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ENGINEERING INSTRUCTIONS

FOR

PREPARATION OF FEASIBILITY STUDIES FOR
TOTAL ENERGY, SELECTIVE ENERGY, AND HEAT PUMP SYSTEMS

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1. PURPOSE. These Engineering Instructions (EI) are intended to provide guidance for preparing feasibility studies for Total Energy (TE), Selective Energy (SE) and Heat Pump (HTP) systems. The EI is also intended to provide procedural information for making the necessary studies and a standardized format for reporting results of these studies. The TE, SE, and HTP studies will be made concurrently.

2. REPORTS

2.1 The reports will identify the project, provide a general description and a location map of the facilities studied. Reports will segregate the TE, SE and HTP systems feasibility studies under separate subsections. Each subsection will be prefaced by a narrative summary of the conclusions and recommendations reached in that subsection. The remainder of each subsection will address, in an orderly fashion, all raw and supporting data, and methods used, including sources thereof, in arriving at the conclusions and recommendations. The report will also include the rationale for equipment and subsystem selection and rejection.

2.2 Results of the studies will be documented and reviewed. Ten (10) copies of report and five (5) copies of back-up material will be forwarded to DAEN-MCE-U together with the recommendations of the District and Division.

3. DEFINITION AND DESCRIPTION OF ENERGY SYSTEMS

3.1 DEFINITION OF SYSTEMS

3.1.1 CONVENTIONAL SYSTEM. A conventional system is any typical energy system employed on military installations which uses commercial electrical power and generates steam or hot water in a central or self-contained energy plant. Chilled water for air conditioning may be generated in a central plant/and or decentralized in various buildings.

3.1.2 TOTAL ENERGY SYSTEM. A total energy system is a concept of an on-site electrical power generating system arranged for maximum use of input fuel energy by using the waste heat for space heating, space cooling and domestic water heating. Generally, a total energy system is completely independent of commercial power.

3.1.3 SELECTIVE ENERGY SYSTEM. A selective energy system is a concept where part (generally but not limited to 40 percent to 70 percent) of the required electrical power is generated on site by a generating system arranged for maximum use of input fuel energy by using the waste heat for space heating, space cooling and domestic water heating. The balance of the electrical power requirements is obtained from commercial sources.

3.1.4 HEAT PUMP SYSTEM. A heat pump system concept is a modified air conditioning system in which the refrigeration equipment is arranged in such a manner that it can be used either to cool or heat and/or do both simultaneously. The refrigeration compressor may be driven by an electric motor or by a prime mover.

3.2 DESCRIPTION OF TYPICAL TOTAL ENERGY SYSTEMS

3.2.1 DIESEL ENGINE GENERATORS WITH CENTRALIZED HEATING AND COOLING SYSTEMS. Diesel TE systems will usually consist of a number of diesel electric generator modules capable of meeting the peak electrical demand of the facility plus at least one spare module for standby purposes. The diesel engines are equipped with heat recovery units. The on-site electrical generating equipment is combined with a central heating and cooling plant which is essentially energized by the recovered waste heat from the diesel engines. The waste heat is also used for heating the domestic hot water, and any recovered waste heat from this plant that cannot be utilized is rejected to a cooling tower. The fuel for the diesel engines will be either No. 2 fuel oil, 2-D or 1-D diesel fuel oil, depending on availability at the site. In the event that waste heat is insufficient to satisfy thermal demand, an auxiliary boiler will be provided. The selection of diesel engine generators will be in accordance with ETL 1110-3-220.

3.2.2 DUAL-FUEL ENGINE GENERATORS WITH CENTRALIZED HEATING AND COOLING SYSTEMS. The dual-fuel TE systems are essentially similar in design to the diesel total energy plants with the exception that the engines are specially designed for simultaneous consumption of natural gas and diesel fuel. In the event of any shortage or interruption of the natural gas supply, the engines can be operated as full diesel engines on fuel oil alone.

