

"ENERGY STUDY OF CITY HALL BUILDING"
Port Arthur, Texas
1980-1981

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ABSTRACT

As may be noted by the title, this is a detailed study of the energy consumption of this building. It deals in the real world of actual energy utilization and it concludes with a "How To" approach to reduce and/or control the amount of energy used, commensurate with the practicality of the day to day operation of the structure. It also recognizes the absolute need to respect the fact that the most important aspect of any recommended changes is how they will affect the occupants of the building in their working conditions, as well as their health and safety.

INVESTIGATIVE STATEMENT

City Hall is a 61,500 square foot, masonry building approximately ten years old. The building is sound and should be of service another twenty years. The building uses energy to provide HVAC, lighting, hot water, communications and business machine power.

In the transmittal letter to the city manager, credit was given to numerous private companies for their assistance in compiling the actual methodology used in the recommended improvements. I cannot stress too highly the importance of involving outside vendors and maintenance and operating personnel at the onset of any major study. Their experience factors, weighed, represent an asset to the engineering firm that will be positively reflected in the final analysis of the problem and some of the solutions. We started the study in a meeting with Mr. Jack Brown, who was their energy coordinator and is a Certified Energy Auditor, plus several department heads and at this time, we discussed what we were there for - and what our method of procedure would be. I am including this information to stress the absolute importance of involving the various departments and individuals so they would not feel that a group of "outsiders" was coming in to criticize and otherwise fault them, but rather that we were there to assist in reducing their overall operating costs and to build in an operating system which would be more practical and comfortable as well.

PRELIMINARY ENERGY AUDIT

We began the study by conducting a Preliminary Energy Audit (PEA) which resulted in establishing (1) the Energy Utilization Index (E.U.I.) in BTU/square foot/year, (2) the Energy Cost Index (E.C.I.) in \$/square foot/year, and (3) building energy saving potential, weighting factor (W.F.).

The form used was developed by DOE for use by Certified Energy Auditors and Engineers, and should be used by trained personnel to avoid problems downstream, as the PEA is the foundation for the entire study and accuracy is a must.

I will not presume to act as an auditor instructor, but will rather provide form names, etc., and let each individual make their determination as to whether they are qualified to perform this PEA and the Energy Audit (E.A.) which followed.

Our first move was to secure the plans and specs of the structure, and work with the City Engineering Staff to ensure that the drawings, etc., were indeed "as built" and quietly attempt to ascertain if they knew of any problems with the systems and if there were to be anticipated future expansions, particularly in the EDP field that would affect our final recommendations. We established an operating base in quarters furnished by the city within the subject building and started the investigation by beginning to amass the data we required to determine the problem areas and where ECM's could be implemented.

The first walk through offered no great surprises, other than the discovery of an almost complete lack of water treatment equipment and no testing methods, nor records, yet the bore brushes used to clean the tubes were carefully racked and had obviously been used well, and frequently.

THE AUDIT

The next step was to review the PEA and begin to make first cut determination as to what was needed to be done to reduce energy consumption through ECM's and M & O procedures without regard to cost or degree of effectiveness. Once these items were identified, they were placed in two orders; one, cost effectiveness and two, actual energy reduction. Weighting factors, such as personal comfort, direct dollar

cost, return on investment, time, and general practicality were among the criteria used for a final selection and we then met with various department heads to determine manpower capability and availability to incorporate the maintenance and operating procedures and what, if any, training programs might need to be instituted if these M & O's were implemented. The Energy Audit (E.A.) was begun at this time and with the attendant information developed through the audit, we were able to make final recommendations to the client.

It was determined that two maintenance and operating procedures should be implemented. These are lighting modifications and chilled water treatment. Most lighting changes should be performed on a natural attrition basis so as to minimize cost. The chilled water treatment will clean-up the existing piping loops, heat exchangers and cooling tower. Two energy conservation measures have been identified. The absorption chiller system should be replaced with a centrifugal liquid chiller. The absorption machine was a wise choice in 1970, but its continued operation under 1980 economics is prohibitive. Even greater HVAC savings are available

through the modification of the control system. This will eliminate the cool, then reheat mode of operation presently used.

This building offers little potential for conversion to renewable resources (primarily solar). However, no codes nor ordinances are known to exist which would inhibit the installation of renewable energy equipment.

The recommended energy conservation program is attractive from the standpoints of both energy and economics. A simple payback occurs at 3.65 years. When an energy escalation rate of 15% is applied to the saved energy, the program cost of \$279,519 saves the City of Port Arthur nearly \$1,800,000 during the first ten years of operation. Continued energy savings accumulate at an annual rate in excess of 127% of initial investment.

