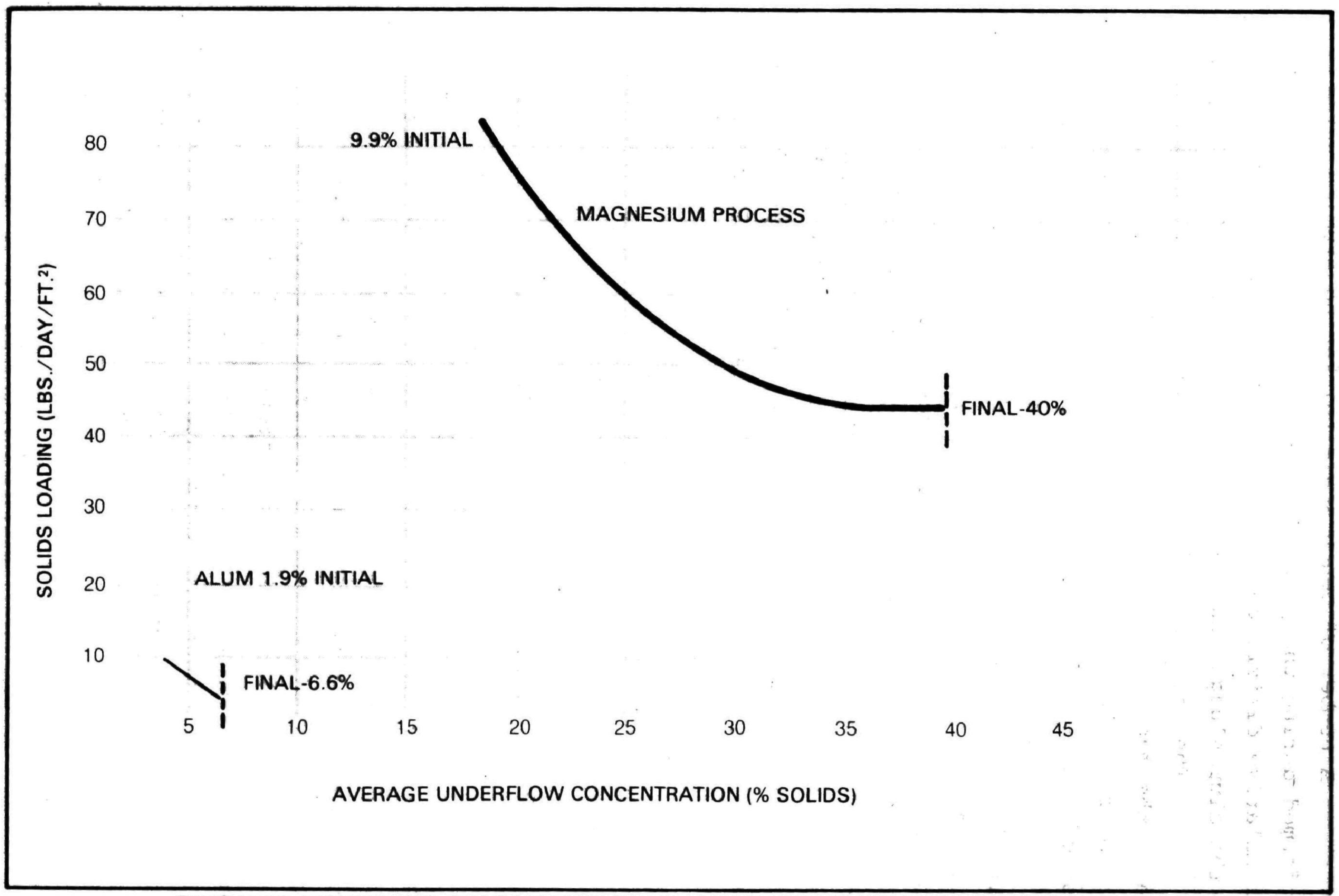


FIGURE 13. THICKENING CHARACTERISTICS OF ALUM AND MAGNESIUM STUDIES

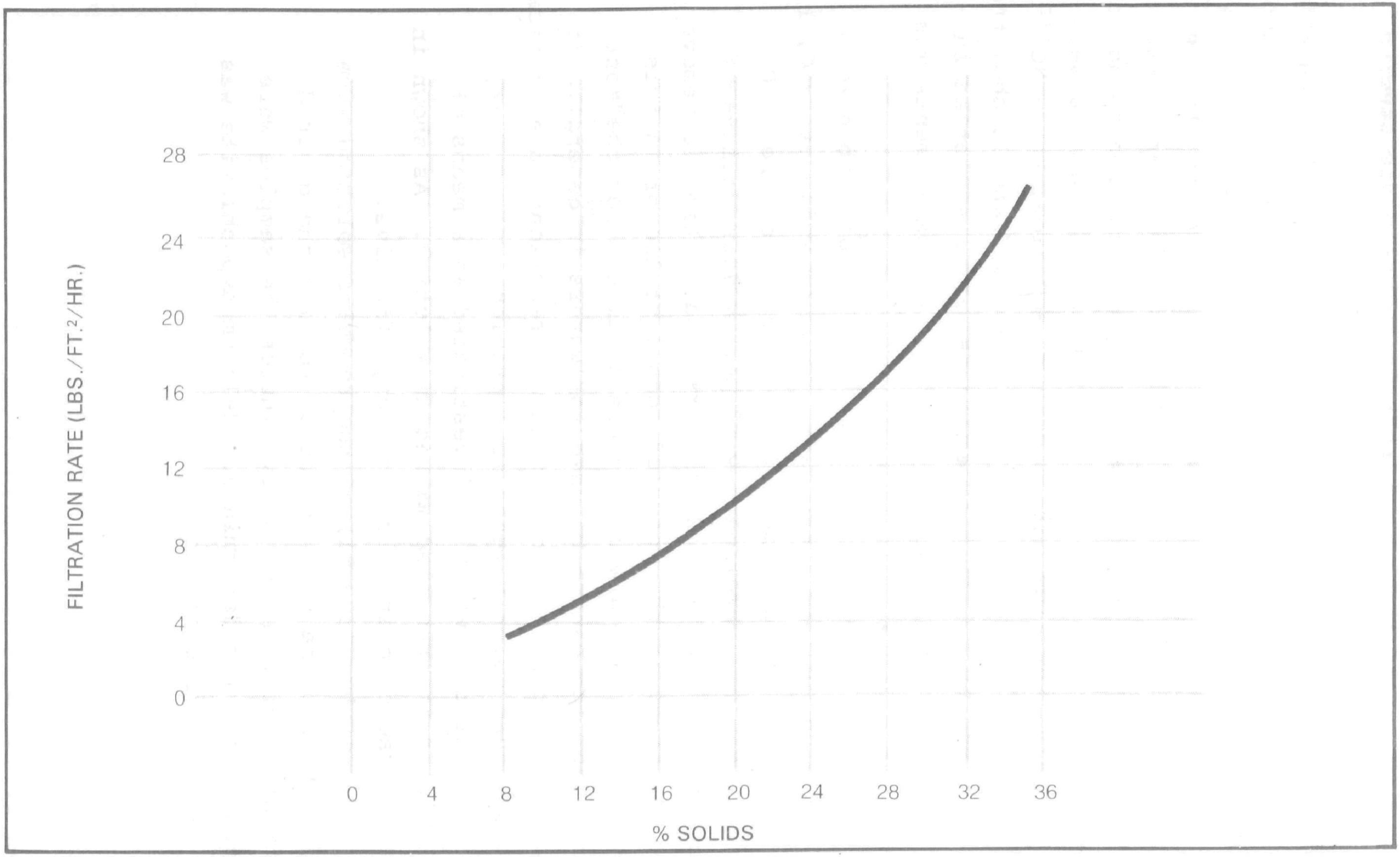


FIGURE 14. % SLUDGE SOLIDS VERSUS VACUUM FILTER RATE – MONTGOMERY

ization of the magnesium bicarbonate solution was studied using activated carbon.

Powdered FILTRASORB #400 carbon (by Pittsburg Activated Carbon) was used in this study. The studies were conducted on a batch basis maintaining constant temperature by means of a water bath. Average magnesium bicarbonate contrations of 6,000 mg/l as calcium carbonate were present in the solution tested with no magnesium reduction found as a result of the color adsorption. The resulting data were plotted using the Fruendlich isotherm equation, $X/M = KC^{1/n}$, to obtain the adsorptive capacity. Tables 9 and 10 show the data obtained in two such experiments and are plotted in Figure 15. The only variable in these two experiments was temperature.

At a temperature of 35°C, 1 gram of carbon would completely decolorize 3,600 ml of solution while at 22°C, 1 gram would only decolorize 1,200 ml. Based on the 35°C figure a cost of approximately $2 per million gallons of water treated is estimated for carbon adsorption to remove the color found in the recycled coagulant liquor in this study. These costs are only crude estimates for the Montgomery water and cannot be used for waters in general. It would seem that carbon adsorption may represent an economical solution where color release is a problem.

Chlorine was also investigated as a means of decolorizing the recycled magnesium solution. As shown in Table 11, the chlorine was also very effective.

Samples (100 ml) of the recycled solution were dosed with chlorine stock solution to give the desired treatment levels. After sixty minutes the samples were filtered and color determined. Calcium hypochlorite was used as a chlorine source.

TABLE 9. CARBON ADSORPTION OF RELEASED ORGANIC COLOR (Temperature = 22°C, 200 ml of solution used and contact time of 20 minutes)

| (M) Carbon (grams) | (C) Residual Color | (X) Adsorbed Color (grams) | X/M |
|---|---|---|---|
| Blank | 550 | 0 | |
| .1 | 282 | 268 | 2680 |
| .2 | 124 | 436 | 2180 |
| .3 | 68 | 482 | 1606 |
| .4 | 36 | 514 | 1285 |
| .5 | 23 | 527 | 1054 |

TABLE 10. CARBON ADSORPTION OF RELEASED ORGANIC COLOR (Temperature = 35°C, 200 ml of solution used)

| (M) Carbon (grams) | (C) Residual Color | (X) Adsorbed Color (grams) | X/M |
|---|---|---|---|
| Blank | 425 | 0 | |
| .1 | 130 | 295 | 2950 |
| .2 | 91 | 334 | 1670 |
| .3 | 50 | 375 | 1250 |
| .4 | 38 | 387 | 967 |
| .5 | 33 | 392 | 784 |

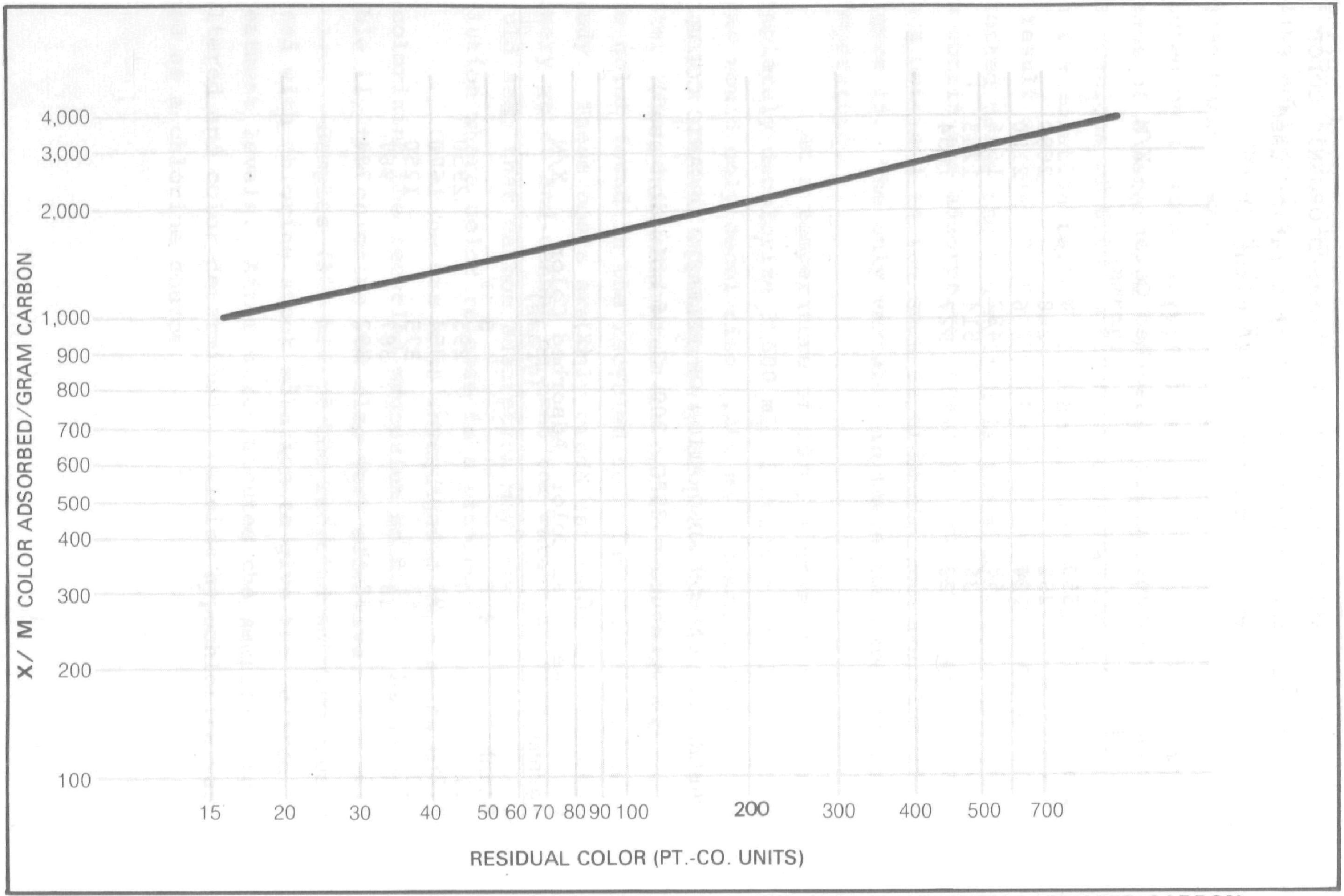


FIGURE 15. FRUENDLICH ISOTHERM FOR CARBON ADSORPTION OF ORGANIC COLOR WITH ACTIVATED CARBON

TABLE 11. USE OF CHLORINE TO REDUCE ORGANIC COLOR

| Chlorine (mg/l) | Original Color (Pt-Co) | Residual Color (after 60 minutes) | % Removal |
|---|---|---|---|
| 50 | 647 | 202 | 69 |
| 100 | 616 | 103 | 83 |
| 150 | 591 | 63 | 90 |
| 200 | 566 | 55 | 91 |
| 250 | 544 | 53 | 91 |

## CADMIUM STUDY

The effectiveness of this new process in the removal of heavy metals was studied in both jar tests and in the pilot plant. Cadmium was chosen because of its easy and accurate determination by atomic adsorption as well as for the fact that it would likely be solubilized at a pH of 7.0, the pH of sludge carbonation. The results of jar tests are shown in Tables 12, 13 and 14.

TABLE 12. EFFECTIVENESS OF ALUM IN REMOVING CADMIUM

| Alum Dosage (ppm) | Cadmium Residual (mg/l) |
|---|---|
| 5 | 1.04 |
| 7 | 1.09 |
| 9 | 1.09 |
| 11 | 1.10 |
| 13 | 1.07 |

Initial cadmium level - 1.1 mg/l
Comments - Good floc formed in all jars

## TABLE 13. EFFECTIVENESS OF LIME IN REMOVING CADMIUM FROM WATER IN JAR TESTS[a]

| Lime Dosage (ppm) | pH | Cadmium Residual (mg/1) |
|---|---|---|
| 40 | 10.65 | 0.73 |
| 50 | 10.70 | 0.81 |
| 60 | 10.95 | 0.72 |
| 80 | 11.10 | 0.71 |
| 100 | 11.25 | 0.60 |
| 120 | 11.30 | 0.60 |

[a] 1.0 mg/l cadmium present in raw water.

## TABLE 14. EFFECTIVENESS OF MAGNESIUM HYDROXIDE IN REMOVING CADMIUM FROM WATER IN JAR TESTS

| Magnesium Precipitated (mg/1) | Cadmium Residual (mg/1) | % Removal |
|---|---|---|
| 2.9 | .36 | 58 |
| 7.5 | .15 | 82 |
| 13.4 | .05 | 94 |
| 21.4 | .02 | 98 |
| 31.4 | .01 | 99 |
| 42.2 | .01 | 99 |

Reagent grade cadmium chloride was used as a source of cadmium in all studies. Samples taken after settling were filtered through Whatman #40 paper prior to analysis. Unfiltered samples taken during the study reported in Table 15 showed similar removals.

During pilot plant studies cadmium chloride was added continously to the raw water for a period of ten days. The magnesium and lime dosage was 40 and 100 mg/l respectively. The raw water cadmium level ranged from 0.75 to 1.0 mg/l. The settled water ranged from 0.003 to 0.007 mg/l and the filtered water ranged from 0.000 to 0.005 mg/l of cadmium. Table 14 summarizes the analytical results.

Cadmium was not released in any appreciable amounts on carbonation regardless of the pH to which carbonation was carried. A pH range of 6.8 to 7.7 generally resulted in a cadmium concentration of 0.1 mg/l or less in the recycled magnesium bicarbonate solution.

## FILTRATION STUDIES

Two identical 1.5 square foot pilot filters with continuous turbidity monitoring equipment were made available to the project by the Taulman Company, Atlanta, Georgia. Combinations of sand and various sized anthracite media were evaluated as to water quality produced and operating characteristics. Initial studies compared the filterability of the alum treated water, piped from the full scale plant, with the stabilized magnesium treated water. Later studies were made using the proper stabilization pH, type media, and depths of sand anthracite required.

These studies allowed the following conclusions:

1) Filtration efficiency is directly related to

## TABLE 15. PILOT PLANT RESULTS - CADMIUM STUDY

(Cadmium concentration - ppm mg/l)

| Date/ Time | Raw Water | Carbonate Sludge | Clarified Water | Filtered Water |
|---|---|---|---|---|
| 7/20: | | | | |
| 1400 | 0.92 | -- | -- | -- |
| 1600 | 0.75 | -- | -- | -- |
| 7/21: | | | | |
| 0930 | 0.94 | -- | 0.005 | 0.005 |
| 1300 | 1.00 | -- | 0.007 | 0.005 |
| 1510 | 0.78 | -- | 0.003 | 0.000 |
| 7/25: | | | | |
| 1300 | 0.80 | -- | 0.030 | 0.00 |
| 1500 | 0.81 | -- | 0.030 | 0.00 |
| 1610 | 0.82 | -- | -- | 0.00 |
| 7/26: | | | | |
| 0830 | 0.55 | 0.12 | 0.030 | 0.00 |
| 1320 | 0.60 | -- | 0.060 | 0.003 |
| 1530 | -- | 0.12 | -- | 0.005 |
| 7/27: | | | | |
| 0930 | 0.87 | 0.14 | 0.060 | -- |
| 1415 | -- | 0.16 | 0.050 | -- |
| 1540 | 0.90 | 0.10 | 0.030 | -- |
| 7/28 | -- | 0.05 | -- | -- |

coagulation and clarification efficiency for both the alum and magnesium process. When proper pretreatment has not been accomplished, filtration will not provide adequate treatment.

2) The carryover of calcium carbonate will not shorten filter runs or reduce the quality of the filtered water.

3) In Montgomery, filtration of waters which had not been stabilized below pH 9.0 resulted in calcium carbonate precipitation on the anthracite and sand media. Precipitation occurred more rapidly and extensively on the sand. Extremely short filter runs were obtained under these conditions and the calcium carbonate formed could not be washed from the filter. These "balls" gradually worked their way into the gravel underdrain, eventually requiring acidification treatment of the filter. These studies provided a severe warning as to the necessity of adequately maintaining the proper stabilization pH in full scale operation.

4) Maximum filter runs were obtained with four inches of 1.2 mm anthracite media over twenty-four inches of standard filter sand. Increase in anthracite media depth did not increase filter performance either in length of filter run or water quality produced.

5) In general, two filter rates were studied, 2 and 3.5 gal./sq.ft./min. The higher rate on the average produced a slightly better water quality. It appeared that backwash requirements were essentially the same, based on percentage of the water

produced during the run.

6) The geometry of the pilot filters was such that backwashing was not equivalent to the full scale filters. Side wall friction was considerably higher, resulting in an unusual backwash pattern. Considerable care was required to prevent backwashing of media from the system. Backwash rates of 15 gal./sq.ft./min were not possible, so that some of the calcium found on the media could possibly have been removed at higher backwash rates.

7) Finished water stabilization appears to enhance filtration efficiency. Clarifier turbidity carryover serves as a nucleus for calcium carbonate precipitation, enlarging the particle size and changing the chemical-physical properties, increasing the opportunity for removal by filtration.

8) Calcium carbonate carryover to the filters does not shorten filter runs and can be easily removed on backwash. Calcium carbonate precipitation on the filter media drastically shortens filter runs and cannot be removed efficiently by backwashing.

## MONTGOMERY FULL SCALE STUDIES

From November 1972 until June 1973 full scale evaluation of the Magnesium Process was conducted in Montgomery. The Magnesium Process was found to compare favorably with the alum process in both overall operation and water quality produced.

During the study voluminous data were collected at many points of the process. Figure 16 illustrates a summary of process control points and a brief discussion as to

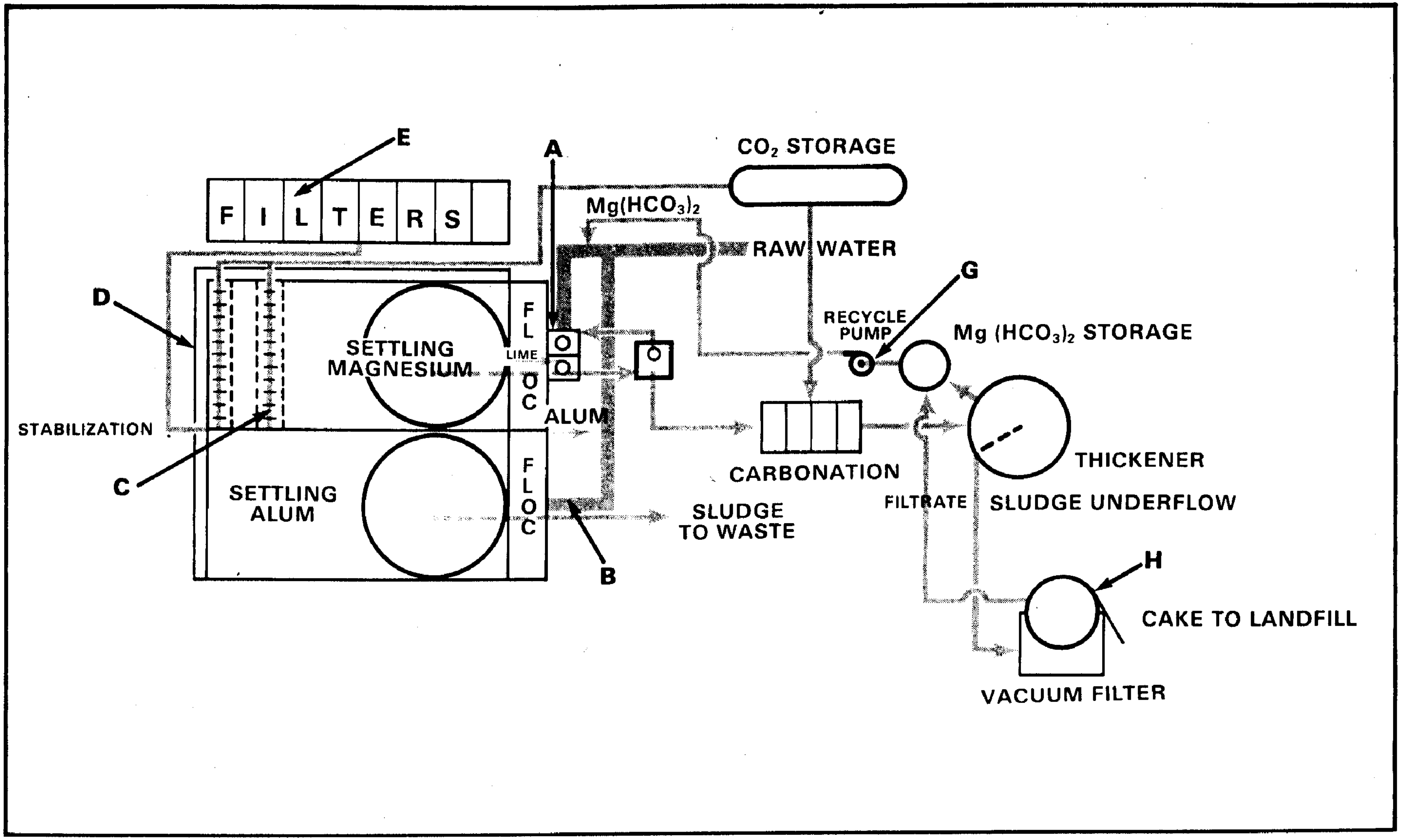


FIGURE 16. PROCESS CONTROL POINTS AND SAMPLING LOCATIONS — MONTGOMERY

which tests were performed are listed in Table 16. Data sheets to illustrate typical results are included in the Appendices under Appendix A.

The full scale studies found the magnesium coagulation system to be much more stable than the alum system, particularly in the coagulation process. Under certain raw water conditions, the alum coagulation pH must be maintained within ± 0.1 pH unit in order to treat the water satifactorily. Slight variance from the optimum pH results in greatly decreased coagulation efficiency. The low alkalinity water used by Montgomery has a very poor buffer capacity, particularly after the addition of alum when the alkalinity is seldom above 1 mg/l as $CaCO_3$. Slight changes in either pre-lime or alum feed can affect the coagulation pH to a large degree.

Automation of the lime feed and carbon dioxide feed for sludge carbonation proved to be very satisfactory. Control of both feeds are such that less than 0.1 pH from the desired pH occurs.

Recovery of magnesium as the bicarbonate was routinely carried out at a constant rate sufficient to provide the average coagulation requirements. When raw water conditions required additional magnesium feed, make-up magnesium sulfate was fed. After feeding make-up magnesium for a period of approximately twenty-four hours, increased magnesium content in the recovered solution eliminated the need for make-up magnesium.

Figure 17 illustrates the relationship between raw and settled turbidity as a function of time and magnesium dosage. These results indicate an important point. As the operators became more familiar with the process, a significant improvement in treatment efficiency was noted.

Figure 18 shows the total and magnesium hardness of the Montgomery stabilized water as a function of

# TABLE 16. CONTROL SYSTEMS AND SAMPLING LOCATION

A) Rapid Mixer #1. Total and calcium hardness were determined on a filtered sample from which the magnesium feed could be determined.

B) Rapid Mixer #2. Automatic pH control of lime feed.

C) Carbonation Point 1. pH measurement and manual control of $CO_2$ rotameter to maintain a pH of 10.3. When the pH is too low or too high, the water is clear indicating that calcium carbonate precipitation is not taking place.

D) Settled magnesium water flume. pH, turbidity, total hardness, calcium hardness, alkalinities, and acid turbidity were determined on a routine basis.

E) Filtered magnesium treated water - continuous turbidity monitoring along with alkalinities, pH, and hardness determined on a routine basis.

F) Carbonated Sludge - Automatic pH control of the carbon dioxide flow along with alkalinity titrations on a routine basis.

G) Recycled magnesium control system - alkalinities measurement and flow control.

H) Vacuum filter - filter rates, solids inflow, filtrate alkalinities, filter cake solids, and filter cake composition are determined on a routine basis.