3.2.3 HIGH COMPRESSION GAS ENGINE GENERATORS WITH CENTRALIZED HEATING AND COOLING SYSTEMS. The TE systems using high-compression natural gas engines are similar in design to the diesel or dual-fuel plants. All diesel and dual-fuel engines are compression ignited. High compression natural gas engines are spark ignited and operate essentially on natural gas. However, they can also be arranged to operate on propane, butane or manufactured synthetic gases.

3.2.4 GAS TURBINE GENERATORS WITH CENTRALIZED HEATING AND COOLING SYSTEMS. Gas turbine TE systems will usually consist of a number of gas turbine electric generator modules capable of meeting the peak electrical demand of the facility plus at least one spare module for standby purposes. The fuel used in these gas turbines could be either distillate fuels, such as No. 2 fuel oil or jet fuels; or gas fuels, such as natural gas or methane gas, etc. Where gas fuels are used, provisions will be made for alternate distillate fuels. The waste heat available from the gas turbines is recovered from the exhaust gases by means of a heat recovery unit. The recovered heat is utilized for energizing the central heating and cooling systems of the TE plant. Because of the relatively high oxygen content (about 17 percent) of the exhaust gases of gas turbines, the heat recovery also can be fired with supplemental fuel.

3.2.5 STEAM TURBINE GENERATORS WITH CENTRALIZED HEATING AND COOLING SYSTEMS. The steam turbine TE systems are similar to the electric utility company plants where steam is generated in boilers and expanded in steam turbines to drive electrical generators. The steam turbines could be of either the fully-condensing, non-condensing, or steam extraction types. Most of the "all steam" total energy systems use a variety of two or three types of steam turbines and utilize exhaust or extraction steam for energizing the central heating and cooling systems. The fuel to fire the boilers will be either coal, fuel oil, or natural gas. Where gas fuels are used, provisions will be made for alternate distillate fuels.

3.2.6 COMBINED CYCLE GAS TURBINES WITH STEAM TURBINE GENERATORS AND CENTRALIZED HEATING AND COOLING SYSTEMS. The combined cycle type of TE system usually combines the use of gas turbines with steam turbines, both driving electrical generators. The recovered waste heat from the gas turbine exhaust is used to generate steam that drives the steam turbines and is also used to energize the central heat and/or the cooling plant. All other features are similar to the gas turbine and the steam turbine types of total TE systems.

3.2.7 COMBINATION SYSTEM. Some designs of TE systems may benefit by combining more than one type of prime mover to generate electricity. For example, gas turbines and diesel engines may be used in combination, where the daytime base load is carried on the gas turbine generators and the night load on small diesel generators. Similarly, there could be a combination of steam turbines with diesel generators.

3.2.8 OTHER SYSTEMS. Other optional systems may be considered provided the suggested system is submitted to DAEN-MCE-U for approval before proceeding with the study.

Note: At least one example, but not more than two examples of each type of the above described TE systems will be studied. Selection of the types studied will be based on the experience of the Architect-Engineer (A/E). Rationale for the selection of the types studied or not studied will be indicated in the report.

3.3 DESCRIPTION OF TYPICAL SELECTIVE ENERGY SYSTEMS. Selective Energy (SE) systems are similar in every respect to TE systems. However, the installed capacity is sized to carry only a portion (generally 40 to 70 percent) of the facility load. Except where otherwise prohibited by existing criteria or local utility regulatory agreements, consideration may be given to parallel operation of both power sources, with due regard given to economics and the operating practicalities of the specific design proposed. Normally, however, nonparallel operation of both sources will be given prime consideration. When alternate sources of power for emergency purposes are required, the critical loads normally should be served by one power source and the non-critical loads served by the other source. Where economically feasible, some non-critical loads may be served by the same source serving critical loads to provide optimum utilization of the nominal equipment capacities selected to serve the critical loads alone. Provisions will be made in the system design to automatically shed non-critical loads and transfer all critical loads from the critical load source to the non-critical load source in the event of failure of the critical load source. The description and definitions outlined in paragraphs 3.2 are applicable also for SE systems.