The following graphs and charts reflect the findings and are included to demonstrate graphically how much can be saved through sensible energy conservation. Data sheets covering the specific area are included at the appropriate points and comments will conclude the analysis of this study.

ENERGY CONSERVATION PROGRAM

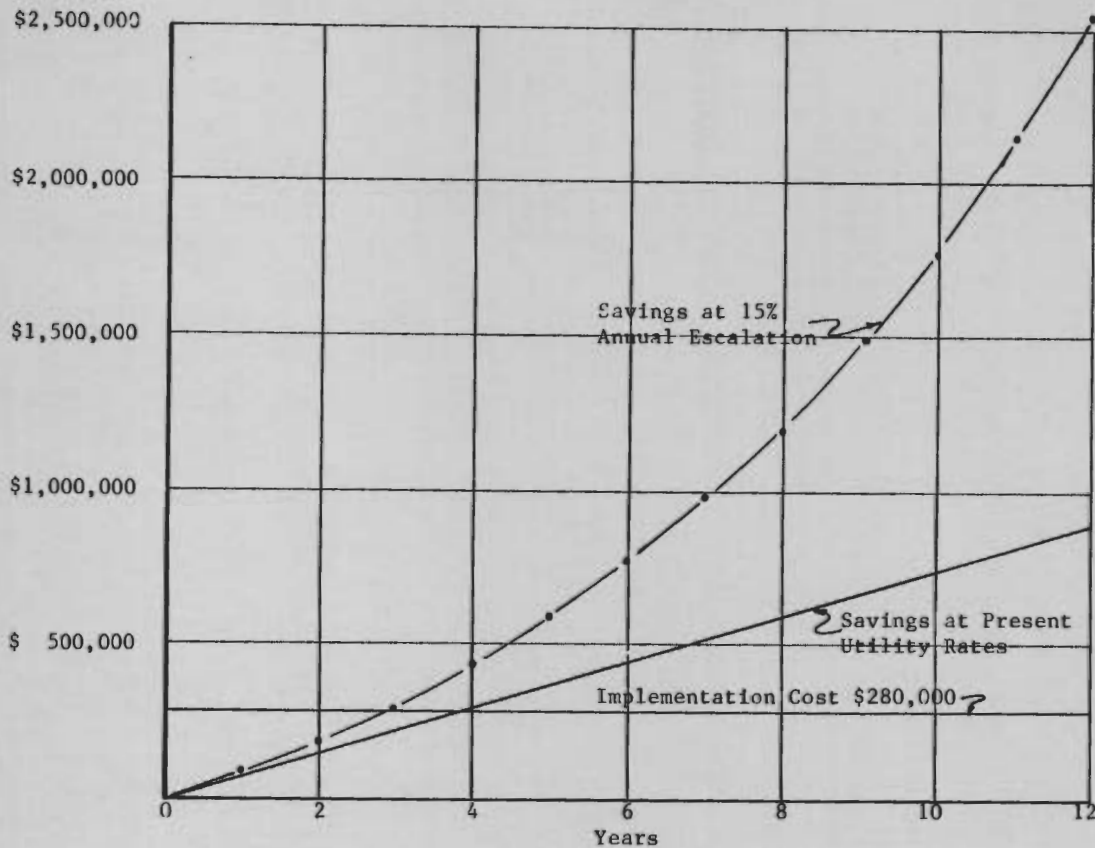
Building Area in Gross Square Feet: 61,500

	TOTAL ANNUAL BTU	BTU/SQ.FT./YEAR	ANNUAL ENERGY COST (\$)	COST (\$) SQ. FT./YEAR
CURRENT CONSUMPTION	38,178 x 10 ⁶	620,780	129,318	2.10
M & O SAVINGS	1,408 x 10 ⁶	22,893	7,518	0.12
CONSUMPTION FOLLOWING M&O SAVINGS	36,770 x 10 ⁶	597,887	121,800	1.98
ECM SAVINGS	14,775 x 10 ⁶	240,245	69,013	1.12
CONSUMPTION FOLLOWING RECOMMENDED ECM IMPLEMENTATION	21,995 x 10 ⁶	357,642	52,787	0.86
GRAND TOTAL SAVINGS	16,183 x 10 ⁶	263,138	76,531	1.24

