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DISTRICT COOLING ENGINEERING & DESIGN PROGRAM

Final Technical Report

March 1994

Energy / Facilities Management Division
Public Works Department
Federal Project No. DE-FG01-91CE26617

Prepared for:
U.S. Department of Energy
Washington, D.C. 20585

City of Phoenix

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March 1994

DISTRICT COOLING ENGINEERING & DESIGN PROGRAM

**U.S. Department of Energy
Office of Procurement Operation
Washington, D.C.**

Federal Project No. DE-FG01-91CE26617

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City of Phoenix

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Conducted by

**Energy \ Facilities Management
Public Works Department
Phoenix, Arizona**

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ACKNOWLEDGEMENTS

The originator of the project was Darshan Teji P.E., Energy Conservation Administrator for the City of Phoenix (retired). The project was completed under Bill Murphy P.E., Energy / Facilities Management Administrator for the City of Phoenix and Dimitrios Laloudakis, Energy Management Superintendent for the City of Phoenix. Energy / Facilities Management staff worked with Bridgers & Paxton, Consulting Engineers, in reviewing and making recommendations on the District Cooling System design. M. "Chip" Rabinowitz P.E., Energy Management Engineer for the City of Phoenix prepared this technical report. System evaluations and energy usage projections were performed by Bridgers and Paxton Consulting Engineers, Phoenix.

Thanks for approving and funding this innovative cooling system go to the administrators of the City of Phoenix and City Council. Special thanks go to the U.S. Department of Energy for providing the grant which made this project possible.

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CHAPTER 1 - OVERVIEW

ABSTRACT

Phoenix, Arizona is located in the Sonoran desert. Daytime temperatures typically rise to over 100°F during the three summer months. Average and peak temperatures have tended to rise over recent decades. This is generally attributed to what is known as the "heat island effect", due to an increase in heat absorbing concrete and a decrease in irrigated farmland in the area.

Phoenix is the eighth largest city in the United States with a population of just over one million (1,000,000). The metropolitan area is one of the fastest growing in the nation. Over the last ten years its population increased by over 40%. It is not an exaggeration to say the general availability of refrigerated air conditioning, both for buildings and automobiles has been an important factor enabling growth.

The cost of operating public buildings has risen significantly in the last decade. In fiscal year 92/93 the City of Phoenix had energy expenses of over thirty four million dollars (\$34,000,000). Because the City was planning a major new construction project, a new high-rise City Hall, it was decided to study and then optimize the design and selection of building systems to minimize long term owning and operating costs.

The City Hall was to be constructed in downtown Phoenix. Phoenix presently owns other buildings in the area. A number of large cooling systems serving groups of buildings are currently operating in the Phoenix area. The City requested that the design consultants analyze the available options and present recommendations to the City's engineering staff.

PROJECT PURPOSE

The purpose of this project was to evaluate the cooling options available for the new City Hall, and other City owned buildings in the vicinity. Decisions needed to be made regarding overall mechanical systems planning for a number of buildings.

Rather than being merely a study, the City Hall project architect and his sub-consultants needed direction from the City regarding the type of mechanical systems the City preferred. The Department of Energy awarded the City of Phoenix Public Works Department an \$80,000 grant to assist in carrying out the engineering study and design process. City engineers coordinated with the consultants in analyzing alternatives and providing direction.

Because the overall goal was to construct a large building provided with "state of the art" systems, actual construction documents (plans and specifications) were prepared.

The purpose of this report is to provide information to the Department of Energy and other government jurisdictions regarding our experience with the design of a large chilled water district cooling system. The analysis, tables, and samples of computer outputs are provided to enable the reader to understand the type of work required to analyze the economics of the alternatives.

The requirements and specific factors for each project are such that it would be improper to generalize decisions reached for this project to other projects. Each project must be individually analyzed. Among the factors influencing the economics of a project are land costs, existing building systems (if any), utility rate structures and rebate programs, facility usage schedules, and local climate.

REPORT ORGANIZATION

Four main chapters and four appendices comprise this report. The major sections are organized as follows:

Chapter 1 -- an abstract and overview of the document.

Chapter 2 -- the technical background on chilled water systems, district cooling systems, and thermal storage systems which will allow the reader to understand the terminology and concepts presented in the text.

Chapter 3 -- a description of the funded project including it's history, Department of Energy goals, overall project organization, the alternatives investigated, and conclusions reached regarding the optimal configuration for the actual system design.

Chapter 4 -- a description of the overall project, as it was designed and constructed, with particular focus on the district cooling system and its associated central chilled water plant.

Appendix A -- lists of equipment for alternative system configurations.

Appendix B -- tables summarizing the energy usage and economics of the system alternatives.

Appendix C -- computer outputs of projected energy usage and energy costs for the alternative systems.

Appendix D -- a detailed list of references.

CHAPTER 2 - TECHNICAL BACKGROUND

INTRODUCTION

This chapter is intended to provide enough background information for understanding the basic terminology, theory, and practices in the design and construction of chilled water air conditioning systems. A basic knowledge of chilled water systems is necessary to understand the more complex variations, such as district cooling and thermal storage. It is not intended to make the reader an expert in any of these areas.

If more information is required than is presented here, refer to Appendix D, References, which lists books, manuals, and references for further study. This chapter begins with a list of definitions covering most of the technical terms used in the report.

DEFINITION OF TECHNICAL TERMS

Absorption Chiller: A refrigeration machine, used to chill water, that uses heat as its driving energy source. These machines do not utilize CFCs.

Air Handler: A unit comprised of coils, a fan, and associated controls used to cool or heat air. Air handlers are similar to fan coil units but much larger. A single air handler may serve an entire building or multiple air handlers may be utilized.

Base Load Demand: Base load demand is the power required to maintain building operation when no cooling or heating is required.

Base Energy Load: The base energy load is the kWh per month used by the building excluding the energy used for heating or cooling.

Centrifugal Chiller: A refrigeration machine, used to chill water, that uses a rotating impeller to compress refrigerant gas. The energy to rotate the impeller is most commonly provided by an electric motor.

CFC: A chlorofluorocarbon refrigerant. These refrigerants are harmful to the ozone layer and are being phased out.

Cogeneration: The simultaneous production of electrical or mechanical energy and useful thermal energy from a single energy source.

Condensing Water System: The heat rejection side of a chilled water system, usually composed of the chiller condenser tubes, condenser water pumps, cooling towers, and associated piping.

Cooling Tower: A piece of mechanical equipment used as a heat rejection device. Most commonly, ambient air is blown across sprayed water to cool it.

Conventional Rate: On a conventional utility rate there are no defined on-peak hours. Peak demand can occur at any hour and the cost of each kWh is fixed for all hours of the day.

Demand: The rate at which electric energy is delivered at a given instant, or averaged over any designated period of time, usually fifteen minutes to one hour. Annual demand is the greatest of all demands which occurred in a calendar year. Billing demand is the demand upon which billing to a customer is based, as specified in a rate schedule or contract. It may be based on the contract year, a contract minimum, or a previous maximum. It may not necessarily be equal to the demand actually measured during the billing period.

District Cooling System: A cooling system serving two or more buildings located in proximity to each other. In this type of system, a central plant supplies chilled water to the various buildings through a network of underground pipes.

Diversity: The phenomenon of different buildings or parts of a single building experiencing peak cooling loads at different times. This allows for a reduction in central plant capacity.

Energy: Energy is the amount of power consumed over a period of time. It is measured in kilowatt-hours (kWh).

Energy Management System: An integrated control system that allows the optimization of the entire system, as well as standard HVAC control functions. Modern systems are digitally based.

Fan Coil Unit: A small air handler used to cool air to be supplied to a room. Units typically have a fan, chilled water coil, and various accessories.

Full Storage: Full storage is a term used with thermal storage systems. In such a system all the energy required to heat or cool a building during the utility on-peak hours is used during off-peak hours and stored.

Load Factor: The ratio of the average load supplied or required during a designated period, to the peak or maximum load occurring in that period. The abbreviation of load factor is lf.

Partial Storage: An arrangement whereby the energy storage capacity of the thermal storage tank, is not sufficient to cover the total energy needs of the facility during on-peak hours. The capacity is sufficient to cover on-peak needs, provided the chiller runs at constant load, 24 hours per day. Partial storage requires less equipment capacity than the other storage options and usually results in the fastest payback on investment.

Payback: The incremental cost of a system enhancement divided by the yearly energy cost savings. Payback is measured in years.

Power: The time rate at which energy is produced or used, usually expressed in kilowatts (kw). Apparent power is the quality of power proportional to the mathematical product of the volts and amperes. This product is generally designated in kilovolt-amperes (kva) and is comprised of both real and reactive power. Reactive power is the portion of "apparent power" such as the magnetizing power, that does not do work. It is commercially measured in kilovars (kvar). It is the rate of power supplied or energy, measured commercially in kilowatts.

Power Factor: Power factor (pf) is the ratio of real power measured, in kilowatts, to apparent power measured in kilovolt-amperes.

PVC: Polyvinyl chloride. A plastic used for making pipes.

Ratchet: Ratchet demand (kw) is equal to a specified percentage of the highest actual demand during the ratchet period. Most utilities will show both the actual measured demand and the ratchet demand on the billing.

Time-of-Use Rates: In time-of-use rates the utility company defines a time period during which building peak demand is measured for billing purposes. This is called the on-peak period. All other hours of the day are considered off-peak. KWh charges may also differ between on-peak and off-peak periods.

Thermal Storage Media: A thermal storage system requires a medium to hold heating or cooling capacity for later use. The most common media are water, the freezing and thawing of ice, and specialized phase change media.

Variable Frequency Drive: An electronic device that varies the speed of the driven motor by varying the frequency of the supply voltage.

