ON TARGET:
A COMPLICATED AND SUCCESSFUL ENERGY RETROFIT PROGRAM

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ABSTRACT

The Lone Star Gas Corporate headquarters, in Dallas, Texas, consists of a five building, 355,000 square foot office complex with buildings ranging in age from 14 - 60 years old between 20,000 - 100,000 square feet (SF), and with multiple HVAC systems served by two central plants. The company was facing the inevitable increase in electric utility costs knowing that two reactors at a new construction nuclear power plant would be coming on line over during the next five years. By taking a proactive stance, a six month detailed energy audit commenced after a thorough internal energy analysis was conducted. The result of the audit was a multi-year $1.7 million retrofit project encompassing nearly 20 major items would be implemented over three years. Total energy and cost avoidance savings were calculated to yield a simple pay back of 1.5 years and a cash pay out of 3.5 years. Total energy reductions of 32% were achieved and the predicted economics realized.

The various projects involved the application of nearly 18,000 square feet of window tinting, a total facility relamping and efficiency improvement project, installation of more efficient filtration systems, installation of control valves on the chillwater system, installation of a building automation system, installation of a plate heat exchanger for hydronic free-cooling, isolation of after-hours and 24-hour cooling loads on a separate loop, isolation and conversion of 24-hour steam requirements to reduce excess boiler capacity and run time, improvement of return air systems, the replacement and increase of cooling tower capacity, implement a preventive maintenance program, and improved operating procedures that focused on demand side management without thermal storage. The combined results of these single projects enabled the facility to remove and not replace 25% of the physical plant cooling equipment (one single-effect steam absorber) upon reaching the end of its expected life.

Project costs and avoided savings were tracked monthly throughout the three year period. Additional energy and cost avoidance tracking for two more years was completed. In five years, a positive cash flow of more than $550,00 is only 9% less than the original projection. Improved employee comfort and enhanced space conditions have returned significant benefits to the work force of nearly one thousand people occupying this facility.

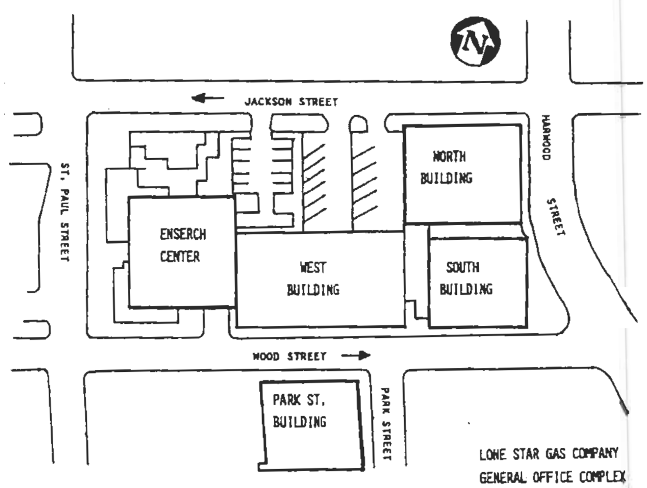


FIGURE 1. GENERAL OFFICE COMPLEX LAYOUT

BACKGROUND

The general office complex (GOC) described in the abstract above consists of five buildings, as shown in Figure 1 above. The North, South, West, and Park St. buildings total approximately 255,000 SF and are served by one central plant located in the West building, until recently. The North and South buildings, 160,000 SF, pre-date central plant systems due to original construction periods from 1924 - 1933. A penthouse equipment room, using single effect absorption chillers, a 2-pipe hydronic exterior zone system with nearly 600 air induction units, and "state of the art" variable air volume (VAV) technology was installed in the North and South buildings in 1949.

During mid 1960's construction of the West Building, the South building HVAC loads were connected to the newer plant and part of the 1949 equipment was abandoned in place. The 80,000 SF West building consisted of a 3-pipe hydronic induction system for the exterior zone, and constant volume air handler's for the interior zone. This new plant was designed with cogeneration, using waste heat to operate 717 tons of single effect steam absorption.