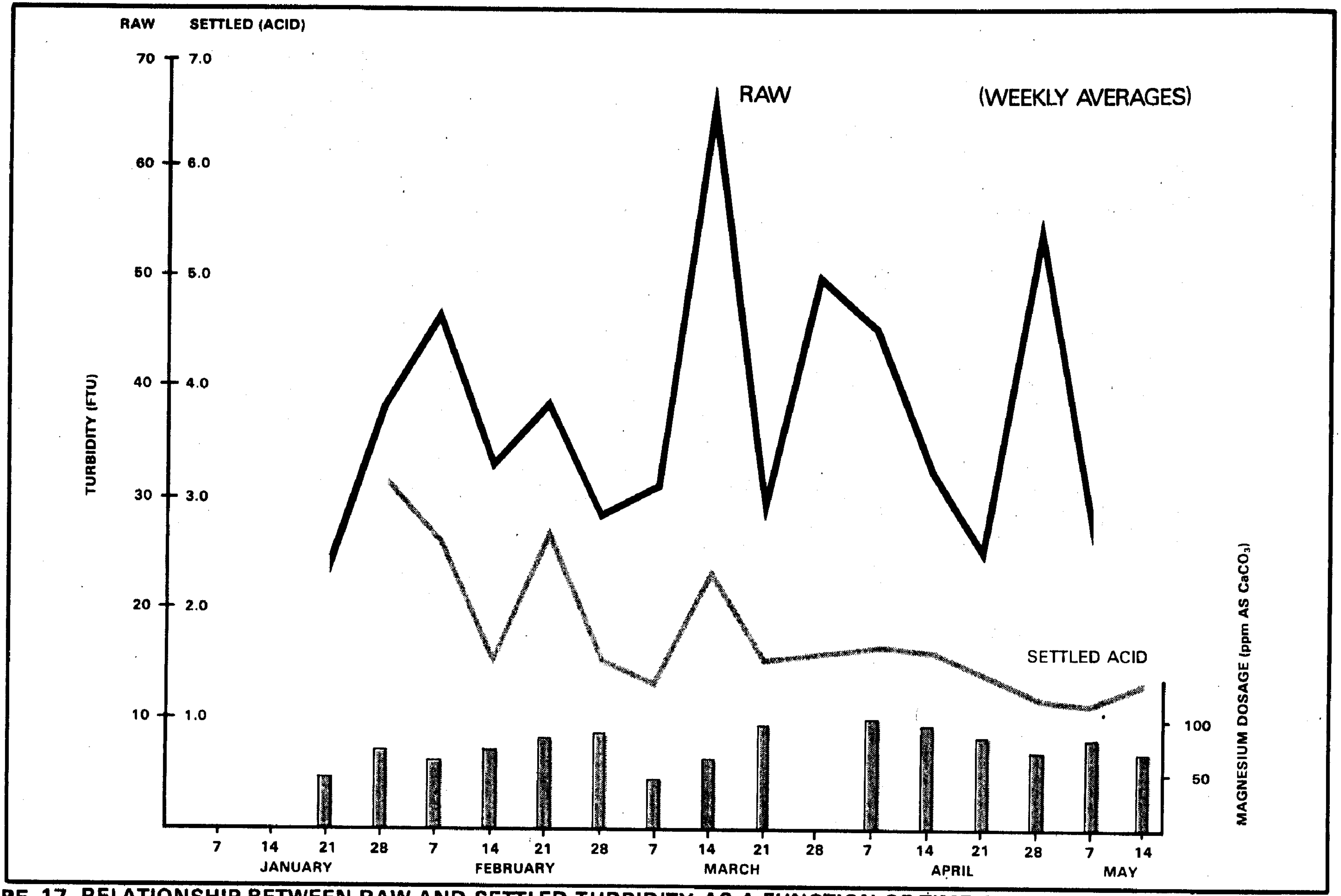


FIGURE 17. RELATIONSHIP BETWEEN RAW AND SETTLED TURBIDITY AS A FUNCTION OF TIME AND MAGNESIUM DOSAGE MONTGOMERY

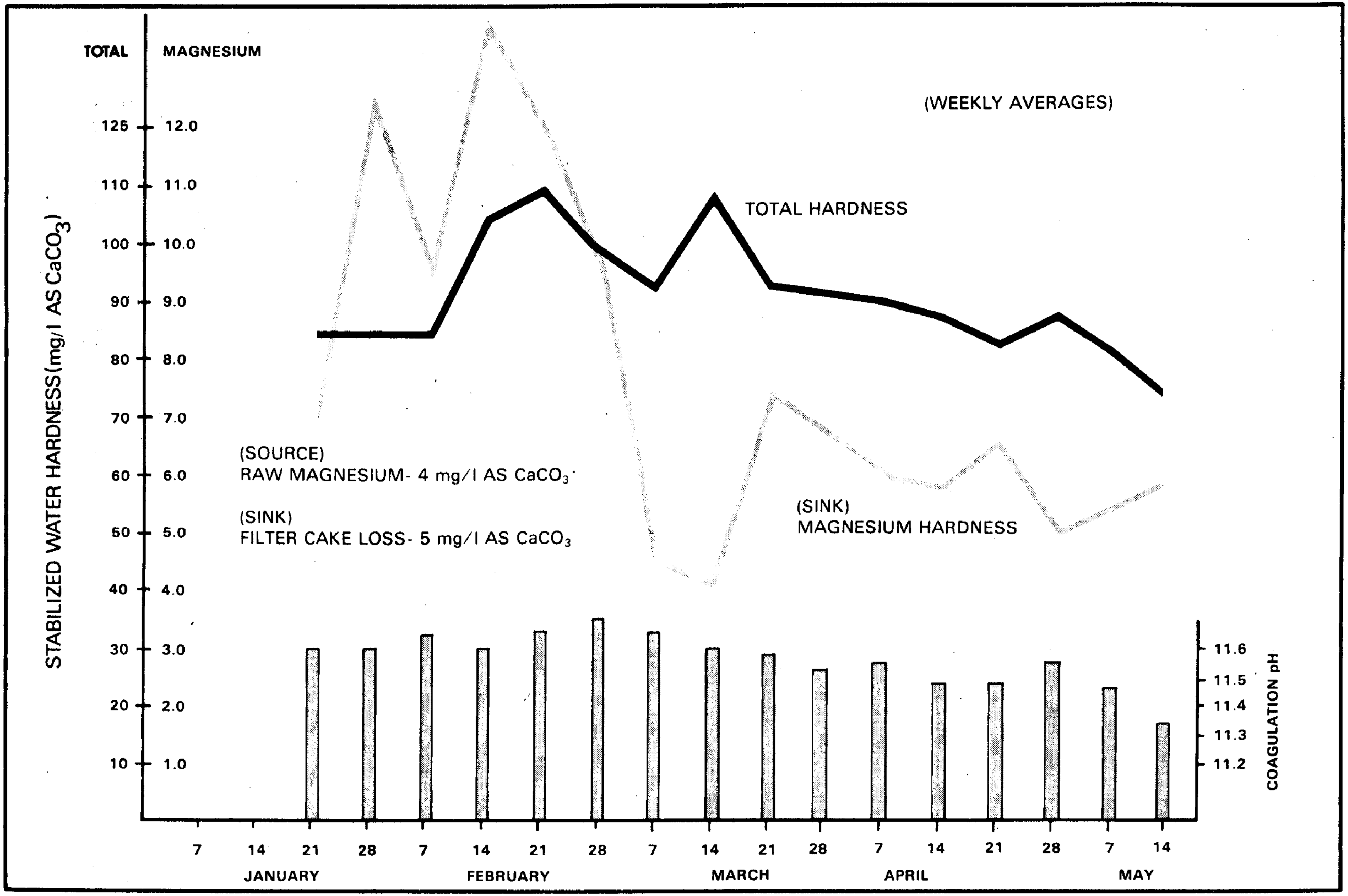


FIGURE 18. MONTGOMERY STABILIZED WATER - TOTAL AND MAGNESIUM HARDNESS

time and coagulation pH. An average total hardness of 82 mg/l as $CaCO_3$ was obtained during the study. A properly designed, two stage stabilization basin will produce a total carbonate hardness of less than 50 mg/l as $CaCO_3$.

## OPERATIONAL CHARACTERISTICS

As the degree of magnesium recovery affects the economic feasibility of the process, it is extremely important to account for all losses or gains in magnesium as previously discussed. The coagulation pH to a large extent controls the magnesium loss in the finished water.

Figure 19 illustrates the effect of coagulation pH on magnesium replacement costs for both magnesium sulfate and magnesium carbonate tri-hydrate. An average of 4 mg/l of magnesium as $CaCO_3$ is normally present in the raw water. As a result of the high magnesium content of the cake liquor, thirty pounds per day of magnesium, as $CaCO_3$ in the filter cake, are lost each day. As the coagulation pH increases less magnesium remains in the finished water, therefore, less make-up is required, decreasing the cost per million gallons for magnesium expressed as calcium carbonate.

Figure 20 illustrates the effect of increased coagulation pH on carbon dioxide and lime costs. Chemical costs are based on 50 mg/l of magnesium bicarbonate as calcium carbonate in recycle.

Figure 21 is a summation of Figures 19 and 20 and represents the total cost for magnesium, carbon dioxide, and lime as a function of coagulation pH. An optimum pH of 11.2 was found for the situation where magnesium carbonate trihydrate was used as the magnesium source with a total chemical cost of approximately $19.00 per million gallons. Using magnesium sulfate, an optimum pH slightly higher than 11.3

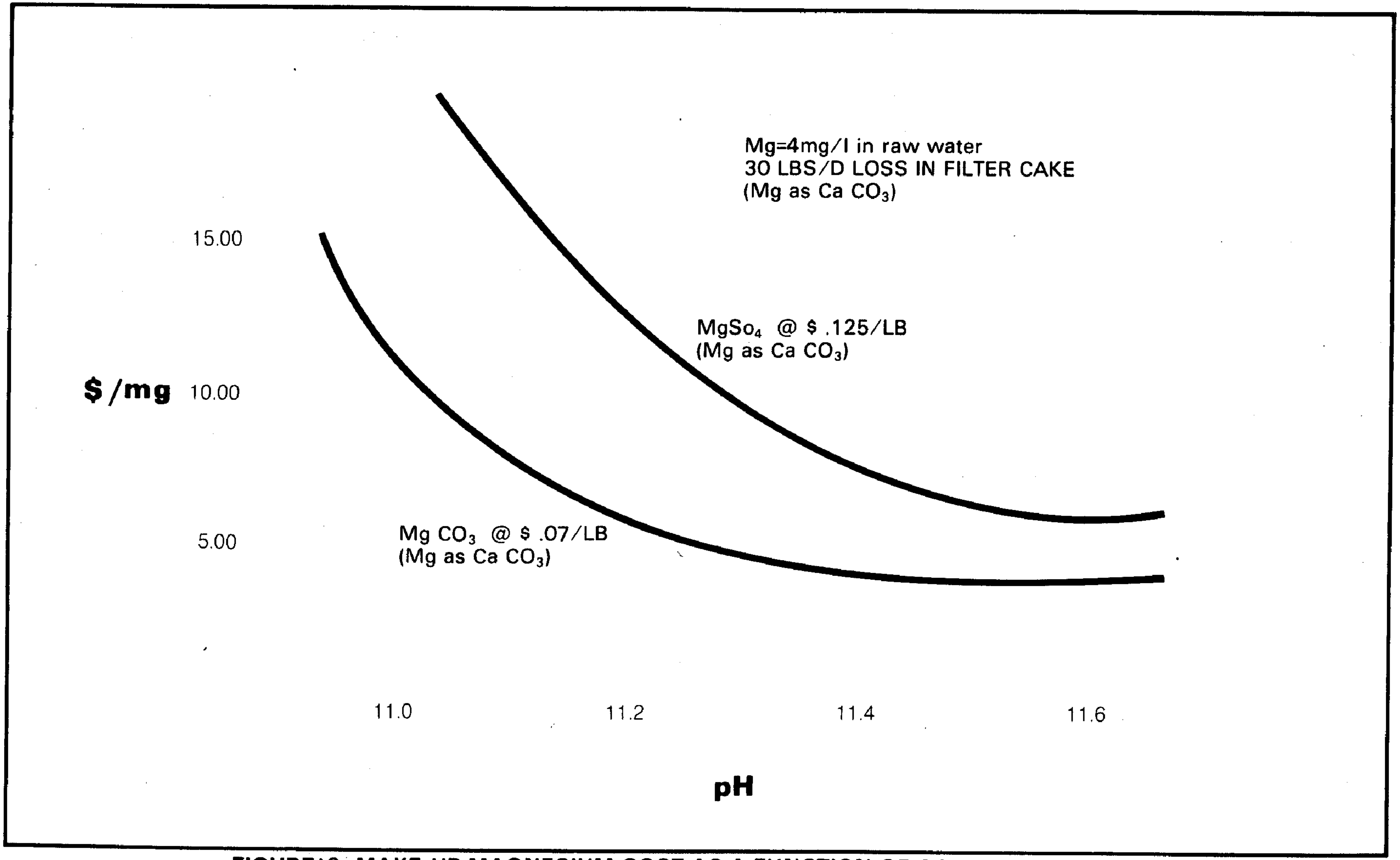


FIGURE 19. MAKE-UP MAGNESIUM COST AS A FUNCTION OF COAGULATION pH
MONTGOMERY

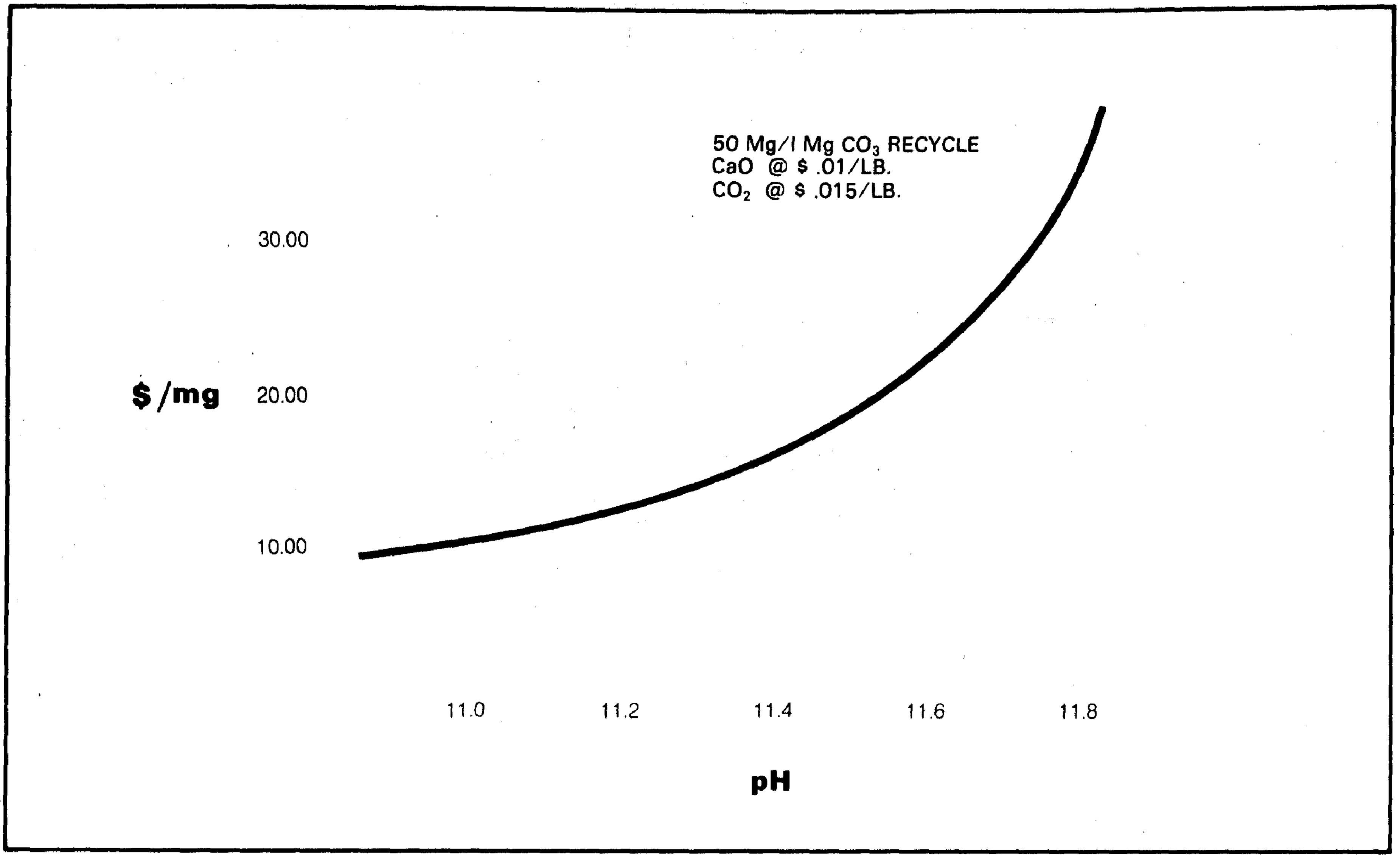


FIGURE 20. LIME AND $CO_2$ COSTS AS A FUNCTION OF COAGULATION pH MONTGOMERY

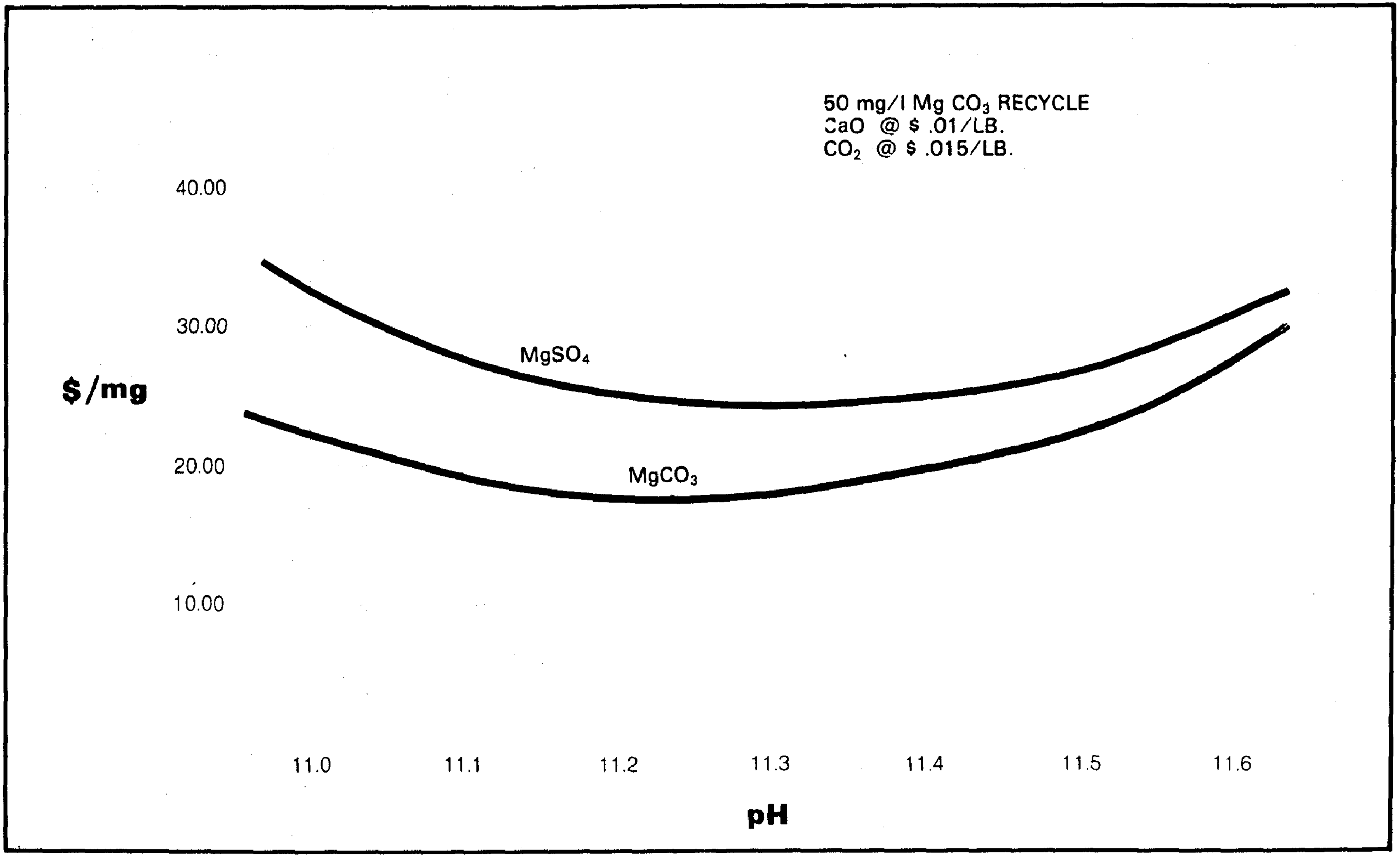


FIGURE 21. LIME, $CO_2$, AND MAGNESIUM TOTAL COST AS A FUNCTION OF COAGULATION pH MONTGOMERY

is found with a chemical cost slightly higher than $25.00 per million gallons.

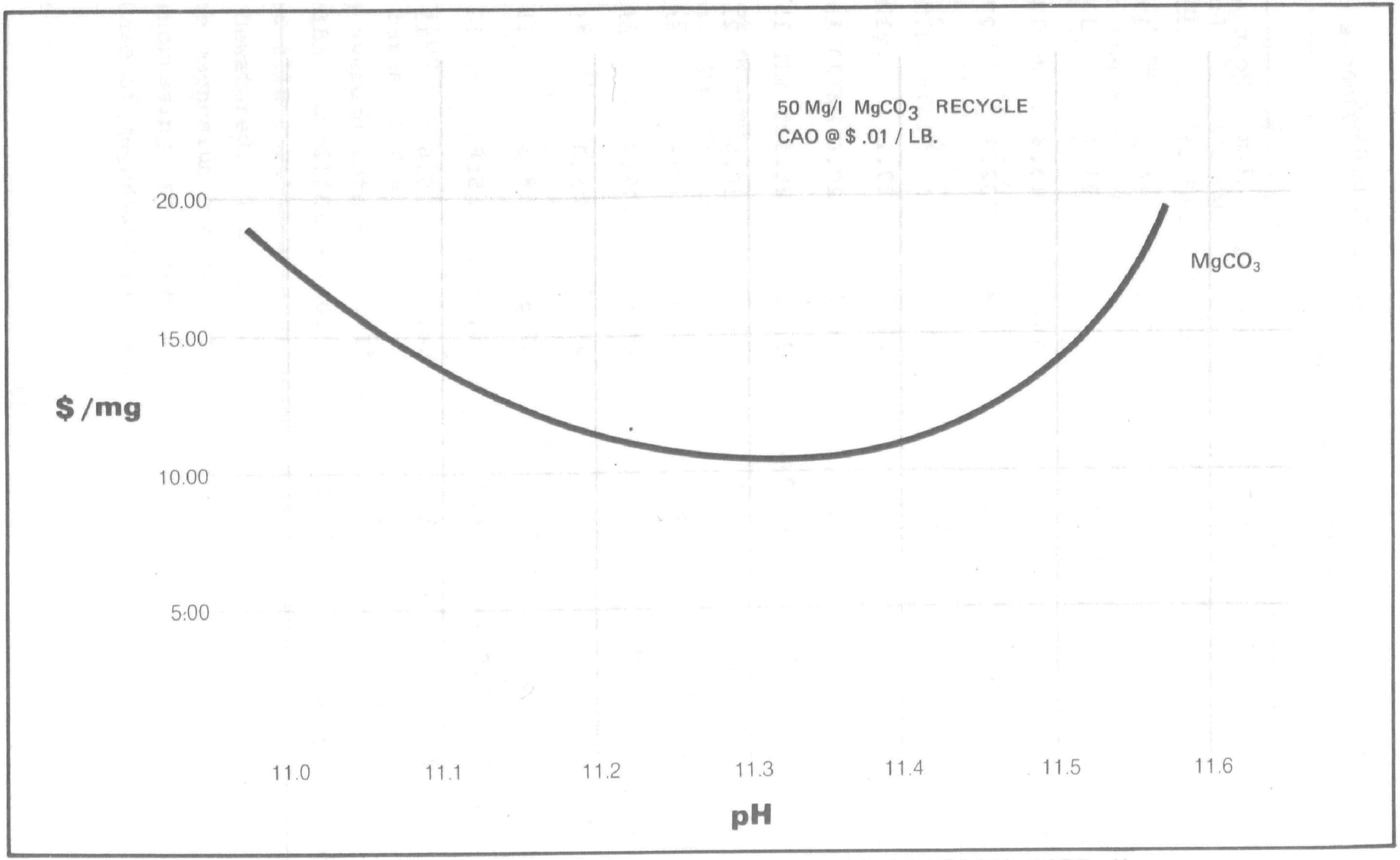
If dolomitic lime is used as a source of magnesium, Figure 22 can be used to calculate chemical costs. The only restraint on coagulation pH in this case is to keep the magnesium content in the finished water below some maximum level for hardness consideration; generally requiring the coagulation pH to be kept above 11.0 which would result in a chemical cost of only $10.00 per million gallons.

The results would indicate that the cost estimates published in the earlier papers were conservative. The predicted cost for Montgomery's water of $18.23 was based on a purchase price for carbon dioxide of $20/ton rather than the $30/ton now being paid. Table 17 illustrates the average raw water quality and alum chemical dosages utilized during the study period.

## FILTRATION OF STABILIZED WATERS

Filtered water turbidity was recorded on one of the four filters treating alum processed water and three of the four magnesium filters. Filters are normally backwashed after 100 hours of operation or 7 feet of head-loss, whichever comes first.

The months of February and March were selected as representative of normal operation and the records indicated that the alum filter had an average filter run of 82.2 hours and an average head loss of 6.4 feet at the time of washing. During this same time period the magnesium filters averaged 97.8 hours with a head loss of only 3.3 ft. The filter capped with anthracite processing the magnesium treated water averaged over 100 hours filter run with only 1.8 ft. of head loss between washing. When comparing the sand filter processing magnesium treated waters with the



50 Mg/l MgCO$_3$ RECYCLE
CAO @ $ .01 / LB.

FIGURE 22. LIME AND MAGENSIUM COSTS AS A FUNCTION OF COAGULATION pH
MONTGOMERY

## TABLE 17. RAW WATER ANALYSES AND ALUM DOSAGES, MONTGOMERY, ALABAMA

| Date | Total Alk (As $CaCO_3$) | Total Hardness (As $CaCO_3$) | Turbidity (FTU) | Alum Dosage (mg/l) | Post & Pre-lime Dosage (mg/l) |
|---|---|---|---|---|---|
| 1/15 - 21 | 12.1 | 11.9 | 23.4 | 16.5 | 17.6 |
| 1/22 - 28 | 13.0 | 12.7 | 37.7 | 31.4 | 18.4 |
| 1/29 - 2/4 | 12.5 | 12.5 | 46.5 | 23.8 | 18.0 |
| 2/5 - 2/11 | 12.7 | 13.2 | 32.8 | 32.3 | 27.0 |
| 2/12 - 2/18 | 13.8 | 15.4 | 38.5 | 35.0 | 21.2 |
| 2/19 - 2/25 | 12.4 | 12.4 | 28.5 | 29.1 | 17.1 |
| 2/26 - 3/4 | 11.8 | 11.4 | 24.7 | 20.4 | 13.2 |
| 3/5 - 3/11 | 13.8 | 15.0 | 31.1 | 23.9 | 15.9 |
| 3/12 - 3/18 | 15.2 | 20.5 | 66.4 | 50.8 | 21.2 |
| 3/19 - 3/25 | 13.5 | 15.1 | 29.1 | 45.1 | 22.6 |
| 3/26 - 4/1 | 14.0 | 15.8 | 50.5 | 47.3 | 14.3 |
| 4/2 - 4/8 | 16.0 | 13.5 | 45.7 | 45.0 | 19.7 |
| 4/9 - 4/15 | 13.0 | 13.2 | 32.5 | 38.3 | 19.1 |
| 4/16 - 4/22 | 12.8 | 14.4 | 25.3 | 35.8 | 17.8 |
| 4/23 - 4/29 | 14.6 | 13.8 | 54.3 | 35.6 | 19.5 |
| 4/30 - 5/6 | 12.3 | 14.3 | 25.1 | | |
| AVERAGE | 13.3 | 14.1 | 37.0 | 31.2 | 18.84 |

anthracite capped filter there is no noticeable difference in filtered water turbidities.

During this time period, an average of 7 FTU (Formizin Turbidity Units) of calcium carbonate turbidity were being placed on the filters. Ideally precipitation will be normal with the better carbon dioxide addition. Based on the experience in Montgomery and the experience of hundreds of softening plants, problems with shortened filter runs are not expected.

Filtered turbidities were generally lower on the magnesium processed water, however, as with the alum process, coagulation efficiency generally determines the filter efficiency.

## SOLIDS HANDLING

The design information provided by the laboratory and pilot scaled studies accurately predict full scale performance. The thickener underflow solids ranged from 30% to 45% depending upon the ratio of calcium carbonate to clay in the sludge. Vacuum filter rates ranged from 3 to 20 lbs/sq.ft./hr. Several daily vacuum filter operational data sheets are included as part of the Appendices. Table 18 summarizes the results of the vacuum filter operation.

In freezing weather the vacuum filter could not be operated due to freezing of the vacuum filtrate. The filter rates increased with thickener underflow concentration with an average rate of 4.4 lbs/sq.ft./hr. at 40% solids concentration. Due to the reduced operating time and lower than expected filter rates an average of only 375 lbs/day of dry solids dewatered. The remaining 4,894 lbs was recycled along with the magnesium bicarbonate and stored in the settling basin increasing the percentage of $CaCO_3$ in the sludge. The percentage of magnesium hydroxide in the sludge was initially

TABLE 18. VACUUM FILTER DATA,
MONTGOMERY, ALABAMA

| Date | Bed Solids (%) | Vacuum Filter Rate ($lb/ft^2/hr$) | Hrs/day | lb/day Dewatered |
|---|---|---|---|---|
| 1/15 - 1/21 | 29.8 | 2.28 | 2.7 | 166 |
| 1/22 - 1/28 | 25.8 | 2.69 | 2.0 | 145 |
| 1/29 - 2/4 | 20.4 | 2.17 | 1.0 | 59 |
| 2/5 - 2/11 | 22.9 | 2.25 | 3.0 | 182 |
| 2/12 - 2/18 | 32.0 | 2.72 | 1.7 | 125 |
| 2/19 - 2/25 | 41.3 | 3.69 | 3.3 | 330 |
| 2/26 - 3/4 | 48.8 | 8.77 | 2.2 | 521 |
| 3/5 - 3/11 | 39.3 | 7.42 | 4.3 | 861 |
| 3/12 - 3/18 | 38.3 | 5.69 | 4.2 | 645 |
| 3/19 - 3/25 | 34.1 | 3.34 | 2.9 | 261 |
| 3/26 - 4/1 | 36.2 | 4.94 | 4.2 | 560 |
| 4/2 - 4/8 | 37.3 | 5.36 | 3.92 | 567 |
| 4/9 - 4/15 | 40.2 | 5.28 | 3.3 | 470 |

Carbonator feed sludge went from 4.0% solids to 20.0% solids maintaining the same 17,000 mg/l alkalinity.