HYDRONIC SYSTEM BASICS

Introduction

Hydronic systems utilize water as the basic heat transfer medium. Both heating (hot water) and cooling (chilled water) systems are in common usage. Hydronic systems have many advantages over all air systems. Water has a higher specific heat (1 btu/lb-°F) than air. Therefore a greater amount of energy can be transferred from one location to another in a smaller conduit. For example the pipe necessary to transfer 100,000 btuh will be several times smaller in cross sectional area, than an air duct transferring the same amount of energy. Because water is incompressible, variations in density, as occur in large all air systems, do not occur.

The basic principle of hydronic systems is that heating or cooling energy is developed at one location and used to heat or cool water. Pumps move the water to terminal units, air handlers, or fan coil units where it passes through coils over which air is moved by fans.

Very sophisticated hydronic systems have been developed since 1940. These systems typically utilize multiple pumps. Certain equipment operates best with constant water flow. Other portions of systems require variable flow. Flow reductions enable closer control of environmental conditions and reductions in energy usage.

Design Temperature Difference

In hydronic heating or cooling systems, energy transferred may be calculated by the formula:

$$\text{Tons} = \frac{\text{gpm} \times (t_2 - t_1)}{24}$$

The greater the temperature difference, the greater the amount of energy transferred for a given flow rate (gpm).

Traditionally hot water heating systems have been designed based on a 20°F temperature drop, while chilled water systems have been designed for a 10°F temperature rise. The implication is that twice as great a flow rate is normally required to transfer a given amount of energy in a cooling system as in a heating system.

The justification for the 10°F chilled water design standard is based on practical experience. Technical issues involve temperature differences between the entering chilled water temperature versus the entering air temperature at air handler coils, and the difficulties involved in balancing the system to ensure "design flow rates" are available at all coils. Even so, hot water systems are normally quite forgiving of low flows, whereas low flows at chilled water coils often result in inadequate cooling of the supply air.

As a result of the sensitivity of chilled water systems to low flow, the 10°F rise became the normal design standard. Comparing a 20° design with a 10° design, the following conclusions result: The 10° design will utilize larger pipes, require twice as great pump motor horse-power, and use twice as much electrical energy to run the pump.

DISTRICT COOLING SYSTEM BASICS

Introduction

A district cooling system (DCS) is defined as a chilled water system serving more than one building. The equipment generating the cooling is located at one central location, the central plant. Pumps distribute the water through piping systems to two or more buildings. Individual buildings utilize the chilled water to cool supply air for the building.

History of District Cooling Systems

Approximately forty years ago, many colleges and universities began to plan district cooling systems served by central chilled water plants. These institutions were interested in long term planning to optimize the economics of owning and operating systems to cool numerous buildings. Some local examples of large successful DCS systems are Arizona State University Main Campus (12,000 tons chiller capacity), Arizona State University West Campus planned for 4,000 tons, a central plant serving the Arizona State Capitol Buildings, and most of the large shopping malls in the Phoenix, Arizona metropolitan area.

Some of the reasons for the trend towards large central plants serving a number of buildings are as follows:

1. The initial equipment cost (per ton of capacity) is much less for larger equipment, used in DCS, than for smaller equipment used for individual buildings.
2. Larger equipment, in general, is more reliable and maintenance costs (per ton) are lower than for small equipment.

3. A DCS may be designed to take advantage of load diversity. Diversity is when different buildings experience their peak cooling loads at varying times.
4. A DCS may be designed with a degree of redundancy (standby equipment) that would be unacceptably costly to implement in multiple individual building systems.
5. The total operating and maintenance cost of chillers and cooling towers, water treatment, is considerably less when they are located at one location, compared to at several locations.
6. The amount of building space dedicated to chiller plant equipment is less with a central plant than the total space required for individual building plants.
7. The unit cooling cost (cost per ton-hr) of cooling is usually less for a central plant than for individual buildings. The reasons are as follows:
 - A. The larger equipment is usually more efficient and thus requires less power (kw/ton).
 - B. The central plant will have a larger electrical service and may qualify for a more favorable electrical rate, depending on the local utility.
8. Noise and vibration problems associated with individual chillers and cooling towers are eliminated.
9. The architectural problems of dealing with cooling towers (noise, esthetics, and outside air access) are easier to solve at one location than at several locations.

The above advantages must be weighed against the disadvantages of extending chilled water piping under public streets and the risk of having major equipment concentrated at one location (World Trade Center Syndrome).

Operating (Manpower) and Maintenance Costs

The cost of operating and maintaining several small chiller plants is greater than one large central plant. For units over 500 tons the cost per year per ton for water treatment and chiller maintenance does not vary significantly.

Additional operating engineering personnel may be required for multiple chiller plants.

THERMAL STORAGE SYSTEM BASICS

Introduction

Thermal energy storage is a comparatively new technology that is receiving attention throughout the United States and the world. The main object of this strategy is to lower overall electrical costs by shifting a large portion of kw demand and kWh usage from utility on-peak hours to off-peak hours.

Cool Storage Media

For a number of practical reasons water dominates the field as a cool storage medium. Water is inexpensive and has good sensible heat capacity (1.0 btu/lb-°F). Conventional air-conditioning chillers and air-handlers use water as the primary heat transfer medium. In addition to chilled water storage systems, other systems have been developed. These other systems utilize freezing and melting of water to ice, and specialized materials known as eutectic salts.

For certain practical reasons chilled water systems, utilizing tanks, dominates the field of large cooling thermal storage systems. That is the system which the City of Phoenix chose to use on its City Hall project. The remainder of this section will focus on chilled water thermal storage systems.

The cost of construction of a thermal storage system consists of the storage tank, the chiller system, the piping to the storage tank, and additional controls. Thermal storage systems require more complex controls than conventional chilled water systems. Engineering cost for the above items must also be included in a comparative life cycle cost comparison.

Some electric utilities offer incentive payments to offset the additional cost of construction of thermal storage systems. Facilities with thermal storage systems benefit the utility as they shift load to off-peak hours, and have a leveling effect on the utility's total load. There is no standardization of incentives from utility to utility.

The comparative economics of the different systems is highly dependent on the electric rates and incentives offered. The City and consultant were not able to get confirmation of the electric rate to be offered during the preliminary analysis phase.

The reader will note tables listing operating costs for the identical mechanical system, but with the alternative electric rates. Note that due to the lack of confirmed rate information during the preliminary stage of system development, the engineer had to perform multiple computer analysis of each system alternative with each possible electric rate.

Chilled Water Storage Tank Systems

Conventional chilled water air-conditioning systems produce chilled water at about 44°F. The water is circulated to cooling coils in air handlers where it is used to cool air. Cool storage can be added to the conventional system by providing a tank to hold a large quantity of chilled water. In the resulting system the refrigeration system produces chilled water, but now the water is piped to chilled water storage tank and only later to the building.

The vessel to contain the chilled water may consist of a set of prefabricated tanks, or a cast-in-place concrete container. The storage volume of the container is generally large and requires significant space allocation during the preliminary architectural design process.

Typical full storage chilled water storage systems have several modes of operation. Chillers charge the system at the start of off-peak hours and then are shut-off. The chillers supply chilled water directly to the facility when there is a demand, typically during early morning hours. At the beginning of on-peak hours, the chillers are shut-off and chilled water is pumped to the building air handlers from the storage tank.

A detailed explanation of the implications of "design temperature difference" is included in Chapter 2, under Hydronic System Basics. Most new large chilled water thermal storage systems are designed for a 20°F temperature rise.

CHAPTER 3 - THE FUNDED PROJECT

INTRODUCTION

This chapter describes the alternative systems and methodology used by the consultant and the City of Phoenix engineering staff to evaluate them. A decision needed to be made regarding which existing buildings to serve with the district cooling system.

Lists of required mechanical equipment for different options and estimated construction costs are included in Appendix A. Energy usage, cost projections, and projected simple paybacks are included in Appendix B. Examples of computer outputs on which the energy and energy cost projection tables are based are included in Appendix C.

PROJECT HISTORICAL BACKGROUND

In January 1990 the City of Phoenix completed a report for the U.S. Department of Energy assessing the feasibility of a district cooling system to serve seventeen existing buildings. These buildings are located in an area several miles from downtown.

The total calculated cooling load was 359 tons, which correlates well with the total installed equipment capacity of 377 tons. Several alternative technologies to generate cooling were evaluated. Those that showed the most promise were cogeneration, absorption chilling, and electrically driven centrifugal chilling.

The estimated construction cost for these systems ranged from \$875,000 to \$1,369,000. The estimated payback for these systems ranged from 5.7 to 6.4 years.

In 1991 the City of Phoenix decided to proceed with plans to construct a new City Hall. The new City Hall was to be located in downtown Phoenix in the immediate vicinity of several existing city owned buildings and other proposed buildings. The City Hall was planned to be a 600,000 ft² 20 story highrise.

This appeared to be an ideal application for a district cooling system (DCS). A mechanical consultant, Bridgers and Paxton Inc. (B&P), had already been selected by the project architect to design the mechanical systems for the City Hall. They were directed to analyze the applicability and economics of incorporating a DCS into the overall design of the City Hall and its associated parking structure.

Basic system alternatives evaluated included which additional existing buildings would be served by the DCS and if a chilled water thermal storage feature would be justified.

CENTRAL PLANT OPTION - STUDY PROCEDURE

The first step was to select equipment for a theoretical cooling plant for each individual building. A conceptual cost estimate for each system was developed with cost data obtained from local equipment vendors. A listing of equipment, with capacities and performance, is included in Appendix A under the heading of **Base Case No. 1.**

The same procedure was followed for a Central Plant of 3,550 tons at the new City Hall to serve all the buildings (new City Hall, new Parking Garage Offices, existing Municipal Building, and existing Orpheum Theater). A listing of equipment for this option is also included in Appendix A, under the heading of **CP Case No. 2.**

In each case redundant chiller capacity was included to serve the facility in the event the largest unit was out of service for maintenance or repairs. For example, if one of the 1,000 ton units were out of service there would remain 2,550 tons of chiller capacity to provide 100% of the load's chilled water requirements.

