DEVELOPMENT AND VALIDATION OF A WATER MANAGEMENT AUDIT PROCEDURE

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PREFACE

This study was conducted to develop and validate a procedure for water management auditing which would provide an effective process to discover ways for industry to save water, energy and money through better water management. The research emphasized water management in industry and did not look at water treatment and distribution.

The results of this study was divided into a water management audit procedure and a validation of the procedure. The water management audit procedure included data needed for water management audit, equipment needed for water management audit and the audit procedure itself. The validation of procedure was done on a case study of water management audit. A technical summary of water management technologies was presented in the appendix.

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CHAPTER 1

INTRODUCTION

Statement of Problem

Fresh water supply is a problem for all the world. The November 1993 issue of National Geographic (1) illustrates that the United States withdraws 339 billion gallons of ground and surface water a day, and uses 1,300 gallons of water per person per day. A large part of the water usage is in industry; thus water management in industry could lead to large savings.

Management is defined as "the process of planning and decision making, organization, leading, and controlling an organization's human, financial, physical, and information resources in an efficient and effective manner."(2) Water management is the judicious and effective use of water in all areas of manufacturing to improve profits. Management of water implies a continuous process, not just a one-time conservation effort. Water management requires constant analysis and evaluation of saving from better water management practices.

The word "audit" is normally used in accounting area for the meaning of "examine an account." In energy management, Mashburn (3) defines energy audit as "an on-going thought process, supplemented by structured events, with the purpose of identifying ways to use energy more efficiently." Kennegy, Turner, and Capehart (4) address an energy audit into three phases: preparing for the audit visit, performing the audit survey, and implementing the audit recommendations.

Water management audit is a cost reduction and profit improvement process involving an eliminating, combining, changing sequence, and modifying of water consumption. The goal of water management audits is to identify and evaluate better water management ideas (usually water conservation) which will be used in an ongoing water management program. This research will develop procedures and checklists for use in water management audits. Thus, in energy and perhaps water management, an audit is a periodic analysis of processes to discover, and hopefully implement, changes in the processes. These changes should lead to significant improvements. Thus, periodically audits are performed to leading to reduced energy (water) consumption.

The research will emphasize water management for industry because of their tremendous water usage and potential savings. Frequently, management does not understand their water billing and details of water consumption which can cause an exorbitant use of water. Water management audits can help them understand where the water is used and how they can save through better water management.

The deliverables of this research include a list of data needed before, during, and after a water management audit, a list of equipment needed for a good survey, a water management audit procedure and its validation, checklists of water management ideas, and a case study showing implementation of the water management audit procedure.

Although water management audits have been done before, a formal procedure or checklists for water management opportunities have never been developed. The following deliverables will be developed in this research for the first time.

- The water management audit procedure will be formalized to help auditors perform an effective water management audit.
- Checklists of water management opportunities will be developed. For the first time a comprehensive checklist is pulled together for using water management audit.
- Calculations on water consuming equipment such as boilers and cooling towers will be pulled together to show their use in water management. Normally, these calculations are used in designing the equipment or process.

Energy management audits concentrate on energy usage and identification of energy savings while water management audits concentrate on usage and water savings. Energy management is done by looking at energy consumption, but water management looks at water consumption at the plant. However, water management studies in water management are frequently uncover large energy savings, also. Most water used in the plant contains some heat or needs to be pumped, so water savings means that the amount of energy used for heating or pumping that water can be saved. Frequently, the dollar impact of energy savings accomplished through water management ideas is larger than the water savings themselves.

Objectives

The purpose of this research is to develop and validate a procedure for water management auditing which will provide an efficient process to discover ways for industry to save water, energy, and money through better water management. The research will emphasize water management in industry and will not look at water treatment and distribution. This is left to other researchers.

The results of this research will be divided into three parts. The first part will include a list of data to be gathered before an audit, during an audit and after an audit. A list of equipment needs for the audit and their priority of need will also be presented in this part. The second part of the research will be a water management audit procedure and a check list of water management ideas. Several case studies will be examined to develop a procedure. The last part of this research will be a validation of the procedure through an analysis of a case study showing use of the procedure thus validating the process. The case study will include a listing of opportunities for water management savings with complete economic analysis.

A technical summary of water management technologies which can be used in industry will be presented in the appendices. Some of these technologies are:

- Reverse Osmosis,
- Ultrafiltration,
- Water treatment processes: Chemical treatment, Electrodialysis and Deionization.

The technologies presented are those identified in the research that meet two criteria.

1. They offer large savings opportunities for industry.
2. They are not universally understood by plant management.

Thus, some technologies will not be covered because they do not meet both criteria.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Water is becoming one of the largest problems the world faces. The problems involve small fresh water supplies to growing populations and safe disposal of wastewater. Water should be treated as a valuable resource that must be allocated properly. Because of the water problems, water management becomes more important. However, there is not much research done in the water management area. Most research is done on water allocation and flood prevention. The literature that is related to this research is reviewed in this chapter.

Winpenney (5) discusses the policies which could be used to treat water as an economic resource. These policies include the environmental and waste considerations which could mean a large increase in cost to industry.

As demand for water usage increases, the role of water management becomes more significant. Water management is considered as a program to reduce water usage and save money. Webb and Turner (6) discuss the need for water management. They indicate that water management is a program which could help industry save cost on both water and energy. The major water usage equipment in industry is also discussed .

In "Water Management: A Case For The Integrated Approach" (7), water management is defined as a consensus among industry, officials, spokespeople for regulatory agencies, and water management professionals. Water management is an interrelated concern of water, wastewater, hazardous waste, and water supply. The disposal of hazardous waste often has an effect on the quality of groundwater. The quality of wastewater effluent has an impact on the quality of surface water that is used as a primary source of water.

Water management usually means water conservation. One approach is repairing pipe leaks. Information from the California Department of Water Resources shows that during 1976-77 the state conducted a statewide water audit to detect leaks and saved a significant amount of money from repairing leaks (8). The paper suggests that improper installation, especially at pipe joints, can lead to erosion which causes leaks. Cathodic protection should be installed to prevent corrosion in pipes.

Water reuse is another approach. Before reuse, process water, which is likely to be contaminated, may need to be treated but often, it can be used with no treatment. The following equipment and processes are most commonly used to prepare water for reuse (Eble and Feathers (9)).

- Chemical oxidation. Oxidizing agents are used to reduce the potential for microbiological growth and chemical oxygen demand (COD) of water before reuse.
- Air stripping. Air stripping is a process of transferring undesired contaminants from water to air by a spraying or aeration system.
- Physical separation. Physical separation is used to reduce total suspended solids (TSS) and turbidity.
- Air flotation. Air flotation is designed to remove oil and grease as well as suspended solids by a gravity separation unit.

- Filtration. Filtration is used for removing suspended solids by gravity flow.
- Clarification. Clarification is used to separate suspended solids from water by coagulation, flocculation, and sedimentation.
- Biological treatment. Biological treatment is used to remove soluble and insoluble organics from water after the primary separation process.
- Carbon filters. Activated carbon filters are used to reduce and remove dissolved organic content, heavy metal, chlorine, and TSS.
- Lime softening. The lime softening process removes calcium hardness, magnesium hardness, phosphates, silica, and alkalinity from water.
- Demineralization. Demineralization uses a process of ion exchange to purify water. Cation and anion resin beds are used to exchange H^+ and OH^- ions respectively.
- Reverse osmosis. Reverse osmosis is a separation technique that employs a semipermeable membrane cell. A pressure differential is created to drive fresh, clean water to one side of the cell while concentrating contaminants on the other side.
- Electrodialysis reversal (EDR). EDR is a method for extracting and concentrating ions in solution by the use of an electric field. The field allows ion passage through anion-selective and cation-selective semipermeable membranes.

Ploeser, Pike, and Kobrick (10) present a study on business and industrial water conservation. The study shows that nonresidential water conservation can help businesses and industrial save significant money. The major areas of water use and nonresidential conservation opportunities are the following.

- Sanitary water use. This includes lavatory faucets, toilets, and urinals. A number of states now require low or ultralow-flow plumbing fixtures which help save both construction cost and water consumption. Shower heads and faucets can be replaced with low-flow versions.
- Cooling process. The authors suggest two options for cooling tower water management. The first option is to install flow meters for makeup water and bleed to enable better coordination of tower water. The other option is to add sulfuric acid to control the pH of the tower water, thus a corrosion inhibitor is needed. Both methods can help reduce water consumption.
- Cleaning, sanitation. Water recycling is suggested for cleaning water. Most larger hospitals and some businesses have steam sterilizers, which use significant quantities of water. Steam sterilizers which use a recirculating closed-loop cooling water system are now available. These steam sterilizers can reduce water consumption.
- Boilers. Steam traps are used for collecting condensate. Suitable condensate should be reused as feedwater for the boiler. This saves large amounts of money, energy, water, and treatment chemicals.
- Process rinsing. Flowmeters and manual valves can be used to control water flow rates. However, automatic control may be used to control rinse water valves. Two types of automatic control are suggested in this paper. The first

type is operated by measuring the amount of total dissolve solids in rinse tanks to control flow. The other control is automatic timer-controlled shut-off rinse flows.

Garay and Cohn's book, High-Quality Industrial Water Management Manual (11) presents a guideline for water treatment. This book covers topics on water quality, problems from water quality, and water quality measurement. Treatment processes such as ion exchanger, deaerating heater, filtration, and evaporation are introduced as a guide for industrial use.

The book Environment (12) summarizes the U.S. government's water management policies from 1964 to 1987. Policies include:

- The Water Resources Research Act of 1964: established a Federal Office of Water Resources and Technology in each state,
- The Water Resources Planning Act of 1965: established the U.S. Water Resources Council,
- The National Environmental Policy Act of 1970 and the Federal Water Pollution Control Act of 1972: shifted the focus of federal funding from dam and canal construction to environmental protection,
- The National Water Commission (1973 report): focused on the need for protection of water resources,
- In 1970s, President Carter's water policy focused on more efficient planning, management, and conservation of water resources,

- In 1981, President Reagan's administration sought to shift most water resources planning and management from the federal government to state governments,
- In 1987, the U.S. Bureau of Reclamation announced that water-resources programs would shift from irrigation development to management.

In order to improve a water management program, coordination among industry owners, government agencies, and water management professionals is necessary (Grigg, (13)). The water management program has to be implemented and updated continuously to achieve the best result which leads to significant savings.

The search and review showed that there is very little literature on water management. As defined in this research the lack of water management literature also indicates that more research is needed in the water management area. Thus, this thesis works on developing a water management audit procedure.

CHAPTER 3

WATER MANAGEMENT AUDIT: DATA AND EQUIPMENT

List of Data to Be Gathered

Data needed for a water management audit can be divided into three categories: data needed before an audit, data gathered during an audit, and data needed after an audit.

Data to Be Gathered Before an Audit

Before an audit, the auditors need to collect some data from the plant to be audited. Then the data will be analyzed so that the auditors can determine what other data they need to collect during the audit. A comprehensive list of the data which the auditors should have before the audit are (examples of these data will be presented in Chapter 5):

- **Facility layout of the plant and operating hours per week.** The layout should be obtained to determine the plant size, equipment location and water lines. Knowing the layout, the audit team can plan a survey and evaluate some water management opportunities ahead of the survey. The operating hours of the plant will help in calculating water usage and savings.
- **Water and energy use data.** The audit team should acquire consumption bills for at least twelve consecutive months before an audit. The bills will show the amount of water and energy usage for each month which will help the team to understand water consumption at the plant. The information on water and energy use should be summarized in tables and charts before a plant visit.

- **Water, energy and wastewater cost rates.** These rates are required for calculating water, energy, and waste cost. The same rates will be used to calculate the savings of each water management opportunity.
- **Equipment list.** A list of plant equipment will provide information on water and energy consumption. Equipment that consumes a large amount of energy and water should be identified. The operating hours of each piece equipment should also be provided.

Data to Be Gathered During an Audit

During an audit, the audit team should gather detail data on the facility and its operation which will lead to ideatification of water management opportunities by looking at major water comsumer equipment. This data may include water heaters, boilers, cooling towers, rinse water tanks, evaporators, and water cooled equipment. Water cooled equipment such as furnace walls, air compressors, gas engines, etc. can be very large consumers of water. Water from this equipment can be reused in rinse tanks, as lawn watering, or in other processes. Before an audit, the auditors can prepare a data collection sheet which will help to provide the following data during an audit. The data needed during an audit are:

- **The actual operating hours of each piece of equipment.** During an audit, the audit team should document the operating hours by equipment. This data will be used to determine water management opportunities and calculate savings for each opportunity.

- **Operating procedures for all processes and each piece of equipment.** The knowledge of operating procedures will help the team to determine if water can be reused, combined with fresh water, or reduced. The operating procedure for each piece of equipment can also be used to determine water management opportunities. While visiting the plant, an audit team should acquire information about water flow in and between each process to determine the possibility of recycling water.
- **Water usage.** Water usage data should be collected for each major water consumer and should include both domestic (non-manufacturing areas) water usage and process (manufacturing areas) water usage. The amount of water usage can be determined by using estimated water flowrates and operating hours of the plant (or each piece of equipment). Water usage data will be used to identify and calculate savings. The data on water usage will also help to indicate where the plant use large amount of water, and whether that water consumption can be reducee.
- **Water flowrate.** The audit team should determine water flowrate at major water comsuming equipment. This flowrate can be measured by using a flowmeter. Knowledge on water flow rates helps auditors to find the major users and to consider if the flowrate can be reduced. This flow rate will be used for calculation in later analysis.
- **Water temperature.** The water temperature for equipment such as rinse tanks, cooling towers, boilers, and domestic water should be measured and documented for determining water management opportunities. Other water temperatures may need to be measured depending on operation and water comsuption of the plant.

- **Boiler water and cooling tower water sample.** The audit team should take boiler and/or cooling tower water back to analyze the properties of water such as ppm (part per million) of impurities or dissolved solids in boiler and cooling tower water. The properties of the water in boilers and cooling towers will be used for analyzing and calculating water management opportunities.
- **Water leakage.** Water leaks should be detected and recommended for repaire. Leaks can occur at pipes, tanks, and at equipment. During a walk-through tour of the plant, the audit team needs to observe water and steam leaks and document them. The audit team may mark water leaks on the plant layout diagram which the team obtained before an audit.

- **Water management opportunities.** If during an audit, the team finds any water management opportunities those opportunities need to be documented for further analysis. That is, a list of ideas should be compiled. Auditors should consider recovering water from water cooled equipment such as furnace walls, air compressors or gas engines. This water is clean and can often be reused in areas such as rinse tanks.

- **The specification of each equipment.** Information on specifications of equipment and processes are used to consider whether water flowrates or temperatures can be reduced. The audit team can acquire this information from the person who is responsible for the plant's process. The data on specifications also includes horsepower of each piece of equipment, water consumption, operating hours, etc.

Data needed after an audit

After examining and reviewing data from an audit, the audit team may need some information for determining water management opportunities. This data can be the data missing from the audit or the data concerning the installation of any water management processes. The data can be obtained from a facility person at the plant or from the manufacturers. If necessary, the team may re-visit the plant to obtain that missing data. The data which an audit team may need includes:

- **The cost of equipment needed for water management.** The cost of equipment installation will be used to calculate the financial justification and to consider the feasibility of each water management opportunity. Equipment may be water restrictors, pipes, water treatment processes, etc.
- **Data for calculating savings on each water management opportunity.** The information needed to calculate the savings may include calculation methods and formulas for items such as boilers or cooling towers, water properties at different temperatures and pressures, steam properties at different temperatures and pressures, etc. depending on the type of water management opportunity. Some of this information including calculation methods and formulas will be provided in the next chapter, and some of the rest can be found in mechanical handbooks, text books, or reference books.

List of Equipment Needed for Water Management Audit

Equipment used to perform a water management audit can be grouped into three different significant levels. The first priority equipment is the minimum amount of equipment required for performing an audit. The second priority equipment is the equipment which is not required but would be very useful for an audit. The last priority equipment is that equipment with has limited use and may not be necessary for an audit. The information of equipment source and cost is provided in Appendix B.

First Priority Equipment

Equipment in this category is required for performing water management audits. It is used to measure data needed for calculating savings of each water management opportunity.

- **Thermometer** - A thermometer is needed for measuring temperature. Electronic thermometers with interchangeable probes are easy to use and measure temperature. Infrared thermometers are used for measuring temperatures of steam lines and other remote or high temperature sources (see second priority equipment). For high temperature measurement, thermocouples may be needed. Appendix B presents typical digital thermometers on page 75.
- **Flow meter** - A flow meter is necessary for determining the flow rate of water in a process. Ultrasonic doppler flowmeters may be used to measure the flow of water. The principle of operation of ultrasonic flowmeters is an ultrasonic signal reflected by suspended particles in water (16). The meter ultilizes the physical phenomenon of the

sound wave changing frequency when it is reflected by moving discontinuities in a flowing liquid. The different frequency of ultrasonic wave is directly proportional to the flow of liquid. Appendix B presents a typical ultrasonic flow meter on page 76.

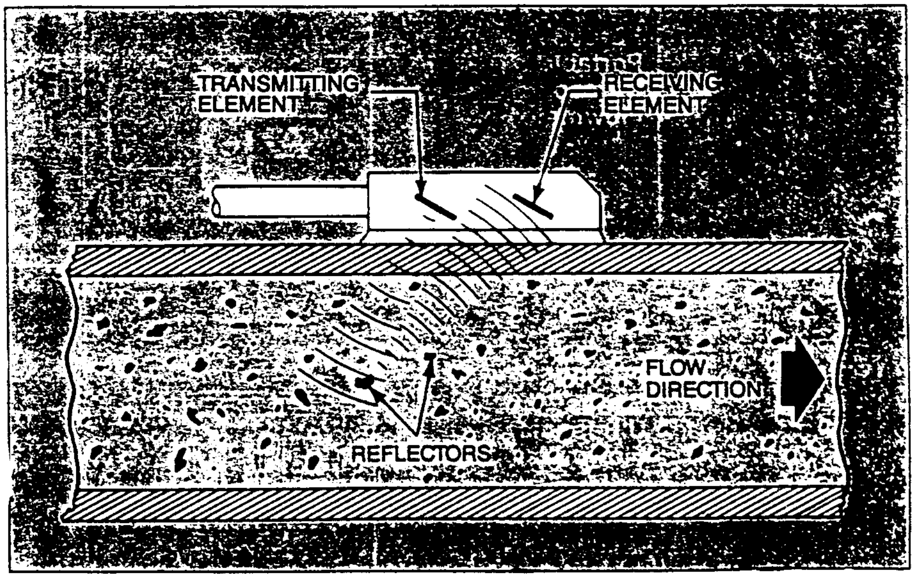

FIGURE 3.1 THE ULTRASONIC DOPPLER FLOW SENSOR [16]

- **Water Test Kit** - A water test kit contains chemicals, beakers, droppers, pipettes, etc. Water samples from sources such as boilers and cooling towers are needed for analysis of for ppm of chloride and ppm of dissolved solids. This information can be also used to calculate optimum blowdown or bleed rates (see Chapter 4 page 23 and 27). This kit can be used to measure chloride level, water hardness, total dissolved solids, pH of water and other properties of water. A typical water test kit is presented in Appendix B on page 77.
- **Wattmeter**- A wattmeter is necessary for determining power consumption of equipment. The meter usually has a clamp-on feature which can connect it to the

current-carrying conductor and has probes for voltage connections. Appendix B presents typical wattmeters on page 78.

- **Tape Measures** - A tape measure is needed to determine the length of pipe, distance between equipment, etc. A 25-foot and a 100-foot tape are suggested.
- **Safety Equipment** - Safety is very important for an audit. Safety equipment needs to be provided for auditors to use during a plant visit. This equipment should consist of ear plugs, safety glasses, gloves, and safety hats. Respriators may be needed if the process contains hazardous chemicals. Some necessary safety equipment is presented in Appendix from page 79-81.

Second Priority Equipment

The items listed as second priority equipment are not absolutely required for an audit, but they would be useful to the auditors to have them.

- **pH meter** - A pH meter is used to measure pH of water. The most common pH meter is an electronic pH meter which can show the pH value of the liquid measured. If a pH meter is not available, the auditors can bring samples of water back to analyze later using a water test kit. Appendix B presents typical pH meters on page 82.
- **Infrared Thermometer** - An infrared thermometer can be used for measuring temperatures of steam lines that are difficult to reach. The temperature of steam or hot water inside a pipe can be measured by using an infrared thermometer. Appendix B presents typical infrared thermometers on page 83.

Last Priority Equipment

The last priority equipment has limited use and is expensive; however, it could be very useful during a water management audit to have this equipment.

- **Combustion Analyzer** - A combustion analyzer is used to determine efficiency of boilers, furnaces, or other equipment which burn fuel. The efficiency of boiler is necessary for boiler calculation which will be used in the water management opportunity's saving calculation. There are two types of combustion analyzer: digital analyzer and manual analysis kits. Digital combustion analysis equipment measures and reads out in percent combustion efficiency. The manual combustion analysis kits require more measurements including exhaust stack, temperature, oxygen content, and carbon dioxide content. The efficiency of the combustion can be calculated after that. Although the digital combustion analyzer is more convenient, it is also more expensive than the manual kits. Appendix B presents an example of oil and gas burner combustion test kit components on page 84.

CHAPTER 4

WATER MANAGEMENT AUDIT: PROCEDURE AND CHECKLIST

Water Management Audit Procedure

Although a water management audit can be performed without following this exact procedure, following the procedure may help an audit team avoid missing some data and spending more time than required. This procedure can also help auditors who are not familiar with water management perform successful audits with fewer problems. The procedure begins with preparation and finishes with analysis.

Before starting an audit, audit team members must be selected. The team may consist of two to four people including a team coordinator. The team needs to have more than one person to make sure that all the necessary information will be collected and to encoruage generation of ideas. In the author's opinion, more than four audit team members means they interfer with each other. Also, safety problems may exist as the team crowds around a process.

The number of team members can depend on the size and complexity of the audited plant. For example, a large plant with lot of water consuming equipment could need a larger team; but a plant with little water usage could easily be done with two - may be even one - people.

Team members need to have good technical skills and have knowledge about water consuming equipment such as boilers or cooling towers. The team should also be familiar with manufacturing process and have a good understanding water management. Each member will have an assigned responsibility. For example, one could take notes, another and a third measure needed data, or interview the plant manager or supervisor(s).

Water management audit procedure consists of five steps. The first two steps are the preparation steps. The third step is a survey step. And the last two steps are the analysis and report steps. The first two steps may take two to three weeks to contact the company and receive the information needed before an audit from the company. The survey step normally take about one day. And the last two steps may take two weeks to one month to complete depending on the number of water management opportunities and time needed to obtain product information for each water management opportunity.

The cost of water management audit includes:

- salaries for the members of an audit team,
- cost of equipment used in an audit (one time investment),
- cost of travelling to the plant,
- cost of contacting the company and manufacturer(s) of products,
- cost of analyzing water management opportunities, and
- cost of producing a water management audit report.

The five steps water management audit procedure is presented in the following. The results and validation of the procedure will be presented in the next chapter.

1. <u>Contact company for auditing.</u>

Before an audit, the audit team should contact the company which needs a water management audit. Companies which can benefit most from water management are companies with large water and energy bills and with a large amounts of water discharge. The executives at the company also need to be interested in participating in a water management program in order for the company to benefit from the audit. The team needs to contact facility people at the company and ask them to send detailed information on water and energy bills, products or services of the company, processes, equipment in the plant, operating hours of the company and each equipment, etc. Chapter 5 presents examples of these information in the validation of the proposed water management audit procedure. The information needed before an audit is presented in the first part of Chapter 3. If any needed information is missing, the team must contact a representative at the company to obtain that data before a plant visit. The team also needs to schedule the date to perform an audit the plant with a representative at the company to make sure that there will be at least one person available to lead the team around the plant.

2. Analyze data before an audit.

After receiving data from the company, the audit team can perform some preliminary work before visiting the plant. The water and energy bills should be examined and analyzed so that water management opportunities can be determined during the plant visit. An equipment list should be prepared with the location and operating hours of each piece of equipment. Data on water and energy usage in the past twelve months needs to be summarized and presented in the form of a table and a chart. Rate structures (costs) for water and energy as well as wastewater must be determined and documented. The facility layout and overall process of the plant needs to be studied, and the large users of water need to be identified. Examples of rates and twelve-month period water consumption is presented in Chapter 5.

3. Conduct water management audit visit.

Once the data on water and energy bills, process operation, and equipment have been obtained and studied, a plant visit should be made to identify water management opportunities. An audit should start with a facility manager and supervisor(s) to discuss the purpose of the audit. After a meeting, an audit will be conducted by a walk-through tour and interview. The walk-through tour would be done by following the process of the plant. After following the process, the team may need to go back and look at major water consuming equipment such as cooling towers, boilers, and water cooled equipment for water management opportunities. All water cooled equipment needs to be examined carefully for the opportunities to save or reuse water and/or heat.