42% as $CaCO_3$ reducing to 8.5% near the end of the study. The increase of calcium carbonate and turbidity within the system could be expected to increase the magnesium coagulant requirement.

A series of experiments were performed to evaluate the dewatering characteristics of the carbonated, thickened sludge on sand drying beds. Four beds, 4 ft X 4 ft each with six inches of .5 mm sand on top of three inches of gravel with undrain were constructed. Solids concentrations in excess of 50% were typically found with a drying time of two days to one week required dependent upon climatic conditions. Assuming a one week drying time, it was found that 3 lbs of dry solids could be dewatered each week per square foot of filter area. The dried cake was easily handled and could be removed readily by front end loader.

## CORROSION STUDIES

A Magma Model 8001 Corrosometer was used to compare relative corrosion rates for the alum and magnesium treated waters. Various metal probes are available which change in resistance as corrosion proceeds. The instrument was used to measure this change in resistance each day. A tank was constructed with two compartments open to the atmosphere. Filtered magnesium and alum treated waters were fed during the study with the results illustrated in Figure 23. During this study period, the alum treated waters had an average pH of 8.9 and carbonate hardness of 43 mg/l. The magnesium treated water had a carbonate hardness of 75 mg/l and pH of 8.6. The corrosion rate for the alum treated water was more than double that of the magnesium treated water. Although the pH of the alum treated water was adjusted to a pH in excess of the pH's of calcium carbonate, little corrosion protection was provided due to the low level of calcium and carbonate alkalinity present in Montgomery's water.

## COMPARISON WITH ALUM PROCESS

Table 19 summarizes the comparison between the alum and magnesium for treatment of the Montgomery water.

## PROCESS ECONOMICS AND ENERGY CONSIDERATIONS

### Economics

Considering process economics, one must include chemical costs, capital costs, operating and maintenance costs,

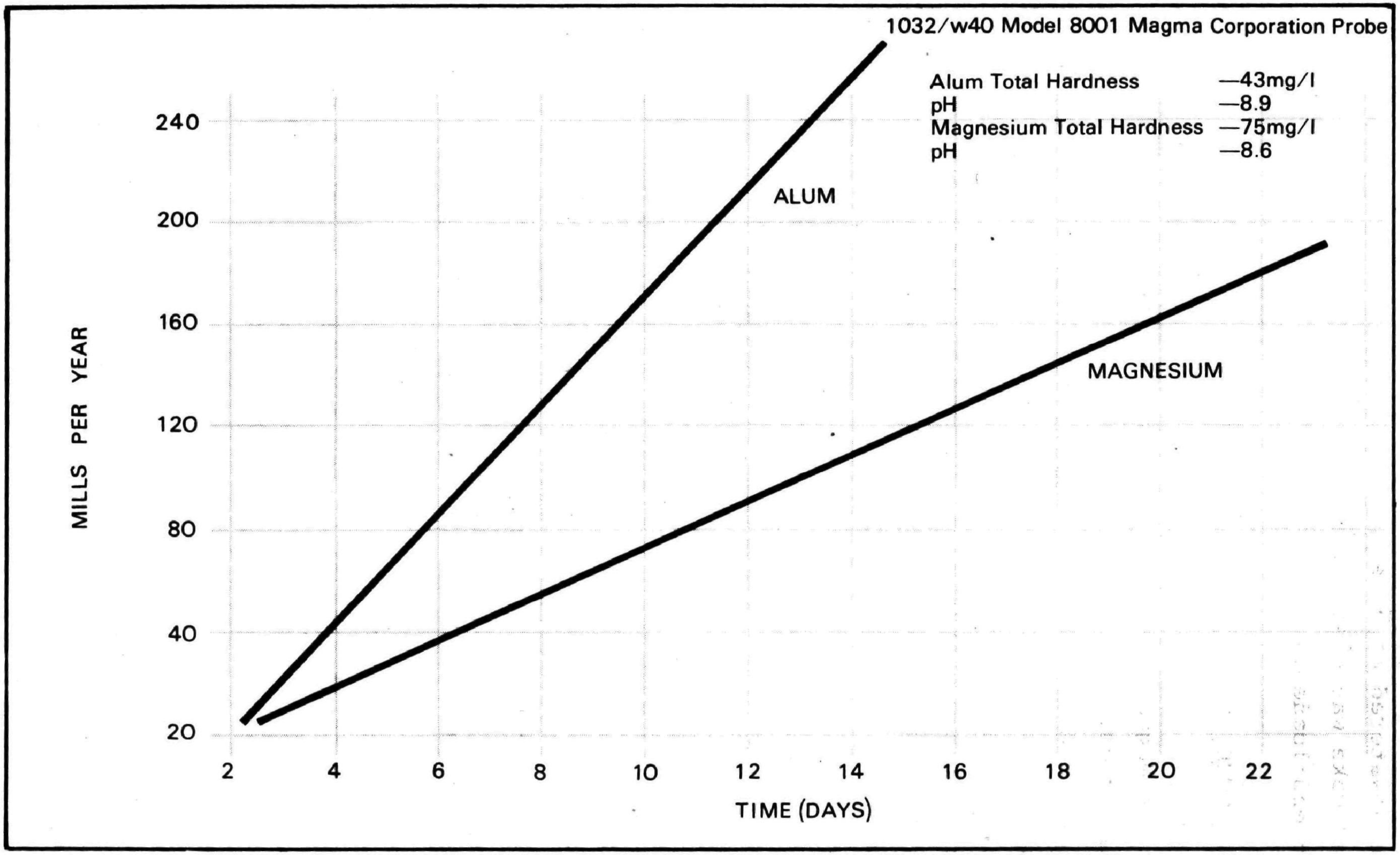


FIGURE 23. CORROSION RATES FOR ALUM AND MAGNESIUM TREATED WATER MONTGOMERY

TABLE 19. COMPARISON OF THE MAGNESIUM AND ALUM TREATMENT PROCESSES AT MONTGOMERY

| Parameter | Magnesium | Alum |
|---|---|---|
| Chemical Dosages & Coagulation pH | 875 #/M.G. CaO, 800 #/M.G. $CO_2$, and 100 #/M.G. of $MgSO_4$, pH 11.2, highly buffered | 250 #/M.G. of alum, 208 #/M.G. of $Ca(OH)_2$, pH from 6.0 - 6.4 poorly buffered. |
| Floc Characteristics | Precipitation products, dense, granular Form rapidly, and not as kinetically dependent upon water temperature. | Hydrolysis products, flocculant much larger in size, form slowly with gentle mixing much slower at colder temperatures. |
| Settling Characteristics | Rapid, increased clarifier loading rates, between lower rate for alum and high rate for softening plant. High pH disinfects. | Generally less than .75 gal/sq. ft./min. loading rate, sensitive to velocity gradients in settling basin |
| Sludge Characteristics | Carbonated sludge thickens to 40% to 50% solids. Approximately 1000 #/M.G. produced but all solids are dewatered as an integral part of the process. All sludge water recovered. | Gelatinous sludge normally less 1% solids which can be thickened only to about 6% solids, approximatley 400 #/M.G. |
| Filtration Characteristics | Generally lower filtered water turbidity calcium carbonate loading will not shorten filter runs. | Filter runs dependent upon amount of floc carryover. |
| Finished Water Characteristics | Slightly increased hardness and alkalinity; 40 - 50 mg/l as $CaCO_3$, allows pH adjustment for corrosion control. | Very low alkalinity and hardness, generally more red water, corrosion problems. |

TABLE 19. COMPARISON OF THE MAGNESIUM AND ALUM TREATMENT PROCESSES AT MONTGOMERY

| Parameters | Magnesium | Alum |
|---|---|---|
| Chemical & Operations Economics | Less favorable for low alkalinity waters increased chemical cost unless $CO_2$ source becomes available or domonitic lime proces successful. | Lower Chemical cost and less operating and maintenance expense when alum sludge is not treated for disposal. |

[1] Dependent upon water conditions

[2] Assuming more efficient first stage carbonation

as well as the various treatment considerations which includes sludge treatment in many cases.

Based on the previous discussions, a chemical cost of $13/million gallons is a reasonable estimate for the Magnesium Process. During the project period, an average alum dosage of 31.2 mg/l and lime dosage of 18.8 mg/l resulted in a chemical cost of $7.96/million gallons.

In order to convert the Montgomery plant to the magnesium process it is estimated that a capital cost of $300,000 would be required. These costs are summarized in Table 20. Amortizing over thirty years at 6% interest would result in an annual cost of $21,586 or $2.96/million gallons of water treated (assuming 20 MGD production). Based on the operating experience during the study period, no additional labor cost would be expected.

The calcium carbonate-turbidity sludge produced serves as an excellent soil stabilizer. At one plant in south Florida, calcium carbonate sludges are sold to cattle farmers for $1.50/ton, picked up at the plant site by the purchaser. Considerable calcium carbonate is sold for this purpose in Alabama. For this reason, it can be safely assumed that the dewatered sludge can be cleaned from the sand drying beds and disposed of at little or no cost in the immediate area surrounding the water plant.

The additional costs for the application of the magnesium process at Montgomery can be summarized as:

| Additional Chemical Cost | $/MG | $/yr |
|---|---|---|
| $13.00-$7.90 | $5.10 | $37,230 |
| Capital Cost | | |
| $300,000 @ 6% for 30 yrs. | $2.96 | $21,586 |

## TABLE 20. ESTIMATION OF CAPITAL COST FOR MONTGOMERY'S PLANT CONVERSION

| | Cost ($) |
|---|---|
| Stabilization of Settled Water | |
| 20 minutes contact chamber | 50,000 |
| Instrumentation & Controls | 15,000 |
| Mixing Equipment | 10,000 |
| Sludge Thickening | |
| 20' diameter thickener | 50,000 |
| Yard piping, sludge pumping, & control | 30,000 |
| Sludge Carbonation | |
| Carbonation cells | 25,000 |
| Instrumentation & Control | 10,000 |
| Recycle of Magnesium Bicarbonate | |
| Recycle storage tanks, pump & control | 20,000 |
| Sludge Drying Beds | |
| 20,000 sq. ft. @ $2.50/sq.ft. | 50,000 |
| Filtrate recycle & piping | 15,000 |
| | $275,000 |
| Engineering | 25,000 |
| TOTAL | $300,000 |

Maintenance

| | | |
|---|---|---|
| 2% of Capital Cost | $0.82 | $ 5,986 |

Electrical Cost

| | | |
|---|---|---|
| 60 HP @ $0.01/KWH | $0.055 | $ 405 |
| | $8.94 | $65,207 |

OR

$65,207 per year

Allocating these costs to the dry solids produced with the alum process would represent a cost of $34.00/ton for dewatering and disposal. This is significantly lower than would be expected with alternative sludge treatment processes.

Energy Considerations

Approximately 1500 Hp are required to treat and distribute 20 MGD of water in Montgomery. The additional horsepower requirements, 60 Hp, will only add approximately 4% to the existing plant power requirements.

## MELBOURNE FULL SCALE RESULTS

As was the case in Montgomery, the magnesium process has been found to compare favorably with the presently used alum process in both overall operation and water quality produced. Figure 24 illustrates the relationship between raw water color and treated water color as a function of

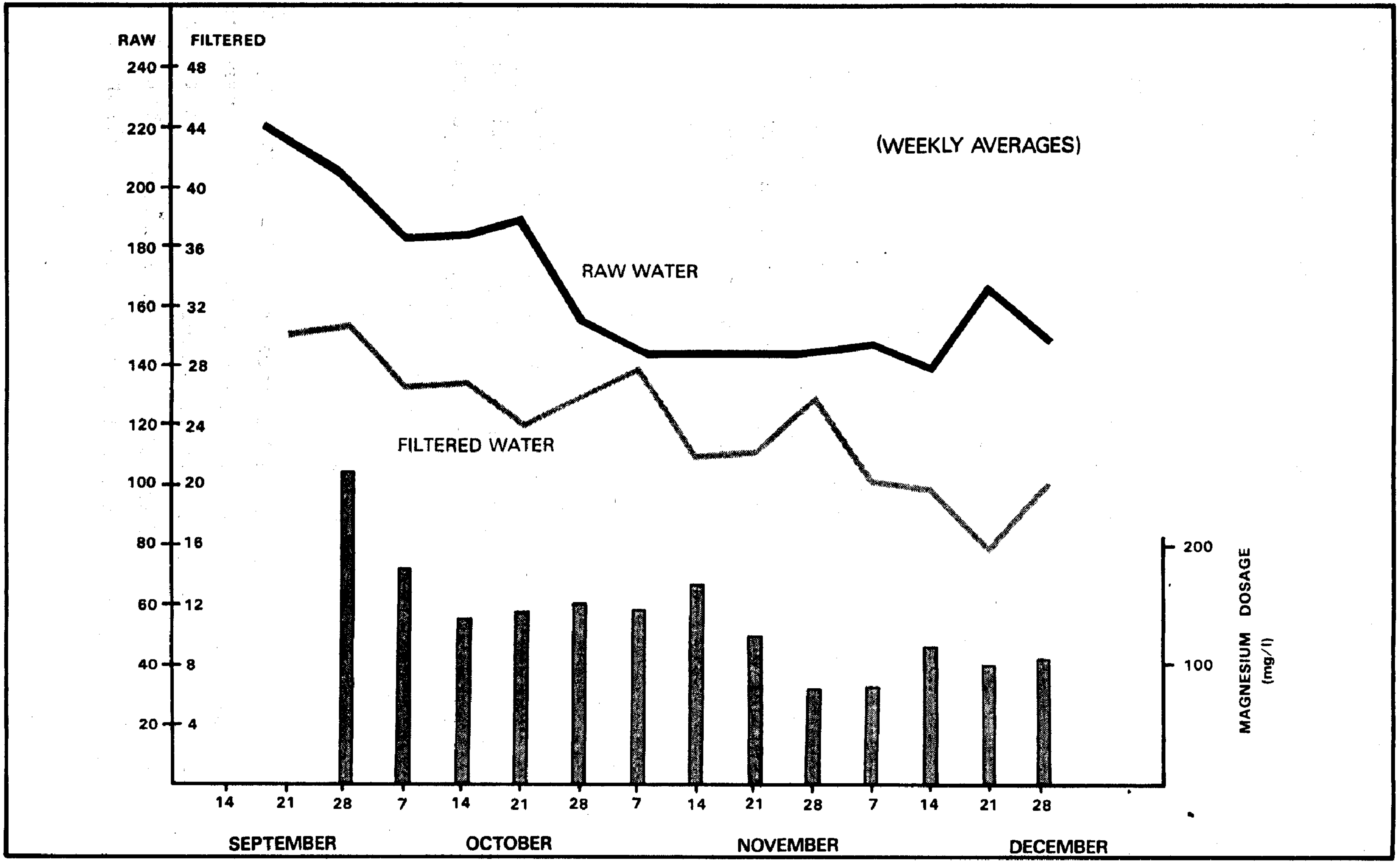


FIGURE 24. RAW WATER COLOR AND TREATED WATER COLOR AS A FUNCTION OF TIME AND MAGNESIUM DOSAGE

time and magnesium dosage. It has been found that the most economical treatment at Melbourne occurs when the color levels are reduced by coagulation to 15 - 20 Pt.-Co. units and chlorine was used to bleach the final color to less than 5 units. It is interesting to note that the treatment efficiency improved after several months of operation even at lower chemical dosages, obviously the result of increased operator proficiency. The organic color level in the raw water did not decrease in the late Fall as would have been predicted from past experience.

As discussed previously, the degree of magnesium recovery somewhat determines the economic feasibility of the process. It is extremely important to account for all losses or gains of magnesium. The losses of magnesium occur in two areas - the magnesium content in the finished water and the magnesium lost in the moisture of the filter cake produced. Sources of magnesium include magnesium present in the raw water as well as any magnesium source fed in the process. Figure 25 illustrates the magnesium balance for Melbourne. The high moisture content in the filter cake resulted in the equivalent loss of 12 mg/l of magnesium as calcium carbonate in the raw water. The finished water produced contained an average of 6 mg/l. An average of 11.5 mg/l of magnesium was found in Melbourne's raw water during the study period. It is probable with proper filter cake washing the magnesium loss in the dewatered sludge can be reduced.

During the course of the study a large amount of data has been collected. Routine data sheets are included as Item 3 in the Appendix and show the type and quantity of data collected each day by the water plant operators. In addition, a summary of daily average results are included.

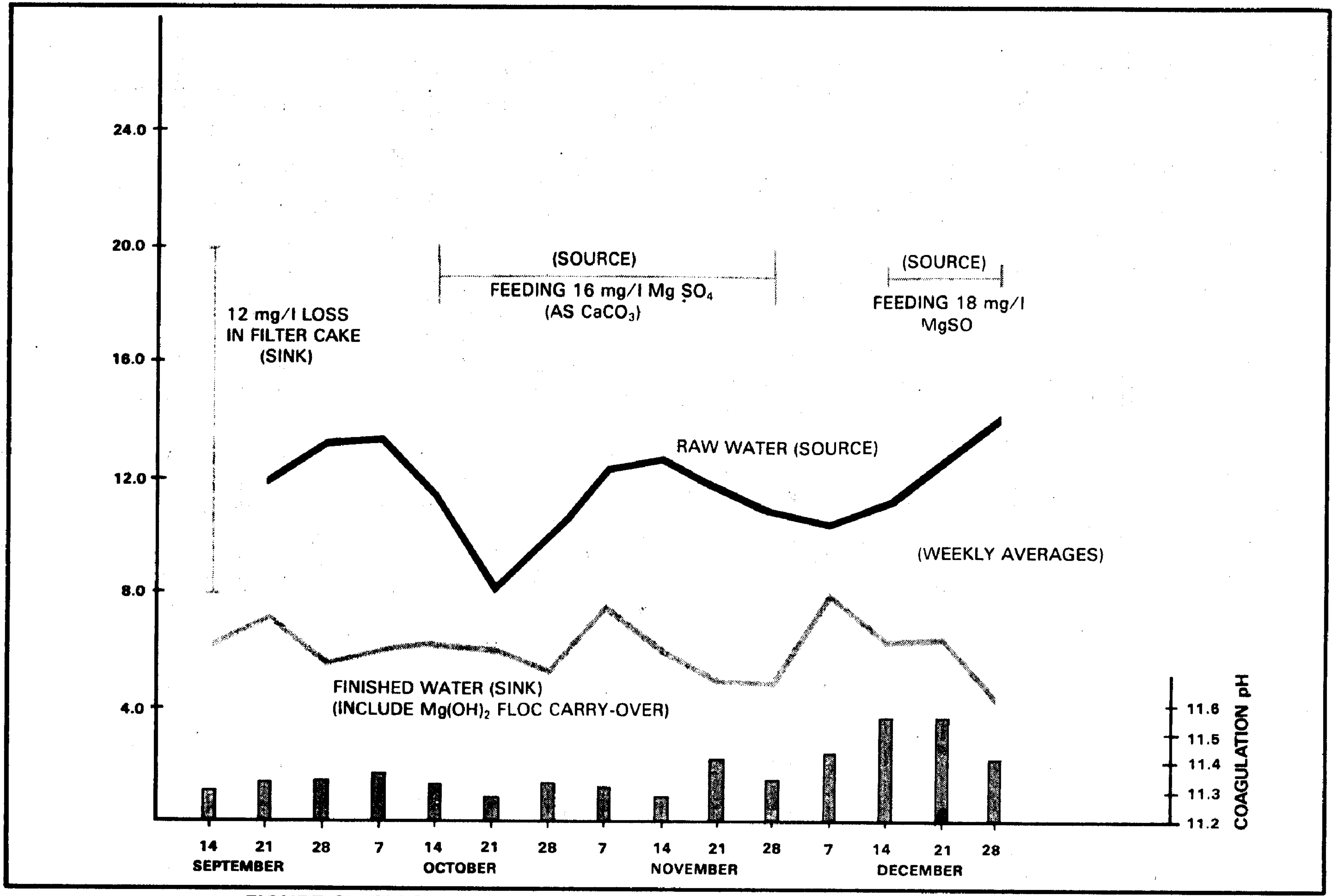


FIGURE 25. MAGNESIUM SINKS AND SOURCES AS A FUNCTION OF TIME — MELBOURNE

## Study of "Color Balance"

One of the most important findings of the Melbourne study is shown in Figure 26. If color release on sludge carbonation was to prove a problem, the ratio of organic color to magnesium concentration in the recycled liquor should have increased with the time that the system is in operation. This was not the case, however, as the ratio tended to decrease. This was probably due in part to the feed of make-up magnesium sulfate as indicated on the graph.

## Chlorine Demand Studies

A series of chlorine demand studies were performed at the Melbourne water plant. These studies were conducted to determine the effect of free chlorine residual on color reduction as well as to determine the chlorine demand for both the alum and magnesium treated waters. Table 21 illustrates typical results from one of these tests.

## Studies of Carbonated Sludge Dewatering and Thickening

Sludge dewatering studies were conducted on the carbonated sludge thickener underflow the week of October 1. Results of leaf filter testing are shown as Table 22. Results of full scale vacuum filter operation are shown as Table 23. A full scale thickening study was made during the period December 20 through January 6. The results are shown in Table 24. Excellent agreement between leaf filter and full scale operation was found, as was the case in Montgomery.

## Taste and Odor Studies

Considerable effort was expended in evaluating the

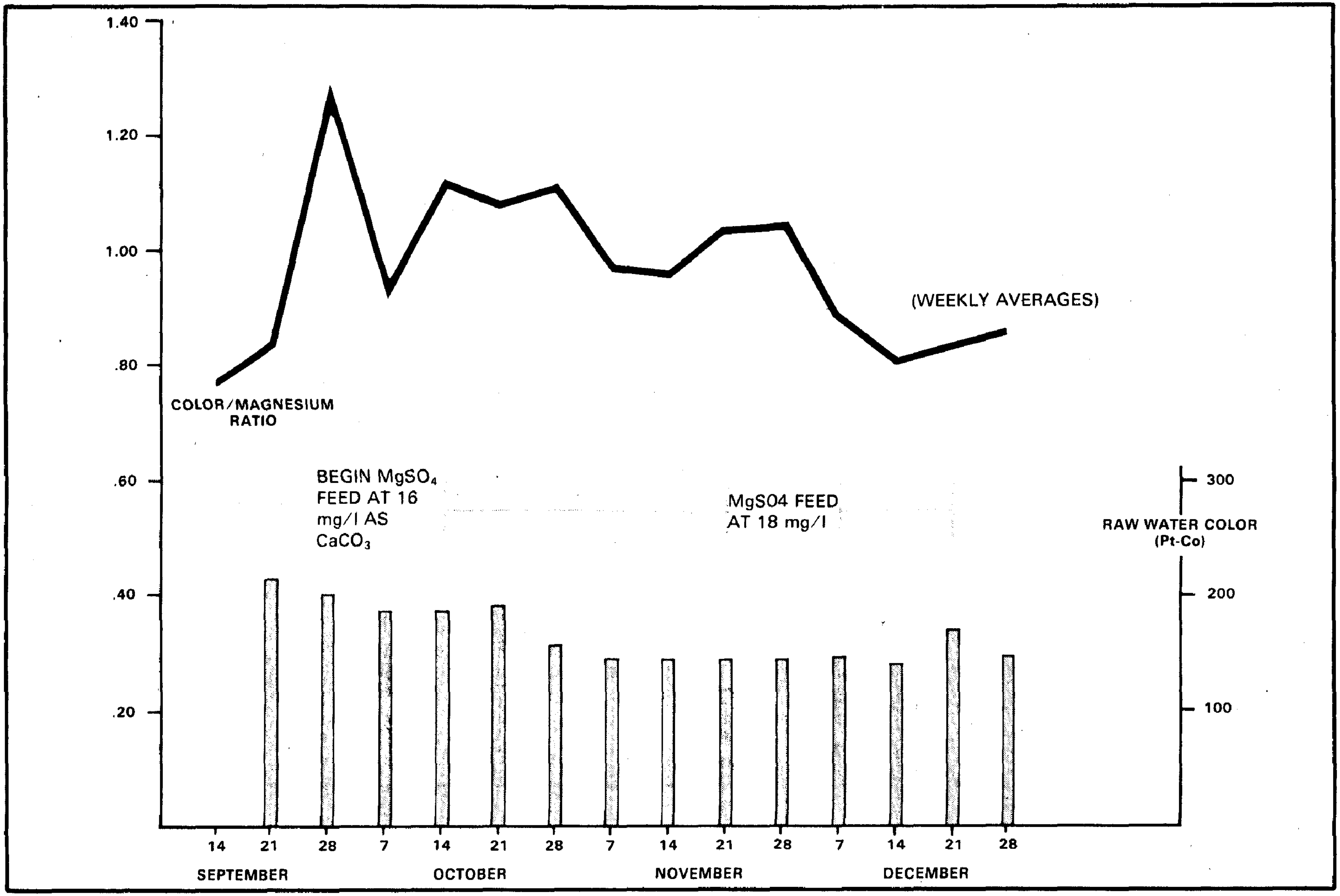


FIGURE 26. COLOR/MAGNESIUM RATIO AS A FUNCTION OF TIME — MELBOURNE

## TABLE 21. CHLORINE DEMAND TEST
(10-5-73)

### Magnesium Treated Water

| Free Chlorine at Indicated Time (Minutes) | ppm of Chlorine Added 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 15 | 0.15 | 0.25 | 1.00 | 1.50 | 1.50 | 1.50 |
| 30 | 0.15 | 0.15 | 0.35 | 0.75 | 1.50 | 1.50 |
| 60 | 0.15 | 0.15 | 0.35 | 0.50 | 0.50 | 1.00 |
| 120 | 0.10 | 0.15 | 0.15 | 0.25 | 0.25 | 0.45 |

Initial color 25; Final color 7 at 7 ppm Chlorine dosage

### Alum Treated Water

| Free Chlorine at Indicated Time (Minutes) | ppm of Chlorine Added 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 15 | 0.15 | 0.35 | 0.50 | 1.00 | 2.50 | 2.50 |
| 30 | 0.15 | 0.15 | 0.30 | 1.00 | 2.00 | 2.00 |
| 60 | 0.10 | 0.15 | 0.15 | 0.40 | 0.50 | 1.00 |
| 120 | 0.10 | 0.15 | 0.15 | 0.15 | 0.20 | 0.50 |

Initial color 10; Final color 5 at 7 ppm Chlorine dosage

TABLE 22. LEAF FILTER TEST RESULTS - MELBOURNE

| Form Time (sec) | Dry Time (sec) | Bed (% solids) | Filter Rate ($lb/ft^2/hr$) | Cake Moisture (%) |
|---|---|---|---|---|
| 30 | 60 | 41.8 | 43 | 45 |
| 60 | 90 | 41.6 | 38 | 45 |
| 90 | 120 | 41.7 | 30 | 46 |
| 120 | 180 | 41.7 | 26 | 44 |
| 30 | 60 | 15.0 | 17 | 44 |
| 60 | 90 | 14.7 | 14 | 46 |
| 90 | 120 | 13.1 | 11 | 45 |
| 120 | 180 | 12.6 | 9 | 45 |

TABLE 23. FULL SCALE VACUUM FILTER RESULTS - MELBOURNE

| Form Time (sec) | Dry Time (sec) | Bed (% solids) | Filter Rate ($lb/ft^2/hr$) | Cake Moisture (%) |
|---|---|---|---|---|
| 171 | 338 | 41.9 | 20.0 | 45 |
| 234 | 278 | 41.9 | 17.6 | 45 |
| 260 | 251 | 41.9 | 19.7 | 45 |
| 342 | 170 | 41.9 | 19.7 | 45 |
| 171 | 338 | 28.9 | 12.6 | 43 |
| 234 | 278 | 28.9 | 11.7 | 44 |
| 260 | 251 | 28.9 | 12.4 | 45 |
| 342 | 170 | 28.9 | 13.5 | 46 |

## TABLE 24. MELBOURNE SLUDGE THICKENING STUDY

| Date | Thickener Feed | | | Thickener Underflow | | | |
|---|---|---|---|---|---|---|---|
| | GPM | % Solids | lb/day | GPM | % Solids | lb/day | $lb/ft^2$ /day |
| 2/20 | 5.0 | 9.33 | 5987 | 1 | 29.22 | 4205 | 53.9 |
| 2/21 | 5.0 | 10.55 | 6580 | 1 | 30.20 | 3929 | 50.0 |
| 2/22 | 7.5 | 9.19 | 8599 | 1 | 27.30 | 3900 | 49.0 |
| 2/23 | 7.5 | 10.29 | 9905 | 1 | 21.58 | 3028 | 38.6 |
| 2/24 | 10.0 | 9.38 | 12,039 | 1 | 24.56 | 3535 | 45.03 |
| 2/24 | 10.0 | 9.18 | 11,779 | 1 | 24.67 | 3492 | 44.49 |
| 2/25 | 10.0 | 10.14 | 13,014 | 1 | 25.15 | 3620 | 46.12 |
| 2/26 | 5.0 | 9.39 | 6019 | 1.5 | 25.85 | 5582 | 71.1 |
| 2/27 | 5.0 | 10.35 | 6645 | 1.5 | 25.48 | 5502 | 70.1 |
| 2/28 | 7.5 | 10.34 | 9953 | 1.5 | 25.50 | 5505 | 70.1 |
| 2/29 | 7.5 | 8.82 | 8490 | 1.5 | 24.90 | 5376 | 68.5 |
| 2/30 | 10 | 9.98 | 12,578 | 1.5 | 25.76 | 5561 | 70.8 |
| 2/31 | 10 | 7.96 | 10,216 | 1.5 | 24.20 | 5224 | 66.6 |
| 3/1 | 5 | 8.55 | 5486 | 2.0 | 20.47 | 5696 | 72.58 |
| 3/2 | 5 | 10.04 | 4671 | 2.0 | 20.28 | 5643 | 71.8 |
| 3/3 | 7.5 | 8.86 | 8529 | 2.0 | 19.07 | 5306 | 67.0 |
| 3/4 | 7.5 | 9.70 | 9337 | 2.0 | 20.04 | 5624 | 71.6 |
| 3/5 | 10.0 | 11.09 | 14,238 | 2.0 | 20.13 | 5601 | 71.4 |
| 3/6 | 10.0 | 7.50 | 9626 | 2.0 | 18.78 | 5226 | 66.6 |

use of potassium permanganate for taste and odor removal. It was found that at the high coagulation pH of 11.3 extremely rapid reactions occurred between the potassium permanganate and the organics present in the water. As the permanganate would not selectively oxidize the compounds producing odor and taste, very large dosages were required to effectively remove taste and odor. The potassium permanganate could be fed at the raw water intake for reaction with the taste and odor components prior to reaching the plant and subsequent pH elevation in rapid mixing. However, as low carbon dosages were adequately preventing taste and odor problems, no action was taken to further investigate the use of potassium permanganate.