The careful reader may note the actual final system selected is based on three, one thousand ton chillers as compared to the 3550 tons initially proposed as **Case No. CP-2.** The final system selected was **Case No. TS-2,** which uses thermal storage. The thermal storage feature of the system provides the capability to satisfy the projected instantaneous cooling loads with a reduced chiller capacity. Additionally the proposal for a 3550 ton chiller plant was preliminary. Good engineering practice should be based on conservative estimates to ensure adequate capacity and projected costs that will be within budget. It is better to be generous in preliminary estimates of cooling loads and construction costs, than to find the system must be upsized as the design progresses.

Estimated contract costs to install the equipment, complete with piping, controls, etc., is also included in Appendix A.

Sketches of the conceptual plant layouts are included in Chapter 4. Sketches such as these are typically required to estimate piping costs.

The buildings were computer modeled to project the annual energy costs for the buildings with their own individual chiller plants. A similar analysis was conducted to project the annual energy usage cost for the same buildings, but supplied with chilled water from a central plant through a district cooling system.

Tables summarizing projected monthly energy consumption and costs are included in Appendix B. Examples of computer model outputs for energy consumption, with a breakdown for cooling, lights, and other equipment are included in Appendix C.

Simple paybacks for the costlier system alternative were calculated based on projected operating costs. A table summarizing these paybacks are presented in this chapter.

<p align="center">SUMMARY OF MAXIMUM PREDICTED COOLING LOADS</p> <p align="center">DOWNTOWN DISTRICT COOLING SYSTEM</p>			
	<u>FT²</u>	<u>TONS</u>	<u>FT²/TON</u>
City Hall (new)	600,000	1650	364
Garage Offices (new)	40,000	133	301
Orpheum Theater (existing)	60,000	240	250
Municipal Bldg. (existing)	184,000	550	335
Personnel Bldg. (existing)	<u>70,000</u>	<u>175</u>	<u>400</u>
TOTAL	954,000	2748	347

THERMAL STORAGE OPTION - STUDY PROCEDURE

This study, paralleled the preceding study, District Cooling System to Serve City Owned Downtown Buildings. The purpose of this study was to determine the economics of adding thermal storage to the proposed central chilled water plant and district cooling system. That option had been determined to be the most cost effective option. The first option was to supply the new City Hall, new Parking Garage Offices, and existing Orpheum Theater with chilled water. The second option was to supply the existing Municipal Building and existing Personnel Building in addition to the aforementioned buildings.

The first step was to obtain a projected twenty-four hour cooling load profile for a "design day". Cooling load profiles were calculated by computer for all the buildings in this study. The total ton-hrs of cooling required during the on-peak hours was used to size the thermal storage tank. Tank size was calculated for both 18°F and 20°F temperature rises. The final design was based on a 20°F rise.

Two alternative system proposals were identified. They are as follows:

Case No. TS-1

Minimum size thermal storage tank and chiller capacity sized to serve the new City Hall and existing Orpheum Theater.

Case No. TS-2

The thermal storage tank and chiller capacity sized to serve all buildings considered in the Central Plant Study. These buildings are the new City Hall, new Parking Garage Offices, Orpheum Theater, existing Municipal building and existing Personnel Building.

Estimated construction costs for the alternatives were developed. Computer analysis were utilized to project operating costs for the thermal storage alternatives.

Estimated equipment and construction costs are found in Appendix A. Tables summarizing projected operating costs are found in Appendix B. Examples of computer printouts on which the projected operating costs are based are found in Appendix C.

At the time the energy usage and cost analysis were being prepared it was uncertain which of the utility's rates would apply. For this reason multiple computer runs based on both rates were performed.

It became apparent the assumed power factor of the facilities would also affect the cost of power and thus economics of the alternatives being evaluated. Additional computer runs were made for several assumptions of power factor. The results are displayed in tables in Appendix B.

ELECTRICAL RATE SCHEDULES & IMPLICATIONS FOR THIS PROJECT

In order to evaluate the economics of thermal storage it is necessary to account for the different utility rate structures and incentives offered by the utility to shift power usage from the on-peak period to the off-peak period.

Initial energy usage and energy cost estimates were based on Arizona Public Service (APS) Rate Schedules E-32 and E-34. E-32 is the rate applicable to most city owned buildings and commercial accounts.

E-34 is a mandatory rate for most large services and is required when the demand exceeds 3,000 kw for three or more months per year. Individual buildings would be on an E-32 rate structure, while the proposed central plant and City Hall would be on E-34.

The projected average energy cost under E-32 was \$ 0.0673/kWh and under E-34 was \$ 0.0871/kWh. This is not what is usually experienced as higher usage usually results in a lower cost per kWh. This unexpected result was discussed by the City, the consultant, and the APS service representative for the City's accounts. The APS service representative explained rates E-34 and E-35 are very sensitive to load factor.

When the new City Hall was computer modeled for energy usage, it was assumed lighting and floor-by-floor HVAC equipment would be off after normal working hours. This assumption resulted in an annual load factor of 30%. The APS service representative stated he had reviewed the accounts of all the high rise buildings in Phoenix and determined the lowest load factor was 42%. The consultant's computer model was then revised to obtain a load factor of approximately 41%. The result was increased projected operating cost savings for Cases TS-1 and TS-2.

At the time the thermal storage study was prepared, APS had an experimental rate, E-35, that was being offered to only a few large customers. It was soon determined that the E-35 rate would be highly favorable to the thermal storage option. This rate has zero demand charge and a low kWh charge for energy during off-peak hours. On-peak energy charges are high.

Arizona Public Service defines the on-peak hours to be 11:00 A.M. to 10:00 P.M. APS offers a lump sum incentive for the load shift at \$ 125/kw, if the customer does not have a time-of-use meter, that is if the customer is on their E-34 rate. For customer accounts on the E-35 rate the load shift incentive is \$ 75/kw.

The computer analysis determined it would be cost effective to include a thermal storage system to serve the entire district cooling system, regardless of whether the E-34 or E-35 rate would apply. As each rate would result in a different optimal system control strategy, the consultant included two strategies in their design documents. The more advantageous E-35 rate was eventually approved for this project.

The Simple Payback (SP) is defined as the incremental net cost of the enhanced system divided by the annual savings.

Incremental net cost:

TS Case No. 1 compared to Base Case = \$ 1,811,649 - \$ 1,522,103
= \$ 289,546

TS Case No. 2 compared to Base Case = \$ 2,379,029 - \$ 1,522,103
= \$ 856,926

For the APS E-35 rate structure the paybacks are as indicated below.

TABLE No. 1

SIMPLE PAYBACKS BASED ON <u>E-35</u> RATE STRUCTURE	
<u>TS CASE NO. 1</u>	<u>TS CASE NO. 2</u>
$SP = \frac{\$ 289,546^*}{\$ 68,855} = 4.2 \text{ yrs}^*$	$SP = \frac{\$ 856,926^*}{\$139,159} = 6.2 \text{ yrs}^*$
$SP = \frac{\$ 289,546^{**}}{\$ 278,995} = 1.0 \text{ yrs}^{**}$	$SP = \frac{\$ 856,926^{**}}{\$ 351,874} = 2.4 \text{ yrs}^{**}$

* Modeling based on assumed City Hall load factor of 30% (E-35)

** Modeling based on assumed City Hall load factor of 41% (E-35)

CONCLUSIONS REACHED, RECOMMENDATIONS AND DECISIONS MADE

The mechanical consultant recommended that a central plant and chilled water thermal storage system, TS Case No. 2, be designed and constructed to serve the new City Hall, new Parking Garage Offices, existing Orpheum Theater, existing Municipal Building, and existing Personnel Building.

This recommendation was independent of whether City received the E-34 or E-35 rate. Eventually negotiations with APS resulted in agreement that the E-35 rate would be made available to the City for this facility. Based on TS Case No. 2, the simple payback is 6.2 years (assuming a 30% load factor) and 2.4 years (assuming a 41% load factor). Either payback was considered acceptable to the City and justified construction of the system.

The projected electrical energy cost savings for TS Case No. 1 was \$ 278,995 per year vs. \$ 351,874 per year for TS Case No. 2. The additional projected electrical cost savings is due to shifting a greater portion of total electrical consumption to off-peak hours. The costs associated with the larger system would require a relatively small increase in the overall project cost.

Based on the analysis provided by the mechanical consultant, and summarized in this report, the City decided to proceed with a design incorporating a district cooling system featuring thermal storage.

CHAPTER 4 -- THE AS-BUILT PROJECT

INTRODUCTION

This chapter will describe, in narrative terms, the overall district cooling system, central chilled water plant, and mechanical systems selected by the City of Phoenix. These decisions served as the basis of design for the mechanical consultant. This chapter includes relatively detailed descriptions of equipment utilized, some of the technical problems encountered, and the solutions devised.

The actual construction of the New City Hall, Parking Garage, and thermal storage system was completed in November 1993. As of March 1994, final system testing and balancing at the new City Hall is ongoing.

The system is complex. It is normal, and to be expected, that up to several months may be required to "debug" the system and optimize its operations.

Underground piping to serve the existing buildings was installed during the construction of the City Hall. Contracts are soon to be let to connect the district cooling system piping to the existing buildings.

CHILLER ROOM LAYOUT - CP C

MILLER NO. 3 - 550 TONS

PRIMARY
PUMPS

MILLER NO. 4 - 550 TONS

BE NO.1

CHILLER ROOM LAYOUT - CP CASE NO.