During an audit, an audit team may have interviews with the facility manager, chief operators, or supervisors to obtain information about process operation. An audit team may measure temperature of water and water flow rates as needed, detect water leakages, and consider water management opportunities while they walk through the process. All the information about process, product, and water management opportunities that are acquired during an audit need to be written down for further analysis. Water management audit checklists will be presented in the next section of this chapter to help auditors know what to look for during a plant visit.

4. **Perform analysis and determine savings.**

After a plant visit is completed, the analysis should be done as soon as possible. Water management opportunities will be identified by using the checklist in the back of this chapter or the audit team member's idea(s). From the water management opportunities, water and energy savings will be calculated based on the amount of water, hot water and steam saved. Common water management opportunities can be founded at the following equipment.

- Cooling tower. In order to identify savings at the cooling tower, calculations for items such as bleed, evaporation rate, and makeup rate are needed. The terms and formulas which are necessary for the calculation include:

– Circulation rate. Circulation rate is the rate at which water is pumped over the tower, volume per unit time.

$$\text{Circulation rate (lbs/min)} = \frac{\text{heat load (BTU / min)}}{\text{range } (^\circ\text{F})}$$

Where range is the difference of temperatures between water input and water output.

– Blowdown or Bleed. Bleed is water discharge from the system to control concentration of impurities in the circulating water.

$$\text{Percentage bleed} = \frac{\text{ppm chloride in makeup water}}{\text{ppm desired chloride in circulating water}} \times 100$$

Bleed can also be calculated by using a table. To calculate bleed:

1. Determine cycles of concentration required.

Cycle of concentration. Cycle of concentration is the inverse of the bleed. It is used for calculating treatment dosage. The higher cycle of concentration, the more efficiently the cooling tower is being utilized.

$$\text{Cycle} = \frac{\text{ppm chlorides in the circulation water}}{\text{ppm chlorides in makeup water}}$$

$$= \frac{\text{total dissolved solids in the tower}}{\text{total dissolved solids in makeupwater}}$$

2. Determine tower tonnage.

Tons = gal/min x 8.33 lb/gal x 60 min/hr x $\Delta t\ ^{o}F$ x ton/12000 BTU x BTU/lb ^{o}F

3. Refer to the Table 4.1 below for bleed rate. Bleed rates from the table are in gallons per minute.

TABLE 4.1

BLEED RATE & TOWER TONNAGE FOR VARIOUS CYCLE OF CONCENTRATION

TOWER TONNAGE	CYCLE OF CONCENTRATION						
	2	3	4	5	6	7	8
50	1.5	.75	.5	.37	.3	.25	.21
100	3.0	1.5	1.0	.75	.6	.5	.42
200	6.0	3.0	2.0	1.5	1.2	1.0	.85
250	7.5	3.75	2.5	1.87	1.5	1.25	1.06
300	9.0	4.5	3.0	2.25	1.8	1.5	1.27
400	12.0	6.0	4.0	3.0	2.4	2.0	1.7
500	15.0	7.5	5.0	3.75	3.0	2.5	2.12
600	18.0	9.0	6.0	4.50	3.6	3.0	2.55
700	21.0	10.5	7.0	5.25	4.2	3.5	2.97
800	24.0	12.0	8.0	6.0	4.8	4.0	3.4
1000	30.0	15.0	10.0	7.5	6.0	5.0	4.25
1500	45.0	22.5	15.0	11.25	9.0	7.5	6.37
2000	60.0	30.0	20.0	15.0	12.0	10.0	8.5

– Evaporation rate. Evaporation rate (volume per minute) is a rate at which water is being evaporated to cool the circulating water.

$$\text{Evaporation rate} = \frac{\text{range }(^{o}\text{F})}{10} \times \frac{\text{circulation rate}}{100}$$

Evaporation rate can also be determine by using the table below.

TABLE 4.2

EVAPORATION LOSS & COOLING RANGE

COOLING RANGE	EVAPORATION LOSS
1 °F	0.18 GPM X DEVELOPED TONNAGE
2 °F	0.36 GPM X DEVELOPED TONNAGE
3 °F	0.54 GPM X DEVELOPED TONNAGE
4 °F	0.72 GPM X DEVELOPED TONNAGE
5 °F	0.90 GPM X DEVELOPED TONNAGE
6 °F	1.0 GPM X DEVELOPED TONNAGE
7 °F	1.2 GPM X DEVELOPED TONNAGE
8 °F	1.4 GPM X DEVELOPED TONNAGE
9 °F	1.6 GPM X DEVELOPED TONNAGE
10 °F	1.8 GPM X DEVELOPED TONNAGE
15° F	2.7 GPM X DEVELOPED TONNAGE
20° F	3.6 GPM X DEVELOPED TONNAGE
25° F	4.5 GPM X DEVELOPED TONNAGE
30 ° F	5.4 GPM X DEVELOPED TONNAGE

– Makeup water. Makeup water is water added to the circulating water system to replace water lost by evaporation, drift, windage, blowdown, and leakage.

Makeup rate = loss due to evaporation + loss due to windage + loss due to bleed

Where loss due to windage = 0.002 x circulation rate

<u>Example 4.1</u> A 1-ton cooling tower can reduce hot temperature from 97°F to 87°F. Calculate circulation rate, drift, and evaporation rate of this cooling tower. (1 ton = 12000 BTU/hr) If the cycle of concentration is 3, what is bleed and make up rate?

$$\text{Circulation rate} = \frac{\text{heat load}}{\text{range}}$$

$$= \frac{12000 \text{ BTU}}{(10^{\circ}\text{F})(1 \text{ BTU}/\text{lb}\cdot^{\circ}\text{F})}$$

$$= 1200 \frac{\text{lb}}{\text{hr}} \times \frac{1 \text{ gal}}{8.33 \text{ lb}}$$

$$= 144.06 \text{ gal/hr}$$

Drift $= 0.002 \times$ circulation rate

$$= 0.002 \times 144.06 \text{ gal/hr}$$

$$= 0.288 \text{ gal/hr}$$

$$\text{Evaporation rate} = \frac{\text{range}}{10} \times \frac{\text{circulation rate}}{100}$$

$$= \frac{10\ ^\circ\text{F}}{10} \times \frac{144.06 \text{ gal / hr}}{100}$$

$$= 1.44 \text{ gal/hr}$$

From Table 4.2; for a cooling tower 100 tons and cycle of concentration of 3, bleed rate is 1.5 gallons per minute. So for a cooling tower of 1 ton, bleed rate equals

$$\text{Bleed} = \left(\frac{1}{100}\right) \times 1.5 \frac{\text{gal}}{\text{min}} \times 60 \frac{\text{min}}{\text{hr}}$$

$$= 0.9 \text{ gal/hr}$$

Make up rate = drift + evaporation rate + bleed

$$= 0.258 \text{ gal/hr} + 1.44 \text{ gal/hr} + 0.9 \text{ gal/hr}$$

$$= 2.628 \text{ gal/hr}$$

Normally, sewer charges will be applied to the total amount of raw water purchased by the plant whether the water is sent out to treat or not. Considering the amount of drift and evaporated water at a cooling tower, a plant can save significant money if they can contact the city to subtract this amount of water from the sewer charges. A case study on a plastic plant (17) shows that the plant can save $3,245 per year.

With an estimation of 25% average cooling load yearly.

Evaporated water will be determined by:

Estimated tower tonnage × Approximate evaporation loss

$$= 2275 \text{ tons} \times 1.8 \ \frac{\text{gallons}}{\text{ton hour}} \times 24 \ \frac{\text{hours}}{\text{day}} \times 0.25 \ = \ 24{,}570 \ \frac{\text{gallons}}{\text{day}}$$

$$\text{Water cost saving} = 24{,}570 \ \frac{\text{gallons}}{\text{day}} \times \frac{\$0.37}{10^3 \text{ gallons}} \times 357 \ \frac{\text{days}}{\text{year}}$$

$$= \$3{,}245 \text{ per year}$$

- Boiler. A typical boiler water system is shown in Figure 4.1.

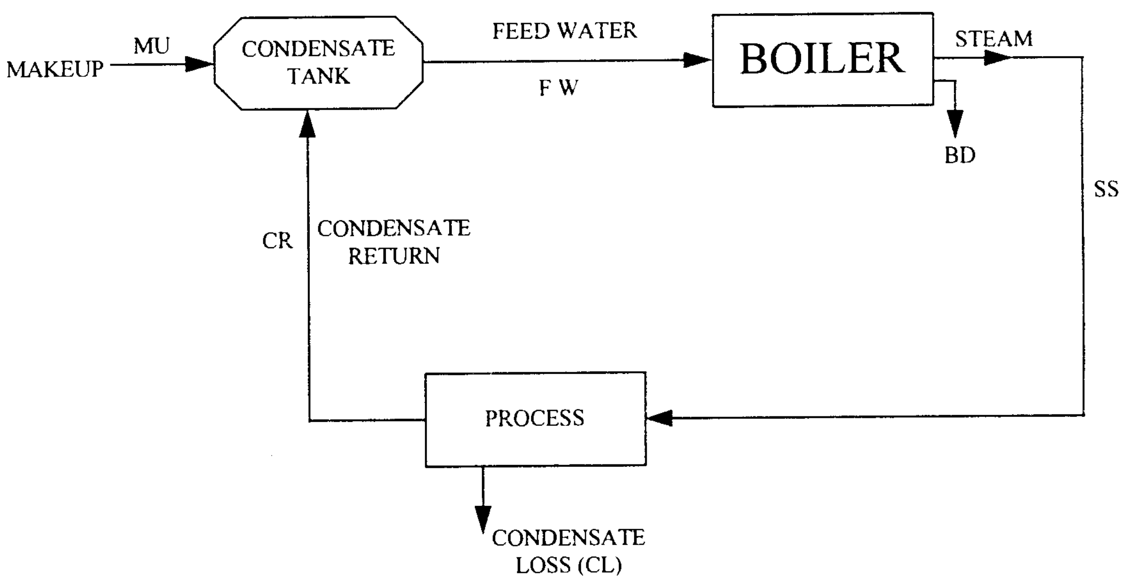

FIGURE 4.1 BOILER WATER SYSTEM

A boiler is another piece of equipment where auditors should look for water management opportunities. Boilers consume a lot of energy to produce steam from water. If it is managed properly, a significant amount of water and energy can often be saved at the boiler. Some of the terms which auditors need to understand are:

- Blowdown. Water from a boiler is discharged for the same reason as water form cooling tower. Actual boiler blowdown can be calculated by equation:

$$BD = \frac{A}{B-A} \times SS \quad \text{(lbs/hr)}$$

Where:

A = ppm of dissolved solid in feed water (FW).

= ppm of dissolved solid in makeup water (%MU = 1- %condensate return(CR)).

B = ppm of dissolved solid in boiler.

SS = steam supply (lbs/hr).

- Makeup water. Makeup water can be determined from boiler horsepower. Boiler horsepower equals the evaporation of 34.5 lbs of water per hour with feed water at 212 °F. (equal to 4 gallons of water evaporated per hour) or boiler horsepower equals 10 sq.ft. of heating surface for old boilers (over 25 years) and 5 sq.ft. of heating surface for boilers less than 25 years old. So:

$$\text{Boiler horsepower} = \frac{\text{lbs of steam per hour}}{34.5 \text{ lbs/hr}}$$

$$= \text{sq.ft. of heating surface}/10 \quad (> 25 \text{ yrs})$$

= sq.ft. of heating surface/5 (< 25 yrs)

$$\% \text{ condensate return} = 1 - \frac{\text{total dissolved solids in feed water}}{\text{total dissolved solids in raw water}}$$

After calculating boiler horsepower and percent of condensate return, the amount of makeup water can be determined by using Table 4.3.

Table 4.4 shows the recommended amount of solids in boiler water at different pressure.

TABLE 4.3

GALLONS OF MAKEUP WATER PER HOUR AS RELATED TO HORSEPOWER AND CONDENSATE RETURN

BOILER HORSE POWER	PERCENT OF CONDENSATE RETURN									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
40	160	144	128	112	96	80	64	48	32	16
60	240	216	192	168	144	120	96	72	48	24
80	320	288	256	224	192	160	128	96	64	32
100	400	360	320	280	240	200	160	120	80	40
125	500	450	400	350	300	250	200	150	100	50
150	600	540	480	420	360	300	240	180	120	60
200	800	720	640	560	480	400	320	240	160	80
250	1000	900	800	700	600	500	400	300	200	100

TABLE 4.4 RECOMMENDED LIMITS FOR BOILER-WATER CONCENTRATION [18]

Drum	Total Solids		Alkalinity		Suspended Solids	
Pressure	ABMA	Possible	ABMA	Possible	ABMA	Possible
0-300	3500	6000	700	1000	300	250
301-450	3000	5000	600	900	250	200
451-600	2500	4000	500	500	150	100
601-750	2000	2500	400	400	100	50
751-900	1500	-	300	300	60	-
901-1000	1250	-	250	250	40	-
1001-1500	100	-	200	200	20	-

Example 4.2 A boiler produces steam 20,000 lb/hr at 350 psig and operates 5000 hours per year. Total solids in the makeup water are 150 ppm, and total solids in the boiler are 2000 ppm. Condensate return is 20%. How much water can be saved by increasing condensate return to 85%? Energy costs \$4.00/10^6 BTU and the boiler is 80% efficient. Water costs \$2.40/10^3 gallon. Makeup water temperature is 60 °F.

1. Increase condensate return from 20% to 85%

At 20% condensate return,

A = 150 ppm x (1-0.2) = 120 ppm

B = 2000 ppm

$$BD = \frac{120}{(2000-120)} \text{ ppm} \times 20{,}000 \text{ lb / hr} = 1{,}276 \text{ lb/hr.}$$

Condensate return = 0.20 × 20,000 lb/hr = 4,000 lb/hr.

At 85% condensate return,

A = 150 ppm x (1-0.85) = 22.5 ppm

$$BD = \frac{22.5}{(2000-22.5)} \text{ ppm} \times 20{,}000 \text{ lb / hr} = 227.6 \text{ lb/hr.}$$

Condensate return at 85% = 0.85 × 20,000 lb/hr = 17,000 lb/hr.

Amount of water saved = (1,276 lb/hr - 227.6 lb/hr) + (17,000 lb/hr - 4,000 lb/hr)

= 14,048.4 lb/hr

$$= 14{,}048.4 \ \frac{\text{lb}}{\text{hr}} \times 5{,}000 \ \frac{\text{hr}}{\text{yr}} \times \frac{1 \text{ lb}}{8.33 \text{ gal}}$$

= 8,432.41 × 10^3 gal/yr.

$$\text{Amount of energy saved} = \frac{\text{water saving from blowdown} \times (h_{\text{liq at 350 psig}} - h_{\text{liq at 60° F}})}{0.8}$$

$$= \frac{629.29 \times 10^3 \text{ gal / yr (409.8 BTU / lb - 28 BTU / lb)}}{0.8}$$

$$= 300.33 \times 10^6 \text{ BTU/yr.}$$

2. From Table 4.4; B can be increased to 3,000 ppm (assume 20% condensate return)

At B = 2,000 ppm, blowdown is 1,276 lb/hr (from the calculation in part 1)

At B = 3,000 ppm

$$BD = \frac{120}{(3000-120)} \text{ ppm} \times 20{,}000 \text{ lb / hr} = 833.33 \text{ lb/hr.}$$

Amount of water saved = (1,276 lb/hr - 833.33 lb/hr)

$$= 442.67 \text{ lb/hr}$$

$$= 442.67 \frac{\text{lb}}{\text{hr}} \times 5{,}000 \frac{\text{hr}}{\text{yr}} \times \frac{1 \text{ lb}}{8.33 \text{ gal}}$$

$$= 265.71 \times 10^3 \text{ gal/yr.}$$

$$\text{Amount of energy saved} = \frac{\text{water saving from blowdown} \times (h_{\text{liq at 350 psig}} - h_{\text{liq at 60° F}})}{0.8}$$

$$= \frac{265.71 \times 10^3 \text{ gal / yr (409.8 BTU / lb - 28 BTU / lb)}}{0.8}$$

$$= 126.81 \times 10^6 \text{ BTU/yr.}$$

5. <u>Prepare a water management audit report.</u>

The last step is to prepare a report for the company's executives. This report contains details of the analysis result and action plan recommendations. The report should begin with a summary of the company's product, operation, and facility. The savings should be presented as total savings, and each water management opportunity should be highlighted. Each water management opportunity should be presented in a table showing total savings, cost, financial justification, savings on water charge, savings on energy charge, and savings on wastewater charge.

The executive summary should be followed by a calculation of the savings from each water management opportunity. The calculation should be presented in detail and in an easy to understand format. This part should include calculation of costs and benefits of each water management opportunity. An example of the table of contents of a water management audit report is shown in Figure 4.3.

In the report, a water management action plan should be suggested. The action plan should recommend which water management opportunities should be implemented first and how much the company needs to invest in that action. Recommendations normally suggest one or more water management opportunities which provide an immediate or very short payback period be implemented first.

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Appendix

FIGURE 4.3 TABLE OF CONTENTS OF A SAMPLE WATER MANAGEMENT AUDIT REPORT

Water Management Audit Checklist

In a water management audit, there are common areas that the auditors should consider in looking for water management opportunities. This checklist will help auditors to identify common water management opportunities easily. It is divided into section for process and domestic water, boiler water and cooling tower water. These areas consume significant amounts of water and typically offer significant potential savings. The abbreviated list for copying will be presented in the back of this checklist.

1. Water management checklist for process and domestic water.

Consider water reuse in both the business and plant areas. Reusing water can help save both water and energy since most process water contains some heat. The goal for water reuse is to minimize raw water consumption and effluent water discharge. Reuse of water can also help the company save water discharge costs. Water management ideas for process and domestic water include:

- <u>Reduce domestic hot water temperature.</u> Since domestic water does not have to be 140 or 150 ° F, it can be reduced to 90-100° F. Consider reducing process water temperatures to the minimum required. This will not save water but will save energy.
- <u>Install flow restrictors.</u> Flow restrictors might be installed in rinse areas, cooling areas, restrooms, etc. For example, flow restrictors should be installed at faucets and shower heads in restrooms to prevent loosing clean water. Flow restrictors should also be installed in rinse areas and cooling areas to prevent unnecessary water loss. A

study at a major university's dormitories shows that if shower heads are replaced with low flow type, $32,891 can be saved yearly (19).

- Recycle rinse water. Sometime rinse water (in a tank) can be reused in the tank before that tank (which is dirtier) or in another process. This reuse can save both water and/or energy for water heating.
- Reuse cooling water in rinse tanks or other processes if possible. Cooling water is almost as pure as raw water and also contains some heat, so it is a good idea to reuse it in rinse tanks or in other processes if possible. For example: water from a water cooled air compressor is clean and contains some heat, so it can be reused in heated rinse tank(s).
- Reduce water flowrate. The higher the water flowrate, the larger the amount of water loss. Rinse areas or cooling areas usually do not need high water flowrates, therefore the amount can often be reduced. Water flowrates for water cooled equipment and rinse tanks can be reduced to minimum specifications to conserve water. Care should be taken to ensure that efficiency and quality do not suffer.
- Reduce and recycle process water. Consider reusing or recycling process water. Sometimes water from one process can be reused in another process without treatment. Figure 4.3 on the next page shows an example of a water reuse system in a chemical process plant. Water is reused both with and without treatment. Frequently wash facilities reuse water through ultrafiltration of other treatment.

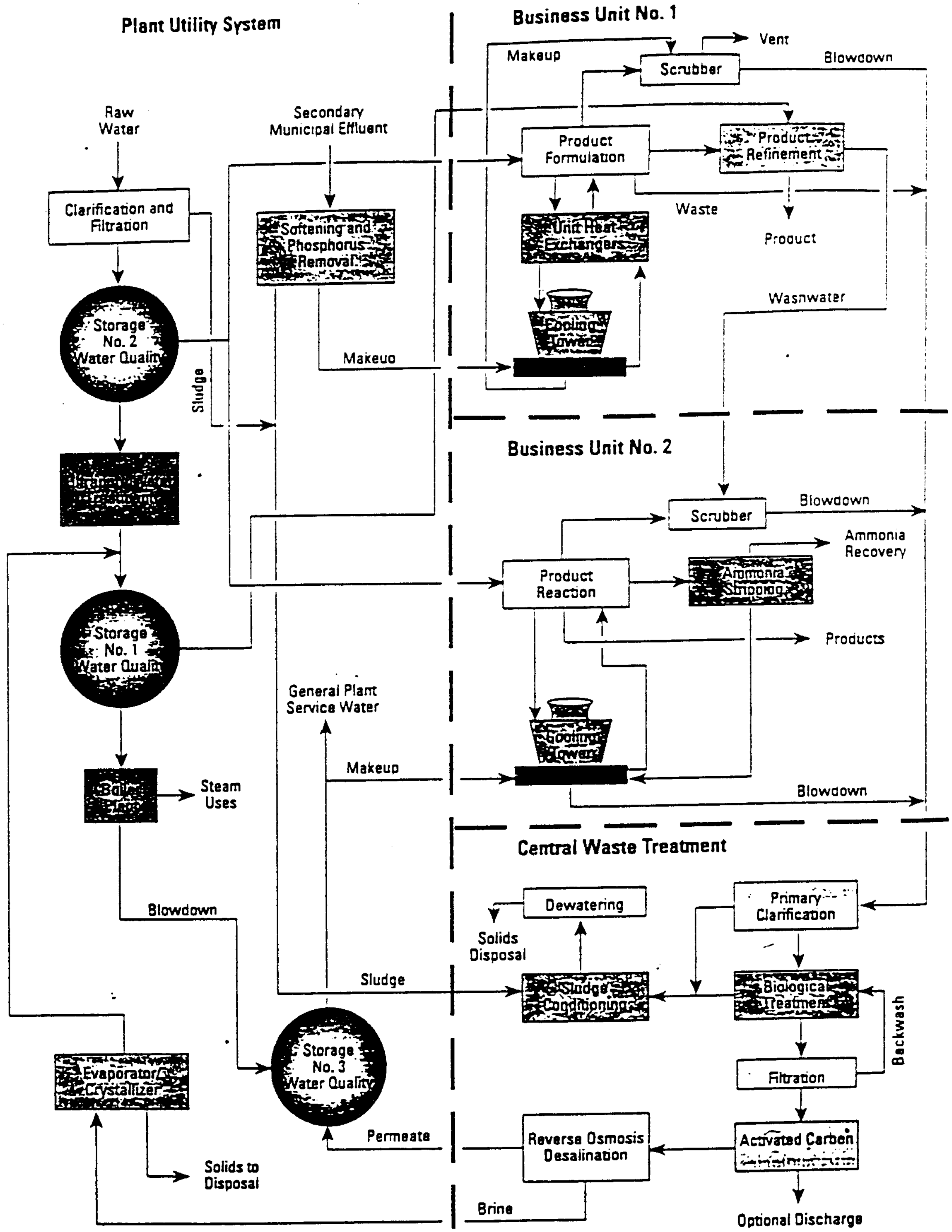


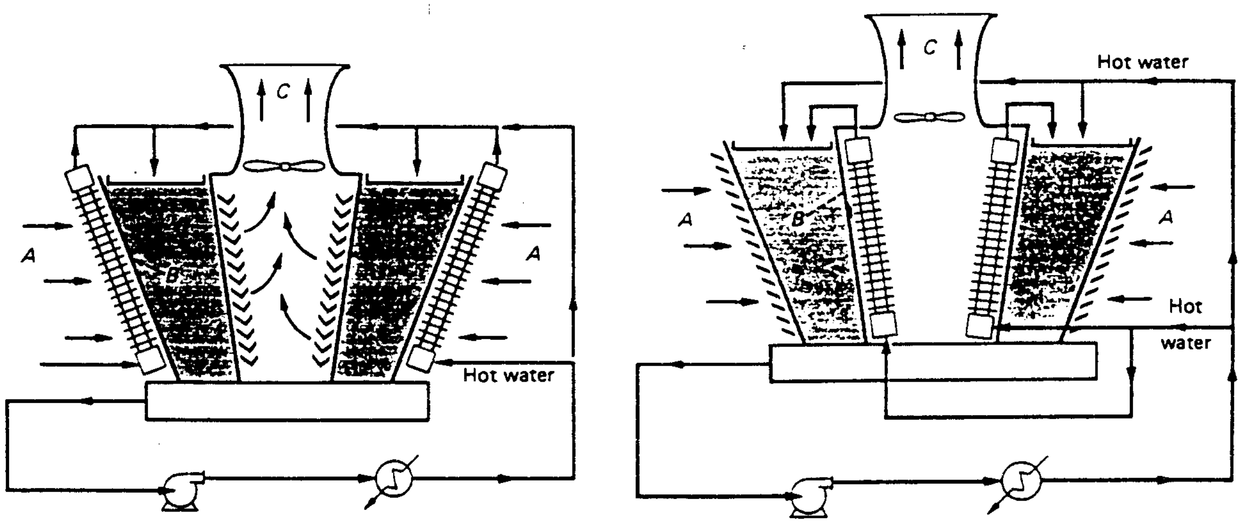
FIGURE 4.3 WATER REUSE SYSTEM IN CHEMICAL PROCESS PLANT [20]

2. Water management checklist for cooling towers.

Cooling towers normally consume a large amount of water and contribute a large amount of effluent water. Good management of cooling towers can conserve both water consumption and energy usage. Water management opportunities for cooling towers are:

- Minimize bleed. Bleed can be reduced to the minimum requirement control the amount of impurities in water in the tower. (see Table 4.1 for bleed requirement)
- Utilize bleed in other areas of the plant such as lawn watering or other process related activities. For example, one plant has a large cooling tower in the front yard for process cooling. The plant uses the cooling tower bleed to watering the lawn. Ensure that water treatment chemicals will not contaminate the grounds.
- Implement preventive maintenance on tower equipment such as baffles, fan, and basin. The maintenance program can be scheduled according to plant maintenance program. During the maintenance, baffles, fans and basins need to be checked, cleaned, and repaired if needed.
- Operate the cooling tower only when necessary. During off-peak hours, cooling towers can be turned off and restarted if the temperature does not meet the requirement. Also, cooling towers may need not to be operated during a plant maintenance period.
- Utilize heat in other plant processes such as rinse tanks before going to cooling tower. High temperature water may be fed to heat exchangers to recover heat before going to a cooling tower. This dramatically reduces the cooling tower evaporation rate.