Ten years later, the North building HVAC load plus the conversion-addition of the 20,000 SF two story Park St. building were added to West building plant when the cogeneration process was removed due to costly operations. The central plant capacity was nearly doubled by adding 650 tons of single effect steam absorption equipment, two additional 350 HP low pressure steam boilers to replace the waste heat source and power all four absorbers, and the primary chillwater loop modified with a "piggyback" main for the two additional secondary building loops.

The plant then consisted of four absorption chillers of 1367 tons on a primary chillwater loop with seven separate secondary loops serving the various zones in the Park St., West, North, and South buildings, and approximately 1700 tons of cooling tower capacity piped as two separate condenser water loops. (See Figure 2.) The "computer loop" was added as cooling requirements exceeded original design capacity for that floor. A separate 160 ton centrifugal chiller was later added to the computer loop to isolate and stabilize the load from the rest of the facility.

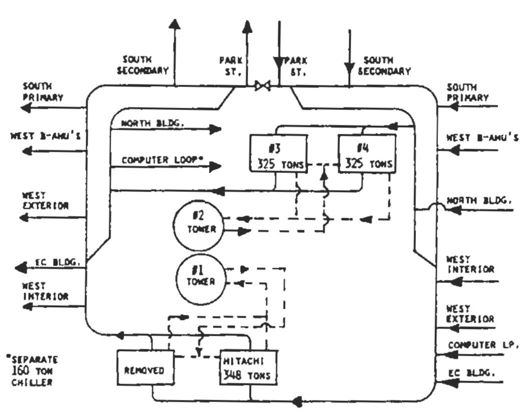


FIGURE 2. MAIN CHILLWATER DIAGRAM.

Only the 4 Park St. building air handlers (AHU's), out of 33 primary AHU's, had any chillwater flow control devices installed on them. Therefore, nearly 90% of the cooling load consisted of "wild coils." Lastly, Figure 2 shows the replacement of one original chiller with a double-effect direct fired absorption chiller, and the complete removal of the other original 372-ton single-effect steam absorber.

The "EC bldg." loop was installed for contingency operations only, six years after the 1981 construction of the 100,000 SF addition to the headquarters office complex. The building was purposely designed to have it's own central plant with 300 tons of centrifugal chillers, hydronic heating, and a VAV system on each floor. Each AHU has a 3-way flow control valve on the chillwater coil. However, no spare cooling capacity was designed into the facility.

PROBLEM

The multiple modifications to the West building central plant presented numerous HVAC climate control problems due to the wild coils. Quite often, two opposing chillers serving the original and "piggyback" loop had to be operated to adequately supply all secondary loops with enough water flow to the suction side of the pumps, even though the actual cooling load was less than 40% of both machines. Additionally, all four absorption chillers were needed for peak summer cooling.

The plant was operated nearly 24 hours a day due to the inability to control secondary zone climate conditions. This practice was also carried over from earlier 24 hour cogeneration operations. Additionally, the house cleaning staff consisted entirely of company employees, and they were provided with conditioned spaces each night until 1:30 a.m..

Anticipation of higher utility costs, the continuing problems with unbalanced water flows, a significant amount of hands-on plant operation, and the near future necessity to replace the remaining original 22 year old steam absorber created a high priority for determining a course of action for the physical plant mechanical systems.

DEVELOPING A PLAN: REALISTIC GOALS

All energy consumption and cost history was analyzed to determine a present benchmark from which future energy goals were to be achieved. The primary steam plant, serving four buildings, operated on 461,000 BTU / SF and averaged 7.29 watts / SF of electrical load for total utility operating cost of $3.26 / SF for 1986. Meanwhile, the EC building operated on nearly 200,000 BTU / SF, averaged 3.0 watts / SF at a cost of $1.25 / SF.