SECTION 'A'
 SCALE: NO SCALE

COOLING TOWER LAYOUT - CENTRAL

COOLING TOWER NO.3 - 1000 TONS
EVAPCO MODEL: AT 24-618
OPERATING WT.: 38,670 LBS
2-30 HP MOTORS

6'-0"
5' MIN.

12'-0"
10' MIN.

TYPICAL 2-POSITION
BUTTERFLY MOTOR
CONTROLLED VALVES
FOR EACH TOWER

12"

12"

12"

12"

12"

10"

LANT - CP NO.2

THE OVERALL PROJECT

For our system the mechanical design consultant elected to utilize a 20°F design temperature rise. A traditional design (10°F) would have required twice as large a chilled water storage tank, at nearly twice the construction cost. The thermal storage portion of the project would not have been economically justified.

Considering the large sums of money involved in constructing a district cooling system and large buildings, it is essential the mechanical design consultant have demonstrated the operational success of comparable systems. The mechanical design consultant for this project was Bridgers & Paxton Consulting Engineers, Phoenix, Arizona. They have a record of successful designs of 20°F chilled water thermal storage systems.

Chilled Water Plant

The plant is located in the basement of the new City Hall. It is based on three, 1000 ton centrifugal chillers. The plant was sized and equipment selected to provide for a redundant chiller, cooling tower and associated pumps. Sufficient capacity exists to fully charge a thermally depleted storage tank, during off-peak hours, with two chillers.

Chillers

The chiller specification was written to allow bidding by the three major manufacturers of centrifugal chillers. The intent was to encourage competitive bidding by the manufacturers to get the lowest possible cost on these major items of equipment.

Various technical design differences exist between the products of the three major manufacturers of centrifugal chillers. Among these differences is the refrigerant used. The mechanical consultant in conjunction with City engineers decided to permit either HCFC (R-22 & R-123) or HFC (R-134A) refrigerants. Only the ozone depleting CFC refrigerants (R-11 & R-12) were not to be permitted.

The chillers were initially scheduled at a maximum of .69 kw/ton. This is considered a moderately efficient unit by today's standards. One of the manufacturers proposed to furnish units rated at .62 kw/ton (a high efficiency unit) at a cost premium. The City performed an economic payback comparison of the alternative chillers and determined the cost premium would not be paid back within a reasonable period. The extremely low cost per kWh, available to the City during the utility off-peak period, resulted in the moderate efficiency chillers being the most cost effective selection. If the system design did not include thermal energy storage and the E-35 electrical rate, the high efficiency chillers would have been selected.

Cooling Towers

Three cooling towers of 1000 tons nominal heat rejection capacity were specified. The units are of induced draft design for lowest horse-power requirements and operating costs. Each tower motor is equipped with a variable frequency drive (VFD) to control cooling water supply temperature, reduce operating cost and extend equipment life.

Condenser Water Pumps

The central plant utilizes four condenser water pumps. One pump is dedicated to each of the three chillers. The fourth pump is piped, with isolation valves, to allow it to substitute for any other pump.

Condenser Water Loop - Heat Exchanger

The central plant condenser water loop includes a plate and frame heat exchanger. This unit enables the system to operate in "free cooling" mode when the ambient wet bulb temperature is low enough. This arrangement allows the transfer of heat from the chilled water loop to the condenser water loop without operating the chillers. The central plant control system will automatically control operating modes to minimize energy usage.

Chilled Water System Piping Arrangement

The chilled water flow arrangement is of necessity quite complex. The system is based on the primary-secondary pumping concept. The vented chilled water storage tank requires the primary system be basically unpressurized. Actually the only pressurization is the result of the elevation difference between the top of the chilled water storage tank and the floor level of the sub-basement where the chiller plant is located.

Heat exchangers, secondary pumps, water turbine/secondary pumps, and motorized valves, are utilized to enable the system to operate in the various modes.

Primary Chilled Water Pumps

There are four primary chilled water pumps. They are piped similarly to the condenser water pumps, in that three of them are each dedicated to a chiller and the fourth is piped with isolation valves to enable it to substitute for any of the first three. These pumps are of necessity "constant flow" to satisfy chiller flow requirements. Water is drawn from the storage tank, pumped through the chiller evaporator, where it is cooled, and then back to the piping header at the bottom of the storage tank.

Heat Exchangers and Secondary Pumps

Plate and frame heat exchangers are utilized to hydrostatically and physically isolate the chilled water piping serving the 20-story City Hall tower from the unpressurized primary system. Because a heat exchanger may need to be disassembled for cleaning, a backup unit is required to ensure an uninterruptable chilled water supply to the tower. Two heat exchangers and two secondary pumps are utilized, each sized for the total cooling load of the tower.

Each of the secondary pumps, on the tower side of the heat exchanger, is furnished with a VFD controlled from a differential pressure sensor. This arrangement enables the pump to operate at the speed necessary to supply the required chilled water flow rate to the loads. The major chilled water loads are provided with 2-way control valves to reduce flow as loads decrease.

Heat Exchanger Pumps

Two heat exchanger pumps provide flow through the primary circuit of the heat exchangers. Each is sized for the total required load. They are piped as secondary pumps across the primary chilled water piping to and from the storage tank. A single VFD is manually switched to the active pump.

Water Turbine / Secondary Pump Combinations

These units are unusual enough to warrant an explanation of their construction and why they are required. Unlike the new City Hall chilled water piping that is pressurized, the other buildings served by the district cooling system are designed as, or will be converted to, unpressurized systems. Because the existing Muni Building is 10 stories high, a chilled water pump would require 100 ft of head just to overcome the height differential involved in lifting the water to the top of the building. Piping and coil pressure drops are additional.

The water turbine/secondary pump combination is a pump and turbine mounted on the same shaft as the motor. This arrangement allows the turbine, driven by the open system head, to directly transfer its developed energy to the pump shaft, thus reducing motor horse power requirements. This particular system allows the recovery of 80 ft of head.

Chilled Water Storage Tank

An essential component of this district cooling system is the million and a half (1,500,000) gallon thermal storage tank. A thermal storage tank is not necessarily a component of a district cooling system. If the system is designed to generate chilled water as it is required by the cooling loads, a storage tank is not required. In our system, computer analysis of the projected cooling loads and time-of-use electric rates determined that the most cost effective system would utilize a tank to store water chilled when electric rates are low.

Storage tanks for chilled water are of necessity large. In a downtown area, space for such a tank will always be at a premium. Coordination between the project architect and mechanical engineer resulted in the tank being located beneath the 10 story parking structure, that is an integral part of this project.

The tank is constructed of poured in place concrete. Piping within the tank is Schedule 80 polyvinyl chloride (PVC) plastic.

The tank design is critical. It is essential the chilled water at 40°F not mix with "used" return water at 60°F. Some previously constructed systems were found to be short on available ton-hrs capacity due to unplanned mixing.

Our system utilizes specially designed piping headers located near the top and bottom of the tank. The headers are specifically designed for low velocity flow to minimize turbulence and mixing. During the "charging cycle" warm (60°F) water is drawn from the top tank header, pumped through the chillers where it is cooled to 40°F, and then returned to the tank through the lower header. During the "discharge cycle" water at 40°F is drawn through the bottom header, pumped through the various DCS loads, and then returned to the top of the tank at approximately 60°F. Pumps and motorized valves controlled by the EMS, are used to switch the

system between operating modes.

The tank is equipped with a system of thermocouples located at 1 ft intervals in depth. Each is connected to the energy management system (EMS) to monitor the temperature differential from top to bottom of the tank. This data is used to determine when the tank is fully charged, and when it is advantageous to shut-off the chillers.

Air Handlers

Air handler coils and fan coil units in the new buildings were specially selected for low flows and 20°F temperature rises. As the material in Chapter 2 explained, flow balance is critical. Local piping at each fan coil unit will include an automatic flow compensating valve. These valves limit maximum flow to a preset value even as differential pressure varies. This prevents starving the most distant coils. The system design utilizes 2-way valves at coils, forcing flow to the more distant coils.

Piping Materials

The chilled water system piping within the buildings is constructed of Schedule 40 black steel pipe. The condensing water system is also constructed of the same material. Pipes 2 1/2" in diameter or less are Type L copper tubing.

Chilled water pipes over 3" in diameter are insulated with 1 1/2" thick fiberglass insulation with a vapor barrier. Smaller diameter pipes are insulated with 1" thick insulation, also with a vapor barrier. Condenser water piping is not insulated.

Underground piping between buildings is schedule 80 PVC.

Control System

The overall district cooling system, central plant, and new City Hall were designed to utilize an integrated direct digital control (DDC) system. The project specifications were written to allow the major manufacturers of these systems to bid the project.

The City presently has several other large downtown building projects under construction or in the design stage. It was decided that it would be desirable to utilize the same manufacturers control system for all of these new projects. Therefore a decision was made that whatever manufacturer's system was utilized on this project, would be specified for the other downtown projects. This decision drew complaints from several local control system vendors, but City management decided that the advantages of utilizing a single system justified requiring a sole source for the energy management systems for the other projects.