Note: At least one example, but not more than two examples, of each type of the SE systems will be studied.

3.4 DESCRIPTION OF TYPICAL HEAT PUMP SYSTEMS. Heat pump systems essentially are modified air conditioning systems where the refrigeration cycle or the equipment is arranged so that heat can be "received" and "rejected" from the working fluid and used either to cool or to heat and/or to do both simultaneously. Heat pump systems are particularly attractive for use in facilities where a relatively constant low level heat source is present. Where an ample supply of water is available, the A/E will consider water-to-water or water-to-air systems. In locations where water supply is at a premium, consideration will be given to the use of air-to-air systems. Where the chiller compressor is driven by an internal combustion engine instead of an electric motor, consideration will be given to reclaiming the waste heat from the prime mover to supplement the heat pump system. Where applicable, consideration will be given to the use of double-bundle condensers, thermal storage, and air cooled screw compressors or centrifugal compressors to balance the heating load, and to the use of waste heat supported absorption chillers to improve the heat balance and to increase the reserve capacity of the water chilling plant. For details, refer to Chapter 11, "Heat Pumps", ASHRAE GUIDE AND DATA BOOK SYSTEMS-1973.

Note: At least one example but not more than two examples of each of the above HTP Systems will be studied. The A/E will select the type of HTP system and equipment on which the study will be performed using his experience as a basis. Rationale for the selection of the system types and equipment studied or not studied will be indicated in the report.

4. IDENTIFICATION OF RELEVANT FACTORS. Before undertaking an "in-depth" feasibility analysis, the following factors affecting economics and plant efficiency will be considered.

4.1 ARCHITECTURAL CONSIDERATIONS.

4.1.1 Size of the facility and provisions for future expansion.

4.1.2 Energy plant location in relation to the facility to be supported and to the surrounding buildings.

4.1.3 The methods of construction and the architectural treatment of the energy plant will be compatible with those of the main facility and will conform to current criteria.

4.2 GEOGRAPHICAL CONSIDERATIONS.

4.2.1 Plant location (altitude, hill top valley seashore desert area, etc.).

4.2.2 Climatic conditions (mild or extreme temperatures, high and low prevailing winds and their severity, seismic considerations, etc.).

4.2.3 Availability of water for heat sink.

4.3 DESIGN CONSIDERATIONS.

4.3.1 Heating (temperatures and humidities).

4.3.2 Cooling (temperatures and humidities).

4.3.3 Ventilating (special exhaust or air change requirements).

4.3.4 Electrical (voltages, frequencies, and power quality).

4.3.5 Domestic Hot Water (temperature, pressure and maximum demand).

4.3.6 Process Heat (steam for sterilizing, etc.).

4.3.7 Thermal storage.

4.4 LOAD REQUIREMENTS AND NATURE OF USAGE

4.4.1 Identification of Building Usage. Assistance of the Facility Engineer (FE) should be obtained to identify building usage hours, etc. The load profiles will be prepared by the A/E.

4.4.2 Thermal Demands (heating, cooling and process loads) and Estimated Load Factors.

4.4.3 Electric Demand and Estimated Load Factors. (See Appendix)

4.4.4 Thermal and Electrical Load Match.

4.5 SECONDARY ENERGY SYSTEMS DESIGN.

4.5.1 Thermal energy required (temperatures and pressures, steam, high temperature water, etc.).

4.5.2 Electrical characteristics required (voltages, frequencies and power quality, etc.).

4.5.3 Critical aspects of the facility and degree of reliability required by the criticality of the thermal and electrical load.