Higher costs and consumption for the larger plant were initially attributed to greater hours of operation to support the corporate data center cooling requirements, the use of single-effect steam absorption instead of electric centrifugals, and the inherent design of the primary and eight secondary chillwater loops each with a separate pump.

The decision was made to retain a professional energy consultant to assist the company in achieving it's goals. Three primary objectives of the goal were stated as:

1. Decide the tonnage size needed when Chiller #1 (372-ton absorber) is replaced.
2. Recommend a broad strategic five year plan for implementing energy and cost saving retrofits.
3. Provide recommendations for automating plant HVAC equipment over five years.
4. Provide facility occupants with a comfortable environment, and potentially cut energy consumption by 50%.

PHASE ONE: A DETAILED ENERGY AUDIT

A nationally experienced energy consultant in the Dallas area was retained. A detailed energy audit was conducted over a five month period in the first half of 1988, focusing on every aspect of the facility that required energy consumption or resulted in the need for space conditioning. Numbers of people, personal computer equipment, fax machines, copying machines, soft drink machines, coffee makers, light fixtures, document shredders, type writers, etc., were counted and inventoried on a floor by floor basis. Detailed information on the building envelope regarding square footage of curtain wall, windows, roofing composition, orientation, insulation values, and shading coefficients were determined. All HVAC equipment, elevator machinery, miscellaneous machinery, and a detailed energy consumption and expense history for 1987 were provided to the consultant.

AUDIT RESULTS AND RECOMMENDATIONS

A computer model of the GOC operations was run on the TRANE Trace mainframe application. The output was compared to a different model that included the retrofit recommendations of the consultant. As expected, the potential to reduce annual consumption by more than 50% was predicted. The consultant's recommendations focused on more than 20 major items. The simple payback method indicated a 1.5 year return on investment (ROI) for a $1.2 million capital program.

The facilities staff further utilized the consultant's skills to develop a four-year retrofit schedule. Specific items addressed were grouped as appropriate, and a budget plan was established. Initial internal evaluations, using a discounted cash flow model (DCF), indicated that a $1.2 million investment would generate a ROI of more than 90% over a 15 year period.

The project schedule included:

1988:

1. Clean 56 AHU coils + 900 induction units. Upgrade filters.
2. Improve pneumatic control air dryer systems.
3. Isolate or convert non-HVAC steam loads from boilers.
4. Retrofit EC boiler with temperature reset controls.
5. Balance West physical plant ventilation air systems.
6. Replace incandescent w/ compact fluorescent lights.
7. replace outdoor quartz lights with high pressure sodium.

1989:

1. Install 18,000 SF of window tinting.
2. Air balance & upgrade EC building VAV system controls.
3. Refurbish 600+ induction units with new controls.
4. Relamp and upgrade facility office lighting.
5. Remove chiller #1 and modify expansion tank system.

1990:

1. Install Hydronic economizer and flow control valves on all AHU's.
2. Install new fancoil interior zone system to South Bldg.
3. Building Automation Systems (BAS) 75% complete,

1991:

1. Complete South bldg. project.
2. Complete all building automation systems work.
3. Train plant staff on advanced BAS operations.
4. Implement automated work-order maintenance system.

The corporate training staff was used to further showcase the project's potential by developing a 23 minute video presentation for Senior management. Approval was granted to commence immediately, and increase the 1988 budget in less than 45 minutes.

1988 PROJECTS AND RESULTS

By mid October, significant work was underway for installing 18,000 SF of window tinting and cleaning all AHU coils and upgrading coils. November 1988 GOC energy consumption was 16% <u>less</u> than November 1987. The increased coil surface efficiency created additional comfort control problems resulting from better heat transfer.

More than $20,000 in lighting retrofits of interior and exterior incandescent lighting was completed by the end of December. The majority of the interior lights are on 24 hours a day year round, in stairwells and elevator lobbies. The calculated ROI for this portion was less than 12 months.