- <u>Combine air-fin or dry cooling with evaporative cooling.</u> Using dry cooling can save both water loss and energy. If air-fin cooling is used instead of cooling towers, the facility water requirement will be reduced by 115 gallons per million BTU heat rejected (for a typical cooling tower with six cycles of concentration) (21). However, air-fin cooling may be combined with a cooling tower in order to reduce the temperature range of the cooling tower and minimize water loss from evaporation. If half of the total load is handled by air-fin coolers, the tower's evaporation rate, blowdown rate, and makeup water requirements are roughly reduced by half (21). Figure 4.4 shows a combination of wet and dry cooling with the dry section preceding wet section and the wet section preceding dry section.



a) Dry section precedes wet b) Wet section precedes dry

FIGURE 4.4 WET AND DRY COMBINATION COOLING TOWER [21]

3. **Water management checklist for boilers.**

A boiler, if properly managed, can save a significant amount of water and energy. Water management opportunities in boiler include:

- Minimize water blowdown. Too much blowdown can cause water and heat loss. Required blowdown can be determined by (18)

$$\%BD_{req} = \frac{A}{B_{req} - A} \times 100\%$$

Allowable drum solids level (B) recommended by American Boiler Manufacturers Association (ABMA) is presented in Table 4.4 in the previous part. By increasing B, blowdown can be reduced which leads to significant savings of money, water, and energy. For an example see example 4.2.

- Insulate boiler and components to reduce heat loss. Significant amounts of heat can be lost if boiler and components are not properly insulated.
- Operate boiler only when needed. Boilers can frequently be shut down or idled during plant maintenance or other non-production times.
- Repair leaks and/or install steam traps to recover hot water and steam. Hot water and steam are valuable product; repairing leaks and steam traps can help recover the loss.
- Return as much condensate to feed water tanks as possible. If condensate can be returned to the boiler for reevaporation into steam, considerable costs can be saved in fuel and water treatment (for raw water). Condensate is much like pure distilled water and does not require the chemical treatment which is necessary for making raw water suitable for boiler makeup. The returned condensate also contains heat which reduced

the need to added heat to make steam. As condensate return is increased, the following benefits will occur.

- The amount of blowdown can be reduced.
- The raw water makeup and treatment costs are reduced.
- The steam required for feedwater deaeration is reduced.
- The cost for raw water and boiler water chemicals are reduced.

- Implement preventive maintenance program. A good maintenance program can increase efficiency of boilers and reduce water and energy losses.
- Lower temperature and pressure of steam when possible. The higher the temperature and pressure, the greater the energy consumed and lost. Steam pressure is varied in some direct function of plant steam load. By adjusting the steam load requirement, the average boiler efficiency can be increased. Reducing steam pressure may result in a lower power requirement for pumping feedwater and lower heat loss (as a result less moisture will be carried in the steam line and makeup water requirement can be reduced). Often after certain hours, steam pressure can be reduced.

TABLE 4.5 ABBREVIATED WATER MANAGEMENT CHECKLIST

Abbreviated Water Management Checklist

Process and domestic water

- Reduce domestic and process water temperature.
- Install flow restrictors.
- Recycle rinse water.
- Reuse cooling water in rinse tanks or other processes if possible.
- Reduce water flowrate to minimum requirement.
- Reduce and recycle process water.

Cooling tower

- Minimize bleed.
- Utilize bleed in other areas of plant such as lawn watering.
- Implement maintenance program.
- Operate the cooling tower only when necessary.
- Utilize heat in other plant process.
- Combine air-fin or dry cooling with evaporative cooling.

Boiler

- Minimize water blowdown.
- Insulate boiler and components to reduce heat loss.
- Operate boiler only when necessary.
- Repair leaks and/or install steam traps.
- Return as much as condensate as possible.
- Implement maintenance program.
- Lower temperature and pressure of steam when possible.

CHAPTER 5

VALIDATION OF AUDIT PROCEDURE AND CASE STUDY

The Need and Method of Validation

Validation is "concerned with the soundness, the effectiveness of the measuring instrument."(22) The objective of this validation is to show that the proposed water management audit procedure can deliver water management opportunities effectively and find improvement for the procedure.

The validation is divided into two phases: using the procedure and analyzing the validity of the procedure. In the first phase, the procedure was used in a water management audit by following each step of the procedure. The results of each step of the procedure will be presented through a case study on a real audit.

The other phase of the validation is the discussion of the validity of the procedure and improvements in the procedure. This part is presented after the case study and discusses improvements identified during the use of the procedure in the audit.

Validation Results and Case Study

The validation of the procedure was done by using the procedure at a company in Stillwater. The procedure was followed step by step to be certain that the procedure includes all the necessary steps for a water management audit. The results of the validation is presented as a case study with examples of each step of the procedure.

1. Contact company for auditing

The validation is done on a press company. The company uses about 11,000 gallons of water each year, and the company has interest in water management. The company produces color magazines and flyers with 200 employees working three shifts. The production is over 457 million magazines, flyers, and inserts each year. This company is divided into a plant (300,000 ft^2) and an office area (30,000 ft^2). The plant area operates 8,400 hours per year, and the office area operates 2,600 hours per year. The plant area consists of a paper storage warehouse, baler room, printing press room, maintenance department and break room, assembly/inserter machines and trimming area, bindery, and storage area (see Figure 5.2). The major pieces of water consuming equipment are three cooling towers. Examples of water bills, plant layout, and equipment in the plant are presented in Figures 5.1, 5.2 and 5.3, respectively.

```
WATER CHARGES
-------------
Current reading:                          1436770
Prior reading:                            1430390
                                        ----------
Constant of:        100   X usage of       6380   = in gallons:     638,000

First 15,000   @   $2.25
Next 285,000   @   $1.85
Remainder      @   $1.65/1000 gallons =                            $1,118.70
                1 water meter(s) @        $3.00 per meter =          $3.00
                                                               ------------
                                                                 $1,121.70
                                                               ============

SEWER CHARGES
-------------
                          638,000 gallons @ .696/1000 gal          $444.05

                1 water meter(s) @        $3.00 per meter =          $3.00
                                                               ------------
                                                                   $447.05
                                                               ============
```

FIGURE 5.1 AN EXAMPLE OF WATER BILLS

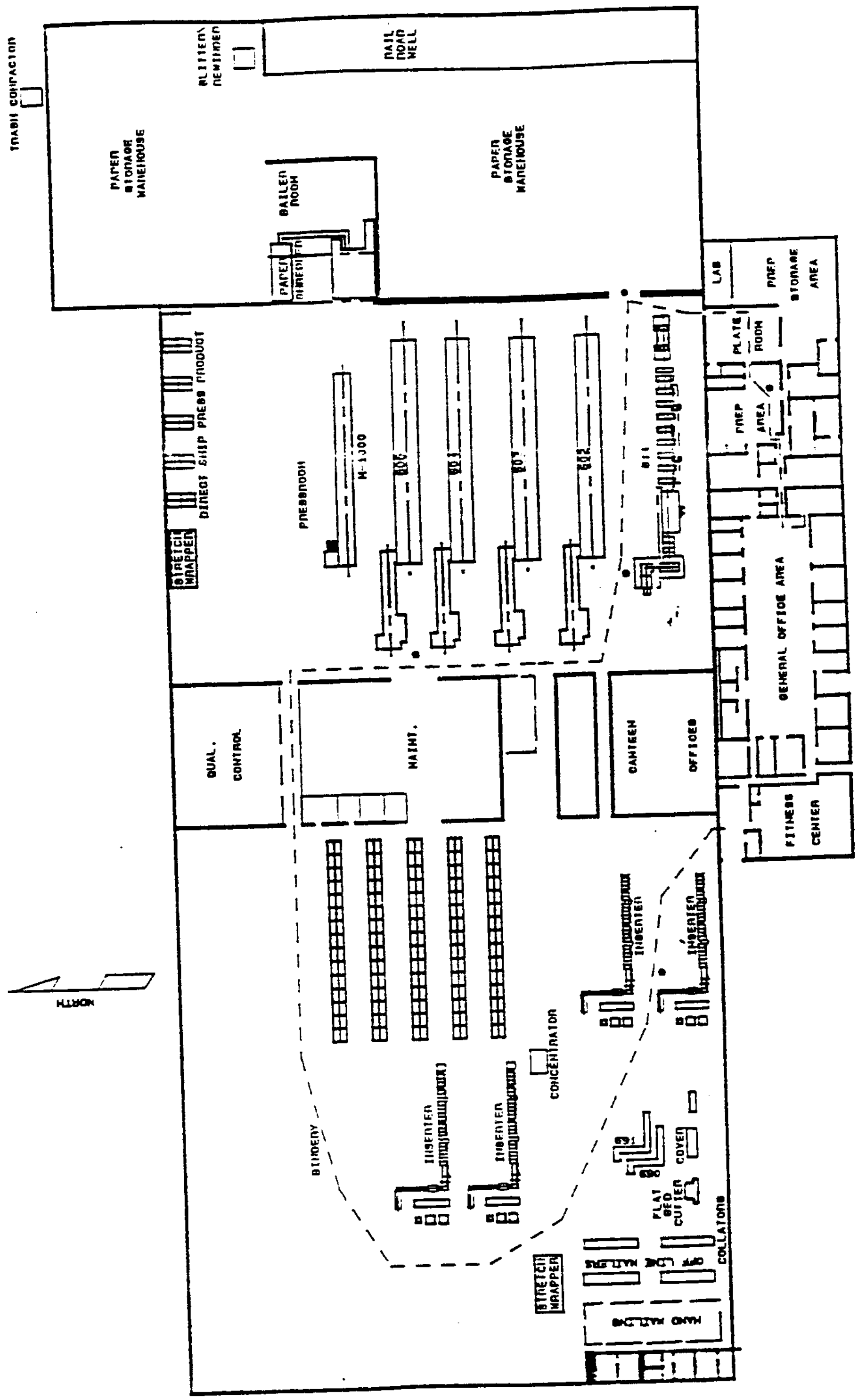


FIGURE 5.2 PLANT LAYOUT OF THE COMPANY

Electricity

Quantity	Description
5	1200 HP Main Printing Press Drives
1	500 Ton Chiller
1	350 Ton Chiller
2	300 Ton Chillers (on stand-by)
1	200 HP Air Compressor
	150 HP Air Compressor
8	27 kW Electric Resistance Heaters (for shrink-wrapping)
2	40 HP Motors for Trim Waste Collection System

The plant is illuminated by Metal Halide lamps and fluorescent task lights. There are numerous energy-efficient motors scattered throughout the plant.

Natural Gas

Quantity	Description
2	Natural Gas Fired boilers
10	Natural Gas-Fired Dryers (2 per Printing Press)

Waters

Quantity	Description
3	Cooling towers
7	Shower heads
1	Reverse osmosis system

FIGURE 5.3 LIST OF EQUIPMENT IN THE PLANT

2. Analyze data before an audit

After receiving the information and water bills, the data was analyzed. The total water consumption of the plant for the twelve-month period is 11,613 Mgal costing $28,108. The major water consumers are three cooling towers. The water rate for the company is:

First 15,000 gallons	$2.25/Mgal
Next 285,000 gallons	$1.85/Mgal
Remainder	$1.65/Mgal

1 Mgal = 1,000 gallons

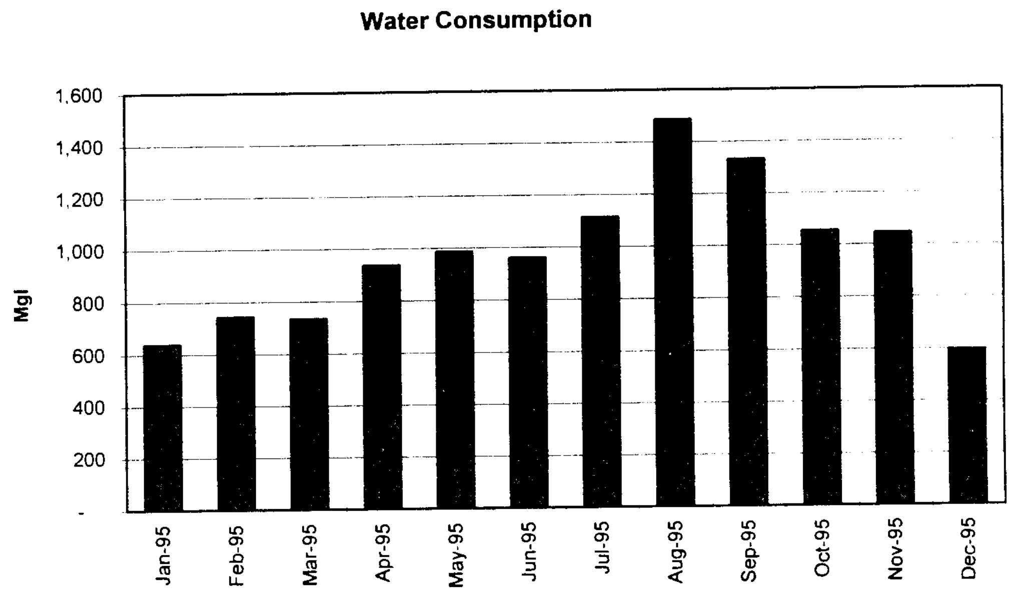
The data on water consumption and cost was analyzed and presented in the form of a table and charts. Table 5.1 and Figure 5.4 show the summary of water usage and cost.

TABLE 5.1 WATER USAGE SUMMARY

WATER CONSUMPTION AND COST
January 1995 - December 1995

Period	Consumption (Mgal)	Cost ($)
Jan	638	1,569
Feb	742	1,812
Mar	733	1,791
Apr	935	2,266
May	984	2,381
Jun	960	2,324
Jul	1,113	2,683
Aug	1,484	3,554
Sep	1,331	3,194
Oct	1,053	2,542
Nov	1,044	2,522
Dec	596	1,470
	11,613	28,108

1 Mgal = 1,000 gal



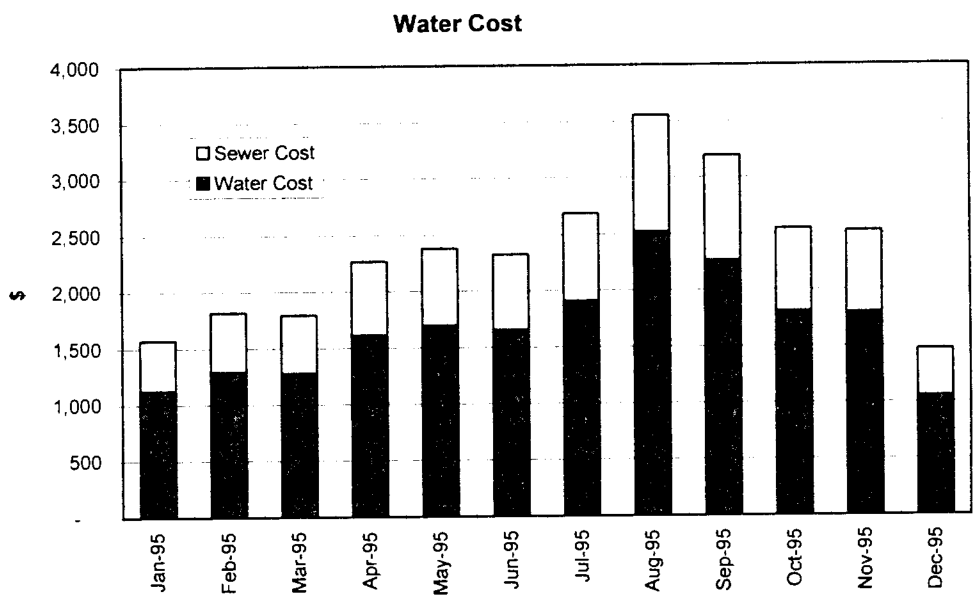


FIGURE 5.4 WATER CONSUMPTION AND WATER COST CHARTS

3. **Conduct water management audit visit**

The plant visit was scheduled after the water bills and other information had been analyzed. The visit started by a meeting with the plant's director of engineering to get information about water usage and equipment. There were three cooling towers at the plant. The first two cooling towers were connected together and the third one stood alone (see Figure 5.5). These cooling towers were connected to chillers.

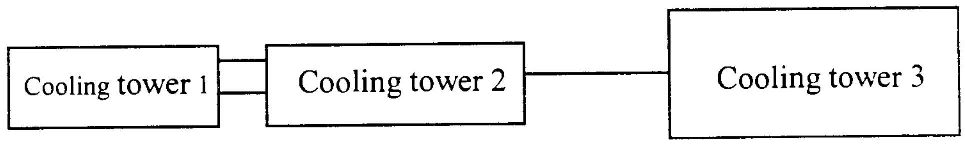


FIGURE 5.5 COOLING TOWERS SETUP AT THE PLANT

During the audit, three water management opportunities (WMOs) were identified. These WMOs are:

- Recover sewer charges related to loss of evaporated water
- Replace existing shower heads with low-flow shower heads, and
- Install air-fin cooling before cooling tower.

4. **Perform analysis and determine savings**

After a plant visit, some data on low-flow shower heads and air-fin cooling were needed. The calculation of potential savings from water management opportunities was done after the missing information was acquired. Appendix C shows a calculation of each WMO. The analysis showed 6,189 gallons of water, 104 MMBtu of energy, and

$20,652 per year could be saved if the water management program was accomplished. Table 5.2 shows a summary of water management opportunities.

TABLE 5.2 SUMMARY OF WATER MANAGEMENT OPPORTUNITIES

WMO No.	DESCRIPTION	SOURCE	ANNUAL SAVINGS				INSTALLED COST	PAYBACK PERIOD
			ENERGY		WATER			
			(MMBtu/yr)	($/yr)	(Mgal/yr)	($/yr)	($)	(yr)
1	Recover sewer charges loss on evaporated water at cooling tower	Water	-	-	0	5,808	0	0.00
2	Replace existing shower heads with low-flow shower heads	Water	104	325	333	781	69	0.06
3	Install air-fin cooling before cooling tower	Water	-	-	5,856	13,738	100,000	7.28
	TOTAL		104	$ 325	6,189	$20,327	100,069	
	Conservation Potential(%)		0.1%	0.0%	53.3%	72.3%		

TOTAL CONSERVATION POTENTIAL: $20,652

5. Prepare a water management audit report

After all the analyses and calculations were finished, a water management report was prepared. The report consisted of :

- Executive summary,
- Summary of water management survey data,
- Summary of water management recommendations,
- Plant background,
- Utility rates,
- Resource management,
- Historical water consumption and cost, and
- Water management opportunities (WMO's).

A water management audit report for this case study is presented in Appendix C.

Discussion and Improvements

Discussion of the Results

The results of the audit show that the company would consume much less water if water management opportunity # 3 is implemented. The major water savings would occur in the cooling towers. Cooling tower water consumption before and after installing air-fin cooling is shown below.

Total cooling tower water consumption before installing air-fin cooling = 7,628 Mgal/yr

Total cooling tower water consumption after installing air-fin cooling = 1,772 Mgal/yr

Because of the large savings at the cooling towers, the calculation needed to be checked. The result from examining the calculation shows that these large savings occur because of process load during many hours when the air temperature alone can do the necessary cooling (see WMO # 3 in Appendix C). However, an effectiveness multiplier might be more realistic. For example, 70% effectiveness of water savings might be used in this case. Thus, water savings will be 70% of 5,856 Mgal/yr, which is 4,100 Mgal/yr.

Opportunity for Improvements

Because of the large savings of cooling towers water consumption, the calculation needed to be re-examined. The total water consumption at the cooling towers before and after installing air-fin cooling were recalculated to check their accuracy. And the conclusion was drawn to explain the savings.

The validation of the water management audit procedure shows that there are opportunities for improvement to be added to step 4 of the procedure (perform analysis and determine savings). In this step, water consumption of the company before and after the water management program will be compared. All the calculations and savings also need to be checked at this step. If the savings seem to be unrealistic, recalculation might be needed. After all the comparison and checking is finished, a water management audit report will be prepared.

Sometimes, the audit team may need to conduct a second trip to the plant to confirm readings when the numbers seem suspicious. For example, if the numbers of energy or water taken into equipment is less than the energy or water discharged from the equipment, the team might need to go back and check the readings.

The team may need to contact the utility company to get an actual copy of rate schedules. Utilities have different billing schedules. Thus, they could not actually tell the team how much their water cost. If the team could get the actual rate used at the company, the analysis might be more accurate.

After an audit, the team may need to contact manufacturers of the equipment that is being audited and equipment being considered for purchase for data as early as possible to avoid delay in the analysis. Sometimes this data takes longer to gather than expected. Contacting the manufacturers earlier will help the team finish an analysis on time.

For some products such as shower heads (see WMO # 3 in the case study), the team should contact more than one manufacturer to compare their products, so that they can suggest the most suitable product for the company. The comparison of products may include cost, properties of the product, reliability, and product operation.

CHAPTER 6

CONCLUSION

Summary

Water management audit is a cost reduction and profit improvement process involving an eliminating, combining, changing sequence, and modifying of water consumption. The goal of water management audits is to identify and evaluate better water management ideas which will be used in an ongoing water management program.

The water management audit procedure and checklists in this research will help auditors to perform a successful audit with fewer problems. The checklists will also help auditors to identify common water management opportunities easily.

The results of this research include a water management audit procedure and checklists for water management ideas. The water management audit procedure is divided into two parts: data and equipment needed for water management audit and the water management audit procedure itself.

Data needed for the water management audit consists of: data needed before an audit, data needed during an audit, and data needed after an audit. Equipment needed for the water management audit is divided by their priority of need as first, second and last priority. The water management audit procedure includes a five steps procedure.

1. Contact company for auditing.
2. Analyze data before an audit.
3. Conduct water management audit visit.

4. Perform analysis and determine savings.

5. Prepare a water management audit report.

The water management audit procedure was validated by a case study. The case study shows results from a water management audit at a press company. The study shows that, if the water management program is accomplished, the company can save 6,189 gallons of water or $20,327 per year.

After the validation, improvements for the procedure have been suggested in Chapter 5. These improvements include:

- compare water consumption of the company before and after the water management program,
- conduct a second visit to confirm readings,
- contact the utility company to get an actual copy of rate schedules,
- contact manufacturers as soon as possible after a plant visit, and
- contact more than one manufacture to get some products' information.

Further Research

The water management audit procedure developed in this research can help in developing a good water management program. For more effective water management, the following research should be done.

1. Development of more water management ideas and details on water consuming equipment (i.e. boilers, cooling towers, rinse tank) and process water including methods and calculations.

2. Study of using control system(s) and computer program(s) to monitor water management programs. The study may includes their efficiencies, types of control systems, and control processes.
3. Study of equipment used for water management and water treatment program such as reverse osmosis systems, water treatment processes, air-fin cooling, steam traps, etc. The efficiency and usage of this equipment in industry should also be studied.
4. Study on maximization of water reuse and recycling in the plant with an economic analysis. The study may include technologies for water recycling and water treatment.
5. Study on minimization of water loss at boilers and at cooling towers with an economic analysis. Water loss at boilers and at cooling towers should be identified. Suggestion for loss minimization methods should be studied.