**APPENDIX A -- PRELIMINARY EQUIPMENT LISTS & INSTALLATION COSTS
OF ALTERNATIVE SYSTEMS**

BASE CASE

**CONVENTIONAL CHILLED WATER PLANTS FOR
INDIVIDUAL BUILDINGS**

NEW CITY HALL & ORPHEUM THEATER

Chillers - four (4) 550 ton units	lot	\$ 460,000
Cooling towers - four (4) 550 ton units	lot	100,000
Pumps	lot	62,810
Installation labor cost, rigging	lot	38,000
Piping cost inc. insulation	lot	62,130
Electrical - controls & misc.	lot	<u>25,000</u>
Total Cost		\$ 747,940
Contractor Mark-up & Profit, 21%		<u>157,067</u>
Total Estimated Contract Cost		\$ 905,007

EXISTING MUNICIPAL BLDG. REPLACEMENT

Chillers - two (2) 550 ton units	lot	\$ 230,000
Pumps	lot	13,877
Installation labor cost, rigging	lot	11,000
Piping cost inc. insulation	lot	30,500
Electrical - Controls & Misc.	lot	<u>40,000</u>
TOTAL COST		\$ 325,377
Contractor Mark-up & Profit, 21%		<u>68,329</u>
Total Estimated Contract Cost		\$ 393,706

CONTINUATION: BASE CASE
CONVENTIONAL CHILLED WATER PLANTS FOR
INDIVIDUAL BUILDINGS

NEW PARKING GARAGE OFFICES

Chillers - two (2) 135 ton units	lot	\$ 92,000
Cooling towers - (2) 135 ton units	lot	13,500
Pumps	lot	13,320
Installation, labor, & rigging	lot	12,800
Central plant piping in bldg.	lot	32,000
Electrical controls & misc.	lot	<u>21,000</u>
Total cost		\$ 184,620
Contractor Mark-up & Profit, 21%		<u>38,770</u>
Total Estimated Contract Cost		\$ 223,390

TOTAL COST FOR ALL INDIVIDUAL BUILDINGS **\$ 1,522,103**

BASE CASE
(Partial Equipment List)

**CENTRAL PLANT FOR CITY HALL &
ORPHEUM THEATER ONLY**

City Hall	1650 tons
Orpheum Theater	<u>240 tons</u>
TOTAL	1890 tons

CHILLERS: Use four (4) 550 ton units
Select: Trane model CVHE IEU28 w/ R123 refrigerant, 550 tons, 56.0°F entering and 42.0°F leaving, 0.644 kw/ton, 943 gpm evaporator flow - 6.44 ft. pd, 1650 gpm condenser flow 94.5°F leaving, 85.0°F entering, 13.0 ft pd.

Electric 460V, 60 Hz, 3336 lra
Maximum rla for motor 561 amps rla
at 354 kw (0.644 kw/ton) 493 amps

Operating Weight 28,451 lbs

Budget cost \$115,000 per machine @ \$209/ton

Total for four (4) machines **= \$ 460,000**

COOLING TOWERS: Use four (4) 550 ton units

Select: Evapco #AT 8-242
Capacity Factor for 5°F approach = 1.19, 85°F leaving, 95°F entering, 80°F wb, Operating weight 16,430, lbs.
Dimensions 7'-10" x 12'-4". Two 20 hp fan motors.

Total for four (4) units **= \$ 100,800**

**CP CASE NO. 2
(Equipment List)**

**CENTRAL PLANT FOR CITY HALL &
OTHER CITY DOWNTOWN BUILDINGS.**

CHILLERS: Use (3) 1000 ton chillers & (1) 550 ton chiller

Select: 1 - 550 ton, Trane model CVHE IEU28 w/ R123 refrigerant, 550 tons, 56.0°F entering and 42.0°F leaving, 0.644 kw/ton, 943 gpm evaporator flow - 6.44 ft. pd, 1650 gpm condenser flow 94.5°F leaving, 85.0°F entering, 13.0 ft pd.

**Electric 460V, 60 hz, 3336 lra
Maximum rla for motor 561 amps
rla at 354 kw (0.644 kw/ton) 493 amps**

Operating Weight 28,451 lbs

Budget cost \$115,000 per machine - \$209/ton

Select: 3 - 1000 Ton, Trane model CVHE w/ R123 refrigerant, 1,000 tons, 56.0°F entering and 42.0°F leaving, 0.644 kw/ton, 1714 gpm evaporator flow - 9.03 ft pd, 3,000 gpm condenser flow 94.5°F leaving, 85.0°F entering, 13.7 ft. pd.

**Electric 460V, 60 hz, 5370 lra
Maximum rla for motor 1023 amps
RLA at 659 kw (0.65 kw/ton) 905 amps**

Operating Weight 46,000 lbs

Budget cost \$170,000 per machine @ \$170/ton

Total (1-550) & (3-1000) = \$ 625,000

**CP CASE NO. 2
(Equipment List Cont.)**

**CENTRAL PLANT FOR CITY HALL &
OTHER CITY DOWNTOWN BUILDINGS.**

Cooling tower: 550 ton

**Evapco - #AT12-818A, Operating Weight 18,840 lbs
Size 11'-10" w x 18' 1 x 16'-4" high.**

Budget cost per tower \$ 25,200

Cooling tower: 1000 ton

**Evapco #AT 24-618A
Capacity Factor for 5°F approach = 1.19, 85°F leaving,
95°F entering, 80°F wb, 1190 tons and 3000 gpm**

**Operating weight 36,870 lbs. Dimensions 23'-9" x 18' x 17'4".
Two 30 hp fan motors.**

Budget cost per tower \$ 45,321

CP CASE NO. 2
(Equipment List)

CENTRAL PLANT FOR ALL BUILDINGS
WITHOUT THERMAL STORAGE

Chillers-	Three (3) 1,000 ton units	lot	\$ 510,000
	One (1) 550 ton unit	lot	115,000
Cooling Towers -	Three (3) 1,000 ton units	lot	135,963
	One (1) 550 ton unit	lot	25,200
Pumps		lot	135,000
Installation labor & rigging		lot	71,600
Central plant piping in bldg.		lot	110,400
Distribution piping to other bldgs.		lot	90,000
Demolition of exist. chlr. plant in Muni bldg.		lot	25,000
Controls & misc.		lot	65,000
Piping in Muni bldg.		lot	<u>57,000</u>
Total Cost			\$ 1,340,163
Contractor Mark-up & Profit, 21%			<u>281,434</u>
Total Estimated Contract Cost			\$ 1,621,597
 Engineering cost, 6%			
\$ [1,458,247 - (905,975 + 223,390)*] x .06			29,534
	Total		\$ 1,651,131
 Additional cost of central plant (over Base Case)			
\$ [1,651,131 - 1,522,103]			\$ 129,028

* Cost City Hall & Parking Garage Office design which is work included in original A/E contract.

**TS CASE NO. 1
(Equipment List)**

**CENTRAL PLANT for CITY HALL &
ORPHEUM ONLY W/ THERMAL STORAGE**

Chillers - four (4) 550 ton units	lot	\$ 460,000
Cooling towers - four (4) 550 ton units	lot	100,000
Pumps	lot	65,329
Installation, labor, & rigging	lot	42,000
Thermal sto. tank, 1,050,000 gal @ \$.50/gal	lot	525,000
Central plant piping in bldg.	lot	71,454
Piping 600 ft, 12", tank to bldg.	lot	87,530
Plate & frame heat exchanger	lot	64,000
Controls & misc.	lot	<u>50,000</u>
Total Cost		\$ 1,465,313
Contractor Mark-up & Profit, 21%		<u>307,716</u>
Total Estimated Contract Cost		\$ 1,773,029
Added engineering cost		
6% of \$ [1,773,029 - (905,975 + 223,390)*]		<u>38,620</u>
TOTAL		\$ 1,811,649

* Cost of conventional chilled water plants for new City Hall & new Garage Offices, for which A/E fees were included in original A/E contract.

**TS CASE NO. 2
(Equipment List)**

**CENTRAL PLANT W/ THERMAL STORAGE
ALL BUILDINGS (CITY HALL, ORPHEUM THEATER,
MUNICIPAL BLDG. & GARAGE OFFICES)**

Chillers - three (3) 1000 ton units	lot	\$ 510,000
Cooling towers - three (3) 1000 ton units	lot	135,000
Pumps	lot	108,170
Installation, labor, & rigging	lot	56,000
Central plant piping in bldg.	lot	96,000
Distribution piping to other bldgs.	lot	90,000
Piping 600 ft, 14", tank to bldg.	lot	88,510
Thermal sto. tank, 1,400,000 gal @ \$.50/gal	lot	700,000
Plate & frame heat exchanger	lot	74,000
Controls & misc.	lot	<u>50,000</u>
Total cost		\$ 1,907,680
Contractor mark-up & profit, 21%		<u>400,613</u>
Total Estimated Contract Cost		\$ 2,308,293
Added engineering cost		
6% of \$ [2,308,293 - (905,975 + 223,390)*]		<u>70,736</u>
TOTAL		\$ 2,379,029

* Cost of conventional chilled water plants for new City Hall & new Garage Offices, for which A/E fees were included in original A/E contract.

CP CASE NO. 2
(Preliminary Pump Selections)

**CITY HALL, ORPHEUM THEATER, MUNICIPAL BLDG., &
NEW GARAGE OFFICES**

Chillers: Use (3) 1000 ton units &
(1) 550 ton unit

Primary Pumps: Typical of four (4) pumps (1000 ton chiller)
1714 gpm @ 40 ft. hd. Aurora series 340.
Size 6 x 6 x 12, 1150 rpm 20 hp,
84% efficiency 25 hp motor, 460 V - 3 phase.,
for 550 ton chiller, two (2) pumps

Secondary Pumps: Typical of three (3) pumps (one standby),
2571 gpm @ 100 ft. head with VFD.
Aurora series 360, Size 8 x 10 x 15A,
1750 rpm, 75 bhp, 78% efficiency, 75 hp motor,
460V, 3-phase. 2 pumps for 550 ton
chiller,

Tower Pumps: Typical of four (4) pumps (one standby),
3000 gpm @ 60 ft hd. Aurora series 360,
Size 8 x 10 x 15A, 1750 rpm, 90 bhp, 76%,
40 hp motor, 460V, 3-phase.