Steam humidification control in several computer room Liebert air conditioning units were replaced with electric quartz elements. The facility domestic hot water (steam) heater was modified, by adding a separate boiler to the system. The steam heat was valved off as a backup source.

The additional air dryer for plant control air had immediate results. While the original unit was sufficient for system capacity, the boiler room environment routinely had high humidity from occasional deareator pop-offs. Once the control air system was dried out, various plant systems began operating more smoothly.

1989 PROJECTS AND RESULTS

The EC building (12 stories) required a complete air balance as well as upgrades to the building control system. Many VAV units were manually locked in various positions. This "solution" was due in part to earlier commissioning of the structure. The ceiling plenum return air path to the AHU room required 100% of the return air to be drawn between two areas with little clearance beneath I-beams. A resulting affect was that hallway ceiling tiles located directed beneath the AHU room intake were lifted from the grid as the air flow took the path of least resistance. A quick fix it solution was to install several 2' X 2' egg crate open tiles. This solved one problem yet short circuited the design of the system causing the hallway to be used as a return air plenum.

To remedy the above situation, new tiles were installed using clamps to prevent lifting. A complete air balance, better placement of the static pressure sensor in the main air ducts, and DDC automation of the 3-way chill water valves improved comfort problems. Cooling tower, chiller, pump controls, KW demand metering, and integration for optimizing building start / stop times was begun.

More than 5000 office fluorescent lighting fixtures received "special" attention. A very laborious process, a detailed lighting survey, with occupant interviews, led to the development of complicated plan. Every fixture was relamped, cleaned, and had new acrylic lenses installed. (The fixtures had not been cleaned prior for over 15 years!) Due to a high fixture density, about 1100 were removed. This later involved additional work to properly dispose of PCB laden ballasts. Many of the remaining fixtures were either delamped to two lamps per fixture and / or relocated. The resulting ROI for the entire lighting project, including the purchase of 1100 ceiling tiles, was under two years. Nearly 300 KW, or 32%, of the beginning lighting energy was removed due to increased efficiencies. Additionally, average light levels throughout the GOC improved by 25%.

Detailed plans to replace temperature control devices on the 600 (35 year old) induction units, and repipe nearly 300 3-pipe induction units into somewhat of a 4-pipe zoned system was canceled. Contractor bids were more than double the original estimates due to excessive risk in working on active systems requiring repeated drain down and fill times, unknown variables about the integrity of the aged chillwater piping, and having to work in occupied building and protect furniture and equipment from potential water damage.

By the beginning of August 1989, the summer peak cooling load served by the West bldg. plant was significantly reduced. A combination of the cleaner coils, better heat transfer, reduced lighting energy load, window tinting, and improved plant controls eliminated the need for the fourth absorption chiller (as a back up). Hence, this 372 -ton chiller was removed and no replacement was necessary.

By the end of 1989, annual energy consumption had been reduced by more than 25% from 1987. Total project costs to date were $401,000. Avoided costs of more than $417,000 gave the project a positive cash flow of $16,000 even though none of the projects requiring major construction and piping changes had yet begun.

Excellent savings and improved energy efficiencies had now been accomplished in two years with a little over one-third of the construction budget. However, more significant changes and detailed planning were necessary as the rest of the projects became the main thrust of the strategic plan for the central plant and future operations.

1990 PROJECTS AND RESULTS

Two significant projects requiring nearly $525,000 took place in late 1990 and early 1991. These projects included 1) installing 2-way flow control valves on the major AHU's and connect 5 of 9 secondary loops to a new plate and frame heat exchanger for free cooling, and 2) extending the "computer loop," supplied by chiller #5, throughout the North, South, and West buildings. This extension would enable future 24 hour, high density HVAC loads to receive cooling separate from the primary systems. Secondly, 24 hour penthouse cooling would be needed for future electronic elevator control equipment as modernization occurs and for present elevator equipment in the West building penthouse when HVAC services were to be cut back on nights and weekends.