4.6 PRIME ENERGY SOURCES (ELECTRICITY, NATURAL GAS OR FUEL OIL, OR HIGH TEMPERATURE WATER OR STEAM FROM A CENTRAL HEATING PLANT).

4.6.1 Availability and reliability (blackouts, brownouts, proximity of the utility company plant).

4.6.2 Cost and charge rates (electric, natural gas and fuel oils).

4.6.3 Compatibility of type, form and level of energy required by the facility with energy available to be recovered from the prime movers.

4.7 UTILIZATION EFFICIENCIES

4.7.1 Equipment (full load, part load).

4.7.2 Available heat recovery from prime movers (full load and part load) and/or heat of compression, etc. from refrigeration systems (percentage of beneficial utilization).

4.7.3 Thermal storage for hot or chilled water.

5. COMPUTERIZED TECHNIQUES FOR EVALUATION OF ENERGY SYSTEMS. There are several commercial computer programs available for conventional or total energy feasibility analysis, such as:

5.1 E-CUBE. Originally developed by the Group to Advance Total Energy (GATE), now sponsored by the American Gas Association (AGA) and presently marketed by Control Data Corporation (CDC). Excellent for energy analysis of total energy and centralized heating and cooling plants. The program initially integrates design point calculations of peak thermal and electrical loads and provides a realistic estimate of the hourly, monthly and annual energy requirements of the building. Next, it determines the energy consumption of various types of systems which may be used to meet those energy requirements. This program essentially consists of three (3) parts: (a) Part 1 - Energy Requirements, (b) Part 2 - Equipment Selection and Energy Consumption, and (c) Part 3 - Economic Comparison. If the E-CUBE computer program is used, the A/E will only apply Part 1 and Part 2. Part 3 will be substituted by use of the Life Cycle Costing (LCC) procedure (See Appendix).

5.1.1 Energy Requirements - Part 1. The Energy Requirement program estimates the amount of energy required by the facility to provide the desired level of environmental control. It takes design point values for various components of thermal load and the base component electric load. These are distributed over each hour of the year in accordance with dry bulb and dew point temperature variations, solar and cloud cover variations, and building use and operation schedules for various types of operational days. The program also evaluates the effects of thermostat setback and periodic system shutdown as well as the resulting thermal storage and lag effects.

5.1.2 Equipment Selection and Consumption - Part 2. This program determines actual energy consumed by various pieces of equipment used to meet the hourly energy requirements as developed in the Energy program. It evaluates the operating characteristics of generator set, chillers, boilers and auxiliary equipment, and prints out a monthly summary of the gas, auxiliary fuel, and electricity consumed; the peak electric demand; the number of operating hours of each generator, chiller and boiler; and an evaluation of thermal energy usage.

5.2 TRACE. This program is developed and marketed by Trane Company. The TRACE program consists of five major phases; load, design, system, equipment and economic. Conventional load input data describing the building and its thermal-time characteristics are determined. Weather data from a U.S. Weather Bureau tape is fed in next to simulate actual weather conditions. Loads are calculated by zone and by hour for a full year. In the design phase, the type mechanical system to be used is described. From this the program calculates the supply air quantities and supply air dry bulb temperatures by zone. The system simulation phase then calculates hourly equipment loads by system, using all the hourly building variables that affect system operations. This data is then fed to the equipment simulation phase, along with a description of the equipment to be used. In this phase, the total energy consumption is calculated for each utility type. If the TRACE program is employed, the economic part will be eliminated and the LCC procedure substituted.

5.3 MERIWETHER'S COMPUTER PROGRAMS. The Energy System Analysis Series is a library of computer programs developed by Ross F. Meriwether and Associates, Inc. for hour-by-hour calculations of the annual energy consumption of various types of air-side systems and mechanical plants. The major programs series consist of:

5.3.1 Energy Requirements Input Data Check (ERCK). A short program to read input data and provide a printout on a unit area basis to help spot input errors.