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APPENDIX A

TECHNICAL SUMMARY OF WATER MANAGEMENT TECHNOLOGIES

APPENDIX A-1

REVERSE OSMOSIS

Reverse osmosis is the process of forcing water through a semipermeable membrane against the natural osmotic gradient (31). When water is forced through the membrane, a large percentage of the dissolved salts and other material in the water are removed from the water with the permeate being relatively pure water. Currently, there are membranes available that can be used to treat a wide range of water quality types.

Figure A-1.1 shows osmosis and reverse osmosis flow. Typical reverse osmosis consists a pump and a membrane as in the figure.

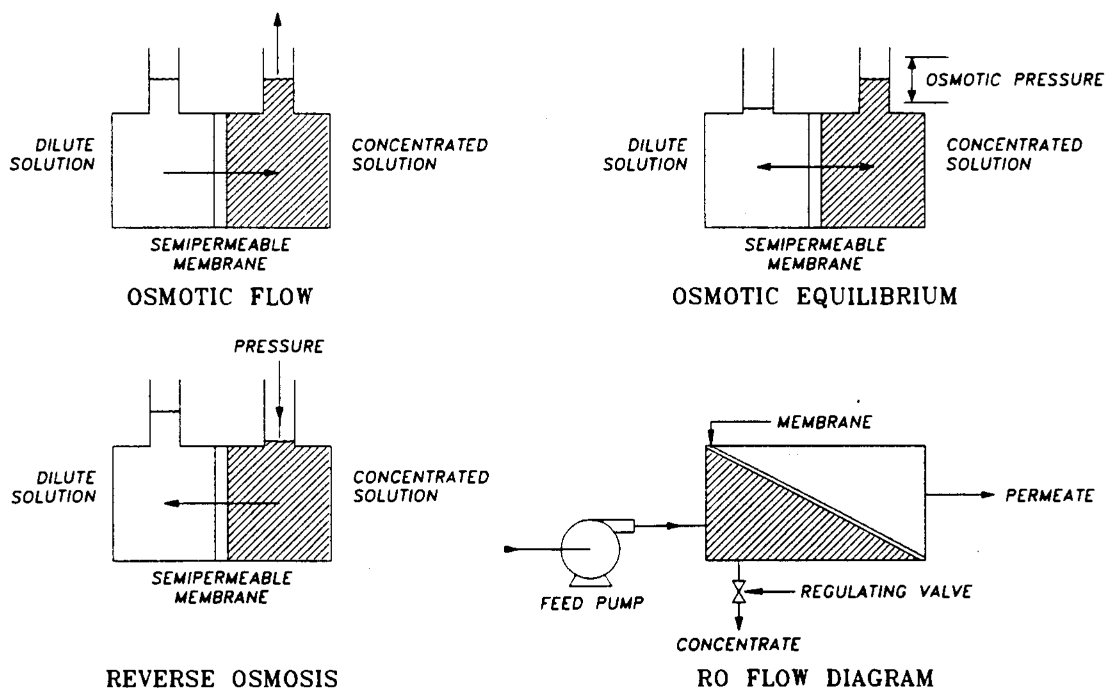


FIGURE A-1.1 OSMOSIS AND REVERSE OSMOSIS [31]

There are many ways to packed membrane for reverse osmosis treatment. The spiral-wound membrane (Figure A-1.2) is believed to allow rapid formulation and testing without a large capital investment in specialized equipment. The hollow figure configuration is shown in Figure A-1.3.

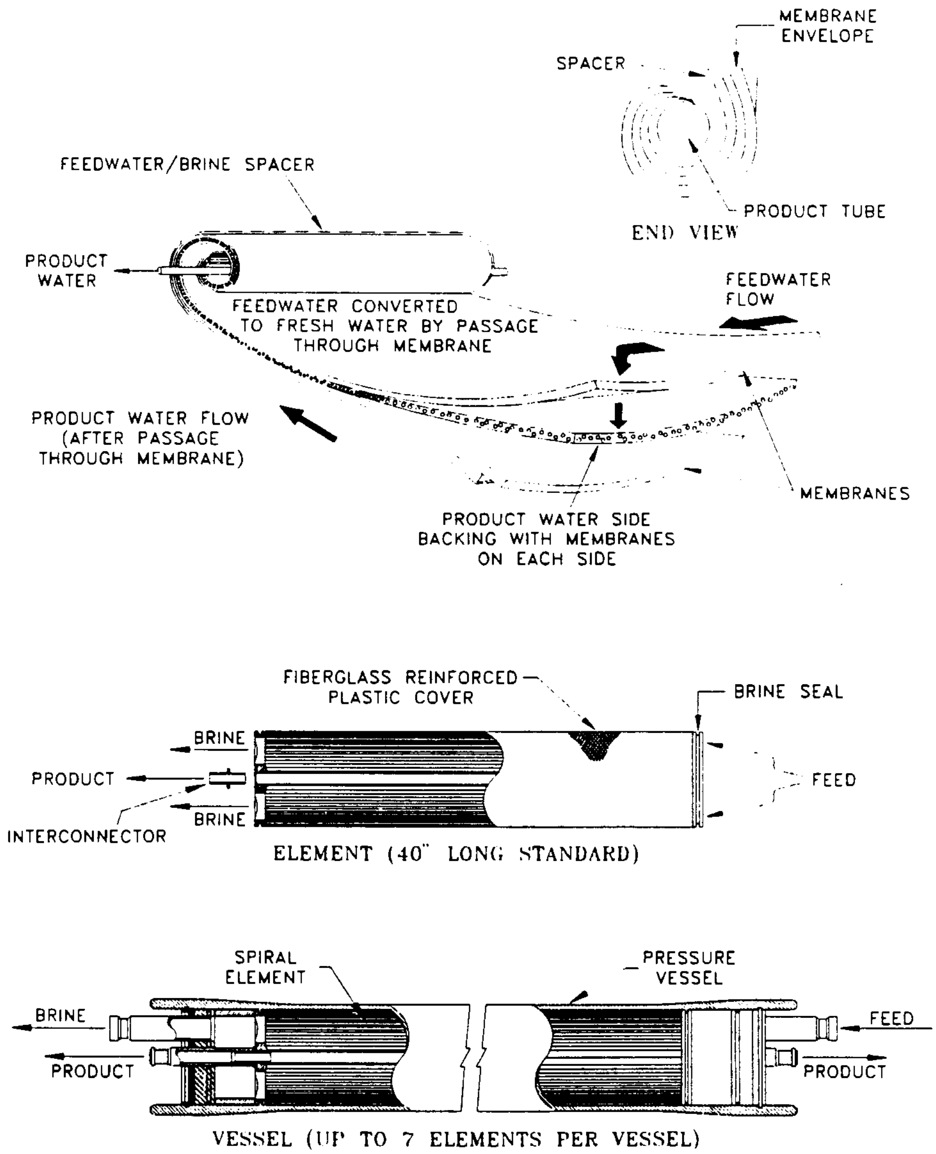


FIGURE A-1.2 SPIRAL WOUND MEMBRANE AND PRESSURE VESSEL [31]

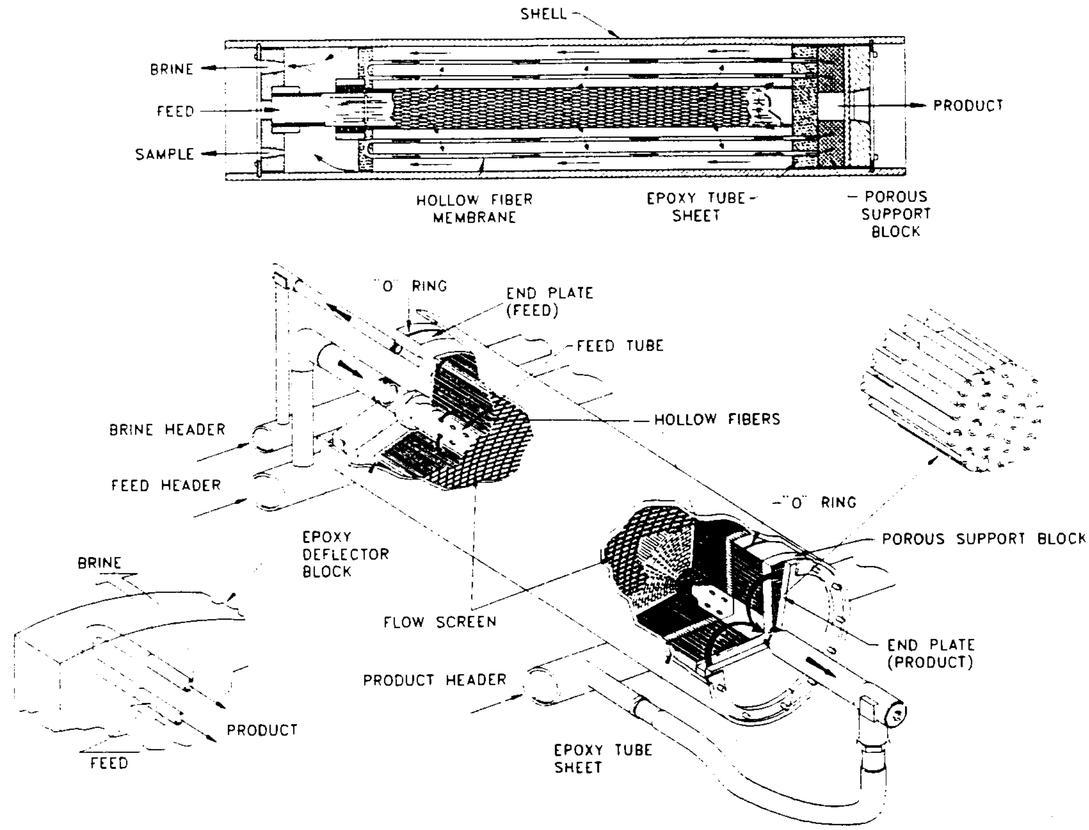


FIGURE A-1.3 HOLLOW FIBER ARRANGEMENT [31]

Tubular (Figure A-1.4) and plate and frame(Figure A-1.4) packages are used primarily in specialized commercial application, such as concentration of liquid, clarification of juices etc.

Reverse osmosis treatment is an effective method for removing large organic molecules. Four general applications of membrane treatment are:

1. The removal of highly colored surface water or groundwater.
2. Special water treatment project such as domestic wastewater recycling and various industrial.
3. Desalination of brackish water or seawater.
4. Desalination of various waters in the desert or interior location.

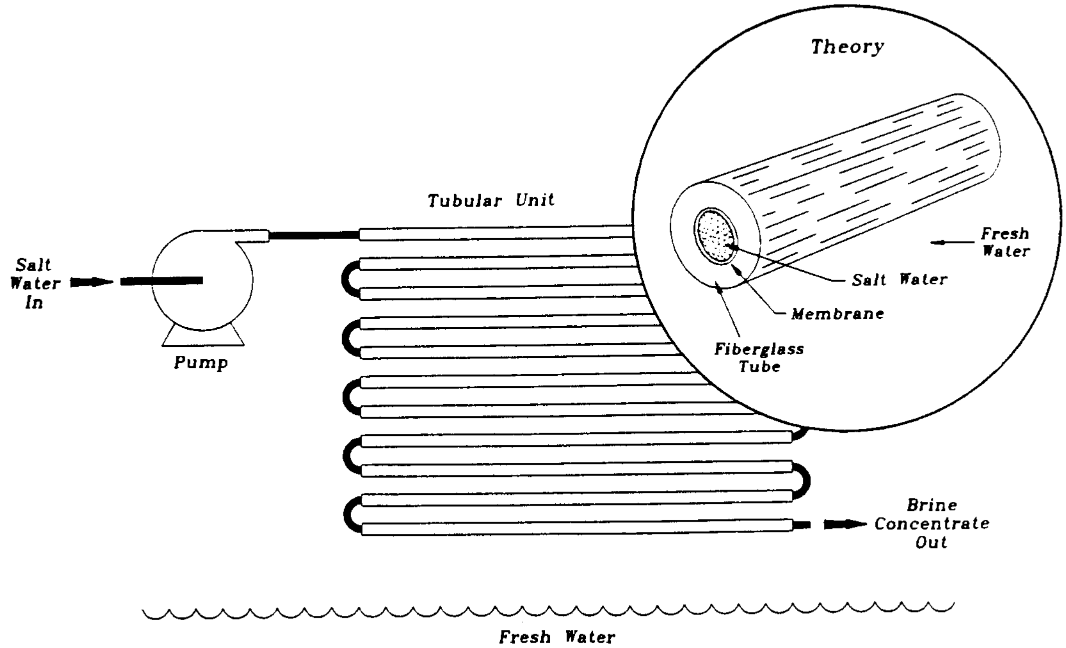
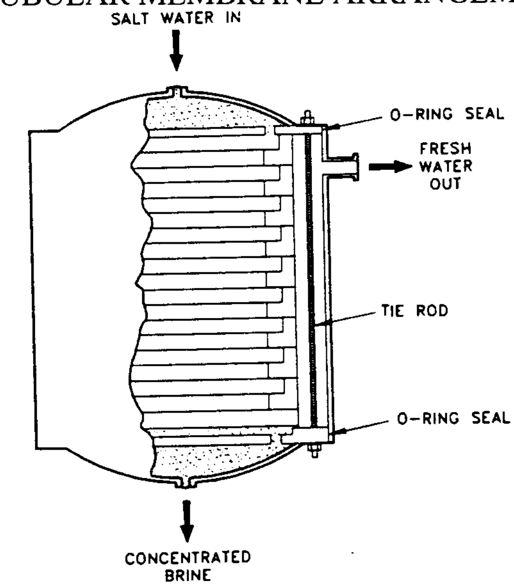


FIGURE A-1.4 TUBULAR MEMBRANE ARRANGEMENT [31]



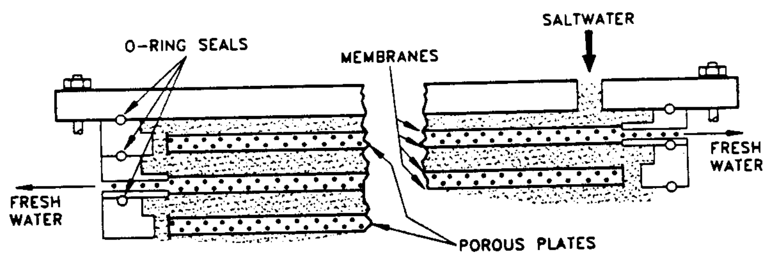


FIGURE A-1.5 TYPICAL PLATE AND FRAME REVERSE OSMOSIS

ARRANGEMENT [31]

APPENDIX A-2

ULTRAFILTRATION

Membrane filtration is defined as the separation of dissolved solutes in liquid streams and for separation of gas mixtures (33). The primary role of membrane is to act as a selective barrier that permits passage of certain components and retains certain other components of a mixture. Ultrafiltration process is a method for simultaneously purifying, concentrating, and fractionating macromolecules or fine colloidal suspensions. In ultrafiltration process, the pressure gradient across the membrane would force solvent and smaller species through the pores of the membrane, while the larger molecules would be retained.

The differences of membrane processes-microfiltration, ultrafiltration, and reverse osmosis- is the size of components separated. In the ideal definition, reverse osmosis retained all components other than the solvent, while ultrafiltration retains only macromolecules or particles larger than about 0.001-0.02 μm. Microfiltration process are designed to retain particles in the micron range which are suspended particles larger than 0.10 μm to about 10 μm. Figure A-2.3 shows a range of different separation processes.

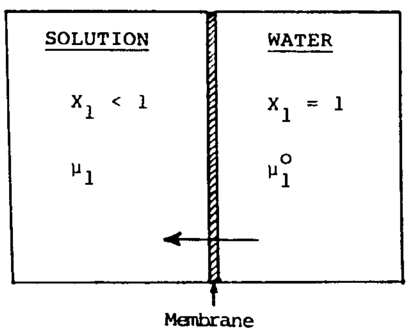


FIGURE A-2.1 THE OSMOSIS PHENOMENON [33]

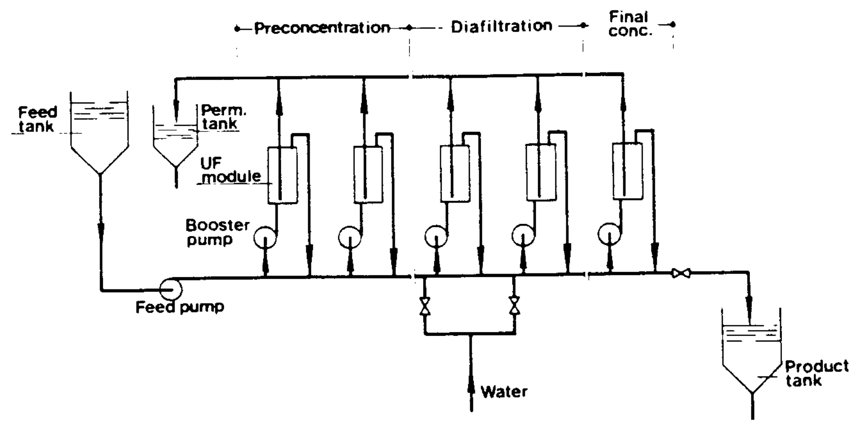


FIGURE A-2.2 CONTINUOUS ULTRAFILTRATION PLANT [34]

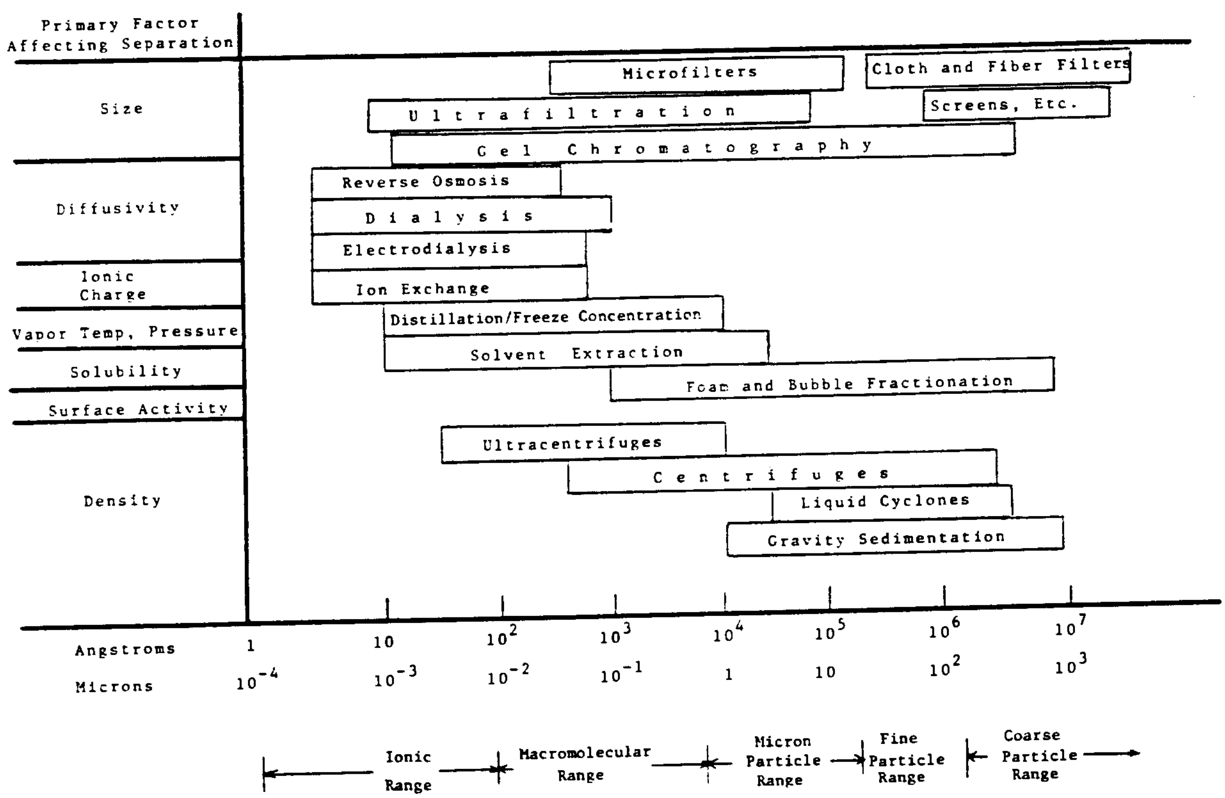


FIGURE A-2.3 USEFUL RANGE OF SEPARATION PROCESSES [33]

APPENDIX A-3

WATER TREATMENT PROCESSES

The type of water treatment process for each plant is determined by the quality of water and the types of impurities in that water. The suggestion for choosing water treatment process is shown in Table A-3.1 and Table A-3.2. Water treatment processes presented in this appendix will include chemical treatment, electrodialysis and deionization.

TABLE A-3.1 SUMMARY OF SUGGESTED TREATMENT METHODS [11]

Ionic Impurities

Impurities	Methods
Cations	
1. Calcium and magnesium	a. Cold, warm, or hot lime-soda process precipitation, settling and filtration
	b. Ion exchange
2. Sodium, potassium and ammonium	a. Hydrogen cation exchange, if bicarbonate present exceeds total hardness
	b. Demineralization
3. Iron and manganese	a. Oxidation (aeration) and precipitation, settling (if high amounts present), and filtration (chlorine and alkali may be needed)
	b. Filtration through manganese zeolite
	c. Ion exchange
Anions	
4. Alkalinity	a. Lime process as in 1a, but without soda ash
	b. Hydrogen cation exchange
	c. Chloride anion exchange salt-splitting (dealkalization)
5. Sulfate, chloride, nitrate and phosphate	a. Demineralization
6. Silica	a. Absorption by ferric hydroxide precipitated by adding ferric sulfate: settling and filtration follow
	b. Absorption by magnesium hydroxide, formed when lime or dolomitic lime is added: settling and filtration follow: adding activated magnesia with lime in warm or hot process is helpful.
	c. Hydroxide anion exchange salt splitting (desilicization)
	d. Demineralization

Nonionic Impurities

Impurities	Methods
1. Turbidity and suspended matter	a. Filtration alone for small amounts of turbidity, adding coagulant directly ahead of filters if clearer effluent desired
	b. Coagulation, settling and filtration for larger amounts of turbidity: prechlorination usually beneficial; alkali addition, if needed for optimal pH value; coagulant aid often improves the floc
2. Color	a. Same as 1b, but addition of clay or other weighting agents, to densify floc: if water has low amounts of suspended matter
3. Organic matter	a. Same as 1b b. Addition of oxidizing agents, such as chlorine or permanganate c. Absorption by powdered or granular activated carbon d. Absorption by anion exchangers
4. Colloidal silica	a. Same as 1b b. Recirculation of boiler blowoff through demineralizer

TABLE A-3.2 SUMMARY OF SUGGESTED TREATMENT METHODS [11]

(CONTINUED)

Nonionic Impurities

Impurities	Methods
5. Plankton and bacteria	a. Same as 1b b. Superchlorination
6. Oil	a. Same as 1b b. Addition of preformed alum floc and filtration
7. Corrosion products in condensate	a. Filtration with cellulose filter and b. Cation exchanger c. Ammoniated cation exchanger for heater drains. d. Combined filtration and ion exchange with mixed bed demineralizer

Gaseous Impurities

Impurities	Methods
1. Carbon dioxide	a. Aeration: open aerator b. Aeration: degasifier (decarbonator) or forced-draft aerator c. Vacuum deaerator d. Heater deaerator for boiler feed
2. Hydrogen sulfide	a. Aeration as in 1a or 1b b. Chlorination c. Aeration plus chlorination
3. Ammonia	a. Hydrogen cation exchange, if the ammonia is present as ionic NH_4^+
4. Methane	a. Aeration as in 1a or 1b
5. Oxygen	a. Vacuum deaerator b. Heater deaerator for boiler feed c. Addition of sodium sulfite or hydrazine d. Anion exchanger regenerated with sodium sulfite, hydrosulfite, and hydroxide
6. Excess residual chlorine	a. Dechlorination by addition of reducing agents such as sodium sulfite, hydrazine or sulfurous acid b. Absorption by powdered or granular activated carbon c. Filtration through granular calcium sulfite

Courtesy of Drew Industrial Division, Ashland Chemical, Inc. Subsidiary of Ashland Oil, Inc.

CHEMICAL TREATMENT

In chemical process treatment, clarification is needed for removing suspended impurities. The common used clarification processes are coagulation, flocculation, and sedimentation. Each process is defined by Garay and Cohn (11) as the following.

"Coagulation is the process of destabilization by charge neutralization. Once neutralized, particles no longer repel each other and are brought together.

Flocculation is the process of bringing together destabilized or "coagulated" particles to form a larger agglomeration or floc.