Figure 3 simplifies the piping schematic involving the free cooling plate heat exchanger installation. Only those loops or building zones requiring cooling year round were added. The computer loop was added for two reasons. First, the opportunity arose to maximize cooling potential in the winter months without the use of chiller #5 when outdoor temperatures drop below 45 degrees F. Second, in the event of extremely cold weather, the heat rejection from the computer loop may assist in preventing freeze damage to the cooling tower cells in use. The frame size for the heat exchanger was specified so that future addition of the EC ("ENSERCH Center" in Figure 3) building winter cooling load could be added. This would finally enable the shut down of all chillers and absorbers between 1000 - 1500 hours a year.

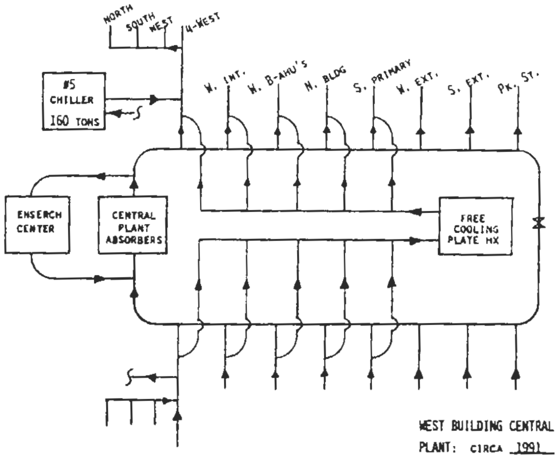


FIGURE 3. FREE COOLING HEAT EXCHANGER.

The staging of pipe sections, valves, rigging equipment, and flanges was crucial for this addition, because it was also coupled with the installation of 2-way flow control valves on the major AHU's. Installation requirements mandated that the computer loop remain in operation and be isolated from the rest of the chill water system that was drained. One condenser water loop also remained in operation.

The 4-day Thanksgiving weekend provided enough time to complete the drain down, install necessary valves, replace original nonfunctional valves, and install cross over valves on the condenser water loop. Cross over valving was added to increase system flexibility during cooling tower replacement in 1991. Figure 4 shows this arrangement which allows the plate heat exchanger to operate on either condenser water loop while absorption machines are operated on the other.

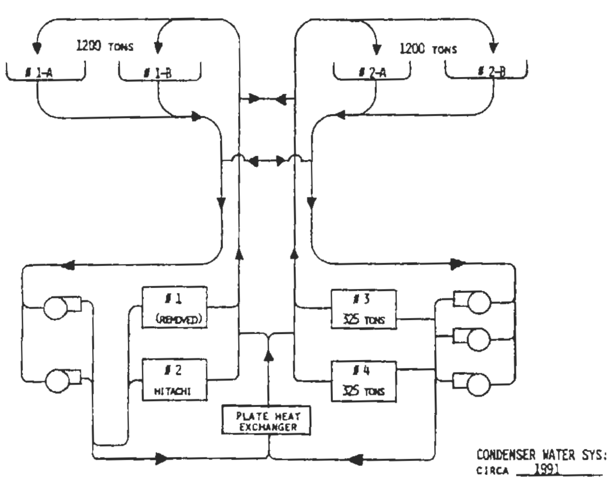


FIGURE 4. CONDENSOR WATER LOOPS.

By the end of 1990, an additional $450,000 in project expenses were incurred covering year end work. Total program costs of $856,000 minus avoided utility expenses netted a negative cash flow of $110,000. Even though the cash flow model change of $126,00 from a positive to a negative number occurred, the amount was still $100,000 less than was originally estimated and acceptable to the company.

1991 PROJECTS AND RESULTS

The project involving the addition of an interior zone system to the South Building was canceled, again due to extremely prohibitive construction costs. Instead, the focus remained on completing piping connections for the plate heat exchanger loop and gaining automated control of all the new 2-way valves and heat exchanger valving.