COST/BENEFIT:
Simple Payback

$$\frac{\$ 279,519 \text{ (Total Implementation Cost)}}{\$ 76,531 \text{ (Total Annual Energy Cost Savings)}} = 3.65 \text{ (Years Payback)}$$

CUMULATIVE SAVINGS PROJECTION



BUILDING OPERATING CHARACTERISTICS

1. PRELIMINARY ENERGY AUDIT (PEA):

- a. Energy Utilization Index (E.U.I.) in BTU/Square Foot/Year: 620,780
- b. Energy Cost Index (E.C.I.) in \$/Square Foot/Year: \$2.10
- c. Building Energy Saving Potential, Weighing Factor (W.F.): 85

2. ENERGY AUDIT (EA):

- a. Metered Building: Percent savings of energy from current Maintenance and Operating Energy Conservation Procedures: 12.6 %

3. SYSTEM DESCRIPTION:

- a. VENTILATING SYSTEMS: Ventilation of this building is a fairly straightforward system comprised of roof and wall mounted fans to handle rest room and kitchen exhaust. The system appears to operate in a satisfactory manner commensurate with building needs and is in good operating condition. With periodic cleaning and routine preventative maintenance, the system should meet foreseeable future requirements.
- b. HEATING SYSTEM: Boiler currently interfaced with the 200-ton absorption chiller will continue to be used for heating.

- c. COOLING SYSTEM: Recommend replacing the 200-ton absorption chiller with a centrifugal chiller.
- d. LIGHTING SYSTEM: Lighting is primarily fluorescent with the notable exception of council chamber fifth floor area and certain areas of the fourth floor, which are incandescent. By following recommended change out to high efficiency lamps and ballasts of the fluorescent fixtures, and lamp style modifications to the incandescent fixtures should not only result in reduction of overall operating costs but will not adversely affect the light quality throughout the building.
- e. AIR AND WATER DISTRIBUTION SYSTEM: By addition of supplemental domestic hot water heating, brought about by changing the heating and cooling method recommended in this report, we can tie into the existing circulation system with a minimum of initial expense and with considerable operating and maintenance cost savings in the future. The existing fan coil air distribution system is adequate but needs to be cleaned and properly maintained, particularly in the control and filter areas.
- f. CENTRAL PLANT: The system as it now stands and the recommended change out is covered in Paragraphs b & c of this section.
- g. PROCESS SYSTEMS: EDP equipment is now functioning on the existing system, and unless future expansion or conversion dictates a need for supplemental cooling and/or heating, there appears to be no need for additional or supplemental

equipment at this time.

4. ESTIMATED REMAINING USEFUL LIFE OF BUILDING: 20 Years.

CURRENT ENERGY CONSUMPTION RECAP					
For prior 12-month period beginning September, 1979 and ending August, 1980					
ENERGY SOURCE	FUEL UNITS PURCHASED ANNUAL TOTAL	BTU's ANNUAL TOTAL	BTU PER S.F./YR.	TOTAL COST OF ENERGY (\$)	CURRENT ENERGY COST RATES
Electricity	1,150,080	13,341 x 10 ⁶	216,926	39,112	\$.034/KWH
Natural Gas	24,113	24,837 x 10 ⁶	403,854	90,206	\$3.74/MCF
ANNUAL TOTALS	---	38,178 x 10 ⁶	620,780	129,318	----

TABULATION OF SYSTEMS ENERGY CONSUMPTION									
For Period <u>September, 1979</u> to <u>August, 1980</u>									
SYSTEM	Electrical		Natural Gas		Pur. Thermal		Other Fuels	Totals Each System	
	KWH (4) (E ₀)	BTU (E ₆)	MCF (E ₀)	BTU (E ₆)	BTU (E _{___})	BTU (E _{___})		BTU (E _{___})	BTU (E ₆)
	HEATING	--	--	4,838	4,983	--	--	--	4,983
COOLING (1)	--	--	18,771	19,334	--	--	--	19,334	314,373
AIR DISTRIBUTION	252,000	2,923	--	--	--	--	--	2,923	47,528
WATER DISTRIBUTION	352,800	4,092	--	--	--	--	--	4,092	66,536
DOM. HOT WATER	--	--	504	520	--	--	--	520	8,455
LIGHTING	329,832	3,826	--	--	--	--	--	3,826	62,211
ELEVATORS	18,800	218	--	--	--	--	--	218	3,544
MISC. USES & EQUIP. (2)	57,500	667	--	--	--	--	--	667	10,845
OTHER	139,148	1,615	--	--	--	--	--	1,615	26,260
ANNUAL CALCUL. TOTALS (3)	1,150,080	13,341	24,113	24,837	--	--	--	38,178	620,780
ANNUAL METERED TOTALS (3)	1,150,080	13,341	24,113	24,837	--	--	--	38,178	620,780