The information on this sheet is presented as an example of the
type of information a consultant must develop as part of the
preliminary cost estimating process.

TS CASE NO. 1
(Preliminary Pump Selections)

CITY HALL & ORPHEUM THEATER

Chillers: Use (4) 550 ton units

Primary Pumps: Typical of five (5) pumps (one standby),
943 gpm @ 40 ft hd. Aurora series 340.
Size 5 x 6 x 11, 1150 rpm 10 hp,
89% efficiency 15 hp motor, 460 V - 3 phase.

Secondary Pumps: Typical of three (3) pumps (one standby),
1883 gpm @ 75 ft head with VFD.
Aurora series 340, Size 6 x 6 x 12, 1750 rpm
42 hp, 83% efficiency, 50 hp motor,
460V, 3-phase.

Tower Pumps: Typical of five (5) pumps (one standby),
1650 gpm @ 60 ft hd Aurora series 340,
Size 6 x 6 x 12, 1750 rpm, 34 bhp, 80% eff.,
40 hp motor, 460V, 3-phase.

The information on this sheet is presented as an example of the type of information a consultant must develop as part of the preliminary cost estimating process.

**APPENDIX B -- TABLES OF PROJECTED ENERGY USAGE &
OPERATING COSTS OF ALTERNATIVE SYSTEMS**

BASE CASE - ENERGY COST SEPARATE CHILLED WATER PLANTS FOR INDIVIDUAL BUILDINGS				
	KWH	COST	RATE	AVG \$/KWH
City Hall/CP	12,750,031	\$ 1,142,215	E-34	.0896
Muni Bldg.	7,640,949	514,162	E-32	.0673
Garage Off.	1,018,852	95,924	E-32	.0941
Orpheum	<u>830,757</u>	<u>75,242</u>	E-32	.0906
TOTAL	22,240,589	\$ 1,827,543		.0822

This is the Base Case.

CP CASE NO. 2 - ENERGY COST CONVENTIONAL CENTRAL PLANT @ CITY HALL to SERVE ALL BUILDINGS				
	KWH	COST	RATE	AVG \$/KWH
City Hall/CP	14,719,812	\$ 1,281,600	E-34	.0871
Muni Bldg.	5,811,943	383,464	E-32	.0660
Garage Off.	832,213	78,241	E-32	.0940
Orpheum	<u>830,757</u>	<u>75,242</u>	E-32	.0906
TOTAL	22,194,725	\$ 1,818,547		.0819

Savings compared to Base Case = \$ 8,996

CP CASE NO. 2 - ENERGY COST					
CENTRAL PLANT & CITY HALL E-34 RATE					
	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	12,786,809	\$ 970,069	E-34	.0759	40.7%
Muni Bldg.	7,640,949	514,162	E-32	.0673	66.8%
Garage Off.	1,034,211	90,664	E-32	.0877	44.6%
Orpheum	<u>838,441</u>	<u>72,783</u>	E-32	.0868	59.8%
TOTAL	22,300,410	\$ 1,647,678		.0739	

Savings compared to Base Case = \$ 179,865

CP CASE NO. 2 - ENERGY COST					
CENTRAL PLANT & CITY HALL E-35 RATE					
	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	12,786,809	\$ 1,029,247	E-35	.0805	40.7%
Muni Bldg.	7,640,949	514,162	E-32	.0673	66.8%
Garage Off.	1,034,211	90,664	E-32	.0877	44.6%
Orpheum	<u>838,441</u>	<u>72,783</u>	E-32	.0868	59.8%
TOTAL	22,300,410	\$ 1,706,856		.0765	

Savings compared to Base Case = \$ 120,687

CP CASE NO. 2 - ENERGY COST

**CENTRAL PLANT SERVING
CITY HALL, ORPHEUM, MUNI BLDG. GARAGE OFF.
40.3% LOAD FACTOR & CITY HALL
E-34 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	14,724,319	\$ 1,110,962	E-34	.0755	40.3%
Muni Bldg.	5,811,943	383,464	E-32	.0660	79.8%
Garage Off.	864,346	74,674	E-32	.0864	58.7%
Orpheum	838,441	<u>72,783</u>	E-32	.0868	59.8%
TOTAL	22,239,049	\$ 1,641,883		.0738	

Savings compared to Base Case = \$ 185,660

CP CASE NO. 2 - ENERGY COST

**CENTRAL PLANT SERVING
CITY HALL, ORPHEUM, MUNI BLDG. GARAGE OFF.
40.3% LOAD FACTOR & CITY HALL
E-35 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	14,724,319	\$ 1,177,855	E-35	.0800	40.3%
Muni Bldg.	5,811,943	383,464	E-32	.0660	79.8%
Garage Off.	864,346	74,674	E-32	.0864	58.7%
Orpheum	<u>838,441</u>	<u>72,783</u>	E-32	.8068	59.8%
TOTAL	22,239,049	\$ 1,708,776		.0768	

Savings compared to Base Case = \$ 185,660

TS CASE NO. 1 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL & ORPHEUM THEATER
30 % LOAD FACTOR
E-34 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>
City Hall/CP	12,714,482	\$ 1,136,787	E-34	.0894
Muni Bldg.	7,640,949	514,162	E-32	.0673
Garage Off.	1,018,852	95,924	E-32	.0941
Orpheum	<u>830,757</u>	<u>75,242</u>	E-32	<u>.0906</u>
TOTAL	22,205,040	\$ 1,822,115		.0821

Savings compared to Base Case = \$ 5,428

TS CASE NO. 1 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL & ORPHEUM THEATER
30 % LOAD FACTOR
E-35 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>
City Hall/CP	12,714,482	\$ 1,073,360	E-35	.0844
Muni Bldg.	7,640,949	514,162	E-32	.0673
Garage Off.	1,018,852	95,924	E-32	.0941
Orpheum	<u>830,757</u>	<u>75,242</u>	E-32	<u>.0906</u>
TOTAL	22,205,040	\$ 1,758,688		.0792

Savings compared to Base Case = \$ 68,855

TS CASE NO. 1 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL & ORPHEUM THEATER
41 % LOAD FACTOR
E-34 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	12,744,124	\$ 966,704	E-34	.0759	41.0%
Muni Bldg.	7,640,949	514,162	E-32	.0673	66.8%
Garage Off.	1,034,211	90,664	E-32	.0877	44.6%
Orpheum	838,441	<u>72,783</u>	E-32	.0868	59.8%
TOTAL	22,257,725	\$ 1,644,313		.0739	

Savings compared to Base Case = \$ 183,230

TS CASE NO. 1 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL & ORPHEUM THEATER
41 % LOAD FACTOR
E-35 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	12,744,124	\$ 870,939	E-35	.0683	41.0%
Muni Bldg.	7,640,949	514,162	E-32	.0673	66.8%
Garage Off.	1,034,211	90,664	E-32	.0877	44.6%
Orpheum	<u>838,441</u>	<u>72,783</u>	E-32	.0868	59.8%
TOTAL	22,257,725	\$ 1,548,548		.0696	

Savings compared to Base Case = \$ 278,995

TS CASE NO.2 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL, ORPHEUM THEATER,
MUNICIPAL BLDG. & GARAGE OFFICES
30% LOAD FACTOR
E-34 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG</u> <u>\$/KWH</u>
City Hall/CP	14,734,037	\$ 1,279,639	E-34	.0868
Muni Bldg.	5,811,943	383,464	E-32	.0660
Garage Off.	832,213	78,241	E-32	.0940
Orpheum	<u>830,757</u>	<u>75,242</u>	E-32	<u>.0906</u>
TOTAL	22,208,950	\$ 1,816,586		.0818

Savings compared to Base Case = \$ 10,957
Savings compared to CP Case No. 2 = \$ 1,961

TS CASE NO.2 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL, ORPHEUM THEATER,
MUNICIPAL BLDG. & GARAGE OFFICES
30% LOAD FACTOR
E-35 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG</u> <u>\$/KWH</u>
City Hall/CP	14,734,037	\$ 1,151,464	E-35	.0781
Muni Bldg.	5,811,943	383,464	E-32	.0660
Garage Off.	832,213	78,214	E-32	.0940
Orpheum	<u>830,757</u>	<u>75,242</u>	E-32	<u>.0906</u>
TOTAL	22,208,950	\$ 1,688,384		.0760

Savings compared to Base Case = \$ 139,159
Savings compared to CP Case No. 2 = \$ 130,163

TS CASE NO. 2 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL, ORPHEUM, MUNI BLDG. & GARAGE OFFICES
LOAD FACTOR 41%
E-34 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	14,732,398	\$ 1,106,926	E-34	.0751	40.7%
Muni Bldg.	5,811,943	383,464	E-32	.0660	79.8%
Garage Off.	864,346	74,674	E-32	.0864	58.7%
Orpheum	838,441	72,783	E-32	.0868	59.8%
TOTAL	22,247,128	\$ 1,637,847		.0736	

Savings compared to Base Case = \$ 189,696
Savings compared to CP Case No. 2 = \$ 342,878

TS CASE NO. 2 - ENERGY COST

**(THERMAL STORAGE)
CITY HALL, ORPHEUM, MUNI BLDG. & GARAGE OFFICES
LOAD FACTOR 41%
E-35 RATE**

	<u>KWH</u>	<u>COST</u>	<u>RATE</u>	<u>AVG \$/KWH</u>	<u>LOAD FACTOR</u>
City Hall/CP	14,732,398	\$ 944,748	E-35	.0641	40.7%
Muni Bldg.	5,811,943	383,464	E-32	.0660	79.8%
Garage Off.	864,346	74,674	E-32	.0864	58.7%
Orpheum	838,441	72,783	E-32	.0868	59.8%
TOTAL	22,247,098	\$ 1,475,669		.0663	

Savings compared to Base Case = \$ 351,874
Savings compared to CP Case No. 2 = \$ 342,878

THERMAL STORAGE SYSTEM KW SHIFT

These calculations are presented as an example of the type of calculations required to determine the utility company incentive for shifting load from on-peak to off-peak periods.