The original wood cross-flow cooling towers were replaced in 1991. This project was separate from the original proposal submitted by the consultant, yet dove tailed nicely into the overall strategic plan for the facility.

Continuous leakage around the tower basins, some structural steel decay on the submerged I-beam foundations in the basin and the fan gearbox supports resulted in part due to extensive operations this equipment received over the years. After reviewing the cost estimates required to make a 25 year old tower operate like a brand new 25 year old tower (i.e., single speed motors and wooden basins), a complete tower replacement decision received management approval.
The 1700 tons of original tower capacity was replaced and increased to 2400 tons (four 600 ton cells) of fiberglass counter flow towers with 2-speed fan motors. On a side note, nearly 81,000 lbs. of operating weight for the wooden towers became less than 25,000 lbs with the new towers.

The increase in sizing provided future up sizing from 325 ton single effect steam absorption equipment to 400 - 450 ton replacement double effect direct-fired absorption equipment. This up sizing would be crucial since the primary chillwater machinery now consisted of only three instead of four machines.

Analysis of total water consumption showed that nearly 40% of annual usage was associated with the cooling towers. Local rates provided excellent cost savings if more than 10% of total consumption is "nonsewage" type of use. The tower make up and bleed off water was separately metered to get credit for this discount. Total costs of less than $3,500 resulted in a simple ROI of less than four months.

At years end, total project costs were nearly $1.1 million. Nearly $1.2 million in avoided energy costs and 30% energy reductions were achieved in only 36 months.

1992 PROJECTS AND RESULTS

Detailed energy consumption history was used for operations analysis, utility cost forecasting, and project reporting. Changes to the operation of both central plants also reduced operating costs. Primarily, the 300 tons of electric chillers in the EC building are shut down during business hours. Chillwater is provided from the West building absorption plant. While energy consumption has risen, operating costs have been reduced by eliminating the daytime energy and electrical demand costs associated with electric equipment. These machines are only run after hours when the building KW loads had been significantly lowered from the shut down of AHU's and office lighting.

The facilities HVAC operations, excluding minimal 24 hour loads, have been routinely shut down at night and on weekends. The plant staff is now accustomed to predicting operating patterns based on weather conditions. Space conditioning complaints continued to decrease and occupant morale is perceived as continually improving.

The construction budget for training, completing the BAS system, and automating maintenance were already included in previous years costs.

FIVE YEAR PROJECT SUMMARY

Cooling tower replacement costs of nearly $625,000 were included with the $1.1 million multi-year retrofit projects in order to track additional avoided costs and determine a combined cash flow model. While slightly more than $1.7 million had been spent in 3.75 years, a net positive cash flow of $70,000 was generated by the end of 1992. Annual utility costs had dropped by 15% since 1987 and total energy consumption decreased by 32%. Figure 5 presents these trends graphically.

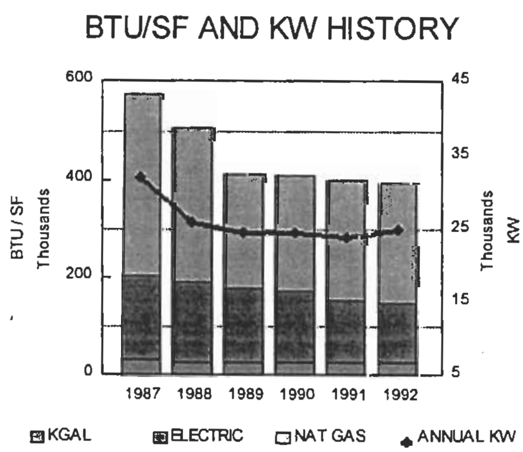


FIGURE 5. ENERGY CONSUMPTION HISTORY.