The elevated pH had little effect on carbon adsorption of taste and odor. Essentially the same carbon dosages were used to maintain similar quality treated waters on both the alum and magnesium treated processes.

## Studies of "Organics" Present in the Raw Water

Samples of raw water, finished water treated with alum and with magnesium carbonate were collected over a twenty-four hour period, separately composited and shipped by Air Express to the Athens, Georgia laboratory of the Environmental Protection Agency for analysis by gas chromatography. In addition, organics in each of the three waters were continuously removed over a two day period in special filters provided by the E.P.A. Cincinnati laboratory and shipped to that laboratory for analysis.

Two sets of samples were analyzed for total organic carbon. The raw water was found to have 37 mg/l on September 12 and 28 mg/l on October 9. The alum treated water ranged in TOC from 10 mg/l on October 9 to 18 mg/l on September 12.

One sample taken October 9 found the magnesium treated water to have 12 mg/l of TOC.

The results of the studies related to determining and quantifying the organics present in Melbourne's raw and treated waters were somewhat indefinite. E.P.A. has developed a procedure for extracting the organic carbon onto carbon columns in a specified manner. These carbon filters were than mailed to E.P.A. for extraction of the organics from the carbon with both alcohol and chloroform. The alcohol extract is called CAE; the chloroform extract is called CCE. The CCE value for the raw water ranged from 1.1 to 1.7. The magnesium treated water ranged from 1.0 to 1.6 and the alum treated water ranged from 2.4 to 2.5. The CAE values for the raw water were 3.9, with magnesium treated water 4.2 and alum treated water 11.3. All of these values are extremely high. It is interesting to note that neither the alum nor the magnesium process removed these organics, although color removal was taking place. This is also upheld in the TOC analysis reported earlier. While the color was essentially completely removed, only 50% of the TOC was removed as a result of the treatment process.

The increase in carbon as a result of the alum process could possibly be explained by the fact that during periods when the filter head loss is high alum floc is actually pulled through the filter which contained high concentrations of organic material absorbed on the floc. These results would indicate that neither process is effective in completely removing the organics adsorbed on these columns.

E.P.A. has completed extensive analysis for heavy metals in both the alum and the magnesium treated waters. The magnesium treated water showed metals concentrations of 50% or less, of those found in the alum treated water. There were no significant concentrations of metals found in either, however. As an example, copper was 17 parts per billion in the alum treated water and 9 parts per billion in the magnesium treated water. Zinc was 190 parts per billion in the alum treated water and 76 parts per billion in the magnesium treated water. These results are included in the Appendices as Appendix D, together with correspondence with the E.P.A. laboratories concerning the organics studies.

## Pilot Calcination Results

Near the end of the study, several drums of dewatered, but unwashed, sludge were shipped to the BSP Division of Envirotech in Brisbane, California for a continuous calcination study in a 30" diameter multiple hearth furnace. The results of this study, as indicated below, were somewhat inconclusive.

The most important aspect of this study was the relatively poor quality lime produced. Only quick-lime containing 63.2% calcium oxide content was produced. This can be explained for the following reasons:

1) The nature of the multiple hearth furnace is such that temperatures in excess of 1750°F are damaging to the mechanical components. In the calcining zone of a rotary kiln temperatures in excess of 2000°F are usually employed. Due to the geometry of the pilot furnace, severe short circuiting between hearths was evident. The increased temperatures would probably have increased the calcium carbonate conversion efficiency and produced a more reactive product.

2) More important, however, relatively poor lime was used initially in the project. So poor that one

shipment was rejected. This lime has approximately 15% inerts and would result in build-up of the inert fraction of the sludge tested. In full scale operation, it would be extremely important to begin with the highest quality lime possible.

3) The sludge studied was the result of many hundreds of cycles of coagulant reuse. It is possible that some build-up of inerts from the raw water is possible after this period of operations. Periodic wasting of lime may be required. However, this will not be more frequent than the six month period of this study. The wasted lime would have considerable value as a soil pH conditioner.

Lime recalcination at Melbourne would appear both economically and technically feasible. Considerable attention should be directed to determining which type of hearth furnace should be used: rotary kiln, multiple hearth furnace or fluosolids reactor. Each offers advantageous features and a thorough evaluation is required.

## Design Table Summary

Table 25 summarizes the design criteria determined from both the Montgomery and Melbourne studies.

In the design of the sludge carbonation device, using furnace exhaust gas as a carbon dioxide source may result in a foaming problem. The 80% air content in the exhaust gas may cause foam due to the surface properties of the organic color in the recovered magnesium bicarbonate liquor. This foam can be collected and drained to the tail

## TABLE 25. DESIGN TABLE SUMMARY

| Unit | Design Parameters | Comments |
|---|---|---|
| Rapid Mix | 10 - 30 seconds | Short rapid mix appears to be desirable in color removal applications. |
| Flocculation | 15 - 30 minutes | Floc forms rapidly. However, contact time increases color adsorption. |
| Clarifier | 1.0 gal/sq.ft./ min. | The use of polymers prevents excessive $Mg(OH)_2$ floc carry-over. |
| Filtration | 2.0 - 4.0 gal./ sq.ft./min. | Filter rates up to 4.0 gal/sq.ft./min. were evaluated in Montgomery. Increased rates improved performance normally. |
| Settled Water Carbonation | 10 - 30 minutes | Two stage, separated by time, shown as design parameters. |
| Sludge Carbonation | | |
| Purchased 100% $CO_2$ | 15 minutes | |
| Kiln Gas 18% $CO_2$ | 60 minutes | Foaming problems solved by collection in launder drained to tail box. |
| Sludge Thickening | 40 - 50 lbs/ sq.ft./day | Increase in loading rate will produce solids underflow less than 30%. |
| Sludge Dewatering | 25 - 35 lbs/ sq.ft/day | Lower rate is for feed solids less than 30%. |

box with a launder on one side of the unit.

## Miscellaneous Studies

Calcium carbonate precipitation within the filter media was not found to be a problem as long as the pH of the stabilized water was kept below 8.6 to 8.8. The anthracite filter seemed to be less affected by calcium carbonate precipitation.

The length of filter operation between backwashing affects the net water produced. For the period October 1 through November 15, the alum process sand filter averaged 37.3 hours between backwashing and the anthracite-capped (3") filter averaged 40.5 hours. During the same time period, the magnesium process sand filter averaged 37.0 hours and the anthracite-capped filter averaged 45.5 hours between washings. Later in the Fall it was reported that the alum filters were being washed considerably more frequently due to "air binding" while the magnesium filters maintained the same total hours of operation. The granular calcium carbonate turbidity produced in the stabilization of the clarified magnesium treated water, while considerable in quantity, does not have the filter-binding properties of alum floc carryover.

During the course of the study an excess of both lime and $CO_2$ was used. Near 100% transfer efficiency is possible with pure $CO_2$ in a properly designed carbonation basin. Due to the short retention time and shallow water depth in the effluent clarifier launders, efficiencies of 50% or less were achieved.

Lime feed was not maintained to provide a uniform coagulation pH. A reduction of approximately 20% in lime requirements would be predicted from the data sheets for an average CaO feed of 275 mg/l. This can be accomplished primarily through the use of properly designed lime handling and feeding equipment as well as automatic pH control.

## ECONOMICS AND ENERGY CONSIDERATIONS

### Economics

The chemical costs will be evaluated both with and without lime recalcination and the purchase of lime and carbon dioxide.

Looking first at the costs associated with lime recalcination and the purchase of lime and carbon dioxide, the recovery of 15 tons/day of lime can be estimated as:

| Capital Costs | $/year | $/ton of CaO |
|---|---|---|
| $900,000 for 25 years @ 6% (25 ton/day kiln) | 69,595 | 12.71 |
| **Maintenance** | | |
| 2% of Capital Cost | 18,000 | 3.30 |
| **Power (Gas & Electricity)** | | |
| $11.00 per ton CaO | 60,225 | 11.00 |
| **Operation** | | |
| Four (4) operators @ $8,000/yr | 32,000 | |
| 1/2 Maintenance @ $8,000/yr | 4,000 | |
| 1/4 Management @ $10,000/yr | 2,500 | |
| | 38,500 | 7.03 |
| TOTAL (Based on an average production of 15 tons/day) | $186,320 | $34.04 |

When producing 10 tons per day, as in the Winter period, the costs will climb to \$45.54 per ton. As lime requirements increase due to increases in water production, the cost per ton will decrease. Producing 25 tons per day of CaO will result in a cost of \$24.82 per ton of lime.

In calculating the chemical costs for water treatment, the following costs are assumed:

Lime - Delivered at \$30/ton CaO

$CO_2$ - Delivered at \$30/ton CaO

Lime - Calcined at \$39.79/ton CaO
(Average production at 12.5 tons/day)

Magnesium Sulfate - at \$240/ton magnesium as Calcium carbonate (magnesium carbonate should be available at \$100/ton within 12 months)

The average chemical dosages on an annual basis are:

CaO - 225 mg/l
$CO_2$ - 155 mg/l
Magnesium - 5 mg/l

With lime recovery, the cost per million gallons would be:

| | | | |
|---|---|---|---|
| CaO | - | 225 X 8.33 X \$0.019 = | 37.29 |
| $CO_2$ | - | | - 0 - |
| Magnesium | | 5 X 8.33 X \$0.12 = | 5.00 |
| TOTAL | | | \$42.29 |

The cost not recovering lime would be:

| | | | |
|---|---|---|---|
| CaO | - | 225 X 8.33 X \$0.015 = | 28.11 |
| $CO_2$ | - | 155 X 8.33 X \$0.015 = | 19.37 |
| Magnesium | | 5 X 8.33 X \$0.12 = | 5.00 |
| TOTAL | | | \$52.48 |

It is interesting to note that chemical costs, with recalcination, are only slightly affected by increases in chemical dosages. This would allow the operation a large safety factor in treatment at a very modest cost.

On an annual cost basis, the cost for coagulation and stabilization chemicals would be:

| | | |
|---|---|---|
| With recalcination | - | \$154,358 |
| Purchase Lime + $CO_2$ | - | \$191,552 |
| Alum and Lime | - | \$94,170 |

This is based on an average water production of 10 MGD.

The capital costs required to modify both the North and South Melbourne plants to use the magnesium process have been estimated to be \$612,900.[15] This cost is only for the additional units required to include the magnesium process and is included for comparable purposes only. The cost does not include plant modification required to increase the capacity to 22 MGD. Amortized over twenty-five years at 6% interest would require \$47,394 per year for capital recovery. Maintenance at 2% of capital cost would amount to \$12,258 per year. Operation would not require any additional personnel with recalcination, as the furnace operators would also be responsible for sludge dewatering. Without recalcination, a cost of \$16,000 has been estimated for operation of the vacuum filter and sludge thickening.

To summarize the total costs for water treatment utilizing the magnesium process:

| Lime Recalcination | $/year |
|---|---|
| Chemical Costs | 154,358 |
| Capital Amortization | 47,394 |
| Maintenance | 12,258 |
| Electrical Power | 3,000 |
| TOTAL COST | $217,010 |

| Purchase Lime and $CO_2$ | |
|---|---|
| Chemical Costs | 191,552 |
| Capital Amortization | 47,394 |
| Maintenance | 12,258 |
| Operation | 16,000 |
| Electrical | 3,000 |
| TOTAL COST | $270,204 |

Lime recalcination will produce some excess lime, amounting to some 2 to 4 tons per day during the hard water season which should have a value of approximately $20,000 per year. No credit is given in this economic comparison. The filter cake, in the case where lime values are not recovered, is composed primarily of calcium carbonate. It could be worth approximately $1.50 per ton to local cattle ranchers as another water treatment plant in the area has made such an arrangement. The ranchers pick up the filter cake at the plant in their trucks.

In order to compare the magnesium process with the present alum process, sludge dewatering using a filter press is included. In addition, as increased clarifier size is required for the alum process but not for the magnesium process, these additional costs are noted as plant additions.

The capital cost for the filter press and appurtenances has been estimated at $1,250,000 and the plant additions at $298,000 for a total capital cost of $1,548,000. These cost estimates are derived from the Smith and Gillespie

Report of 1973.[15] The costs can be summarized as:

| | $/year | $/ton* |
|---|---|---|
| Capital Amortization ($1,548,000 @ 6% for 25 years) | 119,703 | 54.60 |
| Maintenance @ 2% | 30,000 | 14.13 |
| Operation of Press | 20,000 | 9.13 |
| Power (Press) | 5,000 | 2.28 |
| Chemicals (Press) | 32,850 | 15.00 |
| Sludge Hauling to Suitable Landfill | 35,000 | 15.98 |
| Present Chemical Cost | 94,170 | |
| TOTAL COST | $337,683 | $111.12 |

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*Based on 22 MGD production, 6 tons of dry solids per day.

It should be emphasized that sludge hauling costs can be expected to increase in the future as haul distances become longer and hauling costs increase.

Summarizing these costs:

| | Annual Cost |
|---|---|
| Magnesium Process | |
| With recalcination | $217,010 |
| Purchase lime and $CO_2$ | $270,204 |
| Alum Process | |
| Including plant improvements and sludge pressing | $337.683 |

Energy Considerations

Lime recalcination requires considerable on-site energy, thus, careful consideration is in order. The following facts would appear to apply:

A. Commercial quicklime, used in larger tonnage than any other water treatment chemical, requires the following energy-consuming operations for its manufacture:

   1) Mining of limestone or marble in quarry
   2) Transporting to kiln
   3) Crushing and grinding before burning
   4) Burning in vertical shaft or rotary kilns
   5) Bulk shipment (600 miles in Melbourne's case)
   6) Unloading and shipment to the water plant.

B. Recalcining calcium carbonate sludge on-site would:

   1) Eliminate 1, 2, 3, 5 and 6.
   2) The additional heat required to evaporate the moisture from the filter or centrifuge cake is only slightly higher than for (4).
   3) Produces more than sufficient $CO_2$ in the stack gas to carbonate the plant's finished water, for stabilization and sludge carbonation, thus making an important energy saving.
   4) Eliminates the need for hauling dewatered sludge for ultimate disposal.

This very simplistic approach to evaluating the energy balance of the two alternatives would weigh heavily in favor of on-site lime recovery.

## SECTION VI

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# SECTION VII

## APPENDICES

# APPENDIX A

## DATA SHEETS TO SHOW TYPICAL RESULTS, MONTGOMERY, ALABAMA

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | CO2 SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/2<br>0000 | 10.1 | 116 | 30 | 86 | 11.7 | 8.8 | 93 | 87 | 79 | 4.7 | 1.7 | 7.55 | 16000 | 12 | 6.0' | 8.8 | 71 | 10 | 4.2 |
| 0200 | 10.15 | 118 | 30 | 88 | 11.65 | 8.9 | 99 | 90 | 81 | 5.3 | 1.8 | 7.55 | 16600 | 10 | 5.5' | 8.85 | 75 | 10 | 4.2 |
| 0400 | 10.1 | 112 | 29 | 83 | 11.7 | 8.9 | 95 | 87 | 80 | 5.0 | 1.9 | 7.6 | 16100 | 10 | 5.3' | 8.9 | 79 | 10 | 4.2 |
| 0600 | 10.05 | 107 | 27 | 80 | 11.7 | 9.0 | 93 | 86 | 78 | 4.6 | 1.7 | 7.6 | 15900 | 10 | 5.0' | 9.0 | 80 | 10 | 4.2 |
| 0800 | 10.2 | 120 | 24 | 98 | 11.55 | 9.2 | 96 | 89 | 82 | 6.0 | 1.9 | 7.6 | 16100 | 10 | 5.0' | 9.05 | 78 | 10 | 4.2 |
| 1000 | 10.2 | 108 | 28 | 80 | 11.65 | 9.0 | 96 | 89 | 82 | 5.8 | 1.9 | 7.7 | 15600 | 10 | 5.0' | 8.95 | 78 | 10 | 4.2 |
| 1200 | 10.4 | 80 | 28 | 52 | 11.65 | 8.8 | 96 | 90 | 84 | 5.9 | 2.0 | | | | | 8.9 | 76 | 10 | 4.2 |
| 1400 | 10.1 | 160 | 34 | 126 | 11.05 | 8.7 | 110 | 100 | 88 | 6.5 | 1.9 | | | 12 | Full | 8.8 | 82 | 10 | 4.2 |
| 1600 | 10.1 | 130 | 30 | 100 | 11.5 | 9.0 | 115 | 100 | 85 | 6.0 | 2.0 | 7.7 | 15600 | | 4.2' | 8.8 | 72 | 10 | 4.2 |
| 1800 | 10.0 | 96 | 30 | 66 | 11.6 | 8.7 | 100 | 95 | 82 | 5.0 | 2.0 | 7.75 | 15400 | | Full | 8.8 | 72 | 10 | |
| 2000 | 10.1 | 100 | 30 | 70 | 11.5 | 8.5 | 105 | 95 | 84 | 4.5 | 2.0 | Not Taken Because of Pump | | | Full | 8.7 | 70 | 10 | 4.2/4.0 |
| 2200 | 10.2 | 100 | 30 | 70 | 11.65 | 8.0 | 98 | 90 | 80 | 3.8 | 1.5 | 7.7 | 15600 | Full | 3.8' | 8.4 | 72 | 10 | 4.0/3.0 |
| 3/3<br>0000 | 10.35 | 82 | 30 | 52 | 11.75 | 9.0 | 90 | 87 | 77 | 4.5 | 1.8 | 7.8 | 15400 | Max. | 2.0' | 8.8 | 74 | 10 | 2.8/3.0 |
| 0200 | 10.4 | 82 | 28 | 54 | 11.6 | 9.5 | 90 | 82 | 76 | 5.5 | 1.8 | 7.8 | 15200 | 5 | 1.5' | 9.1 | 73 | 10 | 3.0/3.2 |
| 0400 | 10.4 | 82 | 28 | 54 | 11.54 | 9.4 | 87 | 82 | 75 | 4.8 | 1.4 | 7.8 | 15100 | 5 | 1.2' | 9.1 | 73 | 10 | 3.4 |
| 0600 | 10.35 | 80 | 26 | 54 | 11.7 | 9.1 | 85 | 81 | 74 | 4.6 | 1.5 | 7.8 | 15100 | 4 | 1.0' | 9.0 | 71 | 10 | 3.6 |
| 0800 | 10.2 | 88 | 26 | 62 | 11.5 | 9.3 | 90 | 86 | 80 | 6.0 | 1.7 | 7.4 | 16700 | 6 | 2.6' | 9.15 | 64 | 10 | 4.0 |
| 1000 | 10.4 | 86 | 30 | 56 | 11.65 | 8.5 | 96 | 88 | 80 | 5.5 | 1.9 | 7.35 | 17200 | 8 | 3.6' | 9.0 | 70 | 11 | 3.5 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/3<br>1200 | 10.2 | 90 | 28 | 62 | 11.5 | 8.8 | 94 | 88 | 82 | 5.8 | 1.9 | 7.85 | 15100 | 8 | 4.5' | 8.65 | 72 | 11 | 3.5 |
| 1400 | 10.1 | 78 | 28 | 50 | 11.7 | 9.2 | 98 | 92 | 80 | 6.2 | 1.9 | 7.9 | 14900 | 8 | 6.5' | 8.8 | 70 | 11 | 3.7 |
| 1600 | 10.1 | 79 | 28 | 51 | 11.65 | 9.0 | 96 | 90 | 82 | 6.0 | 2.0 | 7.8 | | All | Full | 8.8 | 71 | 11 | 3.7 |
| 1800 | 10.2 | 78 | 27 | 51 | 11.7 | 9.0 | 98 | 96 | 80 | 5.8 | 1.8 | Not | Taken | All | 5.5' | 8.9 | 72 | 11 | 3.7 |
| 2000 | 10.2 | 80 | 30 | 50 | 11.65 | 9.0 | 100 | 92 | 78 | 5.0 | 1.8 | 7.8 | 14500 | All | 4.8' | 8.9 | 74 | 11 | 3.7 |
| 2200 | 10.2 | 85 | 30 | 55 | 11.6 | 9.0 | 105 | 92 | 78 | 4.8 | 1.8 | 7.8 | 14400 | All | 4.8' | 8.9 | 72 | 11 | 3.7/4.0 |
| 3/4<br>0000 | 10.3 | 82 | 30 | 52 | 11.7 | 9.0 | 102 | 92 | 80 | 5.0 | 1.8 | 7.9 | 13500 | All | 4.8' | 8.9 | 74 | 11 | 4.0 |
| 0200 | 10.4 | 80 | 30 | 50 | 11.75 | 9.0 | 97 | 94 | 82 | 5.5 | 1.9 | 8.0 | 13300 | Max. | 5.2' | 9.0 | 78 | 11 | 4.0 |
| 0400 | 10.35 | 82 | 30 | 52 | 11.7 | 9.0 | 98 | 94 | 82 | 5.5 | 1.7 | 7.9 | 13500 | Max. | 5.6' | 9.0 | 78 | 11 | 4.0 |
| 0600 | 10.3 | 78 | 30 | 48 | 11.75 | 8.9 | 90 | 87 | 78 | 5.3 | 1.5 | 8.0 | 13000 | Max. | 6.1' | 8.9 | 76 | 11 | 4.0/3.5 |
| 0800 | 10.25 | 86 | 36 | 50 | 11.7 | 9.0 | 100 | 90 | 82 | 5.1 | 1.6 | 8.1 | 13000 | Max. | 6.6' | 8.9 | 70 | 12 | 3.8 |
| 1000 | 10.3 | 80 | 34 | 46 | 11.7 | 9.0 | 98 | 90 | 80 | 3.0 | 1.5 | 8.05 | 12700 | Max. | 6.5' | 9.3 | 66 | 12 | 4.0 |
| 1200 | 10.1 | 78 | 30 | 48 | 11.55 | 9.0 | 100 | 50 | 80 | 3.0 | 1.3 | 8.05 | 12200 | Max. | 6.8' | 8.9 | 70 | 12 | 4.0 |
| 1400 | 10.15 | 76 | 32 | 44 | 11.7 | 9.1 | 100 | 92 | 80 | 3.8 | 1.4 | 8.1 | 12000 | Max. | 6.8' | 8.85 | 74 | 12 | 4.0 |
| 1600 | 10.25 | 80 | 30 | 50 | 11.7 | 9.0 | 100 | 90 | 78 | 4.0 | 1.8 | 8.0 | 12000 | Max. | 6.7' | 8.8 | 74 | 12 | 4.0 |
| 1800 | 10.2 | 82 | 30 | 52 | 11.7 | 9.0 | 100 | 92 | 78 | 4.0 | 2.0 | 8.1 | 11500 | Max. | Full | 8.8 | 72 | 12 | 4.0 |
| 2000 | 10.2 | 84 | 32 | 52 | 11.7 | 9.0 | 100 | 90 | 80 | 3.8 | 2.0 | 8.0 | 11000 | Max. | Full | 8.8 | 72 | 12 | 4.0/4.4 |
| 2200 | 10.3 | 89 | 32 | 57 | 11.75 | 8.9 | 95 | 90 | 80 | 3.0 | 1.0 | 7.2 | 12200 | Max. | 6.0' Full | 8.8 | 70 | 12 | 4.4 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/5<br>0000 | 10.4 | 70 | 32 | 48 | 11.65 | 9.1 | 95 | 92 | 78 | 3.0 | 1.4 | 8.1 | 13500 | Max | Full | 9.0 | 70 | 12 | 4.4 |
| 0200 | 10.35 | 70 | 32 | 38 | 11.6 | 8.9 | 95 | 90 | 80 | 3.2 | 1.2 | 7.9 | 14400 | Max | Full | 9.0 | 70 | 12 | 4.4 |
| 0400 | 10.35 | 70 | 32 | 38 | 11.7 | 8.9 | 95 | 90 | 80 | 3.3 | 1.2 | 8.0 | 12200 | Max | 7.0' | 8.9 | 72 | 12 | 4.4 |
| 0600 | 10.35 | 70 | 34 | 36 | 11.7 | 8.8 | 94 | 91 | 82 | 3.4 | 1.4 | 8.1 | 10000 | Max | 7.0' | 8.8 | 72 | 12 | 4.4 |
| 0800 | 10.25 | 72 | 37 | 35 | 11.7 | 8.7 | 90 | 89 | 76 | 3.2 | 1.2 | 8.0 | 11500 | Max | Full | 8.8' | 72 | 12 | 4.4 |
| 1000 | 9.9 | 118 | 42 | 76 | 11.65 | 8.8 | 90 | 91 | 76 | 3.5 | 1.1 | 7.5 | | 10 | 4.0' | 3.8 | 70 | 12 | 4.4 |
| 1200 | 9.95 | 92 | 40 | 52 | 11.7 | 8.7 | 93 | 92 | 76 | 2.2 | 1.1 | 7.35 | 16100 | 10 | 2.0' | 8.8 | 70 | 12 | 4.4 |
| 1400 | 10.0 | 100 | 47 | 53 | 11.6 | 9.2 | 91 | 90 | 74 | 3.6 | 1.1 | 7.3 | 16200 | 9.5 | 2.5' | 9.0 | 68 | 12 | 4.4 |
| 1600 | 10.0 | 101 | 44 | 57 | 11.7 | 9.1 | 93 | 91 | 72 | 3.0 | 1.4 | 7.4 | 17900 | 9.5 | 3.0' | 9.1 | 65 | 12 | 4.4 |
| 1800 | 10.0 | 100 | 48 | 52 | 11.7 | 9.0 | 95 | 90 | 74 | 3.2 | 1.1 | 7.4 | 16800 | Max | 3.8' | 8.9 | 68 | 12 | 4.4 |
| 2000 | 10.0 | 102 | 50 | 50 | 11.65 | 9.0 | 92 | 90 | 75 | 3.2 | 1.2 | 7.5 | 17000 | Max | 4.0' | 8.9 | 65 | 12 | 4.4 |
| 2200 | 10.0 | 100 | 52 | 48 | 11.7 | 9.0 | 94 | 90 | 75 | 3.2 | 1.1 | 7.5 | 16900 | Max | 5.5' | 8.9 | 68 | 12 | 4.4 |
| 3/6<br>0000 | 10.1 | 96 | 32 | 64 | 11.85 | 8.9 | 94 | 88 | 78 | 3.2 | 1.2 | 7.5 | 14800 | Max | 5.8' | 8.9 | 68 | 12+ | 4.0 |
| 0200 | 10.15 | 94 | 30 | 64 | 11.7 | 9.0 | 92 | 88 | 78 | 3.5 | 1.2 | 7.5 | 14900 | 11 | 4.8' | 8.9 | 68 | 12+ | 4.0 |
| 0400 | 10.1 | 104 | 30 | 74 | 11.4 | 9.0 | 88 | 86 | 76 | 3.8 | 1.4 | 7.45 | 14900 | 9 | 2.8' | 8.9 | 67 | 12+ | 4.0 |
| 0600 | 10.15 | 102 | 28 | 74 | 11.7 | 8.9 | 84 | 83 | 73 | 3.5 | 1.2 | 7.5 | 15100 | 8 | 4.0' | 8.9 | 65 | 12+ | 4.0 |
| 0800 | 10.1 | 111 | 32 | 79 | 11.65 | 8.6 | 85 | 84 | 73 | 3.6 | 1.4 | 7.7 | 12600 | 8 | 4.0' | 8.8 | 64 | 12 | 4.0/3.7 |
| 1000 | 10.1 | 110 | 30 | 80 | 11.4 | 8.6 | 86 | 84 | 74 | 3.4 | 1.3 | 7.65 | 13000 | 8 | 4.0' | 8.7 | 66 | 12 | 3.7 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

# MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 |  |  |  | RAPID MIX #2 | MAGNESIUM FLUME |  |  |  |  |  | CARBONATED SLUDGE |  |  |  | EFFLUENT FILTER #5 |  | $CO_2$ SETTING (cfm) |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/6 1200 | 10.1 | 114 | 32 | 82 | 11.7 | 8.7 | 91 | 88 | 78 | 3.7 | 1.3 | 7.4 | 14000 | 8 | 3.9' | 8.7 | 65 | 12 | 3.7 |
| 1400 | Working on Sludge Control Valve |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1600 | 10.45 | 69 | 31 | 38 | 11.7 | 8.6 | 91 | 88 | 79 | 3.5 | 1.2 | 7.2 | 15400 | 8 | 1.5' | 8.6 | 68 | 12 | 3.3 |
| 1800 | 10.3 | 55 | 40 | 15 | 11.4 | 8.6 | 87 | 87 | 83 | 4.2 | 1.4 | 7.2 | 15900 | 8 | 6.2' | 8.8 | 73 | 12 | 3.3 |
| 2000 | 10.4 | 65 | 39 | 26 | 11.7 | 8.8 | 87 | 87 | 79 | 4.5 | 1.5 |  |  |  | 6.5' | 8.8 | 65 | 12 | 3.3 |
| 2200 | 10.35 | 69 | 38 | 31 | 11.7 | 7.7 | 88 | 88 | 77 | 4.2 | 1.2 |  |  |  | 6.5' | 7.95 | 71 | 12 | 3.3 |
| 3/7 0000 | 10.4 | 58 | 34 | 24 | 11.75 | 8.8 | 88 | 88 | 76 | 4.1 | 1.2 |  |  |  |  | 8.4 | 70 | 14 | 3.3 |
| 0200 | 10.45 | 54 | 32 | 22 | 11.8 | 8.9 | 89 | 89 | 74 | 3.5 | 1.2 |  |  |  |  | 8.7 | 68 | 14 | 3.0 |
| 0400 | 10.45 | 62 | 30 | 32 | 11.7 | 8.9 | 88 | 86 | 74 | 3.9 | 1.3 |  |  |  |  | 8.8 | 68 | 14 | 3.0 |
| 0600 | 10.45 | 64 | 30 | 34. | 11.75 | 8.9 | 88 | 86 | 74 | 3.5 | 1.2 |  |  |  |  | 8.8 | 69 | 14 | 3.0 |
| 0800 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1000 | 10.4 | 58 | 29 | 29 | 11.7 | 8.8 | 91 | 90 | 73 | 5.0 | 1.7 |  |  |  |  | 8.7 | 70 | 14 | 3.3 |
| 1200 | 10.3 | 67 | 30 | 37 | 11.75 | 9.0 | 85 | 85 | 71 | 5.0 | 1.8 |  |  |  |  | 8.75 | 66 | 14 | 3.3/3.5 |
| 1400 | 10.35 | 65 | 29 | 36 | 11.7 | 8.9 | 88 | 84 | 68 | 4.6 | 1.5 |  |  |  |  | 8.7 | 68 | 14 | 3.5 |
| 1600 | 10.35 | 60 | 28 | 32 | 11.5 | 9.0 | 88 | 82 | 74 | 7.3 | 1.7 | 7.55 | 14900 |  |  | 9.0 | 68 | 14 | 3.5 |
| 1800 | 10.3 | 60 | 30 | 30 | 11.7 | 9.1 | 89 | 80 | 70 | 6.8 | 1.7 |  |  |  |  | 8.9 | 64 | 14 | 3.5 |
| 2000 | 10.3 | 60 | 30 | 30 | 11.7 | 8.7 | 90 | 88 | 74 | 6.7 | 1.6 |  |  |  |  | 9.0 | 66 | 14 | 3.5 |
| 2200 | 10.4 | 62 | 32 | 30 | 11.75 | 9.1 | 90 | 88 | 74 | 5.6 | 1.5 |  |  |  |  | 8.9 | 68 | 14 | 3.5 |

1 TH-Total Hardness
2 CH- Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | CO$_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/8<br>0000 | 10.45 | 66 | 34 | 30 | 11.7 | 8.9 | 87 | 82 | 68 | 5.4 | 1.7 | | | | | 8.9 | 64 | 14- | 3.5 |
| 0200 | 10.35 | 68 | 32 | 36 | 11.7 | 9.1 | 86 | 84 | 70 | 5.1 | 1.6 | | | | | 9.0 | 66 | 14 | 3.5 |
| 0400 | 10.4 | 66 | 32 | 34 | 11.75 | 9.1 | 90 | 86 | 71 | 4.9 | 1.3 | | | | | 9.0 | 68 | 14+ | 3.8 |
| 0600 | 10.45 | 60 | 30 | 30 | 11.7 | 9.2 | 92 | 91 | 75 | 4.4 | 1.8 | | | | | 9.1 | 70 | 14+ | 4.0 |
| 3/13<br>1600 | 8.65 | 80 | 26 | 54 | 11.6 | 9.7 | 106 | 102 | 90 | 9.5 | 6.4 | 7.05 | 15900 | 11 | 3.5' | 9.1 | 80 | 14 | 2.0 |
| 1800 | 9.8 | 98 | 30 | 68 | 11.5 | 9.8 | 100 | 94 | 84 | 9.0 | 5.2 | 8.1 | 9,800 | 10 | 2.9' | 96 | 64 | 14 | 3.0 |
| 2000 | 8.8 | 90 | 30 | 60 | 11.55 | 9.4 | 108 | 108 | 90 | 7.2 | 4.0 | 7.1 | 27,000 | 11 | 3.6' | 9.3 | 70 | 14 | 2.5 |
| 2200 | 8.3 | 72 | 30 | 42 | 11.6 | 8.8 | 108 | 108 | 90 | 9.0 | 5.0 | 6.8 | 6000 | 11 | 4.3' | 8.8 | 88 | 14 | 2.5 |
| 3/14<br>0000 | 8.9 | 180 | 37 | 143 | 11.6 | 9.7 | 113 | 112 | 91 | 6.0 | 4.0 | 7.3 | 24400 | 14 | 3.0' | 9.6 | 75 | 14 | 3.3 |
| 0200 | 9.6 | 108 | 40 | 68 | 11.4 | 9.7 | 110 | 108 | 85 | 6.8 | 4.0 | 7.7 | 20300 | 12 | 3.0' | 9.6 | 75 | 14 | 4.0 |
| 0400 | 9.7 | 100 | 40 | 60 | 11.4 | 9.4 | 104 | 104 | 85 | 6.8 | 3.5 | 7.6 | 17100 | 14 | 4.5' | 9.3 | 75 | 14 | 4.0 |
| 0600 | 9.75 | 112 | 47 | 66 | 11.65 | 9.3 | 113 | 108 | 85 | 7.0 | 3.1 | 7.6 | 16200 | 14 | 4.5' | 9.15 | 70 | 14 | 4.0 |
| 0800 | 9.75 | 110 | 42 | 68 | 11.65 | 9.2 | 113 | 109 | 84 | 7.2 | 2.9 | 7.65 | 16500 | 14 | 4.5' | 9.1 | 76 | 14 | 4.0 |
| 1000 | 9.5 | 130 | 36 | 94 | 11.6 | 9.2 | 112 | 107 | 88 | 7.8 | 2.8 | 7.75 | 14300 | 10.5 | 5.3' | 9.15 | 78 | 11 | 3.5 |
| 1200 | 9.9 | 96 | 44 | 52 | 11.7 | 9.3 | 110 | 106 | 86 | 7.3 | 2.9 | 7.6 | 14000 | 10.5 | 6.0' | 9.15 | 76 | 14 | 4.0 |
| 1400 | 9.85 | 112 | 52 | 60 | 11.45 | 9.4 | 107 | 107 | 89 | 8.0 | 2.8 | 7.5 | 16100 | 10.5 | 5.8' | 9.1 | 77 | 14 | 4.0 |
| 1600 | 9.9 | 110 | 50 | 60 | 11.6 | 9.4 | 106 | 105 | 86 | 8.5 | 2.7 | 7.4 | 15800 | 10.5 | 3.9' | 9.2 | 72 | 14 | 4.0 |
| 1800 | 9.8 | 99 | 47 | 52 | 11.6 | 9.3 | 102 | 102 | 85 | 8.7 | 2.5 | 7.55 | 15200 | 10 | Full | 9.0 | 64 | 14 | 4.0/<br>4.2 |

[1] TH-Total Hardness

[2] CH-Calcium Hardness

[3] MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/14<br>2000 | 10.0 | 102 | 48 | 54 | 11.6 | 9.2 | 100 | 99 | 83 | 9.4 | 2.9 | 7.5 | 15400 | 10 | 6.5' | 8.9 | 64 | 14 | 4.2 |
| 2200 | 10.1 | 106 | 50 | 56 | 11.6 | 9.1 | 101 | 101 | 82 | 9.9 | 3.0 | 7.5 | 15200 | 10 | 6.5' | 9.0 | 63 | 14 | 4.2 |
| 3/15<br>0000 | 10.2 | 80 | 46 | 34 | 11.7 | 9.2 | 100 | 100 | 84 | 9.9 | 2.5 | 7.5 | 14400 | 10 | 6.5' | 9.2 | 72 | 14 | 4.2 |
| 0200 | 9.8 | 64 | 35 | 29 | 11.6 | 9.3 | 99 | 97 | 81 | 15.0 | 3.3 | 7.5 | 14500 | 10 | 6.5' | 9.3 | 78 | 14 | 4.2 |
| 0400 | 9.9 | 98 | 50 | 48 | 11.65 | 9.4 | 101 | 100 | 83 | 20 | 2.5 | 7.5 | 14500 | 14 | 6.3' | 9.1 | 75 | 14 | 4.2 |
| 0600 | 10.2 | 78 | 48 | 30 | 11.7 | 8.6 | 105 | 104 | 87 | 15 | 2.6 | 7.65 | 13300 | 14 | 6.5' | 8.85 | 85 | 14 | 3.3 |
| 0800 | 10.25 | 79 | 49 | 30 | 11.75 | 9.1 | 105 | 104 | 91 | 20 | 2.2 | 7.85 | 13200 | 14 | 6.5' | 9.0 | 83 | 14 | 3.6 |
| 1000 | 10.0 | 134 | 54 | 80 | 11.5 | 9.4 | 107 | 105 | 90 | 20 | 2.0 | 7.8 | 12400 | 11 | 5.9' | 9.0 | 84 | 14 | 3.6<br>4.2 |
| 1200 | 10.1 | 126 | 48 | 78 | 11.7 | 9.0 | 112 | 109 | 86 | 25 | 2.0 | 7.3 | 12900 | 10.5 | 4.0' | 8.9 | 79 | 14+ | 4.2 |
| 1400 | 10.0 | 127 | 50 | 77 | 11.7 | 8.5 | 119 | 116 | 88 | 20 | 2.4 | 7.35 | 15300 | 10.5 | 5.0' | 8.8 | 85 | 14+ | 4.0 |
| 1600 | 10.1 | 112 | 56 | 56 | 11.6 | 8.6 | 116 | 112 | 81 | 19 | 1.8 | 7.5 | 14300 | 10.5 | 6.0' | 8.7 | 81 | 14 | 4.2 |
| 1800 | 10.1 | 115 | 51 | 64 | 11.6 | 8.8 | 116 | 112 | 83 | 18 | 1.7 | 7.5 | 14400 | 10 | 5.0' | 8.7 | 77 | 14 | 4.2 |
| 2000 | 10.1 | 121 | 48 | 73 | 11.6 | 9.0 | 118 | 114 | 86 | 18 | 1.5 | 7.6 | 14600 | 10 | 4.2' | 8.7 | 72 | 14 | 4.0 |
| 3/16<br>0000 | 10.1 | 118 | 50 | 68 | 11.7 | 9.1 | 110 | 109 | 80 | 20 | 1.5 | 7.7 | 14500 | 10 | 4.5' | 8.8 | 80 | 14 | 4.0 |
| 0200 | 10.0 | 115 | 48 | 67 | 11.6 | 9.0 | 115 | 110 | 90 | 21 | 1.5 | 7.65 | 14000 | 10 | 6.5' | 8.9 | 81 | 14 | 4.0 |
| 0400 | 10.0 | 135 | 58 | 77 | 11.7 | 8.7 | 120 | 115 | 90 | 20 | 1.3 | 7.65 | 14200 | 10 | 6.5' | 8.6 | 85 | 14 | 3.5 |
| 0600 | 10.0 | 130 | 52 | 78 | 11.7 | 8.4 | 119 | 119 | 95 | 18 | 1.4 | 7.65 | 14000 | 12 | 5.8' | 8.6 | 90 | 14 | 3.3 |
| 0800 | 10.1 | 116 | 48 | 68 | 11.8 | 8.7 | 109 | 109 | 88 | 18 | 1.5 | 7.65 | 14200 | 12 | 3.5' | 8.7 | 91 | 14 | 3.6 |

[1] TH-Total Hardness

[2] CH-Calcium Hardness

[3] MH-Magnesium Hardness

# MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/16<br>1000 | 10.05 | 124 | 46 | 78 | 11.65 | 8.7 | 111 | 111 | 88 | 18 | 1.4 | 7.5 | 15700 | 11 | 4.5' | 8.7 | 80 | 13 | 3.2 |
| 1200 | 10.15 | 122 | 47 | 75 | 11.7 | 8.7 | 110 | 108 | 85 | 15 | 1.3 | 7.35 | 15100 | 15 | 3.8' | 8.7 | 78 | 13 | 3.2 |
| 1400 | 10.15 | 118 | 47 | 71 | 11.65 | 8.8 | 111 | 110 | 87 | 15 | 2.2 | 7.55 | 15500 | 14 | 4.3' | 8.6 | 79 | 13 | 3.2 |
| 1600 | 10.1 | 121 | 51 | 70 | 11.6 | 8.8 | 110 | 107 | 82 | 14 | 1.4 | 7.1 | 16400 | 14 | 4.5' | 8.7 | 76 | 13 | 3.0 |
| 1800 | 9.9 | 120 | 50 | 70 | 11.5 | 8.4 | 110 | 108 | 95 | 10 | 1.3 | 7.3 | 15900 | 14 | 4.2' | 8.7 | 75 | 13 | 3.0/2.7 |
| 2000 | 10.1 | 122 | 51 | 73 | 11.5 | 8.4 | 112 | 110 | 90 | 10 | 1.7 | 7.25 | 16000 | 10 | 4.0' | 8.7 | 77 | 13 | 2.7 |
| 2200 | 10.1 | 118 | 54 | 64 | 11.5 | 83 | 115 | 114 | 87 | 9 | 2.0 | 7.3 | 15800 | 10 | 3.5' | 8.6 | 80 | 13 | 2.7/2.2 |
| 3/17<br>0000 | 10.25 | 120 | 48 | 72 | 11.6 | 7.3 | 134 | 114 | 90 | 5.8 | 1.7 | 7.1 | 16600 | 9 | 3.0' | 8.3 | 88 | 10 | 2.0 |
| 0200 | 10.3 | 100 | 50 | 50 | 11.6 | 8.5 | 124 | 108 | 85 | 8.5 | 1.9 | 7.1 | 14600 | 8 | 2.0' | 8.5 | 88 | 10 | 2.0 |
| 0400 | 10.3 | 106 | 50 | 56 | 11.6 | 9.1 | 112 | 108 | 85 | 14 | 1.8 | 7.35 | 16500 | 8 | 2.6' | 8.6 | 86 | 10 | 2.0 |
| 0600 | 10.3 | 114 | 50 | 64 | 11.6 | 9.3 | 110 | 100 | 88 | 17 | 1.4 | 7.2 | 16400 | 8 | 3.6' | 8.9 | 67 | 10 | 2.0 |
| 0800 | 10.2 | 94 | 48 | 46 | 11.65 | 9.6 | 97 | 95 | 80 | 18 | 1.5 | 7.7 | 15100 | 5.5 | 4.5' | 9.2 | 78 | 10 | 2.0 |
| 1000 | 10.3 | 104 | 56 | 48 | 11.65 | 9.1 | 108 | 108 | 87 | 17 | 1.6 | 7.25 | 15600 | 5.5 | 4.0' | 9.0 | 77 | 12 | 3.5 |
| 1200 | 10.25 | 110 | 48 | 62 | 11.6 | 8.4 | 112 | 106 | 88 | 12 | 1.7 | 7.3 | 16300 | 5.5 | 4.8' | 8.6 | 82 | 12 | 3.5/2.5 |
| 1400 | 10.1 | 114 | 50 | 64 | 11.65 | 8.7 | 110 | 110 | 89 | 10 | 1.5 | 7.3 | 16200 | 5.5 | 5.2' | 8.6 | 80 | 12 | 2.5/2.0 |
| 1600 | 10.25 | 112 | 48 | 64 | 11.5 | 9.0 | 107 | 106 | 85 | 9 | 1.6 | 7.2 | 16100 | 6.0 | 4.5' | 8.7 | 77 | 12 | 2.1 |
| 1800 | 10.1 | 118 | 52 | 66 | 11.5 | 9.1 | 107 | 104 | 81 | 8.5 | 2.0 | 7.2 | 16000 | 8.0 | 5.0' | 8.8 | 75 | 12 | 2.1/2.4 |
| 2000 | 10.1 | 126 | 52 | 74 | 11.6 | 8.9 | 109 | 107 | 82 | 8.0 | 2.0 | 7.25 | 16200 | 9.0 | 3.0' | | | 12 | 2.4 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/17 2200 | White Elephant on Strike - Corrected at 2230 (From 2130 to 2230) | | | | | | | | | | | | | | | | | | |
| 3/18 0000 | 9.8 | 114 | 42 | 72 | 11.4 | 8.2 | 106 | 100 | 86 | 6.3 | 2.2 | 7.4 | 15900 | 11 | 3.4' | 8.8 | 80 | 12 | 2.4 |
| 0200 | 10.2 | 120 | 54 | 66 | 11.6 | 7.8 | 106 | 09 | 78 | 5.5 | 2.4 | 7.3 | 1600 | 11 | 4.4' | 8.4 | 98 | 12 | 1.9 |
| 0400 | 10.15 | 124 | 52 | 72 | 11.6 | 8.8 | 102 | 98 | 80 | 5.4 | 2.5 | 7.3 | 1600 | 11 | 5.0' | 8.6 | 90 | 12 | 1.0 |
| 0600 | 10.2 | 112 | 50 | 62 | 11.6 | 9.4 | 100 | 92 | 74 | 6.7 | 2.6 | 7.4 | 1600 | 11 | 4.1' | 8.9 | 62 | 12 | 1.0 |
| 0800 | 9.7 | 106 | 40 | 66 | 11.6 | 9.5 | 99 | 96 | 75 | 5 | 2.2 | 7.4 | 15600 | 11 | 4.8' | 9.1 | 63 | 12+ | 1.0/2.0 |
| 1000 | 10.2 | 110 | 46 | 64 | 11.5 | 9.1 | 105 | 99 | 78 | 6 | 2.3 | 7.3 | 15200 | 11 | 4.0' | 9.0 | 64 | 12+ | 2.0/2.5 |
| 1200 | 10.3 | 92 | 50 | 42 | 11.5 | 8.6 | 115 | 110 | 78 | 5.3 | 2.1 | 7.4 | 15400 | 11 | 6.0' | 8.8 | 62 | 12 | 2.5/2.0 |
| 1400 | 10.35 | 92 | 50 | 42 | 11.6 | 8.7 | 115 | 110 | 88 | 5.5 | 2.0 | 7.25 | 15600 | 11 | 6.8' | 8.7 | 80 | 12 | 2.0 |
| 1600 | 10.3 | 93 | 52 | 41 | 11.4 | 8.7 | 110 | 106 | 82 | 5.1 | 1.9 | 7.2 | 15100 | 10 | 6.5' | 8.7 | 82 | 12 | 2.0 |
| 1800 | 9.9 | 97 | 47 | 50 | 11.4 | 9.0 | 108 | 106 | 80 | 5.0 | 1,8 | 7.25 | 15700 | 9 | 4.5' | 8.8 | 77 | 12 | 2.0/2.3 |
| 2000 | 10.0 | 101 | 43 | 58 | 11.6 | 9.0 | 106 | 100 | 75 | 4.8 | 2.0 | 7.25 | 16200 | 9 | 3.0' | 8.9 | 70 | 12 | 2.3/3.0 |
| 2200 | 10.2 | 109 | 42 | 67 | 11.4 | 8.9 | 105 | 98 | 76 | 4.5 | 1.8 | 7.35 | 16400 | 8.5 | 3.0' | 9.0 | 71 | 12 | 3.0 |
| 3/19 0000 | 9.9 | 116 | 46 | 70 | 11.3 | 9.6 | 130 | 98 | 95 | 5.8 | 2.5 | 7.4 | 17600 | | 2.0' | 9.4 | 65 | 12 | 3.0 |
| 0200 | 10.05 | 102 | 40 | 62 | 11.15 | 9.3 | 100 | 90 | 78 | 4.9 | 2.5 | 7.35 | 18500 | | 3.0' | 9.4 | 68 | 12 | 3.0 |
| 3/21 1400 | 9.95 | 142 | 34 | 108 | 11.7 | 7.8 | 82 | 81 | 74 | 6.0 | 3.0 | 7.5 | 16900 | 15 | 5' | | | 9 | 1.5 |
| 1600 | 10.0 | 134 | 40 | 94 | 11.6 | 9.4 | 88 | 84 | 79 | 6.2 | 2.6 | 7.7 | 16200 | 14.5 | 5.5' | | | 9/10 | 1.2/2.0 |
| 1800 | 10.0 | 138 | 42 | 96 | 11.5 | 9.7 | 79 | 75 | 70 | 10 | 3.0 | 7.7 | 15100 | 14.5 | 5.5' | | | 10/12 | 2.0/3.0 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

# MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/21<br>2000 | 10.0 | 140 | 44 | 96 | 11.55 | 9.3 | 81 | 77 | 72 | 11. | 2.5 | 7.7 | 15300 | 14.5 | 5.5' | | | 12 | 3.7 |
| 2200 | 10.0 | 120 | 42 | 78 | 11.6 | 9.2 | 85 | 81 | 77 | 10 | 2.7 | 7.5 | 15600 | 15 | 6.0' | | | 12<br>13 | 3.7/4.0 |
| 3/22<br>0000 | 9.85 | 138 | 40 | 98 | 11.5 | 8.8 | 92 | 84 | 84 | 7.5 | 1.9 | 7.7 | 14700 | 15 | 7.0' | 8.85 | 70 | 13 | 4.0 |
| 0200 | 9.1 | 132 | 38 | 94 | 11.5 | 9.05 | 90 | 84 | 82 | 7.4 | 1.7 | 7.6 | 14900 | 15 | 6.5' | 8.9 | 72 | 13 | 4.0/3.7 |
| 0400 | 10.0 | 130 | 40 | 90 | 11.6 | 8.5 | 90 | 82 | 80 | 6.9 | 1.7 | 7.6 | 14600 | 15 | 6.0' | 8.8 | 72 | 13 | 3.0/2.9 |
| 0600 | 10.05 | 130 | 42 | 88 | 11.6 | 8.9 | 90 | 86 | 82 | 9.0 | 1.6 | 7.7 | 15200 | 15 | 6.2' | 8.6 | 10 | 13 | 2.9/ |
| 0800 | 10.0 | 130 | 46 | 84 | 11.7 | 9.0 | 81 | 78 | 73 | 6.0 | 1.5 | 7.2 | 16300 | 15 | 6.0' | 8.6 | 71 | 13 | 2.9 |
| 1000 | 10.0 | 128 | 42 | 86 | 11.55 | 9.15 | 83 | 78 | 70 | 5.4 | 1.5 | 7.4 | 14300 | 15 | 5.5' | 8.8 | 70 | 13 | 2.9 |
| 1200 | 10.1 | 130 | 45 | 85 | 11.6 | 9.3 | 85 | 80 | 72 | 5.5 | 1.6 | 7.7 | 14700 | 15 | 5.4' | 8.9 | 72 | 13 | 2.9/3.5 |
| 1400 | 10.0 | 127 | 41 | 86 | 11.5 | 9.2 | 83 | 78 | 71 | 7.5 | 2.0 | 7.4 | 14400 | 15 | 5.6' | 8.5 | 70 | 13 | 3.5 |
| 1600 | 10.0 | 126 | 38 | 88 | 11.5 | 8.8 | 80 | 74 | 75 | 9.0 | 2.0 | 7.5 | 13900 | 15 | 0.0' | 8.8 | 69 | 12+ | 3.4 |
| 1800 | 10.0 | 124 | 36 | 88 | 11.5 | 8.6 | 94 | 80 | 76 | 7.5 | 1.5 | 7.5 | 13800 | 15 | 6.0' | 8.7 | 70 | 12 | 3.4/3.0 |
| 2000 | 10.0 | 134 | 42 | 92 | 11.5 | 8.4 | 84 | 81 | 74 | 8.5 | 2.0 | 7.5 | 13600 | 15 | 5.5' | 8.6 | 69 | 12 | 3.0/2.0 |
| 2200 | 10.0 | 118 | 36 | 82 | 11.5 | 9.1 | 79 | 76 | 76 | 8.0 | 1.7 | 7.6 | 13200 | 15 | 6.5' | 8.9 | 71 | 12 | 2.0 |
| 3/23<br>0000 | 10.0 | 148 | 40 | 108 | 11.6 | 9.3 | 90 | 80 | 60 | 8.3 | 1.5 | 7.55 | 15000 | 15 | 6.8' | 9.1 | 64 | 12 | 2.0 |
| 0200 | 10.0 | 140 | 44 | 96 | 11.6 | 9.3 | 90 | 78 | 60 | 7.2 | 1.4 | 7.45 | 14500 | 15 | 5.1' | 9.0 | 68 | 12 | 2.0 |
| 0400 | 10.1 | 144 | 40 | 104 | 11.55 | 9.3 | 98 | 80 | 66 | 14.0 | 2.0 | 7.5 | 13800 | 15 | 3.8' | 9.2 | 64 | 12 | 2.0 |
| 0600 | 10.0 | 140 | 40 | 100 | 11.6 | 9.3 | 82 | 72 | 70 | 7.3 | 1.4 | 7.5 | 13200 | 15 | 4.6' | 9.2 | 64 | 12 | 2.0 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | CO$_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/23<br>0800 | 9.9 | 130 | 40 | 90 | 11.6 | 9.5 | 88 | 75 | 72 | 4.0 | 1.5 | 7.35 | 13500 | 15 | 6.6' | 9.2 | 57 | 12 | 2.0 |
| 1000 | 9.8 | 210 | 45 | 165 | 11.6 | 9.15 | 95 | 82 | 70 | 6.0 | 1.5 | 7.4 | 12600 | 15 | 4.5' | 9.2 | 59 | 12 | 3.0 |
| 1200 | 10.0 | 140 | 42 | 98 | 11.6 | 8.8 | 93 | 82 | 70 | 6.0 | 1.5 | 7.4 | 12800 | 15 | Foamy | 9.2 | 59 | 12 | 2.0 |
| 1400 | 10.0 | 140 | 40 | 100 | 11.6 | 9.0 | 88 | 84 | 68 | 5.5 | 1.0 | 7.4 | 12900 | 15 | 2.5' | 9.2 | 58 | 12 | 2.0 |
| 1600 | 10.05 | 118 | 40 | 78 | 11.6 | 9.0 | 97 | 94 | 64 | 8 | 1.8 | 7.6 | 13700 | 15 | 2.1' | 9.0 | 58 | 12 | 2.0 |
| 1800 | 10.1 | 140 | 40 | 100 | 11.5 | 9.0 | 94 | 88 | 69 | 9 | 1.9 | 7.5 | 14100 | 15 | 1.5' | 8.9 | 62 | 12 | 2.0 |
| 2000 | 10.1 | 136 | 40 | 96 | 11.55 | 9.2 | 90 | 84 | 63 | 9 | 1.9 | 7.5 | 14000 | 15 | 3.0' | 9.1 | 59 | 12 | 2.0 |
| 2200 | 10.1 | 134 | 38 | 96 | 11.6 | 9.1 | 96 | 86 | 67 | 8 | 1.7 | 7.45 | 13900 | 15 | 3.5' | 9.0 | 60 | 12 | 2.0/2.5 |
| 3/24<br>0000 | 10.1 | 130 | 36 | 94 | 11.5 | 9.0 | 95 | 84 | 66 | 8.5 | 1.5 | 7.5 | 14200 | 15 | 4.0' | 9.0 | 62 | 12 | 2.6 |
| 0200 | 10.0 | 137 | 37 | 100 | 11.5 | 8.9 | 101 | 89 | 66 | 7.0 | 1.5 | 7.5 | 13600 | 15 | 4.5' | 8.85 | 57 | 12 | 2.7 |
| 0400 | 10.0 | 137 | 38 | 99 | 11.55 | 8.7 | 97 | 86 | 68 | 5.5 | 1.1 | 7.4 | 14100 | 15 | 5.0' | 8.5 | 61 | 12 | 2.5 |
| 0600 | 10.0 | 136 | 35 | 101 | 11.5 | 8.8 | 99 | 85 | 67 | 5.7 | 1.2 | 7.45 | 14000 | 15 | 5.3' | 8.5 | 60 | 12 | 2.5 |
| 0800 | 10.0 | 132 | 35 | 97 | 11.55 | 8.7 | 98 | 86 | 62 | 5.2 | 1.5 | 7.4 | 13800 | | 4.8' | 8.6 | 64 | 12 | 2.5 |
| 1000 | 10.0 | 135 | 35 | 100 | 11.5 | 8.6 | 96 | 86 | 64 | 5.5 | 1.5 | 7.4 | 13600 | | 4.5 | 8.4 | 62 | 12 | 2.5 |
| 1200 | 9.9 | 135 | 40 | 95 | 11.5 | 8.7 | 95 | 85 | 60 | 5.0 | 1.0 | 7.4 | 13800 | | 4.0' | 8.6 | 65 | 12 | 2.5 |
| 1400 | 10.0 | 138 | 40 | 98 | 11.55 | 8.6 | 98 | 85 | 64 | 5.5 | 1.5 | 7.4 | 14000 | | 4.0' | 8.6 | 65 | 12 | 2.5 |
| 1600 | 10.15 | 122 | 38 | 84 | 11.55 | 8.6 | 98 | 85 | 64 | 5.5 | 1.6 | 7.4 | 14800 | Max | 6.5' | 8.6 | 65 | 12 | 2.5/2.0 |
| 1800 | 10.2 | 126 | 36 | 90 | 11.55 | 8.7 | 90 | 85 | 72 | 5.7 | 1.6 | 7.45 | 14800 | Max | 6.6' | 8.6 | 67 | 12 | 2.0 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/24<br>2000 | 10.2 | 124 | 36 | 88 | 11.5 | 8.6 | 90 | 85 | 68 | 6.0 | 1.7 | 7.4 | 14700 | Max | 7.0' | 8.7 | 58 | 12 | 2.0<br>1.8 |
| 2200 | 9.9 | | | | 11.5 | 8.8 | 90 | 82 | 67 | 6.0 | 1.4 | 7.4 | | Max | 5.5' | | | 12 | 1.8 |
| 3/25<br>0000 | 9.95 | 126 | 32 | 94 | 11.5 | 9.0 | 88 | 81 | 64 | 5.9 | 1.3 | 7.6 | 13500 | Max | 1.5' | 8.9 | 53 | 12 | 1.8<br>2.0 |
| 0200 | 9.9 | 124 | 34 | 90 | 11.5 | 8.9 | 90 | 83 | 65 | 5.8 | 1.2 | 7.5 | 13700 | 15 | 2.0' | 8.9 | 49 | 12 | 2.0<br>2.3 |
| 0400 | 9.9 | 122 | 30 | 92 | 11.5 | 9.2 | 91 | 86 | 70 | 5.0 | 1.0 | 7.5 | 14100 | 15 | 2.0' | 8.9 | 51 | 12 | 2.3<br>2.8 |
| 0600 | 9.95 | 126 | 32 | 94 | 11.55 | 8.9 | 92 | 86 | 68 | 4.5 | 0.8 | 7.5 | 13600 | 15 | 2.2' | 8.9 | 50 | 12 | 2.8 |
| 0800 | 9.9 | 130 | 35 | 95 | 11.5 | 8.8 | 92 | 84 | 65 | 4.5 | 1.5 | 7.5 | 13500 | 15 | 3.0' | 8.8 | 52 | 12 | 2.8 |
| 1000 | 9.9 | 130 | 32 | 98 | 11.5 | 8.9 | 94 | 84 | 66 | 4.5 | 1.0 | 7.5 | 14000 | 15 | 2.0' | 8.9 | 54 | 12 | 2.8 |
| 1200 | 10.1 | 128 | 30 | 98 | 11.5 | 9.0 | 92 | 84 | 64 | 4.8 | 1.0 | 7.4 | 13800 | 15 | 2.0' | 8.9 | 58 | 12 | 3.0 |
| 1400 | 10.0 | 130 | 30 | 100 | 1.55 | 9.0 | 92 | 86 | 65 | 5.0 | 1.0 | 7.4 | 13800 | 15 | 2.0' | 9.2 | 58 | 12 | 3.4 |
| 1600 | 10.0 | 120 | 28 | 92 | 11.55 | 9.2 | 87 | 85 | 75 | 6.0 | 1.4 | 7.45 | 13700 | 15 | 4.5' | 9.2 | 68 | 12 | 3.5 |
| 1800 | 10.05 | 126 | 28 | 98 | 11.6 | 8.6 | 87 | 83 | 72 | 6.5 | 1.4 | 7.55 | 13600 | 15 | 4.3' | 8.9 | 67 | 12 | 3.5 |
| 2000 | 10.0 | 128 | 32 | 96 | 11.6 | 8.8 | 88 | 84 | 76 | 5.8 | 1.2 | 7.5 | 14600 | 15 | 2.5' | 8.9 | 70 | 12 | 3.5 |
| 2200 | 10.0 | 128 | 36 | 92 | 11.6 | 8.9 | 89 | 85 | 80 | 5.5 | 1.2 | 7.6 | 14900 | 8 | 1.5' | 8.9 | 70 | 12 | 3.5 |
| 3/26<br>0000 | 10.0 | 119 | 34 | 85 | 11.5 | 9.0 | 90 | 86 | 76 | 5.2 | 1.0 | 7.45 | 14800 | 15 | 2.0' | 8.9 | 72 | 12 | 3.5 |
| 0200 | 10.0 | 125 | 34 | 91 | 11.5 | 8.9 | 95 | 86 | 76 | 5.2 | 1.2 | 7.5 | 14700 | 15 | 3.0' | 8.9 | 73 | 12 | 3.5 |
| 0400 | 9.9 | 132 | 36 | 96 | 11.55 | 8.7 | 99 | 88 | 78 | 5.2 | 1.2 | 7.4 | 15000 | 15 | 3.5' | 8.8 | 75 | 12 | 3.5 |
| 0600 | 10.0 | 127 | 34 | 93 | 11.5 | 8.7 | 102 | 87 | 72 | 5.0 | 1.0 | 7.4 | 14600 | 15 | | 8.7 | 69 | 12 | 3.3 |

[1] TH-Total Hardness
[2] CH-Calcium Hardness
[3] MH-Magnesium Hardness

# MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/26<br>0800 | 9.9 | 164 | 52 | 112 | 11.6 | 8.7 | 104 | 87 | 94 | 4.5 | 1.0 | 7.4 | 16100 | 15 | | 8.4 | 66 | 12 | 3.3 |
| 1000 | 9.95 | 135 | 59 | 76 | 11.65 | 8.8 | 90 | 88 | 73 | 2.9 | 0.8 | 7.4 | 14500 | 15 | | 8.85 | 68 | 12 | 3.0 |
| 1200 | 9.9 | 120 | 41 | 79 | 11.3 | 9.25 | 90 | 85 | 68 | 5.5 | 1.2 | 7.4 | 14200 | 15 | 4.0' | 9.2 | 64 | 12 | 3.0 |
| 1400 | 9.9 | 121 | 61 | 60 | 11.35 | 8.7 | 86 | 83 | 68 | 6.8 | 1.2 | 7.45 | 14300 | 15 | 3.0' | 8.75 | 62 | 12 | 3.15 |
| 1600 | 10.0 | 130 | 36 | 94 | 11.6 | 7.9 | 82 | 73 | 68 | 7.6 | 1.6 | 7.5 | 14300 | 14 | 4.2' | 8.5 | 66 | 12+ | 3.2/2.0 |
| 1800 | 10.0 | 122 | 34 | 88 | 11.7 | 8.1 | 80 | 72 | 68 | 6.8 | 1.6 | 7.6 | 14200 | 14 | 5.5' | 8.4 | 64 | 12+ | 2.0 |
| 2000 | 10.0 | 128 | 34 | 94 | 11.7 | 9.3 | 87 | 80 | 73 | 6.0 | 1.4 | 7.6 | 13900 | 14 | 5.0' | 8.6 | 59 | 12 | 2.0/2.5 |
| 2200 | 10.0 | 132 | 32 | 100 | 11.65 | 9.5 | 90 | 88 | 76 | 6.0 | 1.4 | 7.6 | 13600 | 14 | 5.0' | 8.8 | 66 | 12 | 2.5/3.0 |
| 3/27<br>0000 | 10.0 | 129 | 37 | 92 | 11.5 | 9.5 | 90 | 86 | 73 | 6.1 | 1.4 | 7.6 | 13800 | 15 | | 9.0 | 62 | 12 | 3.0/3.5 |
| 0200 | 9.95 | 127 | 39 | 88 | 11.6 | 9.4 | 93 | 86 | 74 | 6.4 | 1.6 | 7.55 | 13600 | 15 | | 9.2 | 59 | 12 | 4.0 |
| 0400 | 10.0 | 130 | 37 | 93 | 11.6 | 9.2 | 94 | 85 | 73 | 5.2 | 1.3 | 7.6 | 13800 | 15 | | 9.0 | 61 | 12 | 4.0 |
| 0600 | 9.0 | 132 | 36 | 96 | 11.5 | 8.8 | 96 | 87 | 76 | 4.5 | 1.0 | 7.55 | 14000 | 15 | | 8.9 | 65 | 14 | 4.0 |
| 0800 | 10.0 | 122 | 36 | 86 | 11.6 | 8.8 | 98 | 96 | 80 | 6.9 | 0.9 | 7.55 | 14400 | 15 | 2.5' | 8.8 | 68 | 14 | 4.0 |
| 1000 | 10.0 | 130 | 34 | 96 | 11.55 | 8.9 | 96 | 92 | 84 | 5.5 | 0.9 | 7.45 | 14500 | 15 | 4.0' | 8.7 | 62 | 14 | 4.0 |
| 1200 | 10.0 | 138 | 42 | 96 | 11.6 | 8.8 | 98 | 90 | 78 | 9.2 | 1.0 | 7.5 | 14200 | 15 | 3.11' | 8.8 | 72 | 14 | 4.0 |
| 1400 | 10.0 | 126 | 36 | 90 | 11.5 | 9.0 | 98 | 90 | 80 | 8.5 | 0.9 | 7.45 | 14400 | 15 | 3.3' | 8.8 | 72 | 14 | 4.0 |
| 1600 | 9.95 | 130 | 36 | 94 | 11.6 | 8.8 | 91 | 88 | 80 | 9.0 | 0.9 | 7.5 | 14200 | | 0.8' | 8.8 | 75 | 15 | 4.0 |
| 1800 | 10.0 | 130 | 36 | 94 | 11.6 | 9.0 | 96 | 91 | 82 | 9.5 | 1.5 | 7.45 | 14100 | | 1.2' | 8.8 | 73 | 15 | 4.0 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (qpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/27 2000 | 10.0 | 132 | 34 | 98 | 11.6 | 8.9 | 91 | 88 | 78 | 9 | 1.2 | 7.4 | 14200 | | 0.5' | 8.9 | 68 | 15 | 4.0 |
| 2200 | 10.0 | 132 | 34 | 98 | 11.6 | 9.1 | 88 | 86 | 76 | 9 | 1.2 | 7.5 | 14200 | | 0.8' | 8.9 | 68 | 15 | 4.0 |
| 3/28 0000 | 10.1 | 148 | 65 | 83 | 11.75 | 8.65 | 88 | 86 | 76 | 5.8 | 0.8 | 7.3 | 14300 | | | 8.7 | 67 | 15 | 4.0 |
| 0200 | 9.9 | 112 | 43 | 69 | 11.6 | 8.7 | 90 | 88 | 75 | 5.6 | 1.2 | 7.35 | 13800 | | | 8.7 | 75 | 15 | 3.5 |
| 0400 | 9.9 | 118 | 42 | 76 | 11.6 | 8.6 | 91 | 87 | 75 | 6.8 | 1.2 | 7.4 | 14000 | | | 8.75 | 70 | 15 | 3.5 |
| 0600 | 9.9 | 119 | 41 | 78 | 11.6 | 8.75 | 90 | 88 | 78 | 5.8 | 1.0 | 7.4 | 14000 | | | 8.85 | 70 | 15 | 3.15 |
| 0800 | 10.0 | 132 | 38 | 94 | 11.6 | 8.8 | 98 | 84 | 80 | 8.0 | 1.3 | 7.55 | 14700 | Max | Full | 8.9 | 64 | 15 | 3.15 |
| 1000 | 10.0 | 130 | 38 | 92 | 11.6 | 8.8 | 90 | 80 | 74 | 6.1 | 0.8 | 7.45 | 14600 | Max | 4.6' | 8.9 | 64 | 15 | 3.15 |
| 1200 | 9.9 | 148 | 34 | 114 | 11.6 | 8.8 | 88 | 80 | 68 | 5.0 | 0.9 | 7.4 | 14500 | Max | 4.6' | 8.9 | 64 | 15 | 3.15 |
| 1400 | 9.95 | 128 | 38 | 90 | 11.8 | 8.8 | 108 | 86 | 74 | 9.2 | 0.9 | 7.4 | 13500 | Max | 5.0' | 9.0 | 72 | 15 | 3.15 |
| 1600 | 10.1 | 145 | 42 | 103 | 11.7 | 9.1 | 82 | 75 | 75 | 7.5 | 1.0 | 7.4 | 13400 | | 5.0' | 8.9 | 64 | 15 | 3.15 |
| 1800 | 10.0 | 140 | 40 | 100 | 11.6 | 9.0 | 82 | 75 | 72 | 7.0 | 1.0 | 7.4 | 14000 | | 5.5' | 8.9 | 66 | 15 | 3.15 |
| 2000 | 10.0 | 140 | 40 | 100 | 11.6 | 9.0 | 82 | 74 | 72 | 7.0 | 1.0 | 7.4 | 14200 | | 5.5' | 8.9 | 66 | 15 | 3.15 |
| 2200 | 10.1 | 142 | 40 | 102 | 11.65 | 9.1 | 84 | 78 | 76 | 7.4 | 0.9 | 7.5 | 14000 | | 5.5' | 9.0 | 70 | 15 | 3.15 |
| 3/29 0000 | 10.0 | 110 | 36 | 74 | 11.65 | 8.9 | 81 | 78 | 66 | 6.0 | 1.2 | 7.5 | 14000 | | 5.0' | 9.0 | 64 | 15 | 3.15 |
| 0200 | 10.0 | 104 | 35 | 69 | 11.65 | 9.4 | 87 | 85 | 66 | 6.0 | 1.2 | 7.5 | 13600 | | 5.1' | 9.3 | 68 | 15 | 3.15 |
| 0400 | 10.0 | 110 | 40 | 70 | 11.65 | 9.7 | 88 | 86 | 70 | 5.5 | 1.2 | 7.5 | 14300 | | 5.0' | 9.15 | 66 | 15 | 4.0 |
| 0600 | 10.0 | 110 | 40 | 70 | 11.6 | 8.6 | 89 | 87 | 68 | 5.8 | 1.5 | 7.4 | 14100 | | 5.0' | 9.0 | 73 | 15 | 3.5 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

# MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/29<br>0800 | 10.0 | 120 | 32 | 88 | 11.6 | 9.15 | 86 | 80 | 70 | 8.2 | 1.2 | 7.6 | 14900 | Max | 4.9' | 8.95 | 68 | 15 | 3.6 |
| 1000 | 10.0 | 116 | 28 | 88 | 11.6 | 9.1 | 90 | 86 | 72 | 8.0 | 1.1 | 7.7 | 14200 | Max | 4.0' | 8.9 | 66 | 14 | 4.2 |
| 1200 | 10.0 | 116 | 32 | 84 | 11.5 | 9.15 | 86 | 82 | 68 | 7.9 | 1.2 | 7.8 | 14100 | Max | 4.7' | 8.9 | 62 | 15 | 4.0 |
| 1400 | 10.0 | 120 | 32 | 88 | 11.6 | 9.2 | 88 | 82 | 68 | 6.2 | 3.2 | 7.7 | 14200 | Max | 6.0' | 8.85 | 64 | 15 | 4.2 |
| 1600 | 10.0 | 118 | 32 | 86 | 11.65 | 9.0 | 85 | 82 | 70 | 6.0 | 2.0 | 7.5 | 14000 | | 6.2' | 8.9 | 64 | 15 | 4.2 |
| 1800 | 10.0 | 116 | 32 | 84 | 11.6 | 8.8 | 88 | 84 | 70 | 6.5 | 2.0 | 7.5 | 14000 | | Foam | 8.9 | 66 | 15 | 4.2 |
| 2000 | 10.0 | 115 | 32 | 83 | 11.65 | 8.4 | 88 | 84 | 68 | 6.5 | 2.0 | 7.55 | 14300 | | Foam | 8.9 | 64 | 15 | 3.5 |
| 2200 | 10.0 | 118 | 32 | 86 | 11.6 | 8.8 | 85 | 84 | 72 | 8.0 | 1.0 | 7.5 | 14200 | | Foam | 9.0 | 68 | 15 | 3.5 |
| 3/30<br>0000 | 10.0 | 120 | 32 | 88 | 11.6 | 9.0 | 82 | 77 | 70 | 7.2 | 1.3 | 7.5 | 15000 | 15 | | 8.9 | 15 | 3.5 | |
| 0200 | 9.95 | 122 | 32 | 90 | 11.55 | 8.9 | 80 | 77 | 66 | 6.7 | 1.2 | 7.3 | 15600 | 14.5 | | 8.8 | 65 | 15 | 3.5 |
| 0400 | 9.95 | 125 | 32 | 93 | 11.6 | 8.8 | 82 | 76 | 70 | 6.9 | 1.4 | 7.3 | 15500 | 14.5 | | 8.8 | 64 | 15 | 3.5 |
| 0600 | 9.95 | 127 | 31 | 96 | 11.6 | 8.7 | 84 | 78 | 73 | 7.0 | 1.5 | 7.35 | 15900 | 15 | | 8.8 | 65 | 15 | 3.5 |
| 0800 | 9.9 | 130 | 30 | 100 | 11.6 | 8.5 | 94 | 82 | 64 | 8.0 | 0.8 | 7.6 | 15200 | Max | 5.6' | 8.5 | 65 | 15 | 2.5 |
| 1000 | 9.95 | 124 | 30 | 94 | 11.6 | 8.6 | 88 | 84 | 76 | 7.5 | 0.9 | 7.4 | 15600 | Max | 4.4' | 8.6 | 76 | 15 | 2.5 |
| 1200 | 9.95 | 128 | 30 | 98 | 11.6 | 8.9 | 90 | 80 | 68 | 5.0 | 0.9 | 7.9 | 13900 | Max | 5.0' | 8.6 | 62 | 15 | 2.5 |
| 1400 | 9.95 | 128 | 28 | 100 | 11.65 | 9.1 | 92 | 82 | 68 | 8.4 | 1.4 | 7.4 | 14900 | Max | 7.0' | 8.95 | 64 | 15 | 2.5 |
| 1600 | 9.9 | 126 | 26 | 100 | 11.0 | 9.0 | 90 | 80 | 69 | 8.0 | 1.5 | 7.4 | 14500 | | | 9.0 | 65 | 15 | 2.5 |
| 1800 | 10.0 | 128 | 26 | 102 | 11.7 | 9.0 | 92 | 80 | 70 | 8.0 | 1.5 | 7.4 | 14600 | | 5.5' | 9.0 | 64 | 15 | 2.5 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

# MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | CO$_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 3/30 2000 | 10.0 | 126 | 25 | 101 | 11.6 | 9.0 | 94 | 82 | 72 | 8.0 | 1.0 | 7.4 | 14400 | | 5.5' | 9.0 | 64 | 15 | 2.5 |
| 2200 | 10.0 | 124 | 30 | 94 | 11.65 | 9.0 | 94 | 84 | 72 | 7.5 | 1.5 | 7.4 | 14200 | | 5.8' | 9.0 | 66 | 15 | 2.5 |
| 3/31 0000 | 10.05 | 122 | 34 | 88 | 11.7 | 8.75 | 88 | 86 | 71 | 7.5 | 1.2 | 7.8 | 14300 | 12 | 4.8' | 8.8 | 62 | 18 | 2.7 |
| 0200 | 10.0 | 122 | 32 | 90 | 11.65 | 9.0 | 87 | 86 | 70 | 7.0 | 1.2 | 7.6 | 14400 | 12 | 5.2' | 8.9 | 62 | 16 | 2.7 |
| 0400 | 10.05 | 116 | 34 | 82 | 11.6 | 8.9 | 88 | 84 | 70 | 7.2 | 1.1 | 7.7 | 14200 | 12 | 3.2' | 8.9 | 62 | 16 | 2.7 |
| 0600 | 10.1 | 102 | 36 | 66 | 11.5 | 8.9 | 89 | 84 | 71 | 7.0 | 1.2 | 7.7 | 14000 | 8 | 4.0' | 8.8 | 64 | 16 | 2.7 |
| 0800 | 10.0 | 120 | 36 | 84 | 11.6 | 9.0 | 92 | 84 | 70 | 8.9 | 1.6 | 7.9 | 12600 | Max | 3.5' | 8.8 | 62 | 16 | 2.7 |
| 1000 | 10.0 | 174 | 32 | 132 | 11.6 | 9.0 | 88 | 82 | 72 | 15 | 1.7 | 7.7 | 13800 | Max | 4.0' | 9.05 | 58 | 16 | 3.0 |
| 1200 | 10.1 | 120 | 34 | 86 | 11.6 | 9.8 | 58 | 55 | 72 | 18 | 2.0 | 7.3 | 15500 | Max | 4.1' | 9.3 | 50 | 16 | 3.5 |
| 1400 | 10.0 | 126 | 36 | 90 | 11.6 | 9.5 | 88 | 82 | 72 | 18 | 1.5 | 7.3 | 15700 | Max | 3.0 | 9.15 | 52 | 16 | 4.0 |
| 1600 | 10.0 | 128 | 34 | 94 | 11.65 | 9.4 | 80 | 80 | 70 | 16 | 2.0 | 7.4 | 14900 | | 6.0' | 9.2 | 50 | 16 | 3.5 |
| 1800 | 10.0 | 126 | 32 | 94 | 11.6 | 8.8 | 85 | 80 | 72 | 10 | 2.0 | 7.4 | 14500 | | 6.0' | 9.0 | 50 | 16 | 3.0 |
| 2000 | 10.0 | 128 | 34 | 94 | 11.65 | 8.0 | 87 | 82 | 70 | 5.5 | 2.0 | 7.4 | 14400 | Max | Full | 9.0 | 52 | 16 | 3.0 |
| 2200 | 10.1 | 130 | 34 | 96 | 11.65 | 8.5 | 85 | 82 | 72 | 6.0 | 1.5 | 7.4 | 14500 | | Full | 8.9 | 54 | 16 | 3.0 |
| 4/1 0000 | 10.0 | 130 | 40 | 90 | 11.65 | 8.2 | 95 | 90 | 76 | 6.3 | 1.6 | 7.4 | 15000 | Max | Full | 8.5 | 82 | 16 | 3.4 |
| 0200 | 10.1 | 132 | 40 | 92 | 11.6 | 9.2 | 94 | 90 | 77 | 7.2 | 1.2 | 7.4 | 15100 | Max | Full | 8.8 | 83 | 16 | 3.0 |
| 0400 | 10.0 | 130 | 36 | 94 | 11.55 | 9.2 | 98 | 94 | 74 | 7.0 | 1.0 | 7.4 | 15000 | Max | Full | 8.9 | 70 | 16 | 3.5 |
| 0600 | 9.95 | 138 | 34 | 104 | 11.6 | 9.1 | 98 | 94 | 76 | 7.0 | 1.0 | 7.35 | 14900 | Max | Full | 8.8 | 64 | 16 | 3.7 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 4/1 0800 | 9.9 | 150 | 32 | 119 | 11.55 | 8.55 | 100 | 98 | 64 | 6.4 | 1.3 | 7.45 | 13600 | Max | 0.8' | 8.65 | 64 | 16 | 3.0 |
| 1000 | 10.0 | 146 | 46 | 100 | 11.55 | 9.2 | 94 | 90 | 70 | 5.2 | 1.2 | 7.4 | 13600 | Max | 1.0' | 8.05 | 80 | 16 | 3.0 |
| 1200 | 9.95 | 152 | 42 | 110 | 11.55 | 9.0 | 100 | 100 | 80 | 5.3 | 1.4 | 7.5 | 13800 | Max | 2.6' | 8.75 | 68 | 15 | 2.0 |
| 1400 | 10.35 | 84 | 38 | 46 | 11.75 | 8.8 | 98 | 98 | 84 | 4.4 | 2.0 | 7.2 | 15600 | | | 8.7 | 66 | 15 | 2.0 |
| 1600 | 10.1 | 95 | 36 | 59 | 11.6 | 8.8 | 98 | 96 | 85 | 5.0 | 2.0 | 7.4 | 14800 | | 5.0' | 8.8 | 66 | 15 | 2.0 |
| 1800 | 10.0 | 96 | 34 | 62 | 11.65 | 8.9 | 98 | 95 | 84 | 5.5 | 2.5 | 7.4 | 14600 | | Full | 8.9 | 68 | 15 | 2.0 |
| 2000 | 9.9 | 120 | 34 | 86 | 11.6 | 9.2 | 100 | 96 | 82 | 5.0 | 2.0 | 7.5 | 14200 | | Full | 9.0 | 68 | 15 | 3.5 |
| 2200 | 9.9 | 118 | 34 | 84 | 11.7 | 9.3 | 98 | 94 | 80 | 5.0 | 2.0 | 7.4 | 14200 | | Full | 9.1 | 68 | 15 | 4.5 |
| | | | | | | | | | | | | | | | | | | | |
| 4/2 1800 | 9.8 | 105 | 32 | 73 | 11.5 | 9.4 | 92 | 90 | 72 | 3.5 | 1.5 | 7.6 | 15800 | | 4.5' | -- | -- | Full | Ful |
| 2000 | 9.8 | 105 | 32 | 70 | 11.65 | 9.2 | 95 | 90 | 74 | 5.5 | 1.5 | 7.4 | 15900 | | 3.0' | -- | -- | 14 | Full |
| 2200 | 9.8 | 110 | 32 | 78 | 11.6 | 9.3 | 94 | 92 | 78 | 5.2 | 1.6 | 7.35 | 16200 | | 6.0' | -- | -- | 14/20 | 3.0/Full |
| 4/3 0000 | 9.75 | 110 | 40 | 70 | 11.6 | 8.2 | 96 | 94 | 75 | 6.6 | 2.0 | 7.6 | 16300 | Max | 2.5' | -- | -- | 20/17 | F/4.0 |
| 0200 | 9.9 | 112 | 36 | 76 | 11.7 | 8.5 | 96 | 94 | 76 | 7.0 | 2.0 | 7.6 | 16400 | Max | 2.0' | -- | -- | 17 | 3.0 |
| 0400 | 9.95 | 114 | 34 | 80 | 11.7 | 8.8 | 95 | 93 | 78 | 7.0 | 1.9 | 7.6 | 16700 | Max | 2.0' | -- | -- | 17 | 3.0 |
| 0600 | 9.9 | 110 | 34 | 76 | 11.6 | 9.8 | 97 | 93 | 76 | 6.0 | 1.5 | 7.65 | 16000 | Max | 3.0' | -- | -- | 17 | 3.5 |
| 0800 | 9.8 | 122 | 33 | 89 | 11.6 | 9.8 | 96 | 89 | 75 | 5.6 | 1.6 | 7.3 | 16800 | Max | | -- | -- | 17/18 | 3.5/4.0 |
| 1000 | 9.9 | 107 | 33 | 74 | 11.75 | 9.3 | 105 | 96 | 77 | 5.2 | 1.5 | 7.5 | 14900 | Max | | -- | -- | 18 | 4.2 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | CO$_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 4/3<br>1200 | 9.8 | 124 | 33 | 91 | 11.6 | 9.2 | 96 | 92 | 76 | 5.1 | 1.5 | 7.5 | 15800 | Max | | -- | -- | 15/18 | 4.0/Max |
| 1400 | 9.8 | 111 | 34 | 87 | 11.65 | 9.2 | 106 | 98 | 80 | 4.0 | 1.6 | 7.45 | 15100 | Max | 5.5' | -- | -- | 14 | 4.2/4.0 |
| 1600 | 9.9 | 115 | 32 | 83 | 11.6 | 9.1 | 100 | 98 | 78 | 4.5 | 1.5 | 7.7 | 16000 | Max | 5.0' | -- | -- | 14/17 | 4.0/4.5 |
| 1800 | 9.9 | 120 | 34 | 86 | 11.6 | 9.4 | 98 | 97 | 74 | 4.5 | 1.8 | 7.5 | 15500 | Max | 6.0' | -- | -- | 17 | 4.5 |
| 2000 | 9.9 | 115 | 34 | 81 | 11.65 | 9.3 | 98 | 66 | 74 | 5.0 | 1.5 | 7.5 | 15800 | Max | 6.5' | -- | -- | 17 | 4.5 |
| 2200 | 9.9 | 116 | 34 | 82 | 11.6 | 9.1 | 100 | 96 | 75 | 80 | 1.5 | 7.5 | 15800 | Max | 6.0' | -- | -- | 17 | 4.5 |
| 4/4<br>0000 | 9.9 | 110 | 34 | 76 | 11.55 | 9.4 | 93 | 91 | 78 | 8.0 | 1.5 | 7.7 | 14900 | Max | 6.0' | -- | -- | 17 | 4.5 |
| 0200 | 9.9 | 110 | 34 | 76 | 11.5 | 9.3 | 93 | 90 | 78 | 7.5 | 1.8 | 7.6 | 14900 | Max | 6.3' | -- | -- | 18 | 4.5 |
| 0400 | 9.9 | 106 | 34 | 72 | 11.5 | 8.5 | 91 | 88 | 76 | 7.0 | 1.7 | 7.6 | 14900 | Max | 6.5' | -- | -- | 17+ | 4.5 |
| 0600 | 9.9 | 104 | 34 | 70 | 11.5 | 8.8 | 89 | 86 | 74 | 7.8 | 1.9 | 7.6 | 14700 | Max | 5.0' | -- | -- | 17- | 4.0 |
| *0800 | 9.95 | 102 | 39 | 63 | 11.95 | 8.0 | 91 | 88 | 70 | 6.5 | 2.0 | 7.45 | 14700 | Max | Full | -- | -- | 17 | 4.0 |
| 1000 | 9.75 | 110 | 35 | 75 | 11.5 | 7.8 | 91 | 87 | 75 | 5.7 | 1.8 | 7.5 | 14800 | Max | 5.4' | -- | -- | 17 | 3.3/2.5 |
| 1200 | 9.8 | 115 | 35 | 80 | 11.3 | 8.6 | 90 | 85 | 72 | 5.5 | 2.0 | 7.5 | 15000 | Max | 5.10 | -- | -- | 17 | 2.5 |
| 1400 | 9.9 | 121 | 38 | 83 | 11.65 | 8.1 | 87 | 81 | 70 | 5.3 | 2.4 | 7.7 | 13000 | Max | 5.10 | --- | -- | 17 | 2.5/2.0 |
| 1600 | 9.9 | 128 | 34 | 94 | 11.65 | 7.9 | 86 | 81 | 72 | 8.5 | 2.5 | 7.5 | 15300 | Max | 4.0' | -- | -- | 16 | 1.5/2.0 |
| 1800 | 9.85 | 130 | 38 | 92 | 11.6 | 9.4 | 84 | 80 | 70 | 14 | 2.5 | 7.35 | 15500 | Max | 3.5' | -- | -- | 16 | 2.5/3.0 |
| 2000 | 9.8 | 130 | 36 | 94 | 11.6 | 9.3 | 86 | 82 | 70 | 15 | 2.4 | 7.4 | 15400 | Max | 4.2' | -- | -- | 16 | 3.0/2.8 |
| 2200 | 9.9 | 132 | 36 | 96 | 11.65 | 8.7 | 88 | 82 | 70 | 1.5 | 1.8 | 7.4 | 15600 | Max | 5.0' | -- | -- | 16 | 2.8 |