TS CASE NO. 1

Chillers:	1890 tons x $\frac{0.66 \text{ kw}}{\text{ton}}$	= 1247 kw
Cooling towers:	4 units x 40 hp x .746	= 119 kw
Primary pumps:	4 units x 40 hp x .746	= 119 kw
Cooling tower pumps:	4 units x 40 hp x .746	= 119 kw
	TOTAL SHIFT	= 1604 kw

TS CASE NO. 2

Chillers:	2573 tons x $\frac{0.66 \text{ kw}}{\text{ton}}$	= 1698 kw
Cooling towers:	3 units x 60 hp x .746	= 134 kw
Primary pumps:	3 units x 20 hp x .746	= 45 kw
Cooling tower pumps:	3 units x 75 hp x .746	= 168 kw
	TOTAL SHIFT	= 2045 kw

THERMAL STORAGE TANK SIZING

24 - HOUR COOLING LOAD - DESIGN DAY CITY HALL, PARKING GARAGE & ORPHEUM ONLY

		<u>TS CASE #1</u>		<u>TS CASE #2</u>
		(PRORATED @ 1890 TONS)	% OF load	(PRORATED @ 2573 TONS)
MORNING (OFF- PEAK)	8:00 AM	1135 ton-hrs	0.60	1544 ton-hrs
	9:00	1325	0.70	1807
	10:00	1578	0.84	2148
	11:00	1758	0.93	2392
	TOTAL	5,796 ton-hrs		7,891 ton-hrs
DAY (ON- PEAK)	12:00	1824 ton-hrs	0.97	2483 ton-hrs
	1:00 PM	1858	0.98	2529
	2:00	1881	0.99	2560
	3:00	1888	0.99	2570
	4:00	1890	1.00	2573
	5:00	1514	0.80	2061
	6:00	1266	0.67	1724
	7:00	920	0.49	1165
	8:00	684	0.36	931
	9:00	539	0.29	733
	TOTAL	14,264 ton-hrs		19,329 ton-hrs

		<u>TS CASE #1</u>		<u>TS CASE #2</u>
		(PRORATED @ 1890 TONS)	% OF load	(PRORATED @ 2573 TONS)
NIGHT	10:00 PM	431 ton-hrs	0.23	587 ton-hrs
(OFF-	11:00	361	0.19	491
PEAK)	12:00	299	0.16	406
	1:00 AM	268	0.14	365
	2:00	265	0.14	360
	3:00	234	0.12	319
	4:00	212	0.11	288
	5:00	210	0.11	286
	6:00	368	0.20	502
	7:00	603	0.32	821
	TOTAL	3,251 ton-hrs		4,425 ton-hrs
	<u>24 HR TOTAL</u>	<u>23,311 ton-hrs</u>		<u>31,645 ton-hrs</u>

CITY HALL= 23,311
& ORPHEUM 24 hrs

= 971 ton-hrs avg. for 24 hrs.

CENTRAL= 31,645
PLANT 24 hrs

= 1,319 ton-hrs avg. for 24 hrs.

For 18°F Temperature Rise

Tank size - TS Case #1: $\frac{14,314 \text{ ton-hr} \times 12,000}{18^\circ\text{F} \times 8.33 \text{ lb/gal}} = 1,145,578 \text{ gal}$

Tank size - TS Case #2: $\frac{19,329 \text{ ton-hr} \times 12,000}{18^\circ\text{F} \times 8.33 \text{ lb/gal}} = 1,546,938 \text{ gal}$

For 20°F Temperature Rise

Tank size - TS Case #1: $\frac{18^\circ}{20^\circ} \times 1,145,578 \text{ gal} = 1,031,020 \text{ gal}$
Say 1,050,000 gal

Tank size - TS Case #2: $\frac{18^\circ}{20^\circ} \times 1,546,938 \text{ gal} = 1,392,244 \text{ gal}$
Say 1,400,000 gal

Under the utility's E-35 rate structure an incentive of \$75/kw is offered to customers whose HVAC system design shifts demand from on-peak to off-peak hours.

The "Premium Cost" for TS Case No. 1 (thermal storage), is its cost less the cost of the CP Case No. 1 (conventional plant).

The "Premium Cost" for TS Case No. 2 (thermal storage), is its cost less the cost of the CP Case No. 2 (conventional plant).

TABLE No. 2

	NET PREMIUM COST INCLUDING APS INCENTIVE	
	<u>TS CASE No. 1</u>	<u>TS CASE No.2</u>
System Const. Cost	\$ 1,812,901	\$ 2,413,644
Less Base Case Cost	<u>- 905,975</u>	<u>- 1,613,915</u>
System Premium Cost	\$ 906,926	\$ 799,729
Less APS Incentive	\$ <u>- 115,575</u>	\$ <u>- 156,075</u>
Net System Premium Cost	\$ 791,351	\$ 643,654

CONVENTIONAL SYSTEM ENERGY ANALYSIS
 BRIDGERS AND PAXTON CONSULTING ENGINEERS, INC.
 PHOENIX MUNICIPAL CENTER PHOENIX, ARIZONA
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YEARLY TOTALS

APPENDIX C -- SAMPLE COMPUTER MODEL OUTPUTS:
 ALTERNATIVE SYSTEM ENERGY USAGE PROJECTIONS &
 COSTS

TOTAL COOLING LOAD= 216549. (TON-HRS)
 TOTAL HEATING LOAD= 353073. (MBTU)
 TOTAL BOILER OUTPUT= 353073. (MBTU)
 TOTAL DOMESTIC HOT WATER OUTPUT= 26230. (MBTU)
 YEARLY HUMIDIFICATION LOAD= 0. (MBTU)
 YEARLY AUXILIARY EQUIPMENT, LIGHTING, & ELECTRICAL APPL. USAGE= 832218. (KWH)
 YEARLY LIGHTING USAGE= 509951. (KWH)
 YEARLY ELEC. APPLIANCE LOAD= 0. (KWH)
 YEARLY APPLIANCES W/O METER ASSIGNMENT= 0. (MBTU)
 YEARLY OTHER APPLIANCE LOAD= 0. (MBTU)
 YEARLY ELECTRICAL USAGE= 832218. KWH
 YEARLY NATURAL GAS USAGE= 541862. CU.FT.

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AUXILIARY LOADS--USAGE FOR YEAR

GARAGE/OFFICE SUPPLY FANS = 32720. KWH
TOTAL HOURS OF OPERATION=3225
EQUIV. FULL LOAD HOURS= 971

GARAGE/OFFICE O.A. FANS = 4368. KWH
TOTAL HOURS OF OPERATION=3120
EQUIV. FULL LOAD HOURS= 3120

GARAGE VENTILATION FANS = 264551. KWH
TOTAL HOURS OF OPERATION=8760
EQUIV. FULL LOAD HOURS= 8760

GARAGE/OFFICE SECONDARY CHW PUMP = 6617. KWH
TOTAL HOURS OF OPERATION=2757
EQUIV. FULL LOAD HOURS= 2757

GARAGE/OFFICE COOLING TOWER FAN = 0. KWH
TOTAL HOURS OF OPERATION= 0
EQUIV. FULL LOAD HOURS= 0

GARAGE/OFFICE RETURN/RELIEF FANS = 12137. KWH
TOTAL HOURS OF OPERATION=3225
EQUIV. FULL LOAD HOURS= 971

GARAGE/OFFICE EXHAUST FANS = 1972. KWH
TOTAL HOURS OF OPERATION=3120
EQUIV. FULL LOAD HOURS= 3120

GARAGE/OFFICE PRIMARY CHW PUMP = 0. KWH
TOTAL HOURS OF OPERATION= 0
EQUIV. FULL LOAD HOURS= 0

GARAGE/OFFICE CONDENSING WATER PUMP = 0. KWH
TOTAL HOURS OF OPERATION= 0
EQUIV. FULL LOAD HOURS= 0

BUILDING LIGHTING = 509951. KWH

CONVENTIONAL SYSTEM ENERGY ANALYSIS
 BRIDGERS AND PAXTON CONSULTING ENGINEERS, INC
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YEARLY SYSTEM USAGE PROFILE
 HOURS OF OPERATION AT VARIOUS PERCENT FULL LOAD OUTPUT

	OFF	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	MAX. REQD OUTPUT
CHILLER	6003	141	0	63	315	606	471	378	351	402	30	132.7
							MAXIMUM OUTPUT OCCURRED ON					
											8/ 7 (PERIOD 4)	
BOILER	8151	0	39	111	21	30	33	18	15	6	336	2000.4
							MAXIMUM OUTPUT OCCURRED ON					
											11/28 (PERIOD 3)	

CONVENTIONAL SYSTEM ENERGY ANALYSIS
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YEARLY TOTALS--GARAGE/OFFICE BUILDING