PHASE TWO: THE NEXT STEP

The ability to incorporate strategic design elements into the physical plant modifications has paid handsome dividends. As of mid-summer 1994, additional HVAC plant modifications have included:

1. Complete DDC automation and improved comfort control of the two story Park Street building.
2. Replacement of two 325-ton single effect steam absorption units with one 400-ton and one 450-ton double-effect direct fired TRANE chillers.
3. Adding the EC building winter cooling load to the free cooling plate heat exchanger.
4. Replacement of several 40 + year old AHU's, allowing better space control and full DDC automation in the South building..

Objectives for the immediate five year future include the following:

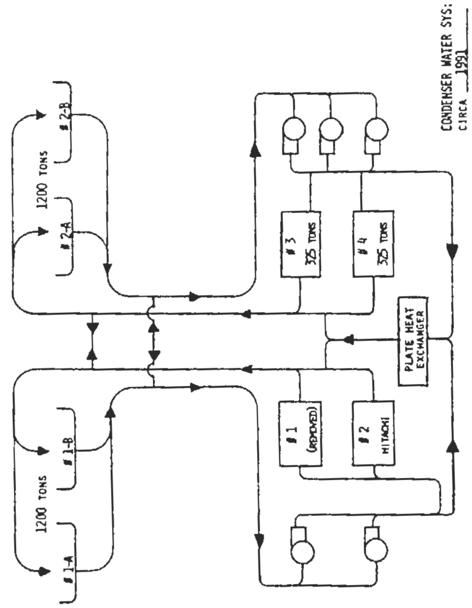
1. Remove all three 350 HP low pressure steam boilers and replace with a series of smaller, more efficient units arranged in a step fired sequence.
2. Removal of 300 tons of electric centrifugals in the EC building and replace with gas equipment.
3. Add 24 hour air conditioning to the two unconditioned elevator equipment rooms during modernization.

SUMMARY

Many facilities possess the potential for tremendous energy conservation opportunities (ECO's). While the dedication and knowledge of the in-house staff can accomplish a lot of individual ECO's, the formulation of an extensive multi-year master plan requires the skill of a knowledgeable professional. Businesses and owners must be willing to embrace the potential when a "reach for the sky" can take you all the way to the stars.

Lone Star Gas did not proceed blindly into this program. Strong supporting evidence regarding the performance history of the TRANE Trace program and the professional energy consultant's experience was meticulously scrutinized. Upon our complete satisfaction, project approval was granted.