BUILDING GROSS AREA: 61,500

BTU/SQUARE FOOT/YEAR: 620,780

- (1) Include refrigeration, cooling tower & cond. wtr. pumps
- (2) Limit to less than 5% of total.
- (3) Annual calculated totals should equal annual metered totals by reconciling any degree day variations and by accounting for reheat, distribution losses, etc.
- (4) E_{___} denotes exponential value.

MAINTENANCE AND OPERATING PROCEDURES

M&O IMPLEMENTATION RECAP					
Estimated energy consumption for prior 12 month period beginning September, 1979, and ending August, 1980, assuming all Energy Conservation, Maintenance and Operating Procedures have been implemented.					
ENERGY SOURCE	FUEL UNITS ESTIMATED ANNUAL TOTAL	BTU'S ANNUAL TOTAL	BTU PER SQ.FT/YEAR	TOTAL COST OF ENERGY (\$)	ENERGY COST SAVINGS (\$)
Electricity	1,028,701	11,933 $\times 10^6$	194,033	31,594	7,518
Natural Gas	24,113	24,837 $\times 10^6$	403,854	90,206	-0-
ANNUAL TOTALS		36,770 $\times 10^6$	597,887	121,800	7,518

APPLICABLE MAINTENANCE AND OPERATING PROCEDURES					
M&O procedures plus energy conservation measures with less than one year simple payback.					
M&O NO.	TITLE	SAVINGS MMBTU/YEAR	SAVINGS \$/YEAR	IMPL. COSTS	PAYBACK YEARS
1	Lighting Modification	105	3,696	3,332	0.9
2	Water Treatment Program	1,303	3,822	2,812	0.7
TOTALS	--	1,408	7,518	6,144	0.8

MAINTENANCE & OPERATING PROCEDURES (M&O DATA)

- a. M&O NUMBER 1 M&O TITLE: Lighting Modifications
- b. M&O PROCEDURE DESCRIPTION: (Provide complete description of Procedure. Enlarge length of narrative when required).

Lighting should be modified as called for in Appendix A-3, Lighting Detail.

c. COST/BENEFIT:

(1)SIMPLE PAYBACK

Savings MMBTU/Year: $\frac{105}{}$
 Savings/Year: $\frac{\$3,696}{}$
 Implementation Cost: $\frac{\$3,332}{}$
 Payback: $\frac{0.9}{}$ Years

MAINTENANCE & OPERATING PROCEDURES (M&O DATA)

- a. M&O NUMBER: 2 M&O TITLE: Water Treatment Program
- b. M&O PROCEDURE DESCRIPTION: (Provide complete description of Procedure. Enlarge length of narrative when required).

Install metering system to introduce balanced chemistry into the chilled and hot water piping loops to reduce or eliminate scale, corrosion, and other build ups within each system. Follow the same procedures in the cooling tower loop. Provide test lab set up for monitoring the overall chemistry.

c. COST/BENEFIT:

(1)SIMPLE BACKBACK

Savings MMBTU/Year:	<u>1,303</u>
Savings/Year:	<u>3,822</u>
Implementation Cost:	<u>2,812</u>
Payback:	<u>0.7</u> Years

SOLAR ENERGY CONVERSION POTENTIAL

1. **DESCRIPTION:** (Evaluation of the building's potential for solar conversion, particularly for water heating systems, including site adaptability, potential use of solar energy, reduction in non-renewable energy source use. Enlarge length of narrative when required).

This building offers little potential for conversion to renewable energy resources (primarily solar). The mixture of multi-story sections would prevent the placing of an effectively sized collector field.

2. **CODES AND ORDINANCE RESTRICTIONS:** (Provide a listing of any known local zoning ordinances and building codes which may restrict the installation of solar systems. Enlarge length of narrative when required).

No codes nor ordinances are known to exist which would inhibit the installation of renewable energy equipment.