SPACE AREA=	40000. SQ.FT.	BUILDING AREA=	40000. SQ.FT.		
	ELECTRICAL	OTHER FUEL	OTHER FUEL	TOTAL ENERGY USAGE	
	USAGE	USAGE	USAGE	PER SPACE AREA	PER BLDG. AREA
AHU COOLING=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
AHU HEATING=	0. KWH	504390.CU.FT.	0.CU.FT.	12610. BTU/SQ.FT.	12610. BTU/SQ.FT.
DOMESTIC HOT WATER=	0. KWH	37472.CU.FT.	0.CU.FT.	937. BTU/SQ.FT.	937. BTU/SQ.FT.
HUMIDIFICATION=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
LIGHTING=	509952. KWH	0.CU.FT.	0.CU.FT.	43512. BTU/SQ.FT.	43512. BTU/SQ.FT.
APPLIANCES=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
FANS=	315648. KWH	0.CU.FT.	0.CU.FT.	26933. BTU/SQ.FT.	26933. BTU/SQ.FT.
PUMPS=	6617. KWH	0.CU.FT.	0.CU.FT.	565. BTU/SQ.FT.	565. BTU/SQ.FT.
MISCELLANEOUS EQUIP.=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
TOTALS	832216.	541862.	0.	84555.	84553.
SOURCE ENERGY CONSUMPTION=	226573. BTU/SQ.FT./YEAR				

CONVENTIONAL SYSTEM ENERGY ANALYSIS
 BRIDGERS AND PAXTON CONSULTING ENGINEERS, INC.
 PHOENIX MUNICIPAL CENTER PHOENIX, ARIZONA
 EXISTING MUNICIPAL BUILDING -- CONVENTIONAL RUN W/O CHILLER & AUXILIARIES

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YEARLY TOTALS--EXISTING MUNICIPAL BUILDING

SPACE AREA=	230076. SQ.FT.	BUILDING AREA=	230076. SQ.FT.		
	ELECTRICAL	OTHER FUEL	OTHER FUEL	TOTAL ENERGY USAGE	
	USAGE	USAGE	USAGE	PER SPACE	PER BLDG.
				AREA	AREA
AHU COOLING=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
AHU HEATING=	0. KWH	4285833.CU.FT.	0.CU.FT.	18629. BTU/SQ.FT.	18629. BTU/SQ.FT.
DOMESTIC HOT WATER=	0. KWH	269634.CU.FT.	0.CU.FT.	1172. BTU/SQ.FT.	1172. BTU/SQ.FT.
HUMIDIFICATION=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
LIGHTING=	4676430. KWH	0.CU.FT.	0.CU.FT.	69371. BTU/SQ.FT.	69371. BTU/SQ.FT.
APPLIANCES=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
FANS=	1065565. KWH	0.CU.FT.	0.CU.FT.	15307. BTU/SQ.FT.	15307. BTU/SQ.FT.
PUMPS=	69944. KWH	0.CU.FT.	0.CU.FT.	1038. BTU/SQ.FT.	1038. BTU/SQ.FT.
MISCELLANEOUS EQUIP.=	0. KWH	0.CU.FT.	0.CU.FT.	0. BTU/SQ.FT.	0. BTU/SQ.FT.
TOTALS	5311939.	4555467.	0.	106015.	106015.
SOURCE ENERGY CONSUMPTION=	278447. BTU/SQ.FT./YEAR				

PHX MUNICIPAL CENTER; MUNICIPAL BLDG W/CHILLER LOAD (E-32 RATE)

PEAK MONTH CHARGES

MONTHLY BASIC SERVICE CHARGE= 15.00

PEAK PERIOD DEMAND CHARGE= 1.84 PER KW OVER 5 KW

CONSUMPTION CHARGE= 0.1120960 PER KWH FOR FIRST 2500 KWH (PLUS 100 KWH PER KW OVER 5)

CONSUMPTION CHARGE= 0.0774560 PER KWH FOR NEXT 42000 KWH

CONSUMPTION CHARGE= 0.0495710 PER KWH FOR ADDITIONAL KWH

OFF-PEAK MONTH CHARGES

MONTHLY BASIC SERVICE CHARGE= 15.00

PEAK PERIOD DEMAND CHARGE= 1.67 PER KW OVER 5 KW

CONSUMPTION CHARGE= 0.1012010 PER KWH FOR FIRST 2500 KWH (PLUS 100 KWH PER KW OVER 5)

CONSUMPTION CHARGE= 0.0698000 PER KWH FOR NEXT 42000 KWH

CONSUMPTION CHARGE= 0.0445250 PER KWH FOR ADDITIONAL KWH

SALES TAX RATE= 6.5195 PERCENT

MONTH	KW DEMAND	PEAK KWH CONSUMPTION	OFF-PEAK KWH CONSUMPTION	TOTAL KWH CONSUMPTION	ELEC. COST	TAX	TOTAL COST
JAN.	1063.	233145.	312552.	545697.	33279.	2170.	35448.
FEB.	1127.	228362.	300202.	528564.	32985.	2150.	35136.
MAR.	1180.	268372.	334910.	603282.	36701.	2393.	39094.
APR.	1188.	244070.	368404.	612474.	37169.	2423.	39592.
MAY	1226.	235514.	395223.	690737.	40933.	2669.	43601.
JUN.	1262.	295543.	400943.	696486.	46040.	3002.	49042.
JUL.	1286.	289999.	453293.	743292.	48555.	3166.	51720.
AUG.	1306.	317364.	425624.	742988.	48701.	3175.	51877.
SEP.	1268.	282662.	410128.	692790.	45906.	2993.	48898.
OCT.	1181.	262282.	396991.	659273.	43540.	2839.	46379.
NOV.	1159.	254493.	329265.	583758.	35678.	2326.	38004.
DEC.	1078.	224713.	316895.	541608.	33207.	2165.	35371.
	14324.	3196519.	4444430.	7640949.	482693.	31469.	514162.

PHX MUNICIPAL CENTER; CENTRAL PLANT CASE NO. 1 (W/CITY HALL) (E-34 RATE)

PEAK MONTH CHARGES

MONTHLY BASIC SERVICE CHARGE= 2430.00
 PEAK PERIOD DEMAND CHARGE= 11.14 PER KW
 CONSUMPTION CHARGE= 0.0350740 PER KWH FOR ALL KWH

OFF-PEAK MONTH CHARGES

MONTHLY BASIC SERVICE CHARGE= 2430.00
 PEAK PERIOD DEMAND CHARGE= 11.14 PER KW
 CONSUMPTION CHARGE= 0.0350740 PER KWH FOR ALL KWH

SALES TAX RATE= 6.5195 PERCENT

MONTH	KW DEMAND	BILLED DEMAND	PEAK KWH CONSUMPTION	OFF-PEAK KWH CONSUMPTION	TOTAL KWH CONSUMPTION	ELEC. COST	TAX	TOTAL COST
JAN.	4017.	4017.	470634.	473072.	943706.	80279.	5234.	85513.
FEB.	4227.	4227.	432899.	467709.	900608.	81107.	5288.	86394.
MAR.	4305.	4305.	500545.	547555.	1048100.	87149.	5682.	92830.
APR.	4357.	4357.	439757.	537793.	977550.	85254.	5558.	90812.
MAY	4537.	4537.	515361.	647916.	1163277.	93773.	6114.	99886.
JUN.	4624.	4624.	500586.	666466.	1167052.	94875.	6185.	101060.
JUL.	4768.	4768.	478737.	699405.	1178142.	96868.	6315.	103183.
AUG.	4818.	4818.	522950.	731325.	1254275.	100095.	6526.	106621.
SEP.	4635.	4635.	476567.	647990.	1124557.	93507.	6096.	99603.
OCT.	4419.	4419.	464135.	571595.	1035730.	87985.	5736.	93721.
NOV.	4324.	4324.	477920.	518186.	996106.	85537.	5577.	91113.
DEC.	4120.	4120.	469657.	455722.	925379.	80784.	5267.	86050.
	53151.	53151.	5749748.	6964734.	12714482.	1067210.	69577.	1136787.

PHX MUNICIPAL CENTER; CENTRAL PLANT CASE NO. 2 (W/CITY HALL) (E-35 RATE)

PEAK MONTH CHARGES

MONTHLY BASIC SERVICE CHARGE= 2450.00
 PEAK PERIOD DEMAND CHARGE= 13.71 PER KW
 PEAK PERIOD CONSUMPTION CHARGE= 0.0401500 PER KWH
 OFF-PEAK PERIOD CONSUMPTION CHARGE= 0.0244070 PER KWH

OFF-PEAK MONTH CHARGES

MONTHLY BASIC SERVICE CHARGE= 2450.00
 PEAK PERIOD DEMAND CHARGE= 13.71 PER KW
 PEAK PERIOD CONSUMPTION CHARGE= 0.0401500 PER KWH
 OFF-PEAK PERIOD CONSUMPTION CHARGE= 0.0244070 PER KWH

SALES TAX RATE= 6.5195 PERCENT

MONTH	PEAK DEMAND	OFF-PK DEMAND	BILLED DEMAND	PEAK KWH CONSUMPTION	OFF-PEAK KWH CONSUMPTION	TOTAL KWH CONSUMPTION	ELEC. COST	TAX	TOTAL COST
JAN.	3361.	4017.	3361.	470634.	473072.	943706.	78972.	5149.	84120.
FEB.	3424.	4227.	3424.	432899.	467709.	900609.	78189.	5098.	93287.
MAR.	3476.	4305.	3476.	500545.	547555.	1048100.	83567.	5448.	99015.
APR.	3494.	4357.	3494.	439757.	537793.	977550.	81135.	5290.	86424.
MAY	3552.	4537.	3552.	515361.	647916.	1163277.	87553.	5715.	93368.
JUN.	3583.	4624.	3583.	500586.	666466.	1167052.	87938.	5733.	93571.
JUL.	3644.	4768.	3644.	478737.	699405.	1178142.	88701.	5783.	94494.
AUG.	3647.	4818.	3647.	522950.	731325.	1254275.	91296.	5952.	97248.
SEP.	3572.	4635.	3572.	476567.	647990.	1124557.	86372.	5631.	92003.
OCT.	3497.	4419.	3497.	464135.	571595.	1035730.	82980.	5410.	88390.
NOV.	3482.	4324.	3482.	477920.	518186.	996106.	82024.	5348.	87372.
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