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

*Increased lime .5 at 0800 - decreased .5 at 0820

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 4/5 0000 | 9.9 | 132 | 34 | 98 | 11.65 | 8.9 | 90 | 88 | 73 | 5.5 | 1.5 | 7.5 | 15000 | Max | 5.4' | -- | -- | 16 | 2.8 |
| 0200 | 9.8 | 128 | 32 | 96 | 11.6 | 9.1 | 89 | 86 | 72 | 6.7 | 1.5 | 7.6 | 14800 | Max | 5.8' | -- | -- | 16 | ~~2.8~~ 3.0 |
| 0400 | 9.9 | 126 | 32 | 94 | 11.7 | 8.85 | 88 | 86 | 71 | 6.0 | 1.4 | 7.5 | 15000 | Max | 6.4' | -- | -- | 16 | 3.0 |
| 0600 | 9.8 | 124 | 34 | 90 | 11.6 | 9.0 | 91 | 89 | 71 | 7.5 | 1.7 | 7.35 | 15700 | Max | 6.8' | -- | -- | 16 | 3.0 |
| 0800 | 9.9 | 133 | 33 | 100 | 11.6 | 8.6 | 94 | 88 | 69 | 6.1 | 1.5 | 7.25 | 16000 | MAx | 6.0' | -- | -- | 15 | 3.0 |
| 1000 | 9.95 | 121 | 34 | 87 | 11.6 | 8.85 | 92 | 89 | 72 | 5.5 | 1.4 | 7.7 | 15800 | Max | 4.0' | -- | -- | 15 | 3.0 |
| 1200 | 9.9 | 118 | 33 | 85 | 11.6 | 8.9 | 93 | 90 | 70 | 5.0 | 1.2 | 7.4 | 15600 | Max | 3.5' | -- | -- | 15 | 3.0 |
| 1400 | 9.8 | 120 | 33 | 87 | 11.6 | 9.2 | 88 | 84 | 71 | 6.2 | 1.5 | 7.5 | 15300 | Max | 3.0' | -- | -- | 15 | ~~3.0~~ 3.5 |
| 1600 | 9.8 | 130 | 36 | 94 | 11.6 | 9.1 | 90 | 84 | 70 | 5.3 | 1.1 | 7.4 | 16000 | Max | 4.6' | -- | -- | 15 | 3.5 |
| 1800 | 9.7 | 130 | 32 | 98 | 11.65 | 9.05 | 90 | 84 | 70 | 5.2 | 1.3 | 7.3 | 15500 | Max | 4.6' | -- | -- | 15 | 3.5 |
| 2000 | 9.8 | 130 | 36 | 94 | 11.6 | 9.05 | 90 | 88 | 74 | 7.5 | 1.0 | 7.4 | 15000 | Max | 4.6' | -- | -- | 15 | 3.5 |
| 2200 | 9.75 | 134 | 38 | 96 | 11.65 | 9.1 | 90 | 90 | 68 | 6.2 | 1.0 | 7.4 | 15800 | Max | 4.6' | -- | -- | 15 | 3.5 |
| 4/6 0000 | 9.9 | 120 | 34 | 86 | 11.65 | 9.15 | 91 | 86 | 69 | 5.6 | 1.1 | 7.6 | 15900 | Max | 6.5' | -- | -- | 15 | 3.5 |
| 0200 | 9.9 | 122 | 32 | 90 | 11.65 | 9.15 | 93 | 88 | 72 | 7.2 | 1.2 | 7.6 | 15900 | Max | 6.5 | -- | -- | 15 | 3.5 |
| 0400 | 9.9 | 128 | 36 | 92 | 11.65 | 9.05 | 95 | 90 | 74 | 6.0 | 1.2 | 7.6 | 15700 | Max | 6.0' | -- | -- | 15 | 3.6 |
| 0600 | 9.9 | 130 | 36 | 94 | 11.65 | 9.1 | 93 | 88 | 72 | 7.0 | 1.1 | 7.45 | 16000 | Max | 5.8' | -- | -- | 15 | 3.7 |
| 0800 | 9.95 | 122 | 36 | 86 | 11.65 | 8.5 | 97 | 90 | 68 | 6.1 | 1.0 | 7.65 | 15800 | Max | 5.6' | -- | -- | 15 | 3.7 |
| 1000 | 9.8 | 125 | 35 | 90 | 11.6 | 8.6 | 95 | 88 | 70 | 5.6 | 1.0 | 7.5 | 16100 | Max | 4.3' | -- | -- | 15 | 3.7 |

1 TH-Total Hardness
2 -CH-Calcium Hardness
3 MH-Magnesium Hardness

## MONTGOMERY DEMONSTRATION OPERATING DATA

| TIME & DATE | RAPID MIX #1 | | | | RAPID MIX #2 | MAGNESIUM FLUME | | | | | | CARBONATED SLUDGE | | | | EFFLUENT FILTER #5 | | $CO_2$ SETTING (cfm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | TH[1] | CH[2] | MH[3] | pH | pH | TH | CH | ALK | TURB | ACID TURB | pH | ALK | PUMP SETTING (gpm) | TANK LEVEL | pH | ALK | #1 | #2 |
| 4/6<br>1200 | 9.8 | 115 | 36 | 79 | 11.7 | 8.1 | 91 | 84 | 74 | 6.0 | 1.2 | 7.2 | 15800 | Max | 3.5' | -- | --- | 15 | 3.7<br>3.2 |
| 1400 | 9.8 | 111 | 32 | 79 | 11.6 | 8.5 | 90 | 84 | 73 | 5.8 | 1.3 | 7.4 | 15300 | Max | 3.2' | -- | -- | 15 | 3.2 |
| 1600 | 9.7 | 122 | 30 | 92 | 11.6 | 8.9 | 86 | 78 | 54 | 6.5 | 1.6 | 7.4 | | Max | 4.3' | -- | -- | 16 | 2.9 |
| 1800 | 9.8 | 128 | 32 | 94 | 11.25 | 9.25 | 86 | 82 | 72 | 7.4 | 1.1 | 7.4 | 17700 | Max | 4.7' | -- | -- | 16 | 3.0<br>2.5 |
| | | | | | | | | | | | | | | | | | | | |
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[1] TH-Total Hardness

[2] CH-Calcium Hardness

[3] MH-Magnesium Hardness

# APPENDIX B

## VACUUM FILTER TESTS,
## MONTGOMERY, ALABAMA

# MAGNESIUM CARBONATE PROCESS

## Sludge Handling Data

## (March 13, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As $CaCO_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 8 a.m. | STARTED | | | | | | | | |
| 9 a.m. | 43.3 | | 406.2 | 1.25 | 7.4 | | | 38.7 | .5 |
| 10 a.m. | | | | | | | | | |
| 11 a.m. | 41.2 | | 343.8 | 1.25 | 6.3 | 430 | 54 | 37.8 | .5 |
| 12 N | | | | | | | | | |
| 1 p.m. | 40.5 | | 280.2 | 1.25 | 5.1 | | | 46.7 | .5 |
| 2 p.m. | | | | | | | | | |
| 3 p.m. | 39.1 | | 289.8 | 1.25 | 5.3 | | | 45.2 | .5 |

# MAGNESIUM CARBONATE PROCESS

## Sludge Handling Data

## (January 11, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As $CaCO_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 9 a.m. | STARTED | | | | | | | | |
| 10 a.m. | NO CAKE | | | | | | | | |
| 11 a.m. | 35.7 | | 209.4 | .88 | 2.7 | 492 | 52 | 40.8 | 0 |
| 12 N | 36.1 | | 205.2 | .88 | 2.6 | | | 40.7 | 0 |
| 1 p.m. | LINE ICED UP | | | | | | | | |
| 2 p.m. | 38.3 | | 190.2 | .88 | 2.5 | | | 40.0 | 0 |
| 3 p.m. | 35.3 | | 173.4 | .88 | 2.2 | 482 | 64 | 42.6 | 0 |

## MAGNESIUM CARBONATE PROCESS

### Sludge Handling Data

(March 12, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As CaCO$_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 8 a.m. | STARTED | | | .88 | | | | | 0 |
| 9 a.m. | 38.6 | | 466.8 | .88 | 7.5 | | | 39.9 | 0 |
| 10 a.m. | | | | 1.25 | | | | | .5 |
| 11 a.m. | 44.3 | | 384.6 | 1.25 | 7.1 | 424 | 60 | 40.3 | .5 |
| 12 N | | | | 1.25 | | | | | .5 |
| 1 p.m. | 43.6 | | 387.0 | 1.25 | 7.1 | | | 39.6 | .5 |
| 2 p.m. | | 7,800 | | 1.25 | | | | | .5 |
| 3 p.m. | 43.2 | | 354.6 | 1.25 | 6.5 | | | 39.1 | .5 |
| 4:30 p.m. | CLOSED | | | 1.25 | | | | | .5 |

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(January 17, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As CaCO$_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 8:30 am | FILTER ON | | | | | | | | 0 |
| 9 am | 14.2 | | 190.2 | .88 | 2.2 | | | 43.7 | 0 |
| 10 am | 20.1 | | 198.6 | .88 | 2.3 | | | 45.4 | 0 |
| 11 am | 27.9 | | 219.0 | .88 | 2.6 | 440 | 56 | 46.6 | 0 |
| 12 N | 29.9 | | 184.2 | .88 | 2.2 | | | 43.5 | 0 |
| 1 pm | 31.3 | | 184.2 | .88 | 2.2 | | | 48.5 | 0 |
| 2 pm | 35.1 | | 165.6 | .88 | 1.9 | 470 | 62 | 45.0 | 0 |
| 3 pm | 32.3 | | 191.4 | .88 | 2.2 | | | 45.9 | 0 |

## MAGNESIUM CARBONATE PROCESS

### Sludge Handling Data

### (February 21, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids $(g/ft^2)$ | Drum Speed (RPM) | Filter Rate $(lb/ft^2/hr)$ | Cake Analysis (As $CaCO_3$) Ca | Mg | % Moisture | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| 9 am | STARTED | | | .88 | | | | | |
| 10 am | | | | .88 | | | | | |
| 11 am | 41.6 | 7,500 | 3.012 | .88 | 3.9 | | | 35.8 | |
| 12 N | | | | .88 | | | | | |
| 1 pm | 46.9 | | 3.018 | .88 | 3.9 | 396 | 56 | 35.2 | |
| 2 pm | | | | .88 | | | | | |
| 3:30 pm | 42.2 | | 3.288 | .88 | 4.2 | | | 35.8 | |
| 4:20 pm | CLOSED | | | .88 | | | | | |

# MAGNESIUM CARBONATE PROCESS

## Sludge Handling Data

(January 18, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids $(g/ft^2)$ | Drum Speed (RPM) | Filter Rate $(lb/ft^2/hr)$ | Cake Analysis (As $CaCO_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 9 am | STARTED FILTER | | | | | | | | 0 |
| 10 am | 26.9 | | 148.8 | .88 | 1.9 | | | 43.5 | 0 |
| 11 am | MISSED | | | | | | | | |
| 12 N | 33.1 | | 154.2 | .88 | 2.0 | 456 | 96 | 45.4 | 0 |
| 1 pm | 33.0 | | 185.4 | .88 | 2.4 | | | 47.0 | 0 |
| 2 pm | 31.7 | | 154.8 | .88 | 2.0 | | | 45.0 | 0 |
| 3 pm | 32.1 | | 162.0 | .88 | 2.1 | 508 | 60 | 46.3 | 0 |
| 4 pm | 30.8 | | 135.0 | .88 | 1.7 | | | 46.3 | 0 |

# MAGNESIUM CARBONATE PROCESS

## Sludge Handling Data

(February 23, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As $CaCO_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 8:15 am | STARTED | | | | | | | | |
| 9 am | 43.4 | | 303.0 | .88 | 3.9 | | | 36.796 | |
| 10 am | | | | .88 | | | | | |
| 11 am | 43.7 | 7,400 | 307.2 | .88 | 4.0 | 344 | 34 | 37.408 | |
| 12 N | | | | .88 | | | | | |
| 1:30 pm | 39.9 | | 353.4 | .88 | 4.6 | | | 36.393 | |
| 2 pm | | | | .88 | | | | | |
| 3 pm | | | | .88 | | | | | |
| 4 pm | 24.2 | | 169.5 | .88 | 2.3 | | | | |
| 4:25 pm | CLOSED | | | | | | | | |

# MAGNESIUM CARBONATE PROCESS

## Sludge Handling Data

## (February 28, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As $CaCO_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 9 am | 50.7 | | 586.2 | .88 | 7.6 | | | 34.43 | 0 |
| 11 am | 57.1 | | 684.6 | .88 | 8.8 | | | 34.31 | 0 |
| 1 pm | 49.9 | | 451.8 | 1.25 | 8.3 | 334 | 38 | 36.18 | .5 |
| 2 pm | 50.4 | | 310.8 | 1.666 | 7.6 | | | 35.25 | 1.0 |
| 3 pm | 49.5 | | 349.2 | 2.727 | 14.0 | | | 35.33 | 2.0 |

## MAGNESIUM CARBONATE PROCESS

### Sludge Handling Data

### (March 5, 1973)

| Time | Feed Sludge Solids (%) | Filtrate Alk | Solids (g/ft$^2$) | Drum Speed (RPM) | Filter Rate (lb/ft$^2$/hr) | Cake Analysis (As $CaCO_3$) | | | Belt Setting |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ca | Mg | % Moisture | |
| 8 am | 49.5 | | 450.6 | 1.666 | 11.0 | | | 38.08 | 1.0 |
| 11 am | 48.8 | | 529.2 | 1.25 | 9.7 | | | 37.84 | .5 |
| 1 pm | 49.2 | 9,000 | 409.2 | 1.666 | 10.0 | 524 | 35 | 39.05 | 1.0 |
| 2 pm | 43.9 | | 367.2 | 1.666 | 9.0 | | | 40.29 | 1.0 |

# APPENDIX C

# ROUTINE DATA SHEETS, MELBOURNE, FLORIDA

CITY of MELBOURNE, FLORIDA
NORTH WATER TREATMENT PLANT

DATE 8 Nov 73 Treatment with $MgCO_3$ as a Recycled Coagulant DAY Thur

| TIME | #1 CENTER | | | | | CLARIFIER (WEIR) | | | | | | | FILTERED FINISHED WATER | | | | | | | | | SLUDGE CARBONATOR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | P ALK | TOTAL ALK | OH | $CO_3$ | pH | P ALK | T ALK | T H | T Ca | COLOR | THRES. ODOR | pH | P ALK | T ALK | T HARDNESS | N C H | Ca | Mg | COLOR | THRES. ODOR | pH | ALK | COLOR |
| 2400 | 11.4 | 154 | 202 | 114 | 88 | 8.1 | | | | | 31 | | 7.55 | 0 | 188 | 212 | 24 | 200 | 12 | 35 | | 7.3 | | |
| 0100 | 11.2 | | | | | 8.7 | 6 | 128 | 182 | 164 | 30 | | 8.1 | | | | | | | | | 7.3 | 6400 | 4600 |
| 0200 | 11.2 | | | | | 8.6 | | | | | 36 | | 8.2 | | | | | | | | | 7.55 | | |
| 0300 | 11.4 | | | | | 8.7 | | | | | 28 | | 8.3 | ODOR TEST | | | | | | | neg | 7.5 | | |
| 0400 | 11.3 | 162 | 190 | 134 | 56 | 8.6 | | | | | 29 | | 8.3 | 0 | 124 | [illegible] | 42 | 152 | 14 | 30 | | 7.4 | | |
| 0500 | | | | | | 8. | | | | | | | | | | | | | | | | | | |
| 0600 | | | | | | | | | | | | | | | | | | | | | | | | |
| 0700 | 11.2 | | | | | 8.5 | | | | | 29 | | 8.2 | | | | | | | | | 7.8 | | |
| 0800 | 11.25 | 169 | 210 | 126 | 84 | 8.5 | | | | | 32 | | 8.25 | 0 | 140 | 184 | 44 | 182 | 2 | 25 | | 7.28 | | |
| 0900 | 11.1 | | | | | 9.4 | 2 | 102 | 146 | 142 | 32 | | 7.95 | | | | | | | 28 | | 7.42 | 6400 | 7000 |
| 1000 | 11.25 | | | | | 8.8 | | | | | 35 | | 8.3 | | | | | | | 32 | neg | 7.32 | | |
| 1100 | 11.14 | | | | | 8.15 | | | | | 28 | neg | 8.6 | | | | | | | | | 7.0 | | |
| 1200 | 11.15 | 142 | 182 | 152 | 80 | 8.8 | | | | | 32 | | 8.3 | | 164 | 144 | 20 | 140 | 4 | 52 | | 7.0 | | |
| 1300 | 11.2 | | | | | 8.8 | 6 | 94 | 126 | 122 | 28 | | 8.3 | | | | | | | 30 | | 7.05 | 7600 | |
| 1400 | | | 1308 | | | Plant Off | | | | | | | | | | | | | | | | | | |
| 1500 | | 1445 | | | | Plant On | | | | | | | | | | | | | | | | | | |
| 1600 | 11.2 | 5.8<br>116 | 5.0<br>164 | 72 | 56 | 8.7 | | | | | 25 | | 8.5 | 2 | 100 | [illegible]<br>120 | 20 | 5.7<br>114 | 6 | 30 | neg | 7.5 | | |
| 1700 | 11.25 | | | | | 8.5 | 8 | 6.5<br>130 | 9.6<br>150 | 9.2<br>164 | 25 | | 8.4 | | | | | | | | | 7.6 | [illegible] | 5000 |
| 1800 | 11.4 | | | | | 8.42 | | | | | 20 | | 8.3 | | | | | | | | | 7.4 | | |
| 1900 | 11.25 | | | | | 8.2 | | | | | | | 8.2 | | | | | | | | | 7.25 | | |
| 2000 | 11.3 | 8.8<br>176 | 11.2<br>220 | 132 | 88 | 8.0 | | | | | | neg | 8.2 | 2 | 8.6<br>172 | 10.4<br>202 | 28 | 10.4<br>202 | 6 | 21 | | | | |
| 2100 | 11.3 | | | | | 8.1 | 4 | 8.6<br>170 | 10.5<br>215 | 10.4<br>208 | 37 | | 8.2 | | | | | | | | | 7.21 | 9000 | 5000 |
| 2200 | 11.35 | | | | | 8.6 | | | | | 30 | | 8.1 | | | | | | | | | 7.9 | | |
| 2300 | 11.45 | | | | | 8.4 | | | | | | | 8.7 | ([illegible]) | | | | | | | | 7.1 | | |
| TOTAL | 225.22 | 1222 | 1164 | 680 | 484 | 170.97 | 26 | 620 | 850 | 796 | 504 | | 164.78 | 4 | 828 | 1026 | 156 | 985 | 38 | 270 | | 175.53 | 31400 | 21600 |
| AVG. | 11.26 | 154 | 194 | 113 | 81 | 8.5 | 5 | 124 | 170 | 160 | 30 | neg | 8.23 | 1 | 138 | 171 | 26 | 165 | 6 | 30 | neg | 7.29 | 6280 | 5400 |

RAW WATER

| Time | pH | Total Alk | Hardness | | | | Chloride | Total Iron | Fluoride | Color | Temp. F° | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | N C H | Ca | Mg | | | | | | |
| 0100 | 7.4 | 36 | 62 | 16 | 50 | 12 | | | | 125 | 74 | |
| 0800 | 7.2 | 38 | 60 | 22 | 48 | 12 | 38 | | | 150 | 73 | |
| 1600 | 7.4 | 43 | 58 | 15 | 50 | 8 | | | | 105 | 73 | |
| Total | 22 | 117 | 180 | 63 | 148 | 32 | 38 | | | 380 | 220 | |
| Average | 7.3 | 39 | 60 | 20 | 49 | 11 | 38 | | | 127 | 73° | |

| SHIFT | OPERATOR |
|---|---|
| 2400-0800 | Carter |
| 0800-1600 | Lynch |
| 1600-2400 | Jones |

REMARKS

0230 PH weir 8.6

CITY OF MELBOURNE, FLORIDA

NORTH WATER TREATMENT PLANT

DATE: 8 Nov 78

Treatment with $MgCO_3$ as a Recycled Coagulant

DAY: Thur

| TIME | RAW/ MGD | MAGNESIUM |  | $CO_2$ |  | COAGULANT AID |  |  | LIME |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Recyc GPM | Make-Up lb | Weir GPM | Sludge GPM | Pump Set. | ML/ Min | Time Mix | Mach. Set. | Lbs. Load |  |  |
| 12MN | 1.3 | 15 | 21 | 16 | 320 | 2.5 |  |  | 375 |  |  |  |
| 1AM | 1.3 | 15 | 21 | 16 | 320 | 2.5 |  |  | 375 |  |  |  |
| 2 | 1.3 | 15 | 21 | 16 | 330 | 2.5 |  |  | 375 | 750 |  |  |
| 3 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 4 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 5 |  | Plant | off | 0415 |  |  |  |  |  |  |  |  |
| 6 |  | Plant | on | 0625 |  |  |  |  |  | 500 |  |  |
| 7 | 1.3 | 15 | 21 | 16 | 360 | 2.5 |  |  | 375 |  |  |  |
| 8 | 1.3 | 15 | 21 | 16 | 360 | 2.5 |  |  | 375 |  |  |  |
| 9 | 1.3 | 15 | 21 | 16 | 360 | 2.5 |  |  | 375 |  |  |  |
| 10 | 1.3 | 15 | 21 | 16 | 360 | 2.5 |  |  | 375 |  |  |  |
| 11 | 1.3 | 15 | 21 | 16 | 360 | 2.5 |  |  | 375 |  |  |  |
| 12N | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 1PM |  | PlANT | OFF | 13:00 |  |  |  |  |  |  |  |  |
| 2 | 1445 | PlANT |  | On |  |  |  |  |  |  |  |  |
| 3 | 1.3 | 15 | 21 | 16 | 300 | 2.5 |  |  | 375 | 1500 |  |  |
| 4 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 5 | 1.3 | 15 | 21 | 17 | 300 | 2.5 |  |  | 375 |  |  |  |
| 6 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 7 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 8 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 9 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 | 1150 |  |  |
| 10 | 1.3 | 15 | 21 | 16 | 340 | 2.5 |  |  | 375 |  |  |  |
| 11 | 1.3 | 15 | 21 | 16 | 320 | 2.5 |  |  | 375 | 1050 |  |  |
| 12MN |  |  |  |  |  |  |  |  |  |  |  |  |
| TOTAL |  |  | 420 |  |  |  |  |  |  | 4550 |  |  |

| M G D METER READING (RAW) # I SIDE |  |
|---|---|
| PRESENT | 280726 |
| PREVIOUS | 279624 |
| M G D PUMPED | 1102 |

OPERATORS

12 - 8 Curtis

8 - 4

4 - 12

| FILTERS | #1 | #2 |
|---|---|---|
| PRES. WASH | 768 | 768 |
| PREV. WASH | 728 | 729 |
| HRS. RUN | 40 | 39 |
| B.W. END | 390 | 490 |
| B.W. START | 290 | 390 |
| GALS. USED | 100 | 100 |
| GAL./MIN. | 6 | 6 |
| MIN. WASH | 20 | 20 |

REMARKS

1200 [illegible] Carb $CO_2$
PLANT OFF AT 13:00 FOR MAINT:
1445 Plant On

CHEMICAL INVENTORY

|  | QUICK LIME | COAGULANT AID | $CO_2$ | $KMnO_4$ | HYDRATED LIME | $MgSO_4$ | CHLORINE | CARBON |
|---|---|---|---|---|---|---|---|---|
| Pounds on hand |  |  | 27000 |  |  | 3720 |  |  |
| Used |  |  | 4,000 |  | 4550 | 420 |  | 45 |
| Pounds on hand |  |  | 23,000 |  |  | 3.300 |  |  |
| P. P. M. |  |  | 436.01 |  | 495.97 | 45.79 |  | 4.91 |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