Energy reductions of more than 50% were not achieved because all of the original recommendations were not completed. Should the company have agreed to proceed with the seemingly cost prohibitive construction items, then an additional 18% energy reduction may have occurred. In turn, the project ROI and cash pay out may not have been affected at all. However, the 32% reduction and repeated cost reduction in annual energy costs is a clear example that energy engineering can return significant dividends to the user.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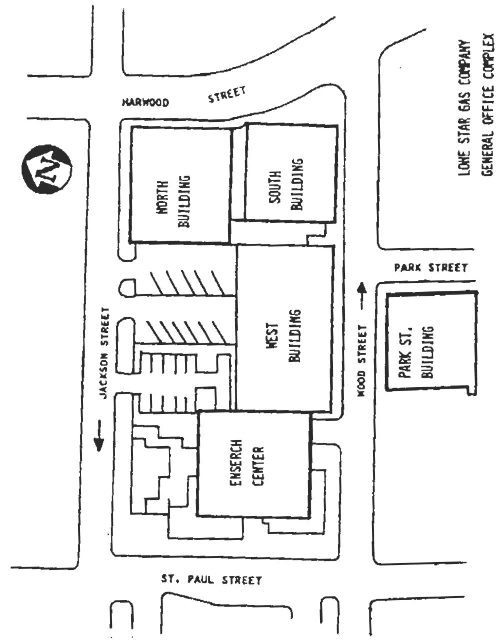
#1-B
1200 TONS
#2-A
#2-B
#1 (REMOVED)
#2 HITACHI
#3 325 TONS
#4 325 TONS
PLATE HEAT EXCHANGER
CONDENSER WATER SYS: CIRCA 1991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NORTH BUILDING
SOUTH BUILDING
WEST BUILDING
ENSERCH CENTER
PARK ST. BUILDING
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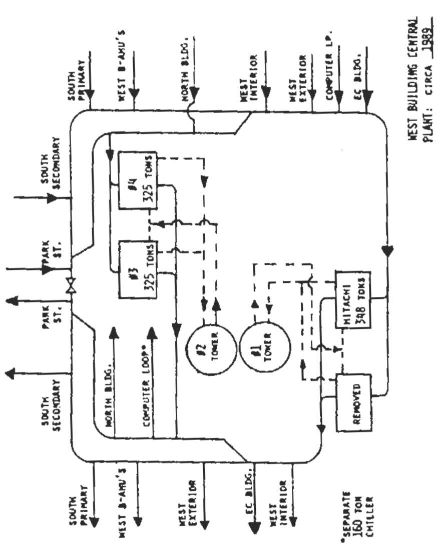
JACKSON STREET
WOOD STREET
ST. PAUL STREET
LONE STAR GAS COMPANY
GENERAL OFFICE COMPLEX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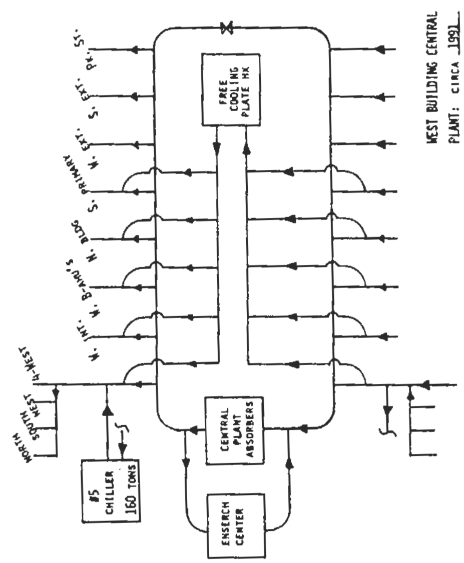
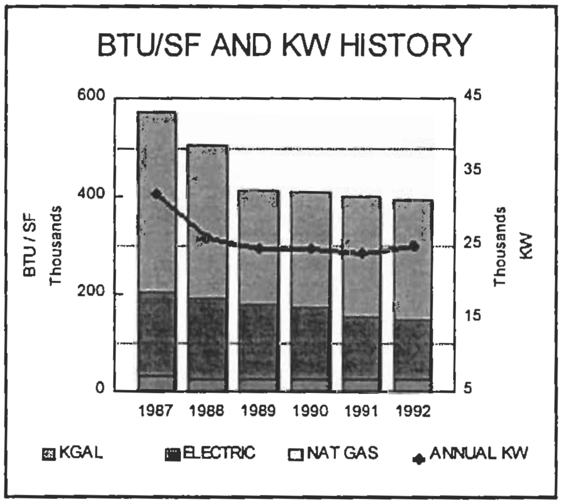
WEST B-AHU'S
NORTH BLDG.
WEST INTERIOR
WEST EXTERIOR
COMPUTER LP.
EC BLDG.
SOUTH SECONDARY
PARK ST.
#4 325 TONS
#3 325 TONS
#2 TOWER
#1 TOWER
HITACHI 348 TONS
REMOVED
NORTH BLDG.
COMPUTER LOOP*
*SEPARATE 160 TON CHILLER
WEST BUILDING CENTRAL PLANT: CIRCA 1989


FREE COOLING PLATE HX
CENTRAL PLANT ABSORBERS
ENSERCH CENTER
#5 CHILLER 160 TONS
NORTH
SOUTH
WEST
4-WEST
WEST BUILDING CENTRAL PLANT: CIRCA 1991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