5.3.2 Energy Requirements Estimate (ERE). A program to calculate hour-by-hour thermal and electrical loads for a building (or building section) and to simulate the operation of the air distribution system in meeting these loads.

5.3.3 Total Coincident Requirement (TCR). A program to sum the hour-by-hour loads from multiple ERE runs for various buildings or sections to find total system loads with actual diversity.

5.3.4 Equipment Energy Consumption/B (EEC/B). A program to simulate the operation of the various pieces of equipment as they respond to loads imposed by the building's air-side systems to find monthly and annual energy consumption for the various systems being evaluated. If the Meriwether program is used, the ECSB part will be eliminated and substituted by use of the LCC procedure.

5.3.5 Monthly Utility Costs (MUC). A program to calculate the monthly and annual energy costs for each system using the local utility rate schedules.

5.4 AXCESS. Originally developed by the Electric Energy Association (EEA), now sponsored by the Edison Electric Institute (EEI). This program is very similar to TRACE and is primarily concerned with analysis of secondary energy systems.

5.5 OTHER PROGRAMS. There are numerous other programs, such as the HUD-MIUS "ESOP", the Postal Service's "GATX", and those sponsored by Westinghouse Electric, Pittsburgh Plate Glass, Caterpillar Tractor, etc. Programs such as Automated Procedures for Engineering Consultants (APEC) can only be used for limited applications like heating and cooling load calculations.

6. PROCEDURAL STEPS FOR DETAILED ALTERNATIVE ENERGY SYSTEMS ANALYSIS. The following data must be assembled to proceed with a detailed system analysis. The A/E must perform the following steps to provide the input for the selected computer program:

6.1 BASIC HEATING AND COOLING DESIGN DATA

6.1.1 Summer and winter outside and inside design dry bulb (DB) and wet bulb (WB) temperatures.

6.1.2 Physical building characteristics. Determination of glass, wall, and roof areas; type of shading; building orientation.

6.1.3 Total summer design load, MBTU/HR per ASHRAE Guide.

6.1.4 Winter design load, MBTU/HR per ASHRAE Guide.

6.1.5 Electrical loads (KW demand), lighting, HVAC, etc.

6.1.6 Domestic hot water, MBTU/HR.

6.1.7 Process loads, MBTU/HR.

6.2 BASIC FACILITY OPERATIONAL DATA

6.2.1 Functions (i.e. administration, hospital, barracks, etc.)

6.2.2 Operational data from consultation with local Facilities Engineer (FE) for typical day types, such as weekday, Saturday, Sunday, holiday, etc., and daily use profiles with number of days each. (See Appendix for method of constructing the load profiles, Tables 1-8).

6.2.3 Construction of daily load profiles. There are essentially three (3) demand profile estimation methods:

6.2.3.1 Metered profiles are those that have been developed for similar buildings. They will be used to the maximum extent possible.

6.2.3.2 The standardized profile is based on typical demand profiles. (See Appendix for examples and Figures 1 and 2).

6.2.3.3 Derived profile. Using the above profiles to the extent possible, a load profile of the facility being studied will be derived by making a detailed analysis of the projected peak, diversified demands, and the building operating characteristics, throughout a 24-hour period.
An error in the development of the load profiles could materially change the outcome of the study. Therefore, the analyst must strive to attain a high degree of accuracy in the development of the load profiles since these will be the basis of energy consumption calculations. Based on operational data developed by the A/E, develop the appropriate load profiles expressed in units suitable for the computer program selected. The following are required:

6.2.4 Hourly people load profile.

6.2.5 Hourly lighting load profile.

6.2.6 Hourly miscellaneous electric load profile.

6.2.7 Hourly domestic hot water combined with process load profile.

6.2.8 Cooling system shut-off hours in each month based on each day type.

6.2.9 Outside air and heating system shut-off in each month based on each day type.

6.2.10 Distribution of day types for each month.

6.2.11 Number of hours and degree of setback temperature in each month based on each day type.

6.2.12 Additional profiles must be developed to reflect the difference that exists between the normal working day and on Saturdays, Sundays or holidays.