# APPENDIX D

# SUMMARY OF DAILY AVERAGE RESULTS

# MELBOURNE, FLORIDA

| Date | Raw Water |  | Coagulation | Filtered Water |  |  | Carbonated Sludge |  |
|---|---|---|---|---|---|---|---|---|
|  | Magnesium | Color | pH | Hardness |  | Color | Alkalinity | Color |
|  |  |  |  | Total | Magnesium |  |  |  |
| 9/13/73 |  |  | 11.35 | 157 | 2.4 | 35.4 | 20,666 | 15,400 |
| 9/14/73 |  |  | 11.31 | 172 | 10.0 | 44.8 | 23,166 | 18,666 |
| 9/15/73 |  |  | 11.27 | 132 | 7.3 | 35.3 | 21,083 | 14,066 |
| 9/16/73 |  |  | 11.31 | 152 | 10.3 | 37.4 | 21,333 | 13,516 |
| 9/17/73 |  |  | 11.28 | 173 | 6.0 | 38.7 | 20,900 | 13,800 |
| 9/18/73 |  |  | 11.37 | 181 | 6.67 | 47.9 | 22,000 | 12,033 |
| 9/19/73 | 12.66 | 195 | 11.43 | 146 | 7.33 | 42 | 27,700 | 18,000 |
| 9/20/73 | 12 | 215 | 11.29 | 167 | 7 | 59 | 11,733 | 14,750 |
| 9/21/73 | 11.3 | 230 | 11.39 | 117 | 5.3 | 30 | 11,333 | 17,250 |
| 9/22/73 | 13.3 | 220 | 11.38 | 137 | 6.3 | 38.6 | 9,866 | 14,166 |
| 9/23/73 | 12 | 227 | 11.4 | 154 | 11 | 36 | 8,134 | 11,884 |
| 9/24/73 | 15.3 | 200 | 11.44 | 171 | 8.3 | 41.8 | 9,033 | 10,750 |
| 9/25/73 | 14 | 208 | 11.45 | 126 | 3 | 36 | 8,966 | 10,000 |
| 9/26/73 | 12 | 208 | 11.38 | 130 | 2 | 41 | 8,633 | 9,750 |
| 9/27/73 | 14 | 185 | 11.43 | 141 | 2.8 | 42.7 | 7,866 | 10,083 |
| 9/28/73 | 12 | 178 | 11.41 | 141 | 5.6 | 36 | 7,000 | 9,666 |
| 9/29/73 | 15 | 175 | 11.41 | 124 | 4.5 | 38 | 8,333 | 11,416 |
| 10/1/73 | 14 | 183 | 11.29 | 155 | 4 | 39 | 7,300 | 7,250 |
| 10/2/73 | 14 | 175 | 11.41 | 111 | 3 | 35 | 6,543 | 6,350 |
| 10/3/73 | 12 | 175 | 11.45 | 133 | 3.5 | 36 | 6,350 | 7,083 |
| 10/4/73 | 12 | 176 | 11.38 | 137 | 9 | 91 | 7,433 | 6,916 |
| 10/5/73 | 14 | 190 | 11.35 | 171 | 5 | 34 | 7,100 | 7,000 |
| 10/6/73 | 12 | 208 | 11.38 | 164 | 11 | 26 | 7,400 | 7,100 |
| 10/7/73 | 15 | 175 | 11.33 | 169 | 6 | 31 | 6,366 | 3,983 |
| 10/8/73 | 10 | 167 | 11.33 | 204 | 13 | 35 | 6,100 | 6,600 |
| 10/9/73 | 12 | 158 | 11.35 | 132 | 5 | 29 | 6,400 | 5,700 |
| 10/11/73 | 12 | 216 | 11.28 | 112 | 2 | 30 | 5,616 | 6,116 |
| 10/12/73 | 11 | 200 | 11.33 | 117 | 4.6 | 34 | 5,053 | 7,316 |
| 10/16/73 | 7 | 188 | 11.24 | 196 | 5 | 34 | 5,900 | 6,850 |
| 10/17/73 | 8 | 222 | 11.4 | 166 | 6.8 | 36 | 6,200 | 7,640 |
| 10/18/73 | 10 | 192 | 11.2 | 158 | 8 | 34 | 4,833 | 5,350 |
| 10/19/73 | 11 | 175 | 11.24 | 183 | 1.5 | 34 | 6,250 | 6,925 |
| 10/20/73 | 7 | 167 | 11.34 | 204 | 4.6 | 33 | 6,233 | 5,500 |
| 10/21/73 | 6 | 195 | 11.25 | 211 | 10 | 34 | 5,800 | 5,930 |
| 10/22/73 | 9 | 172 | 11.27 | 209 | 4.66 | 33 | 5,770 | 5,430 |
| 10/23/73 | 15 | 147 | 11.25 | 226 | 5.7 | 38 | 5,367 | 4,917 |
| 10/24/73 | 11 | 177 | 11.27 | 191 | 4.7 | 34 | 5,766 | 5,255 |
| 10/25/73 | 7 | 138 | 11.25 | 184 | 7 | 37 | 5,566 | 7,633 |
| 10/26/73 | 10 | 138 | 11.28 | 196 | 7 | 32.5 | 6,040 | 6,940 |
| 10/27/73 | 13 | 138 | 11.64 | 221 | 0 | 36 | 4,050 | 11,250 |
| 10/28/73 | 5 | 183 | 11.36 | 215 | 7 | 41 | 5,167 | 7,316 |
| 10/29/73 | 8 | 125 | 11.23 | 195 | 12 | 33 | 5,800 | 6,700 |
| 10/30/73 | 9 | 175 | 11.2 | 154 | 8 | 28 | 6,900 | 7,233 |
| 10/31/73 | 8 | 183 | 11.32 | 154 | 6 | 31 | 4,700 | 4,900 |
| 11/1/73 | 8 | 148 | 11.26 | 185 | 4 | 31 | 5,400 | 4,233 |
| 11/2/73 | 11 | 116 | 11.22 | 186 | 10 | 31 | 5,366 | 5,350 |
| 11/3/73 | 11 | 146 | 11.3 | 153 | 5 | 33 | 5,333 | 6,566 |
| 11/4/73 | 6 | 146 | 11.5 | 161 | 12 | 28 | 5,800 | 6,016 |
| 11/5/73 | 13 | 130 | 11.26 | 155 | 7 | 29 | 5,967 | 4,283 |
| 11/6/73 | 28 | 150 | 11.33 | 186 | 8 | 30 | 6,700 | 6,250 |
| 11/7/73 | 11 | 185 | 11.4 | 198 | 6 | 30 | 7,567 | 7,267 |
| 11/8/73 | 11 | 127 | 11.26 | 171 | 6 | 30 | 6,280 | 5,400 |
| 11/9/73 | 8 | 147 | 11.29 | 165 | 4 | 23 | 5,967 | 6,733 |

| Date | Raw Water |  | Coagulation | Filtered Water |  |  | Carbonated Sludge |  |
|---|---|---|---|---|---|---|---|---|
|  | Magnesium | Color | pH | Hardness |  | Color | Alkalinity | Color |
|  |  |  |  | Total | Magnesium |  |  |  |
| 11/11/73 | 15 | 150 | 11.4 | 209 | 5 | 32 | 6,167 | 5,067 |
| 11/12/73 | 15 | 138 | 11.4 | 175 | 5 | 26 | 6,267 | 6,650 |
| 11/13/73 | 14 | 142 | 11 | 218 | 10 | 34 | 6,600 | 6,167 |
| 11/14/73 | 13 | 168 | 11.38 | 197 | 5 | 42 | 7,400 | 7,200 |
| 11/15/73 | 19 | 142 | 11.3 | 206 | 6 | 34 | 8,400 | 7,317 |
| 11/16/73 | 12 | 175 | 11.9 | 212 | 5 | 39 | 9,550 | 10,500 |
| 11/17/73 | 12 | 150 | 11.4 | 192 | 7 | 33 | 10,520 | 11,100 |
| 11/18/73 | 9 | 133 | 11.3 | 205 | 6 | 36 | 11,833 | 12,500 |
| 11/19/73 | 12 | 147 | 11.38 | 201 | 2 | 31 | 7,400 | 6,800 |
| 11/20/73 | 7 | 133 | 11.33 | 192 | 2 | 29 | 8,560 | 8,880 |
| 11/21/73 | 11 | 142 | 11.38 | 201 | 5.3 | 28 | 8,700 | 11,680 |
| 11/22/73 | 7 | 147 | 11.35 | 177 | 1.6 | 23 | 8,160 | 9,500 |
| 11/23/73 | 13 | 147 | 11.44 | 139 | 5.6 | 36 | 8,080 | 10,200 |
| 11/24/73 | 14 | 166 | 11.4 | 184 | 5 | 27 | 8,600 | 10,300 |
| 11/25/73 | 17 | 160 | 11.32 | 195 | 4 | 37 | 8,680 | 8,800 |
| 11/26/73 | 13 | 134 | 11.3 | 190 | 7 | 40 | 7,850 | 8,500 |
| 11/27/73 | 5 | 133 | 11.3 | 155 | 8 | 34 | 8,700 | 7,700 |
| 11/28/73 | 7 | 142 | 11.3 | 179 | 4 | 34 | 9,200 | 9,300 |
| 11/29/73 | 6.3 | 183 | 11.45 | 172 | 3.6 | 27 | 6,966 | 4,883 |
| 11/30/73 | 12 | 142 | 11.47 | 185 | 13 | 31 | 7,333 | 6,750 |
| 12/1/73 | 8 | 130 |  |  |  |  | 8,740 | 9,000 |
| 12/2/73 | 10 | 129 |  |  |  |  | 8,266 | 7,733 |
| 12/3/73 | 8 | 158 |  |  |  |  | 6,800 | 6,600 |
| 12/4/73 | 12 | 150 | 11.45 | 151 | 4 | 24 | 6,500 | 5,750 |
| 12/5/73 | 11 | 157 | 11.4 | 122 | 13 | 29 | 6,120 | 4,920 |
| 12/6/73 | 16 | 142 | 11.35 | 134 | 9 | 30 | 6,570 | 5,550 |
| 12/7/73 | 8 | 167 | 11.52 | 192 | 5.5 | 29.1 | 6,560 | 5,900 |
| 12/8/73 | 8 | 163 | 11.45 | 226 | 8 | 34 | 6,800 | 5,800 |
| 12/9/73 | 17 | 183 | 11.5 | 226 | 4 | 30 | 6,900 | 6,025 |
| 12/10/73 | 9 | 125 | 11.5 | 246 | 6 | 26 | 8,633 | 7,400 |
| 12/11/73 | 12 | 113 | 11.6 | 244 | 5 | 13 | 7,200 | 6,143 |
| 12/12/73 | 11 | 133 | 11.65 | 200 | 4 | 12 | 7,467 | 5,800 |
| 12/13/73 | 12 | 142 | 11.7 | 197 | 12 | 11 | 6,700 | 5,350 |
| 12/14/73 | 9 | 125 | 11.53 | 252 | 4 | 11 | 6,600 | 4,500 |
| 12/15/73 | 9 | 133 | 11.5 | 210 | 4 | 10 | 6,800 | 4,983 |
| 12/16/73 | 14 | 138 | 11.6 | 229 | 14 | 9 | 6,880 | 5,200 |
| 12/17/73 | 10 | 252 | 11.6 | 236 | 7 | 21 | 7,760 | 6,960 |
| 12/19/73 | 10 | 125 | 11.6 | 207 | 1 | 15 | 8,267 | 7,467 |
| 12/20/73 | 14 | 152 | 11.5 | 170 | 7 | 20 | 6,700 | 5,317 |
| 12/21/73 | 19 | 208 | 11.6 | 216 | 5 | 19 | 7,920 | 8,200 |
| 12/22/73 | 9 | 193 | 11.5 | 222 | 5 | 21 | 7,100 | 5,717 |
| 12/23/73 | 16 | 125 | 11.6 |  | 7 | 22 | 6,800 | 8,340 |

# APPENDIX E

## E.P.A. ANALYSIS FOR HEAVY METALS AND COMMENTS, MELBOURNE, FLORIDA

## RESULTS OF TRACE ANALYSIS, MELBOURNE, FLORIDA
## PERFORMED BY SOUTHEAST ENVIRONMENTAL
## RESEARCH LABORATORY, U.S.E.P.A., ATHENS, GEORGIA

| Parameters | Raw Water | Magnesium Treated Water | Alum Treated Water |
|---|---|---|---|
| Chloride | 50 | 48 | 46.0 |
| Sulfate | <25 | <25 | 47.0 |
| Sodium | 20 | 20 | 20.0 |
| Lithium | <0.1 | <0.1 | <0.1 |
| Barium | <0.05 | <0.05 | <0.05 |
| M.B.A.S. | <0.25 | <0.25 | <0.25 |
| Arsenic | <0.005 | <0.005 | <0.005 |
| Selenium | <0.005 | <0.005 | <0.005 |
| Cyanide | <0.02 | <0.02 | <0.02 |
| Chromium | 0.00 | 0.00 | 0.00 |
| Silver | 0.00 | 0.00 | 0.00 |
| Copper | 0.00 | 0.009 | 0.017 |
| Manganese | 0.00 | 0.00 | 0.006 |
| Lead | 0.00 | 0.00 | 0.00 |
| Iron | 0.24 | 0.025 | 0.046 |
| Cobalt | 0.00 | 0.00 | 0.00 |
| Cadmium | 0.00 | 0.00 | 0.00 |
| Zinc | 0.031 | 0.076 | 0.19 |
| Nickel | 0.00 | 0.00 | 0.00 |

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Southeast Environmental Research Laboratory, College
Station Road, Athens, Georgia 30601

SUBJECT: Organic Analysis of Samples from North Melbourne Water Treatment Plant

DATE: December 14, 1973

FROM: 4ASC/Finger

TO: Gary Hutchinson

## Summary

There were no organic chemicals detected in the three water samples taken November 1973 from various sources in the treatment process. The analysis was by gas chromatography, therefore only organics that vaporize under our GC conditions would be detected.

## Action

Transmittal of data.

## Background

Your memo of October 5, 1973 to Mr. John A. Little.

James H. Finger
Chief
Chemical Services Branch

EPA Form 1320-6 (Rev. 6-72)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Southeast Environmental Research Laboratory, College
Station Road, Athens, Georgia 30601

SUBJECT: Significance of Organic Analysis of North Melbourne Samples

DATE: January 8, 1974

FROM: 4ASC/Finger

TO: 4AWW/Hutchinson

## Summary

This memo is to provide further comment on our organic analysis of the three North Melbourne, FL Water Treatment Plant samples received November 15 and labeled Alum, Raw and Mag. The sampling dates were not reported to us.

As I mentioned in my last memo on these samples, we used gas chromatography for analyzing the samples, therefore we would only detect organics that vaporize at our GC operating conditions. CCE and CAE data can't be compared to GC data because they are based on the weight of the residue remaining after evaporating the chloroform and aocohol extracts. Since these samples are from Florida I would guess that the CCE and CAE could consist of high boiling natural organics that do not vaporize at GC conditions such as the tannic acids.

## Action

For your information.

## Background

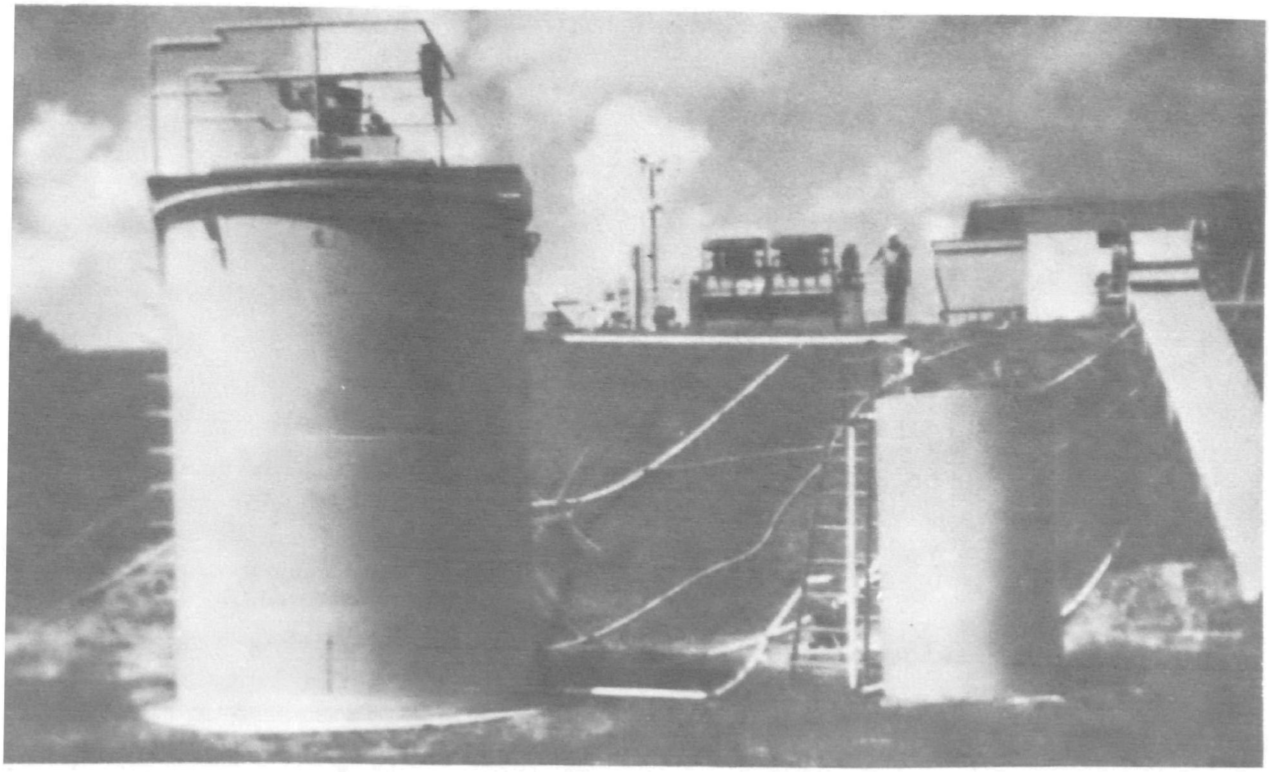
Further comment pertaining to my memo of December 14, 1973.

James H. Finger
Chief
Chemical Services Branch

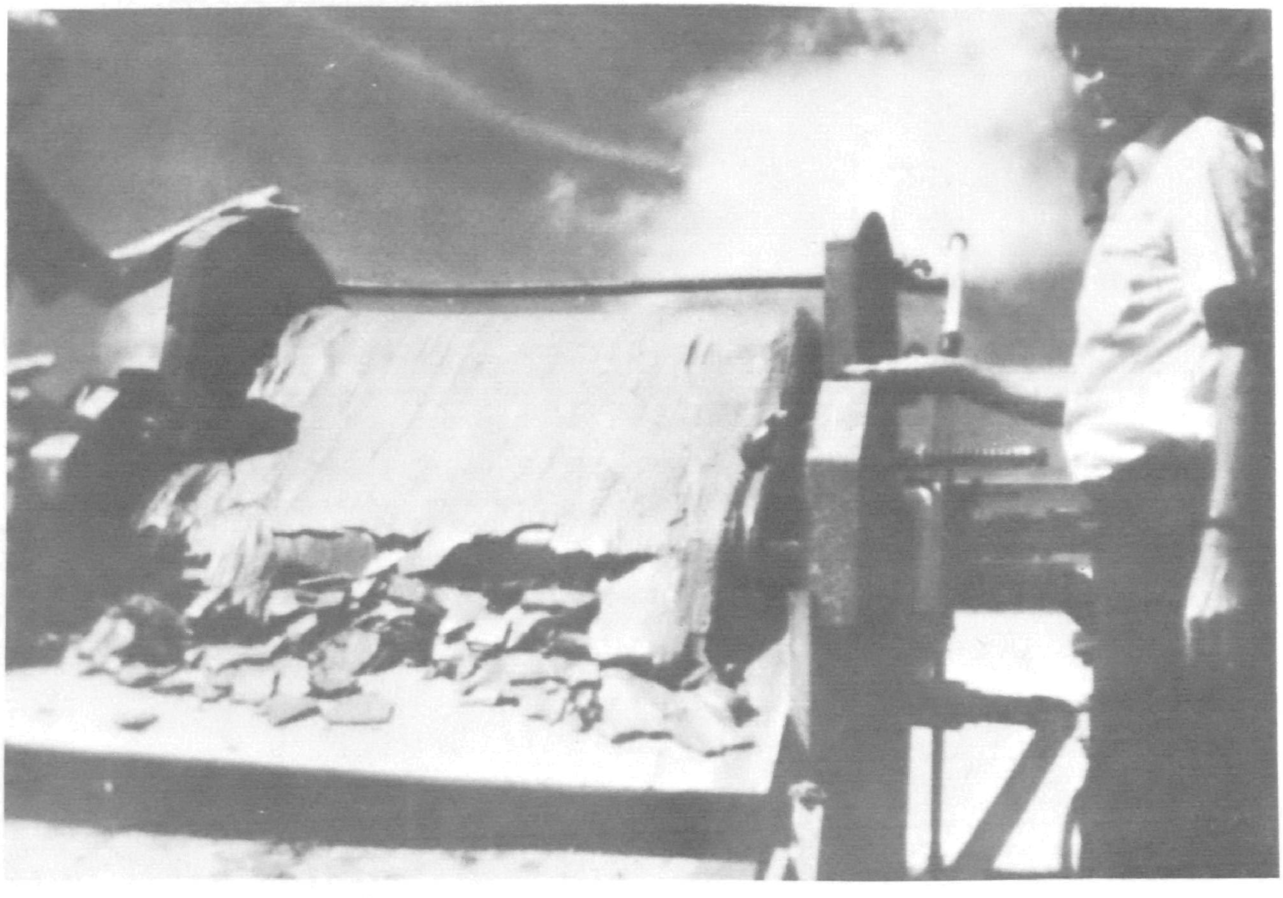
EPA Form 1320-6 (Rev. 6-72)

# APPENDIX F

# PHOTOGRAPHS OF THE MONTGOMERY AND MELBOURNE FACILITIES

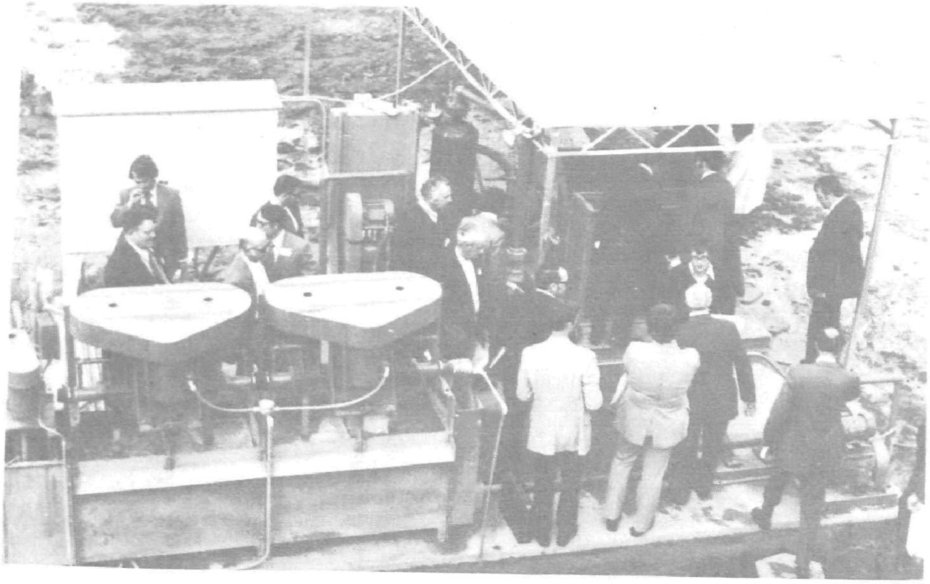


Melbourne Full Scale Facility

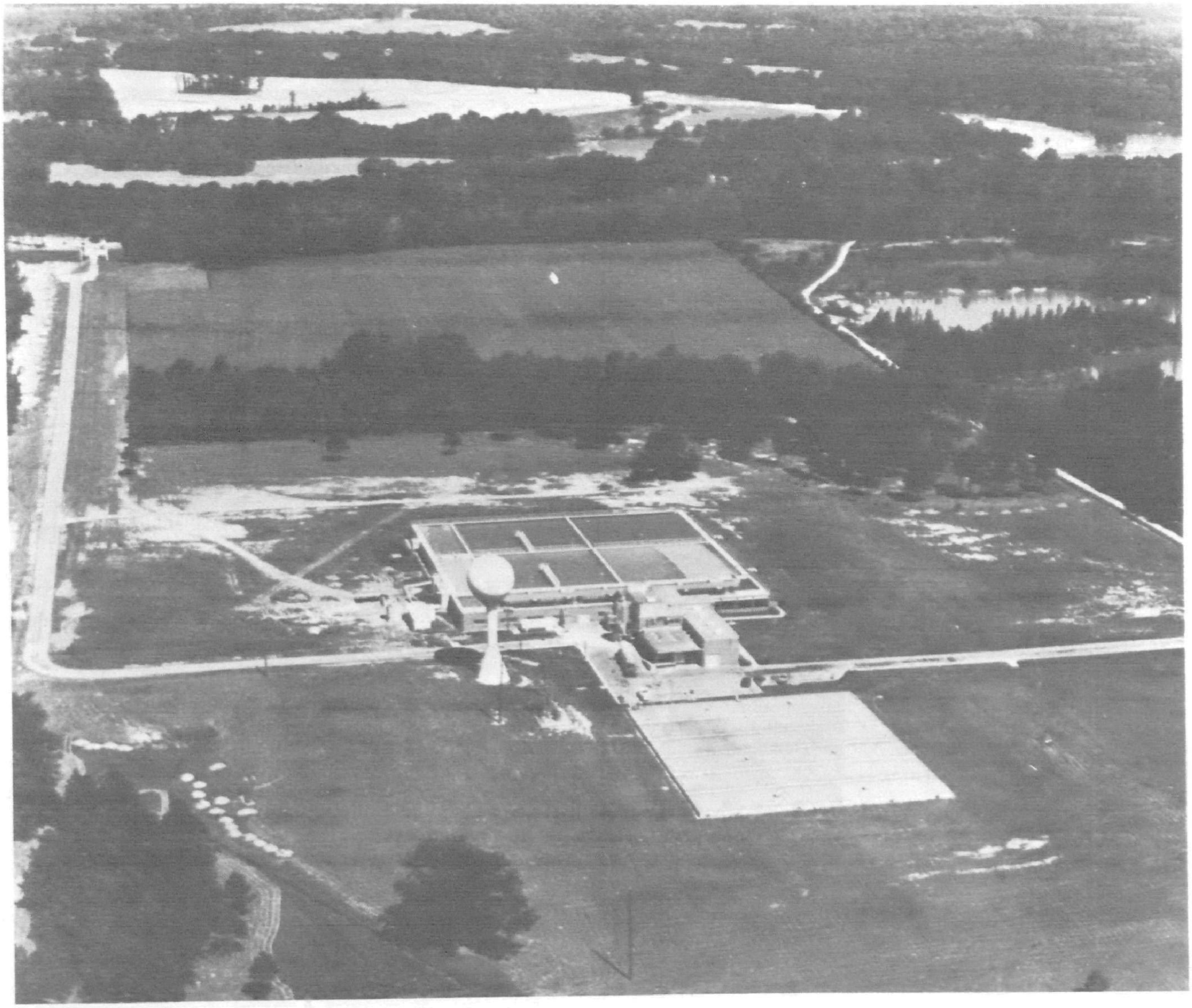


Melbourne Vacuum Filter

Montgomery Pilot Plant Facility



Montgomery Full Scale Magnesium Recovery Facilities



Plant Scale Study Facilities,
Montgomery, Alabama

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO.<br>EPA-660/2-75-006 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE<br>Plant Scale Studies of the Magnesium Carbonate Water Treatment Process | | 5. REPORT DATE<br>September 1974<br>6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S)<br>A. P. Black<br>C. G. Thompson | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Black, Crow & Eidsness, Inc.<br>777 South Lawrence Street<br>Montgomery, Alabama | | 10. PROGRAM ELEMENT NO.<br>1BB036<br>11. CONTRACT/GRANT NO.<br>12120 HMZ |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>Montgomery Water & Sanitary Sewer Bd.<br>P. O. Box 1631<br>Montgomery, Alabama 36102 | | 13. TYPE OF REPORT AND PERIOD COVERED<br>Final<br>14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The magnesium carbonate process of water treatment has replaced alum in a portion of two water plants in full scale studies conducted over the past two and one-half years. This new water treatment technology was compared to the presently used alum process in parallel treatment using identical units in Montgomery, Alabama and Melbourne, Florida.

The results indicate a number of significant advantages; primarily that the existing problem of sludge disposal in Melbourne's case is completely eliminated and at Montgomery is greatly reduced. All water is recycled within the process along with the three basic water treatment chemicals - lime, magnesium bicarbonate, and carbon dioxide. Other advantages found were increased floc settling rates, simplicity of operation and control, reduced costs when sludge treatment and disposal costs are considered, and more complete disinfection. In Melbourne's case, considerable energy would be conserved by on-site lime recovery.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Water Purification<br>Coagulation<br>Chemical Recovery<br>Sludge Treatment<br>Magnesium Carbonate | Recycle<br>Recovery<br>Carbonation<br>Magnesium | |

| | | |
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EPA Form 2220-1 (9-73)