Sedimentation, or settling, is the physical removal from suspension that occurs once the particles have been coagulated and flocculated. Sedimentation (subsidence) alone, without prior coagulation, can only remove relatively coarse suspended solids."

The clarification process begins with coagulation and follows by flocculation. The coagulation occurs by adding coagulant aids. Most of coagulants are acid salts that can lower the pH of treated water. The typical clarification process is shown in Figure A-3.1.

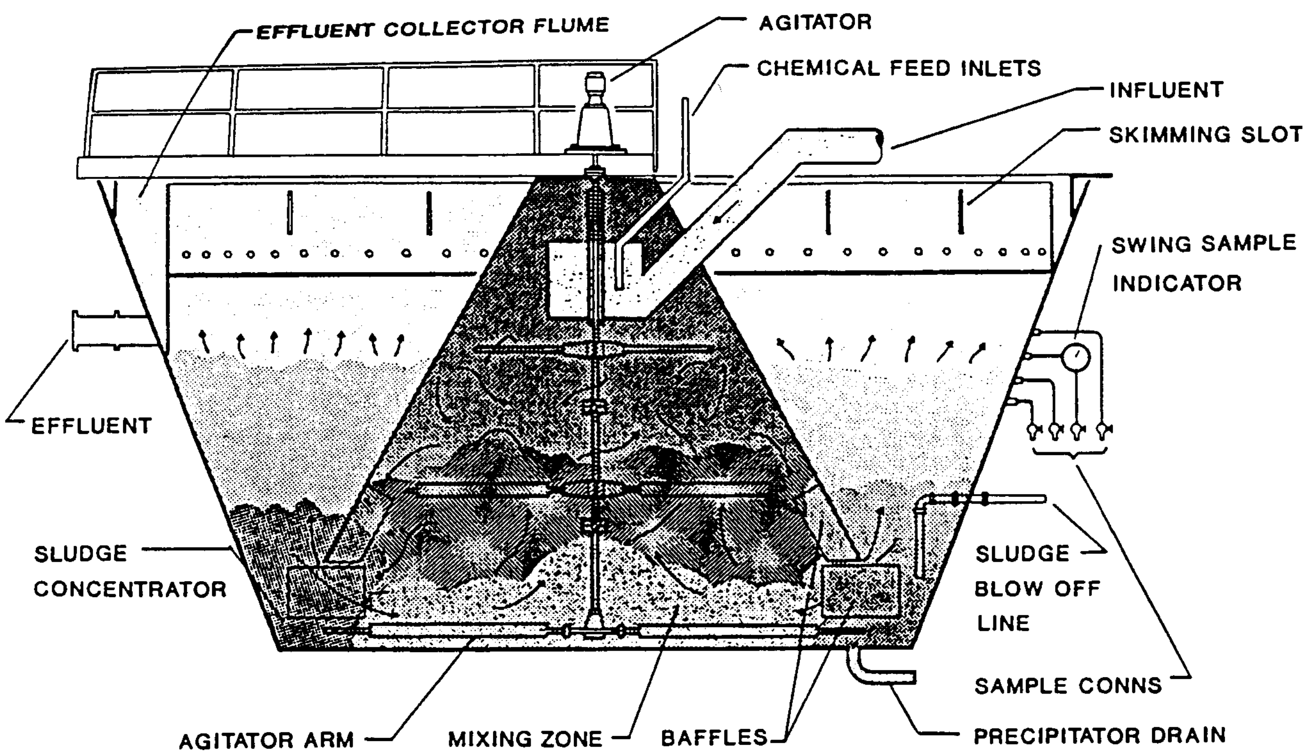


FIGURE A-3.1 UPFLOW SLUDGE BLANKET CLARIFIER [11]

ELECTORDIALYSIS

"Electrodialysis is an ion transfer process using ion selective membrane and small quantities of electrical energy to remove or concentrate dissolved salts in water." (11) Electrodialysis can be used to remove salts to specific value in stead of total removal. Energy requirements for the process are in direct relation to the quantity of salts removed. Electrodialysis unit consists of one or more pair of electrodes and several hundred cell pairs of membranes and water flow spacers. Each cell pair consists of four elements which are cation selective membrane, ion depleting cell, anion selective membrane and ion concentrating cell. Figure A-3.2 shows a cell pair of electrodialysis unit.

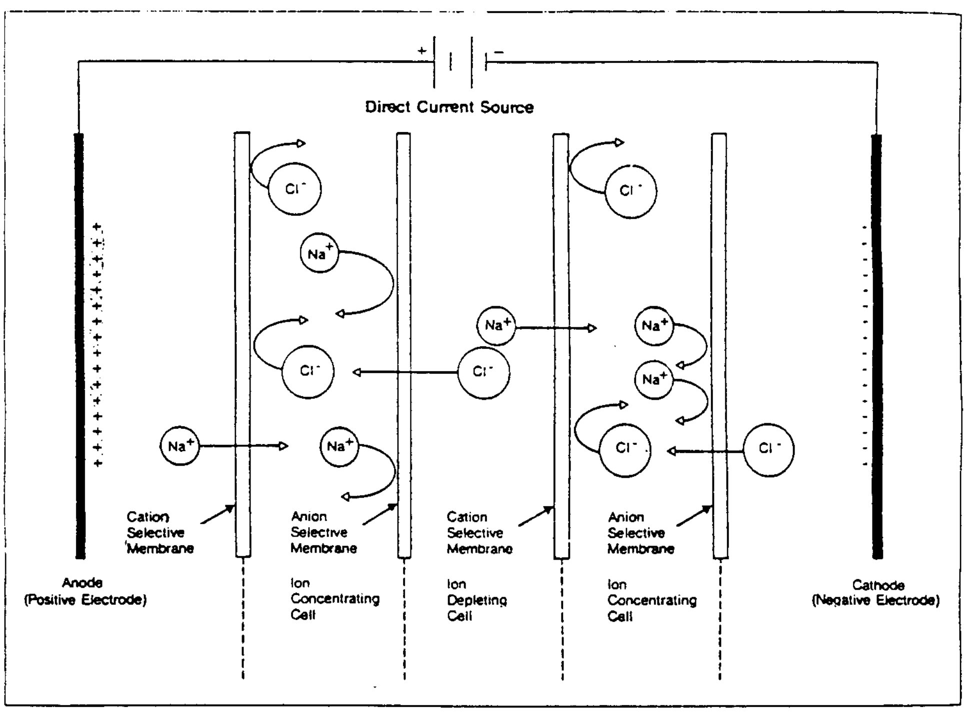


FIGURE A-3.2 OPERATION OF AN ELECTRODIALYSIS CELL [11]

Electrodialysis process operates with a continuous water flow between a pair of electrodes. The membranes are designated as anion permeable or cation permeable. Water passages are distinguished as ion concentrating or ion depleting solution. With a driving force of a direct current electrical field, cations will move in the direction of the negative electrode (cathode) until they are repelled by an anion membrane. Anion will move through the anion membrane and repelled by an cation membrane. The reduction of concentration in the depletion passage is a direct function of the amount of direct electric current applied. Water will exit from an electrodialysis process as two streams: a purified stream and a concentration stream.

DEIONIZATION

Deionization or demineralization is defined as a process of removing inorganic salts by ion exchange. A deionization unit consists of one or more ion exchange resin columns containing cation and anion exchange resin. The cation resin exchanges hydrogen for raw water cations and the anion resin exchanges hydroxyl anions for the highly ionized anions. The typical reactions of ion exchange are in the following.

Cation exchange (R^- represents polymer resin):

1. $R^-Na^+ + M^+X^- \Leftrightarrow R^-M^+ + Na^+X^-$

2. $R^-H^+ + M^+X^- \Leftrightarrow R^-M^+ + H^+X^-$

3. $R^-H^+ + M^+OH^- \Leftrightarrow R^-M^+ + H_2O$

Anion exchange (R^+ represents polymer resin):

1. $R^+Cl^- + M^+X^- \Leftrightarrow R^+X^- + M^+Cl^-$

2. $R^+OH^- + M^+X^- \Leftrightarrow R^+X^- + OH^-$

3. $R^+OH^- + H^+X^- \Leftrightarrow R^+X^- + H_2O$

Deionization system can be arranged as "two-bed" treatment (see Figure A-3.3) which has two different kinds of resins and reactions in each tank. Another arrangement is "mixed bed" system (see Figure A-3.4) which has cation and anion resin separated in two discrete zones (in the same tank).

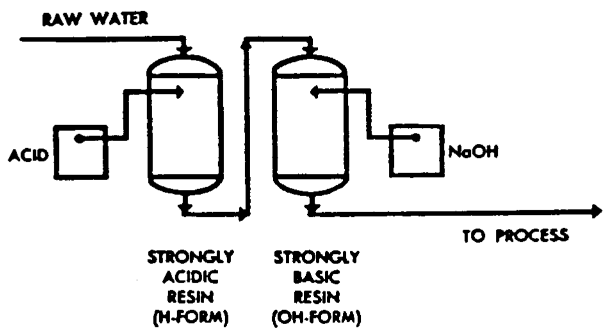


FIGURE A-3.3 DEIONIZATION BY MULTIPLE BED EXCHANGERS [11]

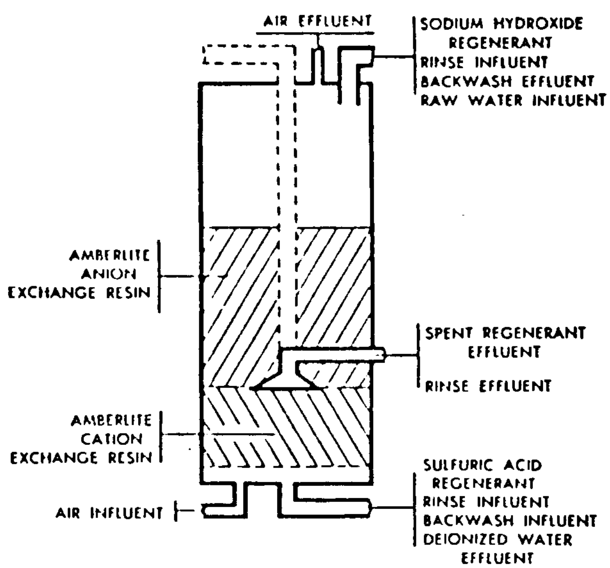


FIGURE A-3.4 A TYPICAL MONOBED DEIONIZATION UNIT [11]

APPENDIX B

WATER MANAGEMENT AUDIT EQUIPMENT INFORMATION

(Information in this appendix is form Grainger's 1995 General Catalog)

TEST INSTRUMENTS TEMPERATURE

THERMOCOUPLE THERMOMETERS

A AMPROBE No. 2T453

- Accuracy: ±2°
- Resolution: 1.0°F
- Retractable sensor with temperature range from −50°F to 300°F; port provided for Type-K thermocouple with range capability to 2000°F
- °F or °C selectable
- 9V battery (not supplied)
- Overrange and low battery indication

B ATKINS Nos. 3T203 and 3T204

- Accuracy Including Probe Error: ±1°
- Resolution: 1°F
- O-ring sealed including probe
- Membrane sealed key pad
- Dust, splash, and drop proof to 3 ft
- Probe withstands up to 50 lbs pull
- Backlit display; temperature hold
- No. 3T203 includes permanent 29" cable with needle probe
- No. 3T204 includes 29" cable with surface/universal probe

C CHECK-IT No. 2T321

- Accuracy ±1% Rdg. ±1 Digit (−100° to 1000°F) ±2% Rdg. ±1 Digit (1000° to 1999°F)
- Resolution: 1°F
- Sensitive 3-in-1 liquid-air-surface probe
- NBS traceable
- Anodized aluminum housing built into high impact ABS plastic case
- Retractable coil probe cord extends to 3 feet
- Annunciators for open probe, overrange and low battery
- Includes 9V battery and No. 2T348 probe

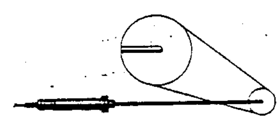
D FLUKE No. 3A024

- Accuracy: ±0.1% of Reading + 1.3°F
- Resolution: 0.2°F
- Drop resistant case
- °F/°C select switch
- K or J-type thermocouple selectable
- Data hold
- 1 second per reading update
- Includes 9V battery and K-type bead probe (1T322); 1200 hour battery life
- CSA Certified (LR44340)
- Three year warranty; see "Manufacturers' Warranties" on page opposite inside of back cover

E FLUKE No. 3A025

- Accuracy: ±0.1% of Reading + 1.3°F
- Resolution: 0.2°F (High) 1.0°F (Low)
- Same features as No. 3A024
- Dual point or differential capability
- Min/max storage and view
- Scan mode and selectable resolution
- Includes two K-type bead probes (1T322)
- CSA Certified (LR44340)

Wide Variety of Temperature Probes Available to Measure Air, Surface, Liquids, and Solids.



See Index for Listings.

FOR THERMOMETRY SELECTION GUIDE SEE PAGE 791

Key	Type	Range*	Display	Probe Connector	Mfr.	Mfr's. Model	Stock No.	List	Each	Shpg. Wt.
A	Thermocouple	−100° to 2000°F	3½, LCD	Mini-K	Amprobe	DP-2001	**2T453**	$106.81	**$85.45**	2.0
B	Thermocouple	−115° to 440°F	3, LCD	—	Atkins	33033-F	**3T203**	143.75	**115.00**	2.0
	Thermocouple	−115° to 440°F	3, LCD	—	Atkins	33034-F	**3T204**	148.75	**119.00**	2.0
C	Thermocouple	−100° to 1999°F	3½, LCD	RCA	Check-It	626	**2T321**	160.00	**128.00**	0.7
D	Thermocouple	−328° to 2498°F (−200° to 1370°C)	3½, LCD	Mini-J/K	Fluke	Fluke-51	**3A024**	179.00	**149.00**	1.0
E	Thermocouple	−328° to 2498°F (−200° to 1370°C)	3½, LCD	Mini-J/K	Fluke	Fluke-52	**3A025**	239.00	**199.00**	1.0

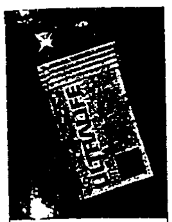
(*) Instrument ranges shown span various probe types. The probe will determine the actual range. See pages 797 and 798.

PORTABLE NON-INVASIVE FLOWMETER

- Battery-Powered, Portable Operation
- Choice of 2 Sensors Including Acoustic Couplant

Model FD10

$765



Supplied with 5 Long-Life Lithium Batteries.

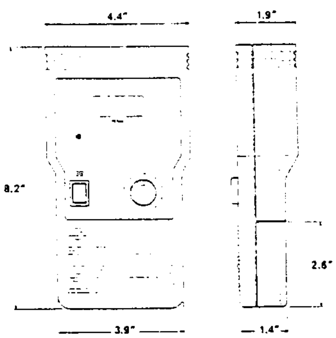
Model FD1SN Shown, Price $130

Sensor Sold Separately

Model FD-10

Comes with Rugged Carrying Case and Complete Operator's Manual

For Complete Specifications See Page E-6



Dimensions in Inches

The FD10 non-invasive ultrasonic hand-held flowmeter gives immediate and reliable velocity measurements with high repeatability for monitoring day-to-day performance of fluids in a pipe anywhere in a system.

The non-invasive measurement of fluid flow in a pipe is achieved using the Doppler frequency shift of ultrasonic signals reflected from contaminants in the flowing liquid. These contaminants can be suspended solids (not dissolved) or bubbles in the flow.

The battery-powered, portable monitor is coupled to the sensor, which in turn is positioned on the pipe using a suitable acoustic coupling jelly. With the monitor turned on, an immediate velocity reading is given. The monitor also features a "good connection" LED indicator and an adjustable calibration knob. The non-invasive sensor with 8 ft cable can be supplied for fluid temperatures up to 158°F (Model FD1SN) or for fluids up to 239°F (Model FD1SN-HT).

Model FD10 can be used effectively to monitor flow through steel, iron, hard plastic PVC and glass pipes, and by its non-invasive application can be used to measure flow of liquids such as cement, sewage, and effluent where in-line flowmetering would be difficult or impossible. Concrete, copper, and lined pipes present a barrier to the ultrasonic signal and thus the FD10 is not suitable for use with these pipes.

To Order (Specify Model Number) *IN STOCK FOR FAST DELIVERY!*

Model No.	Price	Description
FD10	$765	Portable non-invasive flowmeter kit*
U9VL	4.90 ea.	One replacement accessory 9V Lithium battery

**Sensor required; must be purchased separately (see below). Kit includes monitor, batteries, manual, and case*

Sensors with Acoustic Couplant

Model No.	Price	Description
FD1SN	$130	Sensor for fluid from 41 to 158°F
FD1SN-HT	250	Sensor for fluid up to 239°F

E

PLUMBING: WATER TESTING

WATER TEST KITS AND WATER SOFTENER BY-PASS VALVE

DRINKING WATER TEST KITS

Water Test Kits are designed for testing tap water, private wells, and municipal water systems in manufacturing plants, commercial business, municipalities and households. Each kit contains easy to follow directions, plus everything necessary to draw samples properly and ship safely back to Watercheck for analysis. Watercheck will return printed test results showing the measured or calculated amount of each contaminant along with the EPA recommended range for that contaminant. General recommendations for corrective action are included for contaminants greater than the EPA acceptable level. Test kits are not to be used to satisfy EPA certification requirements.

No. 2P882. WaterTest City Scan/Well Scan test kit covers 29 possible contaminants, and is easily tailored to measure common threats to municipal water or private well water. The kit is intended to test for unhealthy contaminants, as well as those which affect taste and odor or stain clothing and fixtures. Specific tests include: 16 metals including lead, aluminum, sodium and arsenic; 9 non-metals including nitrate, nitrite, hardness, and total dissolved solids; the **City Scan** option measures 5 volatile organic byproducts of municipal disinfection, while the **Well Scan** option measures 5 volatile organic indicators of petroleum or industrial solvent contamination.
Shpg. wt. 0.8 lbs. List $69.00. Each $49.90

No. 2P881. Water Check Plus Pesticide Option is a 94 parameter test for those using private wells or small community systems. It includes tests for all primary (unhealthy) and secondary (unpleasant) contaminants identified by the USEPA as having been found in ground water plus many others suspected of being present. Metals including arsenic, aluminum, copper, and lead; organic chemicals from petroleum products, solvents, cleansers, plus pesticides, fertilizers, and coliform bacteria are all included in the test.
Shpg. wt. 3.0 lbs. List $129.00. Each $94.25

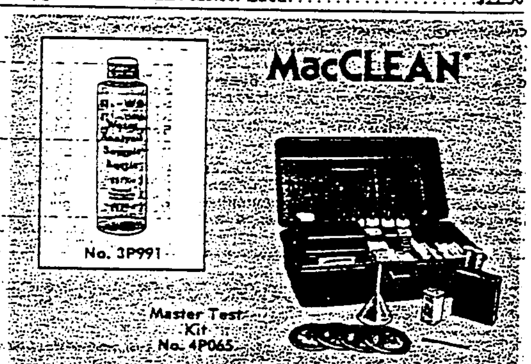
No. 2P883. First Draw and Flush Lead Test is a dual test designed to test for lead contamination which may be contributed to drinking water by a building's own plumbing. Collect a sample which has been standing in the water pipes for several hours, then "flush" the pipes and sample again. Includes prepaid return postage.
Shpg. wt. 0.7 lbs. List $29.00. Each $22.50

WATER ANALYSIS SERVICE KIT

For use when water testing information from local water company or municipal water service is not available. Use the kit to send a sample of water to be treated, with completed data form, to MacCLEAN's laboratory. An analysis will be returned, together with a recommendation of proper softener or filter model. Kit includes plastic bottle, data sheet, and return shipping carton. Read and follow instruction on request for analysis form regarding proper sampling technique and fill out all requested information. Test for sulfur (rotten egg odor) must be performed on site.
No. 3P991. Shpg. wt. 0.1 lbs. List $1.20. Each $1.20

MASTER TEST KIT

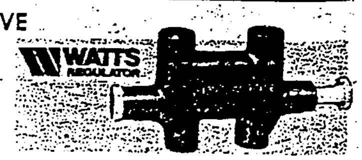
On-site test kit accurately analyzes 7 water contaminants: hardness, iron, pH, manganese, tannic acid, hydrogen sulfide, and copper. Enough reagents are supplied to conduct approximately one-hundred tests for each contaminant. Detailed instructions and premeasured reagents make this professional kit easy to use.
No. 4P065. Shpg. wt. 9.0 lbs. List $328.00. Each $297.75



WATER SOFTENER BY-PASS VALVE

- **Rugged, durable bronze body, Noryl plunger, Buna N O-rings**
- **Easy to operate**
- **Eliminates need for grounding strap**
- **Interchangeable push rods change direction of water flow**
- **In and Out markings cast into body**
- **3/4" Copper sweat connections**
- **3" Center house ports**
- **Watts brand (M9500)**

No. 6A773. Shpg. wt. 2.5 lbs. List $38.00. Each $26.25



WATTMETERS AND POWER PROBE

WATTMETERS

[A] TIF No. 1T967

- Measures true power (KW) consumed at any instant, not apparent power (KVA)
- Combination kilowatt and kilowatt-hour meter
- Cumulative total of power used up to 10,000 KWH
- Accuracy ±2% at unity power factor above 90 volts input
- Electronic monitors warn of potential problems such as power interruption or input overrange
- Measures 3-phase unbalanced loads and 4-wire systems
- Battery back-up protects data up to 30 minutes
- Analog output for chart recorders, data loggers or meters
- LCD display reads KW, KWH and volts/amps; low battery indicator
- Clamp-on current transducers; use with any power factor
- Includes 60 Hz current probe, 3-phase volt probe, 115-9V adapter

[B] TIF No. 1A227

- Reads true power
- Accuracy (typ.): ±2% rdg ±1 dgt
- For single, split, and three-phase power sources
- Reads 0.01 KW to 199.9 KW
- Dual range for low and high kilowatts
- Includes 9V battery and carrying case

[C] AEMC No. 2T590

- Exceptionally wide true RMS measurement range: 0.1W—20 KW
- Accuracy (typ.): ±0.6% FS
- Measures power consumption on single- and three-phase systems
- Measures reactive power on three-phase systems up to 200 KVar
- Direct input for current up to 10A RMS (14.1 peak)
- Maximum crest factor: 6
- 1000/1 clamp-on probe extends capability to 1000A RMS (1414 peak)
- Includes 1000/1 clamp-on current probe, safety voltage leads, current leads, and battery

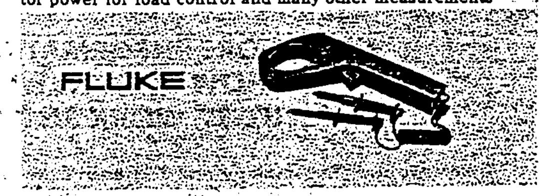
Key	Power (Kilowatts)	Voltage (Volts AC)	Current (Amps AC)	Calibration Frequency (Hz)	Jaw Capacity	Display	Auto-Range	Mfr.	Mfr's. Model	Stock No.	List	Each	Shpg. Wt.
A	200	90-530	1/500*	60	1.25"	3½ LCD	No	TIF	TIFKW220-3AV	1T967	$1299.95	$980.00	9.0
B	19.99/199.9	90-560	0.1/1000	50-400	1.25	3½ LCD	No	TIF	TIF2000A	1A227	499.00	389.00	2.0
C	0.1999/1.999/199.9	700	1/10/1000	48-400	2.1	3½ LCD	No	AEMC	1800	2T590	1118.75	895.00	3.8

(*) Amps continuous; Maximum 600 amps intermittent

POWER PROBE

- Measures DC and AC current and AC power
- Measurements made without breaking the circuit
- Accuracy (typ.): AC/DC amps, ±(2% of Reading +2A); AC power, ±(3.5% of Reading ±0.5KW)
- Protection Class II as defined in IEC 348 and ANSI C 39.5
- Compatible with most Fluke multimeters
- Has dual male banana output connectors
- Case provides storage for additional accessories (accessories not included)
- Output usable for oscilloscopes, DVM and recorders with optional adapter No. 3T048; see page 761
- Includes 9V battery, test leads and carrying case

Suitable for a wide variety of applications involving construction and maintenance of AC and DC electrical distribution systems. Typical applications include measuring power supply ripple, capacitor leakage, residential power consumption, motor power for load control and many other measurements



Current (Amps AC)	Current (Amps DC)	KWAC at 90-660V, 1-500A	Output	Operating Frequency	Jaw Size	Fluke Model	Stock No.	List	Each	Shpg. Wt.
1 to 1000	1 to 1300	0.5 to 330KW	1mV/A or 1mV/KW	DC to 3.2 KHz	2⅞x 2⅜"	80iKW	3T251	$818.75	$495.00	5.3

UVEX ASTROSPEC 3000™ & ASTROMETAL™ 3002 PROTECTIVE EYEWEAR

Protective eyewear for most industrial and construction needs. Polycarbonate, unitary lenses absorb more than 99% of ultraviolet light. Feature universal nose-bridge, adjustable lens angle and lens replacement. Astrospec™ models have nylon frames with adjustable temple length. Also available in small size. Astrometal™ models have single-piece metal frames. Meet ANSI Z87.1-1989 and CSA Z94.3-1992. Gray lens also meets Z80.3 sunglass requirements. Uvex brand.