6.3 CLIMATIC DATA. Hourly local weather tape of computer programs.

6.4 SECONDARY SYSTEM DESIGN DATA. Identify type of system used (double duct, fan coils, variable air volume, induction systems, etc.) and compile data that might affect performance of the primary system which is supporting it. Modify computer input to take into account the effect of secondary system. Identify heating and cooling media (air, water, steam, temperature flow rates, etc.).

6.5 CONVENTIONAL PLANT DESIGN DATA

6.5.1 Operating schedule of equipment and all pertinent data.

6.5.2 Performance curves over full range of permissible operation input and output energy quantities and levels.

6.6 COMMERCIAL ELECTRIC AND GAS DATA

6.6.1 Availability/reliability of commercial power and gas equivalent to the conventional design, also their terms and conditions and quality of power. The sources of fuel used by the local utility in generating commercial power will be shown. Plant capacities, classes of use (base load, peaking, etc.), and kWhr output for the previous year for each fuel source will be indicated in tabular form. Proposed fuel sources for future plant additions will be indicated where available.

6.6.2 Applicable electric and gas rates.

6.6.3 Type and class of service used (i.e. firm or interruptible gas, heating value, etc.).

6.7 FUEL OIL AVAILABILITY AND DATA

6.7.1 Types of fuel oil available and heating value of each.

6.7.2 Cost of fuel oils.

6.7.3 Dependability of supply source.

6.7.4 Delivery and storage conditions.

6.8 DATA FROM SIMILAR EXISTING BUILDINGS

6.8.1 Records of actual energy consumption and costs, monthly demand and energy; load profiles.

6.9 DATA FROM EXISTING BASE CENTRAL ENERGY SYSTEMS

6.9.1 Base electric power plants. Overall heat rate and cost/kWh.

6.9.2 Base heating system. Description and operating cost data (steam or high temperature water).

6.9.3 Base cooling system. Description and operating cost data (steam or electric).

6.10 OPERATIONAL AND MAINTENANCE DATA

6.10.1 Availability of skilled labor. (Contract operation and maintenance).

6.10.2 Preventive maintenance schedule and projected downtime due to preventive maintenance and equipment failure.

6.10.3 Automation consideration (use semi and fully automated plant for this study).

7. ANNUAL ENERGY REQUIREMENTS CALCULATIONS FOR THE BUILDINGS TO BE SERVED

7.1 Calculate the hourly, daily, monthly and annual energy requirements with the help of one or more computer programs described in paragraph 5, and based on the information compiled under paragraph 6.1 to 6.10.

7.2 Tabulate the annual energy requirements for heating, cooling, domestic HW and electricity (Tables 11 and 12).

8. DEVELOPMENT OF ALTERNATIVE PRIMARY ENERGY SYSTEMS. Based on the facility energy use requirements as developed in paragraph 7, alternative methods of satisfying these requirements will be investigated. Develop appropriate one-line conceptual flow diagrams for the conventional TE/3E systems under study.

9. EQUIPMENT USED IN ALTERNATIVE ENERGY SYSTEMS. As applicable, the A/E will compile the following data on all major equipment of the alternative energy systems:

9.1 EQUIPMENT DATA REQUIRED. For power generating, cooling, heating and auxilary equipment;

9.1.1 Maximum continuous rated output (KW or MBTU).

9.1.2 Maximum input required (KW or MBTU).

9.1.3 Maximum recoverable waste heat (MBTU).

9.1.4 Input requirements from No Load to Full Load (at 10% increment) position.

9.1.5 Electrical accessories of the equipment (KW).

9.1.6 Steam accessories (HP). Steam rate (MBTU).

9.2 POWER GENERATING EQUIPMENT TYPES. (See paragraph 3.2)

9.3 COOLING EQUIPMENT TYPES

9.3.1 Absorption chillers.

9.3.2 Electrical motor driven chiller.

9.3.3 Steam turbine driven chiller.

9.3.4 Engine driven chiller.

9.3.5 Heat pump (double-bundled condenser).

9.4 HEATING EQUIPMENT TYPES

9.4.1 Steam boilers.

9.4.2 Hot water boilers.

9.4.3 Exhaust heat recovery units.

9.4.4 Supplementary electric resistance heating elements.

9.5 AUXILIARY EQUIPMENT

9.5.1 Pumps.

9.5.2 Cooling towers.

9.5.3 Compressors.

9.5.4 Fuel handling equipment.

9.5.5 Ventilating fans.

9.5.6 Heat exchangers (converters, load balancing condenser).

9.5.7 Thermal storage tanks. Hot or chilled water.

9.6 ENVIRONMENTAL DATA

9.6.1 Noise pollution.

9.6.1.1 Interior noise. Equipment selection will conform with the Federal OSHA and other noise standards applicable to the facility.

9.6.1.2 Exterior noise. The study will insure an ambient noise level not to exceed 55db at any nearby building.

9.6.2 Air, water and thermal pollution. The study will insure compliance with local requirements.

9.7 GENERAL

9.7.1 Procurement. The A/E will examine and discuss the methods by which prime-mover-driven generators, as well as the TE/SE plant in its entirety, may be most effectively procured. The discussion will reflect the advantages and disadvantages of government versus contractor-furnished procurement, including consideration for one and two-step procedures, conventional procurement, and other methods which may be employed. The report will include, based upon the discussion, a recommendation of the specific method of procurement proposed. Such method will effectively combine conformance to criteria; equipment efficiencies; equipment procurement lead-times versus programing, design, and construction schedules; fuel consumption guarantees and penalities; equipment availability and prospective bidder competition; costs; and other factors considered pertinent to the recommendation.

9.7.2 Load Matching. Equipment proposed for electrical and thermal energy production will be sized to take advantage of available equipment capacities required to most effectively serve incremental loads. Wherever practicable, multiple units of equal capacity will be employed, providing a reliability/availability at least equal to that provided by the conventional system. Proposals to utilize only one baseload powering generating unit, supported by one peaking unit and one standby unit are unacceptable. Annual load profiles indicating thermal/electrical load matching and equipment capacities proposed will be furnished with the report.

9.7.3 System Description. For one system studied, a narrative, step-by-step description of system operation will be provided. The description will be supplemented by flow charts, graphs, or other aids, to permit the overall plant function to be readily understood.

9.7.4 Preliminary Approval. The options proposed for study will be submitted for review and approval to HQDA (DAEN-MCE-J) at the earliest phase of study development. The submittal will include a narrative which details the rationale for the selection of the options proposed and rejection of options not proposed for study.

9.7.5 Costs developed in the report will represent programing costs, and will thus reflect in detail all administrative, design, escalation, and other factors associated with programing requirements.

10. ENERGY DEMAND AND CONSUMPTION CALCULATIONS BASED ON PLANT DESIGN AND EQUIPMENT SELECTION

10.1 MATCHING EQUIPMENT PERFORMANCE WITH THE ENERGY REQUIREMENTS. With the aid of the computer program selected and based on equipment performance and efficiencies at various loads, calculate the hourly energy consumption for the building to be served. Match this with the hourly electrical and thermal load outputs of the TE/SE plant.