ENERGY CONSERVATION MEASURES

(Assume that all savings from M&O procedures have been realized)

<u>APPLICABLE ENERGY CONSERVATION MEASURES</u>						
(With 1.0 to 15.0 Year Simple Payback)						
ECM NO.	TITLE	IMPL. COSTS (\$)	SAVINGS \$/YEAR	SAVINGS MMBTU/YR.	PAYBACK YEARS	
1	Chiller Replacement	210,000	55,036	10,636	3.8	
2	HVAC Control System Modification	63,375	13,977	4,138	4.5	
TOTALS	--	273,375	69,013	14,774	3.96	

ENERGY CONSERVATION MEASURE IMPLEMENTATION RECAP

Estimated energy consumption for prior 12 month period beginning September, 1979 and ending August, 1980, assuming all Recommended Energy Conservation Measures have been implemented, and the building is operating at optimum performance.

ENERGY SOURCE	FUEL UNITS ESTIMATED ANNUAL TOTAL	BTU'S ANNUAL TOTAL	BTU PER SQ.FT./YEAR	TOTAL COST OF ENERGY (\$)	ENERGY COST SAVINGS (\$)
Electricity	1,507,741	17,490	284,390	48,840	17,246
Natural Gas	4,374	4,505	73,252	3,947	86,259
ANNUAL TOTALS	--	21,995	357,642	52,787	69,013

ENERGY CONSERVATION MEASURE (ECM) DATA
(Complete one thus for each ECM)

\$ _____ per year increase
 \$ _____ per year decrease
 \$ X _____ same costs, no charge

- a. ECM NUMBER 1 ECM TITLE: Chiller Replacement
- b. ECM CATEGORY:
 ___ Building Load ___ Distribution Load
X Equipment Load ___ Solar
 ___ Other Renewable Energy Resource
 If "Other," describe _____
- c. ECM DESCRIPTION: (Provide complete description of ECM proposed. Include sketches for clarity where applicable. Enlarge length of narrative as required).

Replace entire absorption chiller system with a centrifugal liquid chiller such as a Carrier 19DH (200 tons). Continue to use all distribution systems, chilled water pumps, cooling water pumps and cooling tower. Continue to use existing boiler for heating. Leave absorption machine in place (save removal costs).

- j. ECM SALVAGE/DISPOSAL COSTS:
 Indicate \$ _____ salvage value, OR \$ _____ disposal costs, OR X no residual costs at end of the useful ECM life.
- k. CALCULATIONS: Identify source(s) for procedures used in calculating energy and energy cost savings for ECM's State of Texas - Energy Auditor Training II Manual

ENERGY CONSERVATION MEASURE (ECM) DATA
(Complete one thus for each ECM)

- a. ECM NUMBER: 2 ECM TITLE: HVAC Control System Modifications
- b. ECM CATEGORY:
 ___ Building Load X Distribution Load ___ Equip. Load
 ___ Solar ___ Other Renewable Energy Resource
 If "Other," describe _____
- c. ECM DESCRIPTION: (Provide complete description of ECM proposed. Include sketches for clarity where applicable. Enlarge length of narrative as required).
 Modification of the control sequence at the individual air handlers, so as to set the unit to heat or cool. Presently the system operates on a cool and reheat program. This modification should be performed by a control manufacturer such as Honeywell, on a negotiated basis.

- d. ECM IMPLEMENTATION COST ESTIMATE:
 1. Professional services for design and administration* \$ ---
 2. Equipment (installed) \$ 140,000
 3. Material (elec. installed) \$ 70,000
 4. Installation Labor \$ ---
 5. Total \$ 210,000
- e. ECM SAVINGS: Indicate estimates of annual energy savings and energy cost savings by fuel type to be realized by this ECM, using CURRENT energy prices. Assume that all energy savings obtained from energy conservation maintenance and operation procedures have already been realized.
 Annual Energy Savings - 8,698 BTU Electricity
 19,334 BTU Natural Gas
 Total Annual Energy Savings 10,636 BTU
 Annual Energy Cost Savings \$- 26,993 Electricity
 \$ 82,029 Natural Gas
 Total Annual Cost Savings \$ 55,036

- d. ECM IMPLEMENTATION COST ESTIMATE:
 1. Professional services for design and administration* \$ ---
 2. Equipment \$ 63,375 (installed)
 3. Material \$ ---
 4. Installation Labor \$ ---
 5. Total \$ 63,375
- e. ECM SAVINGS: Indicate estimates of annual energy savings and energy cost savings by fuel type to be realized by this ECM, using CURRENT energy prices. Assume that all energy savings obtained from energy conservation maintenance and operation procedures have already been realized.
 Annual Energy Savings: 3,141 BTU Electricity
 997 BTU Natural Gas
 Total Annual Energy Savings 4,138 x 10⁶ BTU
 Annual Energy Cost Savings: \$9,747 Electricity
 Total Annual Cost Savings: \$13,977