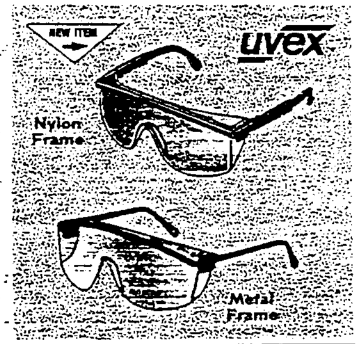
4C+ Coating—Permanently bonded coating that is anti-fog, anti-scratch and anti-static. Provides more than 99% protection from ultraviolet radiation.

Ultradura® Scratch-Resistant Coating (UD)—Permanently bonded silicate-based coating resistant to a wide range of chemicals.

SCT™ Gray Lens—Absorbs more than 99.9% of ultraviolet light and depresses blue light transmission from 400-500 nm for long-term outdoor exposure or short-burst arc radiation. Maintains optimal color recognition.

Infradura® Welding Lens (ID)—For protection against ultraviolet and infrared radiation. Provides filtration requirements outlined in ANSI Z87.1-1989. Available in 3.0 and 5.0 shades.

SCT™ Vermillion Lens—Absorbs blue portion of spectrum to enhance detail and contrast. Aids in inspection and reduces fatigue.



UVEX ASTROSPEC 3000™ EYEWEAR

Frame Color	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.
	CLEAR 4C+ LENS						**GRAY UD LENS**					
Black	S135C	6T270	$8.85	$6.90	$6.56	0.1	S136	6T274	$9.15	$7.30	$6.94	0.1
Blue	S129C	6T271	8.65	6.90	6.56	0.1	S130	6T275	9.15	7.30	6.94	0.1
Red	S1435C	➔5AK31	8.65	6.90	6.56	0.2	S1436	➔4AV78	9.15	7.30	6.94	0.2
Yellow/Black	S141C	6T272	8.65	6.90	6.56	0.1	S142	6T276	9.15	7.30	6.94	0.1
Purple/Green	S138C	➔5AF41	8.65	6.90	6.56	0.2	S139	➔5AZ79	9.15	7.30	6.94	0.2
Patriot*	S116C	6T273	8.90	7.10	6.75	0.2	S117	6T277	9.40	7.50	7.13	0.1
Replacement Lens	S535C	6T278	4.50	3.60	3.42	0.1	S536	6T279	4.75	3.80	3.61	0.1
	MIRROR UD LENS						**AMBER UD LENS**					
Black	S137	➔3AV11	13.15	10.50	9.98	0.2	S145	➔6AV99	9.15	7.30	6.94	0.2
Blue	S131	➔6AZ38	13.15	10.50	9.98	0.2	—	—	—	—	—	—
Red	S1437	➔2AX87	13.15	10.50	9.98	0.2	—	—	—	—	—	—
Yellow/Black	S143	➔6AL73	13.15	10.50	9.98	0.2	—	—	—	—	—	—
Purple/Green	S140	➔2AX63	13.15	10.50	9.98	0.2	—	—	—	—	—	—
Patriot*	S114	➔5AR76	13.40	10.70	10.17	0.2	—	—	—	—	—	—
Replacement Lens	S538	6T544	9.00	7.20	6.84	0.1	S537	➔3AD90	4.75	3.80	3.61	0.1
	SCT GRAY LENS						**3.0 ID LENS**					
Black	S1361	➔5AH17	9.65	7.70	7.32	0.2	S1111C	➔3AX39	13.15	10.50	9.98	0.2
Replacement Lens	S541	➔5AV09	5.50	4.40	4.18	0.1	S542C	➔5AW94	9.00	7.20	6.84	0.1
	5.0 ID LENS						**SCT VERMILLION LENS**					
Black	S1112C	➔3AF26	14.40	11.50	10.93	0.2	S1362	➔2BC78	9.65	7.70	7.32	0.2
Replacement Lens	S543C	➔6AG16	10.25	8.20	7.79	0.1	S539	➔3AW33	5.50	4.40	4.18	0.1

UVEX ASTROSPEC 3000™ S (SMALL) EYEWEAR

Frame Color	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.
	CLEAR 4C+ LENS						**GRAY UD LENS**					
Black	S2700C	➔1D557	8.65	6.90	6.56	0.2	S2701	➔1D556	9.15	7.30	6.94	0.2
Blue	S2710C	➔1D555	8.65	6.90	6.56	0.2	S2711	➔1D554	9.15	7.30	6.94	0.2
Yellow/Black	S2720C	➔1D553	8.65	6.90	6.56	0.2	S2721	➔1D552	9.15	7.30	6.94	0.2
Purple/Green	S2740C	➔1D547	8.65	6.90	6.56	0.2	S2741	➔1D546	9.15	7.30	6.94	0.2
Patriot*	S2730C	➔1D551	8.90	7.10	6.75	0.2	S2731	➔1D550	9.40	7.50	7.13	0.2
Replacement Lens	S570C	➔1D545	4.50	3.60	3.42	0.1	S571	➔1D058	4.75	3.80	3.61	0.1

ASTROMETAL™ EYEWEAR

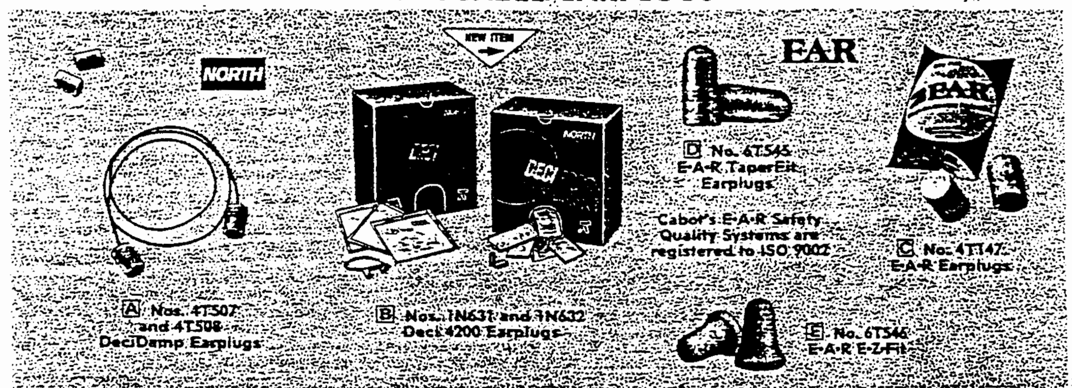
Frame Color	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.	Uvex Model	Stock No.	List	Each	Lots 10	Shpg. Wt.
	CLEAR 4C+ LENS						**GRAY UD LENS**						**MIRROR UD LENS**					
Gold	S2400C	➔3AJ54	$10.40	$8.30	$7.88	0.2	S2401	➔5AV66	$10.90	$8.70	$8.27	0.2	S2403	➔6AX54	$14.90	$11.90	$11.31	0.2
Black	S2410C	➔6AJ84	10.40	8.30	7.88	0.2	S2411	➔1AV15	10.90	8.70	8.27	0.2	S2413	➔3AL14	14.90	11.90	11.31	0.2
Replacement Lens	S535C	6T278	4.50	3.60	3.42	0.1	S536	6T279	4.75	3.80	3.61	0.1	S538	6T544	9.00	7.20	6.84	0.1

(*) Red/White/Blue color.

FOR REPLACEMENT PARTS—SEE PAGE A2 IN FRONT OF CATALOG

HEARING PROTECTION

DISPOSABLE EARPLUGS



[A] **DeciDamp® Disposable Earplugs.** Soft and comfortable PVC foam construction expands to fit ear canal, maximizing wearer protection. Plugs are lightweight, washable, non-toxic and non-irritating. Provide consistent attenuation performance and improved voice communications. One pair per pouch packaging eliminates exposure to dust and dirt. Corded model offers higher visibility for safety checks and reduces incidence of lost plugs.

Attenuation tested in accordance with ANSI S3.19-1974. White color. Without cord, Noise Reduction Rating (NRR): 29 dB. 200 pairs per box, cellophane or paper pouch packaging. With bright orange cord, Noise Reduction Rating (NRR): 27 dB. 100 pairs per box. North brand.

Earplug Description	North Model	Stock No.	List	Each	Lots 4	Shpg. Wt.
CELLOPHANE POUCH PACKAGING						
Without Cord	28-00-05	4T507	$44.00	$22.00	$19.80	0.8
With Cord	28-00-06	4T508	36.00	26.10	23.49	1.0
PAPER POUCH PACKAGING						
Without Cord	28-25-05	➔3AF90	44.00	22.00	19.80	1.0

[B] **Deci 4200 Disposable Earplugs.** Tapered design and polyurethane foam construction optimize wearer comfort and protection even during extended periods of use. Non-toxic, non-irritating plugs automatically conform to almost all ear canal sizes. Demonstrate consistently high attenuation performance. One pair per cellophane pouch packaging eliminates exposure to dust and dirt. Blue corded model offers high visibility for safety checks and reduces incidence of lost plugs. Uncorded models: 200 pairs per box, Corded models: 100 pairs per box.

Attenuation tested in accordance with ANSI S3.19-1974. Purple color. Noise Reduction Rating (NRR): 31 dB on uncorded model. 27 dB on corded model. North brand.

Earplug Description	North Model	Stock No.	List	Each	Lots 4	Shpg. Wt.
Without Cord	28-42-00	➔1N632	$44.00	$26.10	$23.49	8.0
With Cord	28-42-40	➔1N631	36.00	26.10	23.49	1.0

EARPLUG HOLDER-DISPENSER

Clear acrylic dispenser easily holds 200 pairs (one box) of disposable or reusable ear plugs (not included). Can be wall mounted or used free standing. Provides convenient access in work areas. Front tray measures 2¾" deep. 13¼H x 12W x 8"D. Prinzing brand (04439).

No. 5U603. Shpg. wt. 7.5 lbs. List .... $72.00.
Each $61.20; Lots 3 .... $58.14

[C] **E-A-R® Disposable Earplugs** are made of an exclusive soft, energy-absorbing polymer foam. Foam design allows plug to gradually expand and conform to size and shape of any ear canal. Demonstrate consistently high attenuation values and low variability.

Plugs are washable and can be comfortably worn for extended periods of time. Attenuation tested in accordance with ANSI S3.19-1974. Noise Reduction Rating (NRR): 29 dB. Yellow color. 200 pairs per box. Also available with bright blue cord. E·A·R brand.

ORDERING DATA

Earplug Description	E-A-R Model	Stock No.	Per Box List	Per Box Each	Lots 4	Shpg. Wt.
Without Cord	310-1001	4T147	$35.87	$30.70	$29.16	2.0
With Cord	311-1101	5T277	61.50	53.25	50.58	2.0

[D] **E-A-R® TaperFit2 Earplugs** are regular sized for normal ear canals and provide optimum comfort and protection. Tapered shape aids insertions and removals. Soft, self-adjusting foam creates effective move-resistant barrier against noise. Dermatolically safe and non-irritating. Attenuation tested in accordance with ANSI 3.19-1974. Noise Reduction Rating (NRR): 32. Yellow color without cord. 200 pair per box. E·A·R brand (312-1219).

No. 6T545. Shpg. wt. 1.1 lbs. List $52.00. Each $28.00; Lots 4 $26.60

[E] **E-A-R® E-Z-Fit™ Earplugs** provide comfort and protection for regular and small ear canals. Self-adjusting, bell-shaped foam produces a soft, comfortable seal against noise without pressure in ear canal. Attenuation tested in accordance with ANSI 3.19-1974. Dermatologically safe and non-irritating. Noise Reduction Rating (NRR): 28. Yellow color without cord. 200 pair per box. E·A·R brand (312-1208).

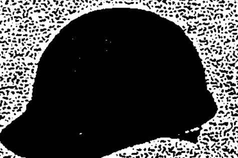
No. 6T546. Shpg. wt. 1.0 lbs. List $52.00. Each $28.00; Lots 4 $26.60

SAFETY EQUIPMENT

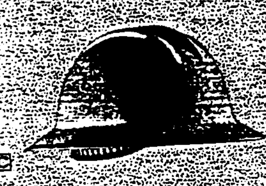
HEAD PROTECTION

- High-density polyethylene hard hats meet ANSI Z89.1-1986 Class A and B requirements, including impact, penetration, and electrical insulation.
- Certified by Safety Equipment Institute

A



B



C

HARD HATS

[A] **Classic-Style Hard Hats** are versatile for most industrial applications and government agency uses. Wide profile and brim provide ventilation and protection from sun.

Available with 6-point self-sizing suspension or 6-point Sure-Lock® ratchet suspension. Equipped with accessory slots that accept many attachments including welding helmets, earmuffs, communication devices, and faceshields.

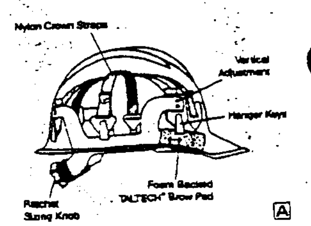
[B] **Economy-Style Hard Hats** have one of the lightest designs available. Trim profile with rain trough for protection against snow, rain, and dirt.

Available with 4-point self-sizing suspension or 4-point Sure-Lock® ratchet suspension. Equipped with accessory slots that accept many attachments including welding helmets, earmuffs, communication devices, and faceshields.

[C] **Full-Brim Classic Style Hard Hats** offer traditional hard hat protection plus extra coverage at sides and back of neck. Come with 6-point self-sizing suspension.

Key	Style	Color	Bullard Model	Stock No.	List	Each	Lots 25	Shpg. Wt.
A	Classic with 6-pt Self-sizing Suspension	White	3000	4T153	$8.76	$7.45	$7.08	0.8
		Yellow		4T154	8.76	7.45	7.08	0.8
		Orange		4T155	8.76	7.45	7.08	0.8
		Red		4T156	8.76	7.45	7.08	0.8
		Blue		4T157	8.76	7.45	7.08	0.8
		Green		4T158	8.76	7.45	7.08	0.8
A	Classic with 6-pt Sure-Lock® Ratchet Suspension	White	3000R	4T925	12.22	11.00	10.45	0.8
		Yellow		4T926	12.22	11.00	10.45	0.8
		Orange		4T927	12.22	11.00	10.45	0.8
		Red		4T928	12.22	11.00	10.45	0.8
		Blue		4T929	12.22	11.00	10.45	0.8
		Green		4T930	12.22	11.00	10.45	0.8
B	Economy with 4-pt Self-sizing Suspension	White	5100	4T161	6.53	5.55	5.27	0.8
		Yellow		4T162	6.53	5.55	5.27	0.8
		Orange		4T163	6.53	5.55	5.27	0.8
		Red		4T164	6.53	5.55	5.27	0.8
		Blue		4T165	6.53	5.55	5.27	0.8
		Green		4T166	6.53	5.55	5.27	0.8
B	Economy with 4-pt Sure-Lock® Ratchet Suspension	White	5100R	4T913	9.67	8.70	8.27	0.8
		Yellow		4T914	9.67	8.70	8.27	0.8
		Orange		4T915	9.67	8.70	8.27	0.8
		Red		4T916	9.67	8.70	8.27	0.8
		Blue		4T917	9.67	8.70	8.27	0.8
		Green		4T918	9.67	8.70	8.27	0.8
C	Full Brim with 6-pt Self-sizing Suspension	White	303	4T919	8.83	7.95	7.55	0.9
		Yellow		4T920	8.83	7.95	7.55	0.9
		Orange		4T921	8.83	7.95	7.55	0.9
		Red		4T922	8.83	7.95	7.55	0.9
		Blue		4T923	8.83	7.95	7.55	0.9
		Green		4T924	8.83	7.95	7.55	0.9

SUSPENSION SYSTEMS



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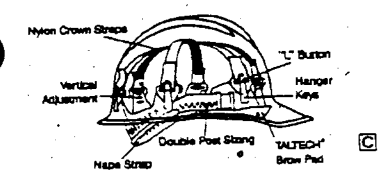

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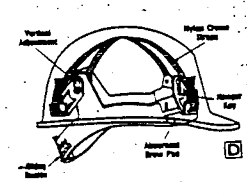

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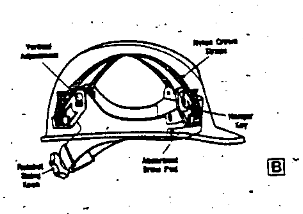


B

Suspension systems offer a high degree of comfort and dependable shock absorption. Breathable brow pad aids ventilation and perspiration absorption. Fits sizes 6½ to 8. Bullard brand.

Two types of suspension systems are available. Sure-Lock® ratchet 6- and 4-point systems, provide instant sizing that will not slip; self-sizing 6- and 4-point systems, fully adjustable with nape strap that can be raised or lowered for comfortable fit. 6-Point suspension equipped with TALTECH® brow pad.

Nos. 4T159 and 4T160 are for use with Bullard classic and full brim hard hats only. Nos. 4T167 and 4T168 are for use with Bullard economy hard hats only.

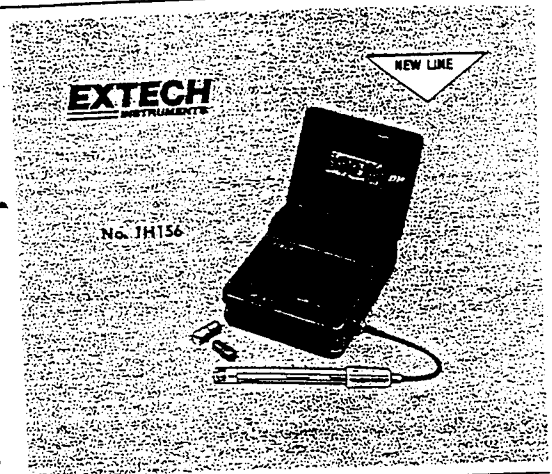
Key	Description	Bullard Model	Stock No.	List	Each	Lots 25	Shpg. Wt.
A	6-point Ratchet	ESRTSL	4T160	$8.96	$8.15	$7.74	0.3
B	4-point Ratchet	TGRT600	4T168	8.55	7.70	7.32	0.3
C	6-point Self-sizing	ES-ULTRA	4T159	5.17	4.65	4.42	0.3
D	4-point Self-sizing	TG600	4T167	4.50	4.05	3.85	0.3

pH METER AND pH TESTERS

EXTECH® pH METER

- Measures pH to 0.01 resolution over full 0-14.00 pH range
- Accuracy: 0.02 pH
- "Flip up" display provides best viewing angle and auto shut-off when cover is closed
- Benchtop or handheld with neckstrap for "hands-free" operation
- Manual temperature compensation (0-100°C)
- Neckstrap, electrode, sample buffer solutions, case and 9V battery included

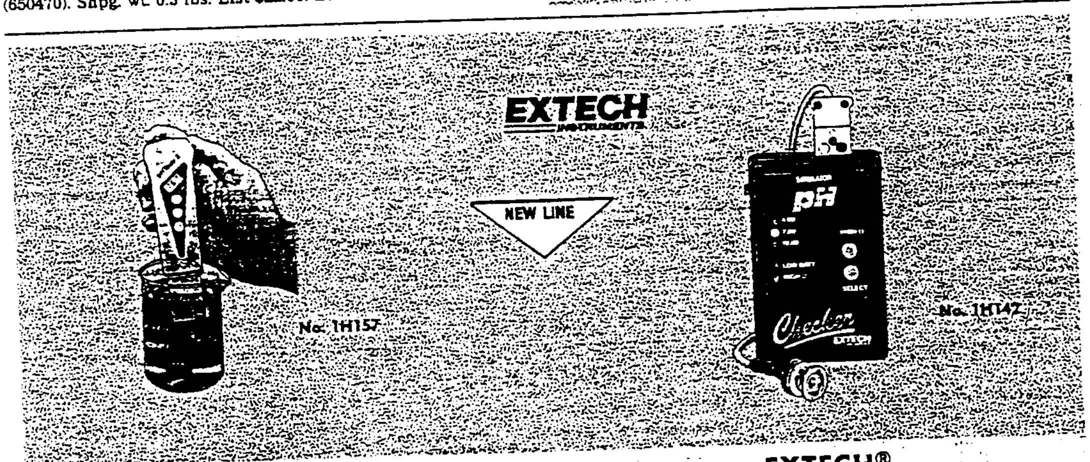
No. 1H156. Extech brand (120505). Shpg. wt. 1.8 lbs. List $199.95. Each $189.00



ACCESSORIES

No. 1H143. Mini Electrode Replacement. Extech brand (60120B). Shpg. wt. 0.2 lbs. List $49.50. Each $45.00

No. 1H141. Buffer Tripak pH 4.0, 7.0 and 10.0. Extech brand (650470). Shpg. wt. 0.3 lbs. List $22.00. Each $20.00



EXTECH® POCKET pH TESTER

- Microprocessor based with Automatic Temperature Compensation
- Easy-to-read LCD display
- Wide measuring range of −1.0 to 15.0 pH
- Accuracy: 0.1 pH
- 3-point calibration: 4, 7 and 10 pH
- Features splash proof keypad, Hold function, and Auto power Off
- Includes 3 watch-type batteries

No. 1H157. Extech brand (050450). Shpg. wt. 0.3 lbs. List $66.00. Each $63.00

VINYL CARRYING CASE

No. 1H154. Belt Loop Vinyl Case. Extech brand (392999). Shpg. wt. 0.1 lbs. List $7.35. Each $7.00

EXTECH® pH CALIBRATION TESTER

- Detects faults in electrodes, pH meters, recorders, transmitters, etc.
- Pushbutton switch simulates 4, 7 and 10 pH values
- High ohm range (1000 MOHM) for checking impedence values of pH devices
- Accuracy: 0.1% reading
- Compact size fits into shirt pocket
- Includes calibration cable with BNC connector, carrying case and 9V battery

No. 1H142. Extech brand (610022-B). Shpg. wt. 0.7 lbs. List $95.00. Each $89.00

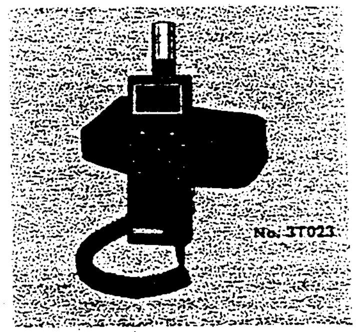
SEE WARRANTY INFORMATION ON PAGE OPPOSITE INSIDE BACK COVER

INFRARED THERMOMETERS

Portable, noncontact, thermometers are designed for predictive maintenance applications. Valuable in monitoring operating temperatures of mechanical and electrical plant or production equipment without removing equipment from service. Also useful for measuring product temperatures during manufacturing, without disturbing the process, to spot problems before they reduce quality or cause production downtime.

THE DICKSON COMPANY

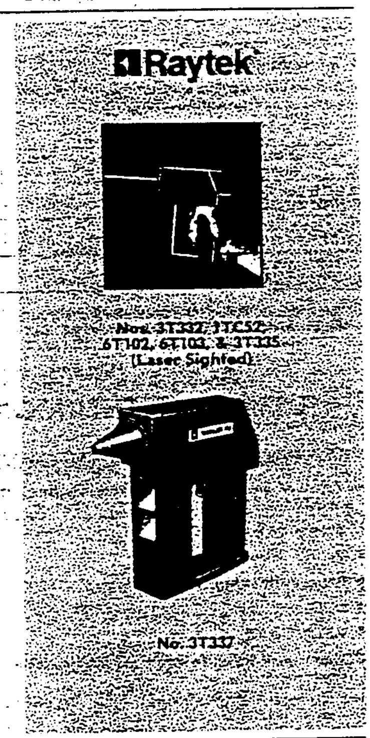
1 point NIST traceable Certificate of Calibration included.



DICKSON No. 3T028

- °F or °C switchable with hold function
- 0.30 to 1.0 adjustable emissivity
- 1mV per degree recorder/controller output
- Includes carrying case and 9V battery
- Pocket-size and splash resistant design
- Accuracy: ±1% FS
- Retractable wand allows one or two hand operation

RAYTEK RAYNGER® SERIES



One-piece, noncontact thermometers are hand-held and portable. Designed with precision laser sighting for pinpointing target temperatures. Accurately measures electrical and HVAC equipment, bearings, motors, compressors, steam trops, rotating machinery, and process monitoring. Easy-to-read backlit display for use in outdoor and dark indoor areas.