- f. **COST/BENEFIT ANALYSIS**
 - (1) Simple Payback
\$210,000 (Total ECM Implementation Cost)
\$ 55,036 (Total Annual Energy Cost Savings)
 equals 3.8 Years Payback
 - (2) Life Cycle Cost (LCC) methodology shall be used here when required by the Texas State Plan.
- g. **ECM DEPENDENCY ON OTHERS OR INCREMENTAL COST DATA:**
 Identify and describe how it is dependent or the manner in which ECM feasibility is physically dependent on one or more of the recommended ECMs. Indicate ECMs that have an "Incremental" value. For instance, the increased costs incurred by the addition of energy saving devices or equipment in the case of replacements (windows, air systems, etc.) will be considered to be justifiable energy conservation measures. That portion of the total costs which achieves energy savings only can be considered as an ECM and payback justified on the basis of incremental cost alone. (Enlarge length of this space for the narrative).
None

- f. **COST/BENEFIT ANALYSIS**
 - (1) Simple Payback
\$63,375 (Total ECM Implementation Cost)
\$13,977 (Total Annual Energy Cost Savings)
 equals 20 Years Payback.
 - (2) Life Cycle Cost (LCC) methodology shall be used here when required by the Texas State Plan.
- g. **ECM DEPENDENCY ON OTHERS OR INCREMENTAL COST DATA:**
 Identify and describe how it is dependent or the manner in which ECM feasibility is physically dependent on one or more of the recommended ECMs. Indicate ECMs that have an "Incremental" value. For instance, the increased costs incurred by the addition of energy saving devices or equipment in the case of replacements (windows, air systems, etc.) will be considered to be justifiable energy conservation measures. That portion of the total

- h. ECM USEFUL LIFE ESTIMATE: 20 Years
- i. ECM IMPACT ON ANNUAL COSTS OF MAINTENANCE AND OPERATION:

costs which achieves energy savings only can be considered as an ECM and payback justified on the basis of incremental cost alone. (Enlarge length of this space for the narrative). NONE

- h. ECM USEFUL LIFE ESTIMATE: 20 Years
- i. ECM IMPACT ON ANNUAL COSTS OF MAINTENANCE AND OPERATION: \$ _____ per year increase
 \$ _____ per year decrease
 \$ X same costs, no charge
- j. ECM SALVAGE/DISPOSAL COSTS:
 Indicate \$ _____ salvage value, OR \$ _____ disposal costs, OR X no residual costs at the end of the useful ECM life.
- k. CALCULATIONS: Identify source(s) for procedures used in calculating energy and energy cost savings for ECM's State of Texas - Energy Auditor Training II Manual.

CONCLUSIONS AND COMMENTS

This building constitutes a classic example of what can happen to a building which was originally well designed, well constructed and maintained, but so gradually became cost ineffective, and energy inefficient that the owners were not aware of the potential for savings due to modern technology.

The investigative dollars and retrofit costs in this case resulted in a savings of 59.2 % per annum the first year and as noted on the graphic presentations, will indeed result in substantial savings during the anticipated life of the equipment. There is no "Black Box" magic to good energy utilization, only applied common sense and good research, combined with communication within the industry/user framework.

GLOSSARY OF TERMS

(as they occur within the text)

- E.U.I.: Energy Utilization Index
BTU/sq.ft./year
- E.C.I.: Energy Cost Index
\$/sq.ft./year
- W.F.: Weighting Factor
- D.O.E.: Department of Energy (Federal)
- P.E.A.: Preliminary Energy Audit
- E.A.: Energy Audit
- E.D.P.: Electronic Data Processing (Equipment)
- E.C.M.: Energy Conservation Measure
- M & O: Maintenance and Operating Procedure
- BTU: British Thermal Unit
- KWH: Kilowatt Hour
- MCF: 100 cubic foot/per hour

CONVERSION FACTORS:

Electrical:	11,600 BTU/KWH
Natural Gas:	1,030,000 BTU/MCF
#2 Oil:	138,690 BTU/Gallon
#6 Oil:	149,690 BTU/Gallon
Butane/Propane:	95,475 BTU/Gallon
Coal:	24,500,000 BTU/Ton
Steam:	1,390 BTU/lb.
Hot Water:	1,000,000 BTU/MMBTU
Chilled Water:	12,000 BTU/Ton-Hour