- Accuracy: ±1% of rdg ±1 dig
- Analog output: 1mV/degree; for thermal printer No. 3T341, see page 806
- Digital output: RS-232C
- °F or °C, switchable
- Includes carrying pouch and 9V battery
- AC power adapter available No. 3T339 (not supplied); see page 806

No. 3T332

- Laser sighting
- 50:1 optical resolution
- Backlit display
- Simple to use; trigger actuated
- Displays actual and maximum temperatures
- Accuracy: ±1%
- Emissivity fixed at 0.95
- °F or °C, switchable
- Includes carrying pouch and 9V battery

Nos. 1TC52 & 6T102

- Laser sighting on No. 6T102
- Backlit display
- 50:1 optical resolution
- Adjustable emissivity
- Displays actual and maximum temp.
- Memory recall
- Lockable trigger

Nos. 6T103 & 3T337

- All features of No. 6T102
- Display and memory of minimum, differential, and average temperatures for each measurement
- User adjustable HI/LO alarms
- Wider temperature range
- Reflected ambient temperature compensation
- Close focus on No. 3T337 for measuring targets as small as 0.09" at 0.1" working distance. Laser sighting not available

No. 3T335

- All features of No. 6T103
- 64-point datalogging memory/interface to IBM databases and spreadsheets; software program No. 3T278 is available. See page 806

Range	Spectral Response	Focus Spot Size & Distance	Repeatability	Response Time	Ambient Operating Range	Mfr.	Mfr's. Model	Stock No.	List	Each	Shpg. Wt.
−50° to 1000°F (−46° to 540°C)	8-14μ	2" @ 10"	±1% of Rdg; ±1 Digit	<1 Sec	32°-120°F	Dickson	IR-550	3T023	$623.75	$499.00	2.0
0° to 1000°F (−18° to 540°C)	8-14μ	1" @ 50 ft.	±0.5% of Rdg; ±1 Digit	350mSec	32°-120°F	Raytek	PM20	3T332	931.25	745.00	2.0
−50° to 750°F (−46° to 400°C)	8-14μ	1" @ 50 ft.	±0.5% of Rdg; ±1 Digit	350mSec	32°-120°F	Raytek	PM3L3SZ	1TC52	1431.25	1145.00	2.0
0° to 1000°F (−18° to 540°C)	8-14μ	1" @ 50 ft.	±0.5% of Rdg; ±1 Digit	350mSec	32°-120°F	Raytek	PM30	6T102	1431.25	995.00	2.0
0° to 1800°F (−18° to 870°C)	8-14μ	1" @ 50 ft.	±0.5% of Rdg; ±1 Digit	350mSec	32°-120°F	Raytek Raytek	PM40 PM4-CF	6T103 3T337	1806.25 1868.75	1295.00 1495.00	2.0 2.0
0° to 1600°F (−18° to 870°C)	8-14μ	1" @ 50 ft.	±0.5% of Rdg; ±1 Digit	350mSec	32°-120°F	Raytek	PM50	3T335	1993.75	1595.00	2.0

OIL AND GAS BURNER COMBUSTION TEST KIT COMPONENTS

INDIVIDUAL COMBUSTION KIT COMPONENTS

In addition to serving as replacement items for components in the No. 6T149 Oil Combustion Test Kit and No. 6T150 Gas Combustion Burner Kit listed on page 777, these items can be used individually for a variety of industrial and residential applications. Key letters apply to items shown on this page and Bacharach kits listed on page 777.

A FIRE EFFICIENCY FINDER

A quick, uncomplicated means of determining combustion efficiency and stack loss from the results of the CO_2 and stack temperature test. Bacharach (10-5064).

No. 6T158. Shpg. wt. 0.3 lbs. List $13.27. Each $11.50

B SAMPLING HOSE ASSEMBLY

Means of extracting a gas sample from sampling location. Use with Bacharach CO_2 and O_2 Fyrite Gas Analyzers. 4 ft 6" long. Bacharach brand (11-7029).

No. 6T160. Shpg. wt. 1.0 lbs. List $49.74. Each $42.00

REPLACEMENT ASPIRATOR VALVE

No. 6T159. (11-0138). Shpg. wt. 0.1 lbs. List $7.12. Each $6.24

C MOISTURE ABSORBENT MATERIAL

Replacement filtering for Sampling Hose Assemblies. Each pkg includes ten 5 ft lengths. Bacharach brand (11-0121).

No. 6T148. Shpg. wt. 0.1 lbs. List $8.02. Each $6.99

D TEMPOINT THERMOMETER

Use to obtain accurate temperature of a boiler or furnace. Range: 200°F to 1000°F. Accuracy is within 10° at any point of indication. Sealed for dust and moisture protection. Bacharach brand (12-7014).

No. 6T162. Shpg. wt. 1.0 lbs. List $59.85. Each $51.00

E TRUE-SPOT SMOKE TESTER

3-component system (pump, scale and filter paper) provides accurate smoke reading in less than a minute. Determines efficiency combustion and evaluates smoke density in flue gases from distillate fuels. Bacharach brand.

COMPLETE KIT

No. 6T165. (21-7006). Shpg. wt. 1.0 lbs. List $93.60. Each $78.00

SPARE SCALE/FILTER PAPER KIT

Includes one replacement scale and 40 sheets of filter paper.

No. 6T161. (21-0020). Shpg. wt. 0.1 lbs. List $32.41. Each $28.00

SMOKE SCALE ONLY

No. 6T166. (21-0018). Shpg. wt. 0.1 lbs. List $23.61. Each $20.00

FILTER PAPER ONLY

No. 6T167. 40 Sheets (21-0019). Shpg. wt. 0.1 lbs. List $12.08. Each $10.51

F MZF DRAFT GAUGE

Highly sensitive instrument with remote sampling tube to measure draft in furnaces and boilers. Pointer's movement is directly proportional to magnitude of draft at test point. Range: +0.05 to 0 to 0.25" W.C. Bacharach (13-7019).

No. 6T164. Shpg. wt. 3.0 lbs. List $186.00. Each $155.00

G DRAFTRITE POCKET DRAFT GAUGE

Pinpoints draft trouble and indicates chimney defects. Easily held in one hand. Free-floating pointer indicates sudden changes from draft to pressure caused by "puffbacks." Range: +0.10 to -0.14" W.C. Bacharach brand (13-3000).

No. 6T163. Shpg. wt. 0.4 lbs. List $88.65. Each $74.00

H MONOXOR® CO DETECTOR

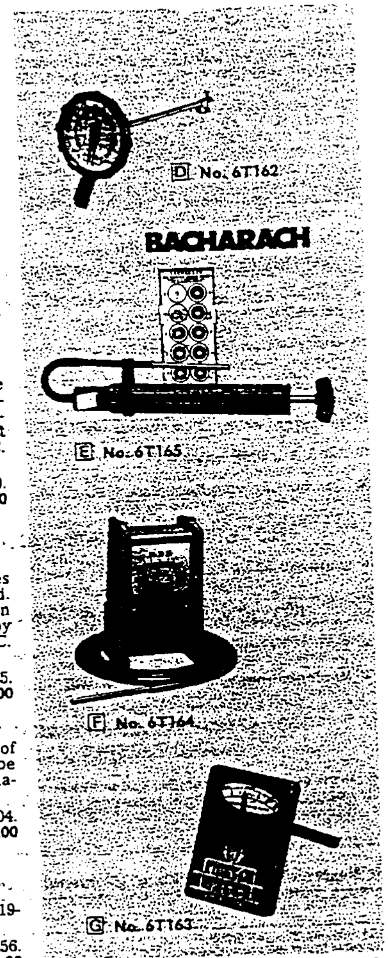
Measures and indicates concentration of CO in sample drawn into a stain tube based on number of pump strokes. Bacharach brand (19-7019).

No. 6T169. Shpg. wt. 1.0 lbs. List $162.04. Each $140.00

I MONOXOR® REPLACEMENT INDICATOR TUBES

Sold in pkgs of 12. Bacharach brand (19-5002).

No. 6T170. Shpg. wt. 0.2 lbs. List $48.56. Each $42.00



APPENDIX C

WATER MANAGEMENT AUDIT REPORT

WATER MANAGEMENT AUDIT REPORT

Plant Location:	Stillwater, OK 74075
County:	Payne
Principal Products:	Magazines and Flyers
Site Visit:	March 4, 1996
Report Date:	March 30, 1996

Faculty Advisor
Wayne C. Turner, Ph.D. PE, CEM, CHMM

Principal Author And Audit member
Puttaporn Pravalpruk

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1. Recover sewer charges loss on evaporated water 17
2. Replace existing shower heads with low-flow shower heads 20
3. Install air-fin cooling before cooling tower 24

EXECUTIVE SUMMARY

The water management recommendation opportunities (WMO's) contained in this report could save an estimated $20,327 each year or 72.3% of your annual water and sewer costs.

WATER
Water consumption for the twelve-month period of January 1995 to December 1995 consisted of 11,613 Mgl. Total water cost was $28,108.

The three WMOs contained in this report are summarized in Table 2.

SUMMARY OF WATER MANAGEMENT SURVEY DATA

Report No.:

Site Date:

PLANT DATA

SIC.No.:
Employees: 200
Location: Stillwater, OK 74107-9810
Products: Magazines, Commercial Printing
Plant Area: 330,000 sq.ft.

Annual Figures
Production: 457 million impressions/yr
Sales: $43 million /yr
Operat. hours: Plant 8,400 hours/year Office 2,600 hours/year

Table 1. WATER CONSUMPTION, WASTE VOLUME

January 1995 to December 1995

Water	11,613 Mgl/yr		$ 28,108

Table 2. SUMMARY OF WATER MANAGEMENT RECOMMENDATIONS

AR No.	DESCRIPTION	SOURCE	ANNUAL SAVINGS				INSTALLED COST ($)	PAYBACK PERIOD (yr)
			ENERGY		WATER			
			(MMBtu/yr)	($/yr)	(Mgal/yr)	($/yr)		
1	Recover sewer charges loss on evaporated water at cooling tower	Water			0	5,808	0	0.00
2	Replace existing shower heads with low-flow shower heads	Water	104	325	333	781	69	0.06
3	Install air-fin cooling before cooling tower	Water			5,856	13,738	100,000	7.28
	TOTAL		104	$ 325	6,189	$ 20,327	100,069	
	Conservation Potential(%)		0.1%	0.0%	53.3%	72.3%		

Cost of plant personnel time: 15 hr @ 50 $/hr = $750

TOTAL CONSERVATION POTENTIAL: $ 20,652 /yr

PLANT BACKGROUND[1]

This company, located in Stillwater, Oklahoma, prints color magazines and flyers. The company operates 8,400 hr/yr for the plant area and 2,600 hr/yr for the office area with 200 employees and produces over 457 million magazines, flyers and inserts each year. Annual sales are worth approximately $43 million.

PLANT DESCRIPTION

see Figure 1

The plant (330,000 ft^2) consists of:

- 30,000 ft^2 Office Area and Prep Area
- 300,000 ft^2 Plant Area
  - Paper Storage Warehouse
  - Baler Room
  - Printing Press Room
  - Maintenance Department and Break Room
  - Assembly/Inserter Machines and Trimming Area
  - Bindery
  - Storage Area east of Bindery

Except for the Paper Storage Warehouse, the entire plant is air-conditioned and heated. In 1992, an Energy Management System (EMS) was installed. The EMS was designed to demand-shed some machinery by duty-cycling some air handling units and air-compressors during peak periods. The EMS has the capability to control additional energy consuming equipment.

When the EMS was installed, a major lighting retrofit was also completed. Four-foot fluorescent fixtures with electronic ballasts and T10 lamps were installed for task lighting in the plant and offices. In offices with recessed fluorescent fixtures, reflectors were also installed. Ambient lighting in the plant is provided by a metal halide lighting system.

PROCESS DESCRIPTION

The process flow through the plant is generally from east to west. Five-foot diameter paper rolls are removed from rail cars and stacked in the paper storage warehouse. When needed, paper rolls are transported by fork lifts to the printing room and loaded on the printing presses. The paper is fed through the press and forms a continuous length of paper (web).

The press uses aluminum "press plates" to make impressions on the paper, one ink color at a time. Each press plate is wrapped around a cylinder that contacts part of the web. As the web travels through the press, the press plate imprints images on the paper with each cylinder rotation.

[1] From "Industrial Assessment Report" by Eric A. Woodroof

Each press plate is engraved with images of 4 to 16 magazine pages, side by side. (A more detailed description of how press plates are engraved with images is provided in the Press Plate Preparation Section). Because each press plate only contains 4 to 16 individual images (associated with the individual pages of a magazine) the plates must be exchanged to print all the pages in a magazine. After enough prints have been made from one press plate, the plates are exchanged until all individual pages for the entire magazine have been printed. The web is cut into pages, which are removed from the end of the press, collected and stored in the storage area, east of the Bindery. A sorting/inserting machine collates the pages and staples the booklets, if necessary. Excess paper is trimmed, and the trim waste is collected by a trim waste collection system. There is a bindery area of the plant where approximately 60% of all printed material is bound. The remaining 40% of printed material consists of flyers (unbound), which are inserted into newspapers or mailed directly to residences.

Mailing labels are often printed (with ink jet printers) onto magazines or flyers before stacking. Products being prepared for mail are presorted and sent directly to the post office. All finished products are stacked on pallets and shipped. Some products are packed in plastic, which is "shrink-wrapped" for protection. Typically, magazines are printed 10 days before their national release date.

Waste Streams

Several waste streams are produced during the cleaning process. While press plates are being exchanged, parts of the press are hand-cleaned with rags ("blankets") saturated with a cleaning solvent ("barsol"). The used rags are stored in a drain-able drum, and some of the used solvent ("press blanket wash") is collected for hazardous disposal.

Excess inks of all colors are blended and reused as black ink. However, occasionally some waste ink is unusable and must be collected for non-hazardous disposal.

Ink distribution lines and ink fountains periodically require cleaning with a solvent. This "fountain cleaning solution" is reused until spent and then collected for non-hazardous materials disposal.

Because inks and dirt frequently accumulate on the floor, a floor cleaner ("power plus") is used to remove stains. The power plus solution is applied and collected with mop water and then disposed of as hazardous waste.

The heads of ink jets are cleaned with a "video ink jet cleaner". When this solution is spent, it is collected for hazardous materials disposal.

This plant collects waste water from personnel hand washing in the machine shop. The "hand wash" waste is collected for disposal, however the concentration of hazardous materials is low enough such that this waste stream is not considered hazardous.

Press Plate Preparation
Each magazine company provides film negatives and proofs for each page of a magazine. The negatives are used to produce images on clear mylar sheets, which are the same size as actual magazine pages. The used negatives contain silver, which is recycled after the developing procedure. Several mylar sheets are laid side-by-side on a developing machine which imprints the images onto a 4 foot by 5 foot specially-coated aluminum plate (press plate). The plate is then bathed in several different solutions to "prep" it for the printing press. The objective of press plate preparation is to leave a copper engraving of the image on the aluminum plate. The following paragraphs describe the procedure to achieve this objective.

Originally, the plate is coated with layer of copper and a thin polymer surface layer. When images (on transparent mylar sheets) are laid on the plate and exposed to ultra-violet light, the light passes though the transparent portion of the images. The polymer that receives light becomes hard, covering and securing the copper to the aluminum. The unhardened polymer is washed off with an organic solvent (gamma-butyrolactone) solution at 72°F. The expended solvent is collected every three weeks and recycled to be used again in the final bath of each plate.

The plate is then bathed in Q-Etch 3000 (an acid solution). The Q-Etch removes all the unwanted copper (copper not secured with polymer). Immediately after the Q-Etch bath, the plate is pressed through two rollers to remove the Q-Etch. The Q-Etch is reused until spent. Spent Q-Etch with suspended copper is collected for hazardous disposal.

The plate then goes through an additional bath of recirculating rinse water to ensure that the Q-Etch is completely removed from the plate. The expended waste rinse water is also collected for hazardous disposal.

The final bath for the plate allows the hardened polymer to be removed. The organic solvent (gamma-butyrolactone) is heated to 135°F and sprayed on the plate. The heated solution removes the polymer from the copper on the plate. The gamma-butyrolactone solution is recycled. Every two months, the solution is considered "spent" and removed by an outside contractor for disposal. After the final bath, the plate is considered to be "engraved" (with the remaining copper) with images and ready to be used on the press.

All solutions in the prep process are collected by an outside contractor, which is the same contractor that supplies the press plates and fundamental materials needed for developing and processing all images in the prep area. The disposal costs of these waste streams are included in the contract price for supplying the materials to complete the press plate preparation.

PRINCIPAL PRODUCTS
Color magazines, mail flyers and newspaper inserts

RAW MATERIALS
Paper
Ink
Solvents
Aluminum Plates

PRIMARY ENERGY AND WATER CONSUMING EQUIPMENT

Electricity

Quantity	Description
5	1200 HP Main Printing Press Drives
1	500 Ton Chiller
1	350 Ton Chiller
2	300 Ton Chillers (on stand-by)
1	200 HP Air Compressor
	150 HP Air Compressor
8	27 kW Electric Resistance Heaters (for shrink-wrapping)
2	40 HP Motors for Trim Waste Collection System

The plant is illuminated by Metal Halide lamps and fluorescent task lights. There are numerous energy-efficient motors scattered throughout the plant.

Natural Gas

Quantity	Description
2	Natural Gas Fired boilers
10	Natural Gas-Fired Dryers (2 per Printing Press)

Waters

Quantity	Description
3	Cooling towers
7	Shower heads
1	Reverse osmosis system

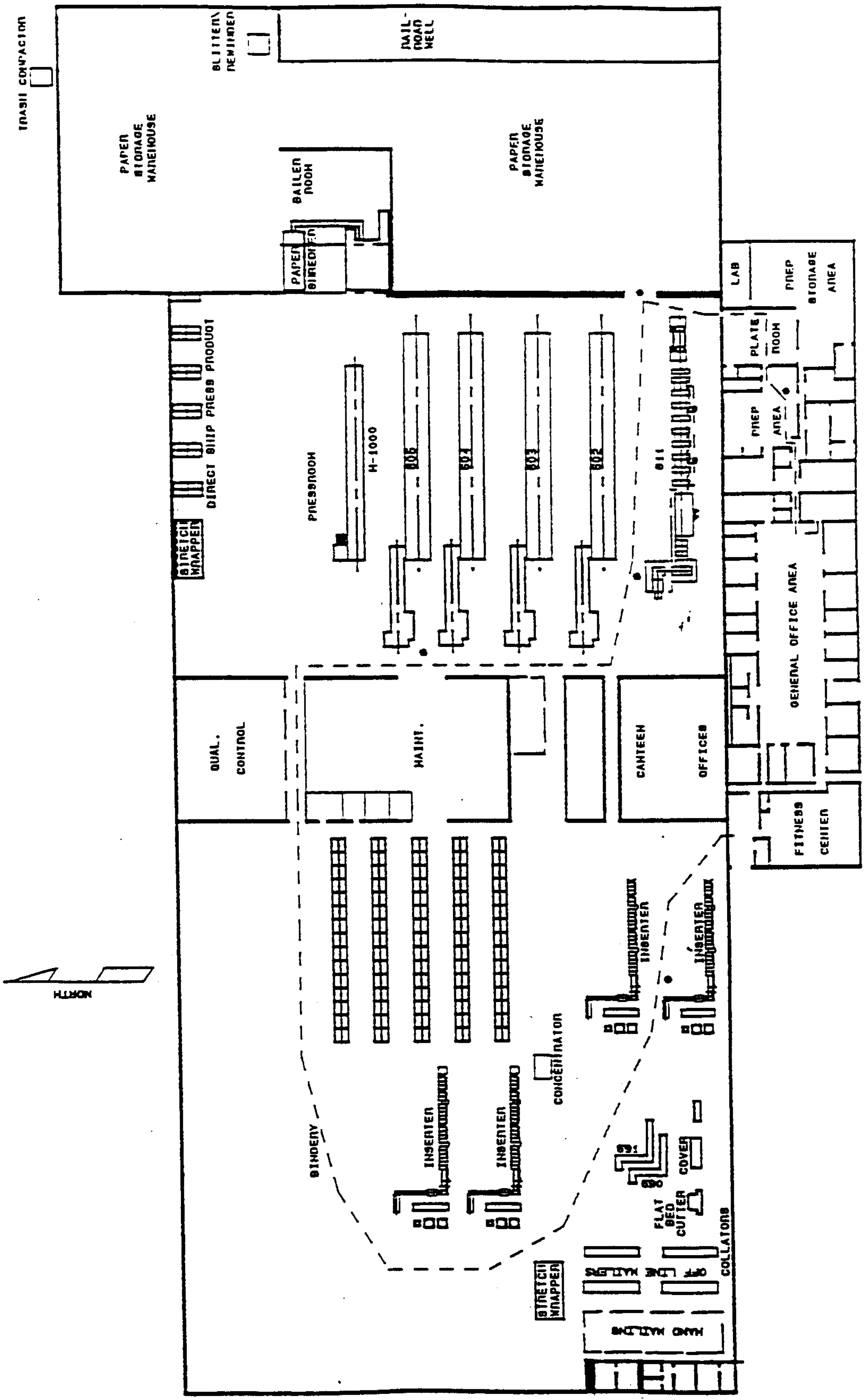


Figure 1. Plant Layout

UTILITY RATES

ELECTRICITY
Utility: City of Stillwater

kW Demand Charge: $ 6.12/kW month

kWh cost: $ 0.0432/kWh

Fuel Adjustment Credit: $-0.002225/kWh

NATURAL GAS
Rate: PGA Rate + Consumption-based Rate

PGA rate: $2.5249/MCF

Consumption-based Rate:	
First 3 Mcf per month	$ 2.40/Mcf
Next 7 Mcf per month	$ 2.10/Mcf
Next 40 Mcf per month	$ 1.80/Mcf
Next 50 Mcf per month	$ 1.55/Mcf
Next 100 Mcf per month	$ 1.45/Mcf
Next 300 Mcf per month	$ 1.105/Mcf
Next 7,500 Mcf per month	$ 0.645/Mcf
Remainder	$ 0.599/Mcf

WATER
Utility: City of Stillwater

Rate	
First 15,000 gallons per month	$ 2.25/1000 gallons
Next 285,000 gallons per month	$ 1.85/1000 gallons
Remainder	$ 1.65/1000 gallons

SEWER
Utility: City of Stillwater

The Sewer charge is based on water consumption. The rate is $0.696 per 1000 gallons of water.

Because this company's consumption usually exceeds 285,000 gallons per month, this report will use ($1.65) + ($0.696) = $2.346/Mgal for water and sewer savings calculations.

RESOURCE MANAGEMENT

The increasing cost of raw materials and the disposal of waste products have a significant impact upon most companies. Regulations and the reduction in the amount and types of waste that can be landfilled will further increase the impact of material management. Rising energy costs and repeated energy shortages also have a significant impact upon these companies. To meet this challenge, a successful company must have a resource management program to consistently take advantage of every conservation opportunity. Several basic steps are required for effective resource management:

- Management commitment
- Data analysis
- Goal setting
- Analysis of conservation opportunities
- Implementation of conservation techniques
- Continued feedback and analysis

The resource management program must have the commitment of management for it to produce a long-term increase in resource efficiency. A brief, early show of support will only result in small, temporary improvements. Management must design the conservation program as a part of its regular, overall company management system. Also, energy and resource costs and the consequences of future regulation and resource shortages should be widely disseminated to create an overall resource awareness. Information must be recorded at regular intervals to support the resource management program. Utility bills, disposal records, and production records may already contain much of the information required. These sources would be adequate to calculate overall energy and material costs and to determine production efficiency in terms of how much energy and/or material (raw and waste) is required to manufacture one unit of production. Allowances must be made in designing the information base to allow more detailed breakdown of energy consumption and waste generation as this information becomes available.

Data analysis of the energy portion of the program will be greatly aided if the records use a standard format for all the company's divisions and if the different energy units (such as kilowatt-hours of electricity, gallons of oil, etc.) are converted to a common energy unit, the British thermal unit (Btu). One Btu is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit. By comparing the cost of various fuels on the basis of cost per million Btu's ($/MMBtu), the true cost of each fuel can be determined. The conversion factors required are:

Energy unit	Btu conversion
1 kWh	3412 Btu

1 MCF of natural gas	1,000,000 Btu
1 cubic foot of natural gas	1000 Btu
1 gallon of no. 2 oil	140,000 Btu
1 gallon of no. 6 oil	152,000 Btu
1 gallon of propane	91,600 Btu
1 ton of coal	28,000,000 Btu
1 gallon of regular gas	130,000 Btu

On a regular basis, whether monthly or annually, progress towards conservation goals should be examined and a new set of goals be defined. All goal setting will depend on the opportunities for resource conservation which data analysis has uncovered. More detailed information on specific mechanisms may be required as the program continues to search for waste.

HISTORICAL WATER CONSUMPTION AND COST
(January 1995 to December 1995)

Table 4. WATER CONSUMPTION AND COST

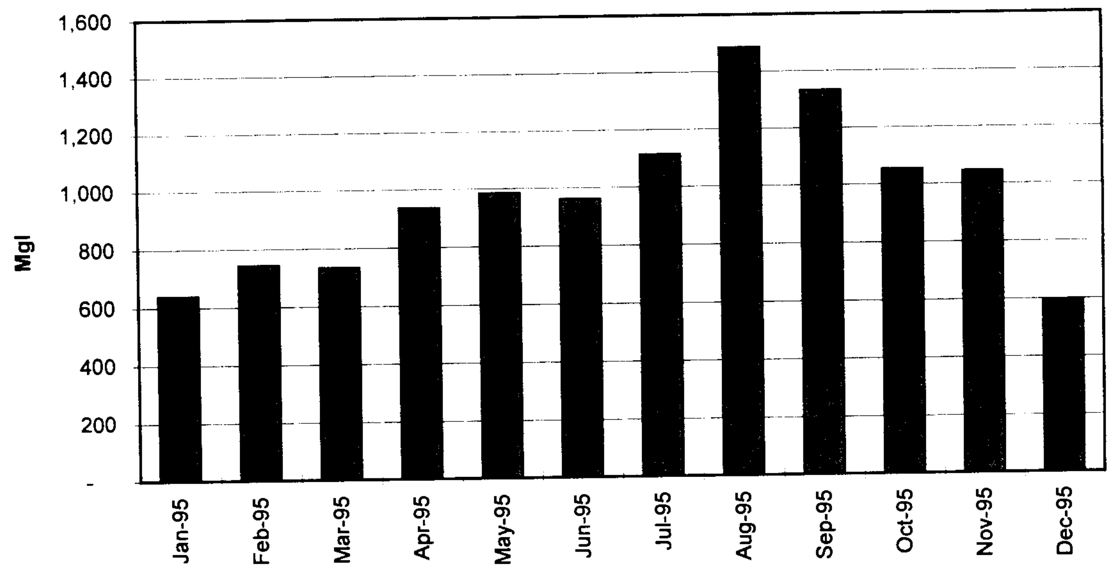
January 1995 to December 1995

	Consumption (Mgl)	Cost ($)		
		Water	Sewer	TOTAL
Jan-95	638	1,122	447	1,569
Feb-95	742	1,293	520	1,813
Mar-95	733	1,278	513	1,791
Apr-95	935	1,612	654	2,266
May-95	984	1,693	688	2,381
Jun-95	960	1,653	671	2,324
Jul-95	1,113	1,905	778	2,683
Aug-95	1,484	2,518	1,036	3,554
Sep-95	1,331	2,265	929	3,194
Oct-95	1,053	1,806	736	2,542
Nov-95	1,044	1,792	730	2,522
Dec-95	596	1,052	417	1,469
	11,613	$ 19,989	$ 8,119	$ 28,108

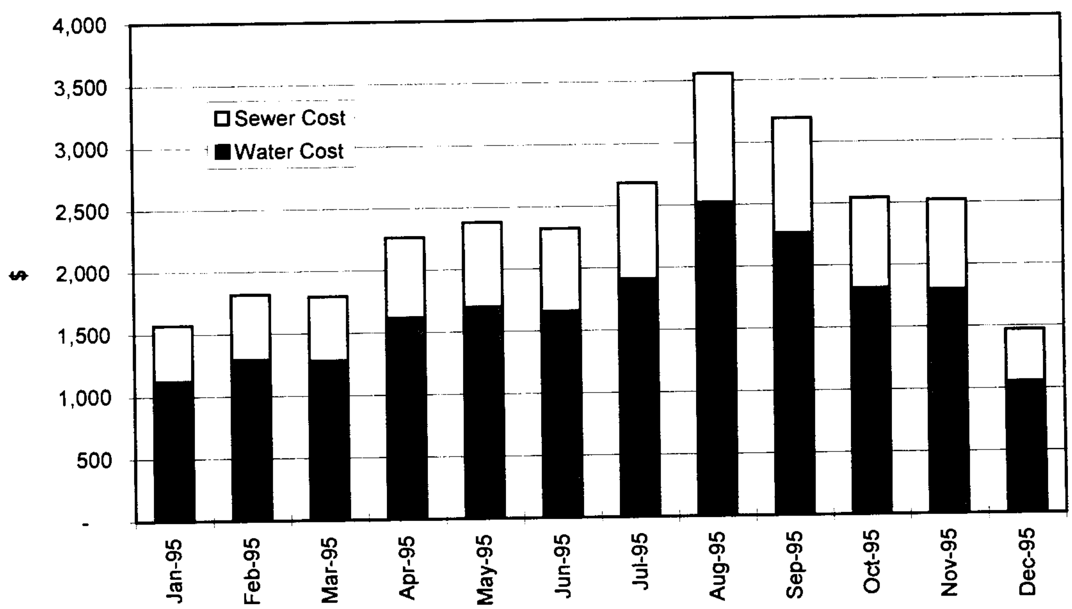
Average water cost: 2.420 $/Mgl

1 Mgl = 1000 gl

Water Consumption



Water Cost



WATER MANAGEMENT OPPORTUNITIES (WMO's)

WMO # 1
RECOVER SEWER CHARGES LOSS ON EVAPORATED WATER

RECOMMENDED ACTION

Presently, the plant pays sewer charges on total amount of water purchased from the city. However, a significant of water is evaporated at the cooling towers. The plant also recycles process water through reverse osmosis (RO). This water is not sent back to the sewer, so the sewer charges on evaporated water should not apply.

We recommend the company call the city and ask for reduction of sewer charge on the amount of water evaporated.

SUMMARY

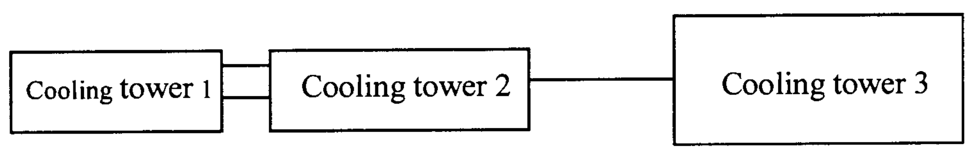
If this WMO is implemented, you will obtain:

- Water savings: none
- Approximate savings: $5808/yr
- Implementation cost: $0
- Payback: Immediately

DATA

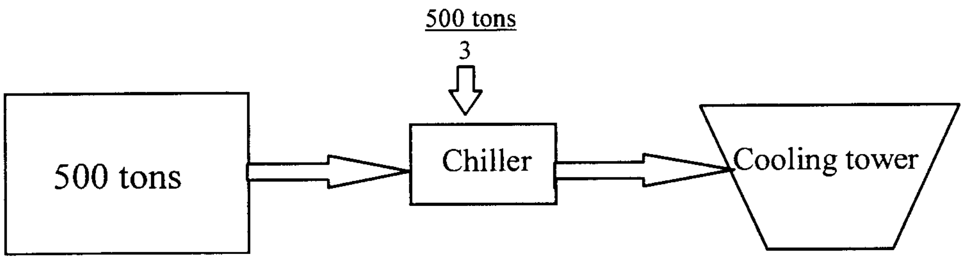
* Annual operational hours .... 8,400 hours/year
* Sewer cost .... $ 0.696/Mgal
* Cooling tower water consumption (from the plant's record) ... 635,640 gal/mo.
* Reverse osmosis water (from the plant's record) .... 59,718 gal/mo.

The plant has three cooling towers, the first two are attached together and the third one stands alone (see figure). Cooling tower 1 and 2 are connected to 350 ton and 300 ton (stand-by) chillers. Cooling tower 3 is connected to 500 ton chiller. The major water consumer is cooling tower 3.



CALCULATIONS

Estimation of water evaporated
If cooling load for chiller is 500 tons/hour:



At 60°F, enthalpy of evaporation (H_{fg}) of water is 1,060 BTU/lb_m. We will assume 1,000 BTU/lb_m to be conservative. Operating hours is 8,400 hours/yr or 700 hours/month

Cooling tower load
= (tons of refrigeration load) + (tons of refrigeration load/$COP_{chiller}$)[2]
= (500 tons) + (500 tons/3)
= 667 tons

Amount of water evaporated
= (cooling tower load)(operating hours)(conversion faction)(enthalpy of evaporation)
= (667 tons)(700 hours/month)(12,000 BTU/hr ton)(1 lb H_2O/1,000 BTU)
= 5.6×10^6 lb H_2O/month

Gallons of water evaporated
= (amount of water evaporated)(conversion factor)
= (5.6×10^6 lb H_2O/month)(1gal/8.34 lb H_2O)
= 671,463 gallons/month

The calculation shows 671,463 gallons of water evaporated per month, but the plant's study shows 635,640 gallons. We will use 635,640 gallons per month for the calculation to be conservative.

Dollar savings
= [(gal of water evaporated/month)+(gal of RO water/month)](sewer charge)
= [(635,640 gal/month)+(59,718 gal/month)]($0.696/1,000gal)
= $ 484/month
= ($484/month)(12 months/year)
= $5,808/year

[2] Energy consumed by the chiller

Implementation cost
= $ 0

Payback period
Immediately

WMO # 2
REPLACE EXISTING SHOWER HEADS WITH LOW-FLOW SHOWER HEADS

RECOMMENDED ACTION
Presently, shower heads in the washing area deliver 4.4 gallons of water per minute (gpm). New shower head can deliver as low as 1.8 gallons of water per minute. A test was conducted at Oklahoma State University dormitories on six different brands and models of low-flow shower heads. A number of factors were looked at to include flow rate, water pressure, type of spray, ease of vandalism, and durability of the fixture. The fixture that proved the best in each category is the 3085M (see attached product literature). The flow rate for this shower head is 2.05 gpm. The fixture is solid brass, chrome plated, and durable and emitted a strong, misting spray. The existing shower heads flow rate used is from the study at Oklahoma State University.

We recommend replacing the existing shower heads with low-flow shower heads. The cost of the fixture is $4.85 per fixture and estimated labor cost is $20 per hour.

SUMMARY
If this WMO is implemented, you will obtain:

• Water savings:	333 Mgal/yr
• Approximate savings:	$1106.11/yr
• Implementation cost:	$68.95
• Payback:	0.06 year

DATA
* Number of fixtures .... 7 fixtures
* Estimated shower length per employee.. .15 minutes[3]
* Showers per employee per day .... 1 shower
* Number of employees shower .... 25[4]
* Estimated shower water temperature .... 105°F
* City water temperature .... 70°F
* Water heater efficiency 80%
* Energy cost $3.124/MCF
* Water cost $2.346/Mgal
* Estimated retrofit labor time per shower head .... 0.25 hour/fixture
* Estimated labor cost $20/hour

---
[3] From study at Oklahoma State University
[4] Estimated by facility engineer at the plant

Existing fixture data

* Flow rate .... 4.4 gpm

Proposed fixture data

* Flow rate .... 2.05 gpm
* Fixture cost $4.85/fixture

CALCULATIONS

Existing annual water consumption

= (present water flow rate/minute)(shower length/employee)(# of employee/day)
(days/year)
= (4.4 gpm)(15 minutes/employee)(25 employees/day)(365 days/year)
= 602,250 gallons/year

Proposed annual water consumption

= (proposed fixture flow rate/minute)(shower length/employee)(# of employee/day)
(days/year)
= (2.05 gpm)(15 minutes/employee)(25 employee/day)(350 days/year)
= 269,062 gallons/year

Annual water saved

= (existing annual water consumption) - (proposed annual water consumption)
= 602,250 gallons/year - 269,062 gallons/year
= 333,188 gallons/year
= 333 Mgal/year

Annual energy saved

= (annual water saved)(specific heat of water)(Δt)(1/heater efficiency)(conversion factor)
= (333×10^3 gallons/year)(1 BTU/lb·°F)(100°F -70°F)(1/0.8)(8.33 lb/gal)
= (104×10^6 MMBTU/yr) (1 MCF/MMBTU)
= 104 MCF/year

Annual dollar saved

= (annual water saved)(water cost) + (annual energy saved)(energy cost)
= (333 Mgal/year)($2.346/Mgal) + (104 MCF/year)($3.124/MCF)
= $1106.11/year

Implementation cost per fixture

= (cost/fixture) + (retrofit labor cost/hour)(retrofit labor time/fixture)
= ($4.85/fixture) + ($20/hour)(0.25 hour/fixture)
= $9.85/fixture

Total implementation cost
= (implementation cost/fixture)(# of fixtures)
= ($9.85/fixture)(7 fixtures)
= $68.95

Simple payback
= (total implementation cost)/(annual dollar savings)
= $68.95/$1106.11
= 0.06 years

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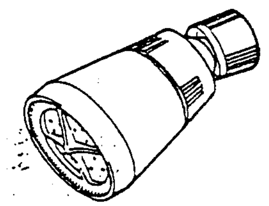
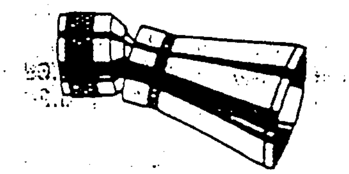
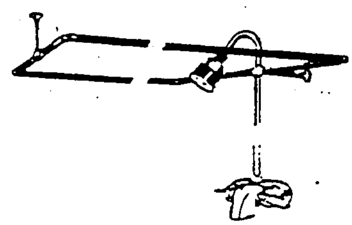
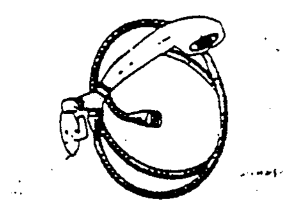
		DESCRIPTION	STD. CTN.	LIST PRICE
		**SHOWER HEAD** 1/2" FIPT METAL Adjustable and removable face, ball-socket type with 1/2" fipt connection. Polished chrome-plated finish. 2.75 G.P.M.	STD. PKG. 12	6.00
	3085	**SHOWER HEAD** 1/2" FIPT Triple vacuum plated, durable. Adjustable nylon face, ball-socket type with 1/2" fipt connection. Polished chrome-plated finish 2.75 G.P.M.	STD. PKG. 24	
	3085M	**SHOWER HEAD** 1/2" FIPT All Brass Chrome Plated 1.8 G.P.M. Flow Rate at 40 P.S.I.	STD. PKG. 12	4.85
	3086	**ADD A SHOWER** With Shower Ring For Leg Tub	STD. PKG. 1	
	3088	**HAND HELD FLEXIBLE SHOWER** Compete with wall bracket with 90° vertical adjustment, 59" flexible metal covered hose with gaskets & nuts. Metal parts polished chrome-plate finish.	STD. PKG. 1	

WMO # 3
INSTALL AIR-FIN COOLING BEFORE COOLING TOWER

RECOMMENDED ACTION

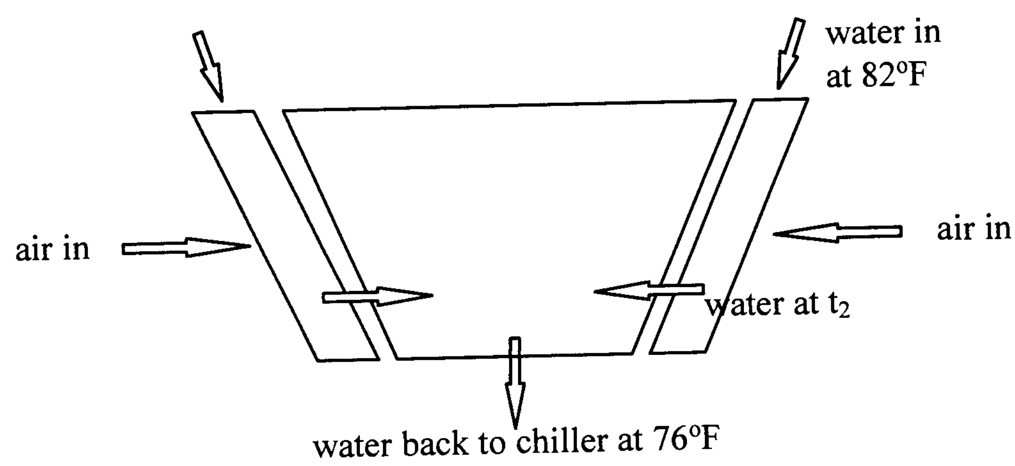
Presently, evaporative cooling (cooling tower) loses approximately 670,000 gallons of water per month (see WMO # 1). By installing dry cooling (air-fin), a significant of water can be saved. For each 1,000 BTU of water pulled from cooling tower, one pound of water will be saved (H_{fg} of water@60°F = 1060 BTU/lb H_2O).

Approach temperature for air-fin cooling 7°F from dry-bulb temperature[5]. Thus, in summer air-fin cooling cannot be used. If we set a controller to start air-fin cooling at air temperature of 74°F or lower.

At range 70°F to 74°F(average 72°F), approach temperature of water coming out of cooling tower will be 79°F.

At temperature lower than 69°F, approach temperature will be low enough to shut the cooling towers (t_2 is 76°F or lower).

Air-fin cooling should be install before cooling tower (see figure). The calculation will show the amount of water which can be saved by adding dry cooling. To be conservative, we will use H_{fg} = 1,000 BTU/lb in the calculation.



[5] From cooling tower manufacturer

SUMMARY

If this WMO is implemented, you will obtain:

- Water savings: 5,856 Mgal/yr
- Approximate savings: $13,738/yr
- Implementation cost: $100,000
- Payback: 7.28 year

DATA

* Cooling load ....667 tons[6]
* Water temperature from chiller (t_1) ....82°F[7]
* Water temperature back to chiller (t_3)..................................76°F[8]
* Proposed water temperature (t_2) at air temp. 70-74°F......... .79°F
* Proposed water temperature (t_2) at air temp. lower than 70°F .76°F
* Proposed air-fin cooling system cost.................................. $100,000[9]
* Annual cooling hours for air temp 70-74°F .... 948 hours[10]
* Annual cooling hours for air temp lower than 70°F............. 5,628 hours[11]

CALCULATIONS

Cooling tower water flow rate

= (cooling load)(1/t_1 - t_3)(conversion factor)
= (667 tons)(1/(82°F-76°F))(1 hr/60 min)(1 gal/8.34 lb)(lb·°F/BTU)(12,000 BTU/ton·hr)
= 2,666 gal/min

BTU savings after installing air-fin cooling (at air temperature 70-74°F)

= (flow rate)(t_1 - t_2)(conversion factor)
= (2,666 gal/min)(82°F - 79°F)(60 min/hr)(8.34 lb/gal)(1 BTU/ lb·°F)
= 4,002,200 BTU/hr

Water savings (at air temperature 70-74°F)

= (BTU savings)/(H_{fg})
= (4,002,200 BTU/hr)/(1,000 BTU/lb H_2O)
= 4,002 lb H_2O/hr

Annual water savings (at air temperature 70-74°F)

= (water savings)(annual operating hours)(conversion factor)
= (4,002 lb/hr)(948 hr/yr)(1 gal/8.34 lb)
= 455 Mgal/yr

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[6] From calculation in WMO#1
[7] From the plant's record
[8] From the plant's record
[9] Estimated by cooling tower manufacturer (the estimated price is $90,000 to $110,000)
[10] From bin data (see attatch bin data)
[11] From bin data (see attatch bin data)

BTU savings after installing air-fin cooling (at air temperature lower than 70°F)[12]
= (flow rate)(t_1 - t_2)(conversion factor)
= (2,666 gal/min)(82°F - 76°F)(60 min/hr)(8.34 lb/gal)(1 BTU/ lb·°F)
= 8,004,400 BTU/hr

Water savings (at air temperature lower than 70°F)
= (BTU savings)/(H_{fg})
= (8,004,400 BTU/hr)/(1,000 BTU/lb H_2O)
= 8004 lb H_2O/hr

Annual water savings (at air temperature lower than 70°F)
= (water savings)(annual operating hours)(conversion factor)
= (8004 lb/hr)(5,628 hr/yr)(1 gal/8.34 lb)
= 5,401 Mgal/yr

Total annual water saving
= annual water savings at air temp.70-74°F + annual water savings at air temp. lower
than 70°F
= 455 Mgal/yr + 5,401 Mgal/yr
= 5,856 Mgal/yr

Total annual cooling tower water consumption before install air-fin cooling
= (monthly cooling tower water consumption)[13](conversion factor)
= (635,640 gal/month)(12 month/yr)
= 7,628 Mgal/yr

Total annual cooling tower water consumption after install air-fin cooling
= (cooling tower consumption before install air-fin cooling) - (total annual water saving)
= 7,628 Mgal/yr - 5,856 Mgal/yr
= 1,772 Mgal/yr

Annual Dollar Savings
= (annual water savings)(water cost)
= (5,856 Mgal/yr)($2.346/Mgal)
= $13,738/year

Implementation Costs
= Installed cost of air-fin cooling system
= $100,000

Payback
= (Implementation Cost)/(Annual Dollar Savings)
= ($100,000)/($13,738/yr)
= 7.28 years

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[12] At air temperature below 70°F, the air-fin cooling can do all the cooling load.
[13] From the plant's study

These large savings occur because of process load during many hours when air temperature alone can do the necessary cooling. However, we find an effectiveness multiplier might be more realistic.

Please note, there will be energy savings because the cooling tower fans will not run nearly as much. These savings are ignored. Thus, the actual pay back is quicker.

TINKER AFB/OKLAHOMA CITY OKLAHOMA

LAT 35 25N LONG 97 23W ELEV 1291 FT

MEAN FREQUENCY OF OCCURRENCE OF DRY BULB TEMPERATURE (DEGREES F) WITH MEAN COINCIDENT WET BULB TEMPERATURE (DEGREES F) FOR EACH DRY BULB TEMPERATURE RANGE

Tempera-ture Range	MAY Obsn Hour Gp			MAY Total Obsn	MAY MCWB	JUNE Obsn Hour Gp			JUNE Total Obsn	JUNE MCWB	JULY Obsn Hour Gp			JULY Total Obsn	JULY MCWB
	01 to 08	09 to 16	17 to 24			01 to 08	09 to 16	17 to 24			01 to 08	09 to 16	17 to 24		
105/109												0		0	72
100/104							0		0	72		7	2	9	73
95/99		0		0	72		3	1	4	74		36	15	51	74
90/94		3	1	4	72		30	12	42	74		59	32	91	74
85/89		21	7	28	70		57	31	88	73	3	53	47	103	73
80/84	0	46	25	71	68	7	63	57	127	71	30	44	68	142	71
75/79	5	54	45	104	66	43	42	66	151	69	95	30	46	171	70
70/74	38	49	57	144	64	91	23	42	156	67	81	14	28	123	68
65/69	66	32	50	148	61	64	14	20	98	63	31	3	8	42	64
60/64	60	22	33	115	57	25	6	8	39	59	6	1	1	8	59
55/59	40	14	20	74	53	9	1	2	12	54	1		0	1	55
50/54	24	5	8	37	48	1	0	0	1	50	0			0	51
45/49	11	1	2	14	44										
40/44	3	0	0	3	40										
35/39	0			0	35										
30/34															
25/29															

Tempera-ture Range	AUGUST Obsn Hour Gp			AUGUST Total Obsn	AUGUST MCWB	SEPTEMBER Obsn Hour Gp			SEPTEMBER Total Obsn	SEPTEMBER MCWB	OCTOBER Obsn Hour Gp			OCTOBER Total Obsn	OCTOBER MCWB
	01 to 08	09 to 16	17 to 24			01 to 08	09 to 16	17 to 24			01 to 08	09 to 16	17 to 24		
105/109		1	0	1	73										
100/104		6	2	8	74		1	0	1	75					
95/99		23	9	32	73		6	1	7	73		0		0	61
90/94		50	24	74	73		19	6	25	72		3	0	3	64
85/89	1	63	42	106	72		33	16	49	71		9	2	11	67
80/84	17	49	64	130	70	3	43	31	77	69		23	7	30	66
75/79	72	33	59	164	69	23	49	51	123	67	0	32	17	49	64
70/74	99	16	37	152	67	57	39	49	145	65	10	38	36	84	62
65/69	46	4	10	60	63	56	24	42	122	62	32	42	41	115	59
60/64	11	1	1	13	58	52	16	28	96	58	43	39	46	128	55
55/59	3	0	0	3	56	32	7	10	49	53	43	32	45	120	51
50/54						11	3	5	19	49	53	17	29	99	47
45/49						4	0	0	4	45	37	8	17	62	43
40/44						1			1	41	21	4	6	31	39
35/39											7	1	1	9	35
30/34											1	0	1	2	30
25/29											1			1	26

VITA

Puttaporn Pravalpruk

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT AND VALIDATION OF WATER MANAGEMENT AUDIT PROCEDURE

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