10.2 ANALYSIS OF ANNUAL ENERGY CONSUMPTION AND CONVERSION TO SOURCE ENERGY. The annual energy consumption calculated in paragraph 10.1 will be converted to source energy for a valid comparison of alternative energy system. "Source energy" is defined as the energy consumed to produce a given effect at the point of usage, and it includes the inefficiencies within the energy conversion plant and the losses throughout the distribution system. As an example, a demand of 3413 BTU (for one KWH) at the "consuming end" in the form of electricity, steam or hot water whould require the following amounts of source energy in terms of coal, fuel oil or natural gas:

10.2.1 One (1) KWH (3413 BTU) of electrical energy would require 12,365 BTU of source energy if power conversion efficiency were 30 percent and transmission losses where 8 percent.

10.2.2 3413 BTU of steam or hot water would require 5132 BTU of source energy if boiler efficiency were 70 percent and distribution losses were 5 percent.

10.3 After conversion to source energy, all the values will be tabulated so that a simple comparison can be made (Appendix, Table 12). Indicate waste heat used in BTUs and percentage of waste heat used. At this point the A/E will be able to determine the most desirable system from an energy conservation viewpoint.

11. DEVELOPMENT OF INITIAL CONSTRUCTION COSTS. After completing the energy analysis for each alternate concept design, an initial cost estimate will be prepared for the facility as served by the conventional system, and for the facility as served by each alternate system studied. The A/E will not use the incremental or differential method of cost comparison. The total cost (current costs without any provision for inflation) for the facility using the conventional system will be compared to the total cost of the facility using the TE, SE or HTP systems. The initial cost estimating will be in accordance with the requirements of TM-5-800-2 and ER-415-345-42.

12. ESTIMATING ENERGY COSTS. The following items are needed for energy cost estimations:

12.1 Purchased electricity and/or natural gas applicable rate schedules and pertinent terms of service to include various charges and adjustments.

12.2 Fuel purchases. Types of fuels and unit costs.

12.3 Fuel cost escalation. In preparing the necessary Life Cycle Cost studies, the fuel costs will be obtained from the Facilities Engineer and the differential cost growth rate (see Glossary) listed on the following page will be applied. Cost figures used for the first year will be based on the anticipated beneficial occupancy date, and will be evaluated at a point 6 months after BOD.

Coal	5.0%
Fuel Oil	8.0%
Natural Gas & LPG*	8.0%
Electricity	7.0%

*In most cases, natural gas systems will be replaced with coal or fuel oil systems; therefore the applicable rate for coal or fuel oil should ordinarily be used. Only where conversion is impracticable and for individual boilers or warm air furnaces under five Mega-BTU should gas be used.

(See Appendix Tabe 13 (page A-36) and the Life Cycle Costing Instructions (starting on page A-28)).

13. ESTIMATING SERVICE CONTRACT OPERATING AND MAINTENANCE COSTS, INCLUDING LABOR AND MATERIALS. Establish realistic costs for operation and maintenance of alternate energy systems, assuming a service operating type contract.

14. DEVELOPMENT OF LIFE CYCLE COST ANALYSIS. After developing the initial construction costs, annual fuel costs and annual O&M costs, perform a Life Cycle Cost analysis for each system studied, in accordance with the procedures in the Appendix.

15. COMPARISON OF ALTERNATIVE SYSTEMS. Tabulate the results for review and comparison of alternative energy systems in terms of initial cost, energy consumption and economic feasibility. See Table 15.

APPENDICES

APPENDIX

LIST OF TABLES AND GRAPHS

GLOSSARY OF TERMS

Exhaust Heat Recovery:	The process of extracting heat from the working medium or mediums, such as diesel engine exhaust gases, and transferring this heat to a source of water, air, etc.
Firm Gas:	Natural gas that is supplied 365 days a year without intentional interruption or curtailment of supply for any period of time.
Module:	In conventional central plants, as well as in total and selective energy plants, the term applies to any number of items of equipment, such as generators, boilers, chillers, pumps, etc., which are usually part of a modular system. In a modular system each module capacity represents a percentage of the installed capacity. The term spare module refers to a stand-by unit.
MBTU:	Thousand (10^3) British Thermal Units.
MMBTU:	Million (10^6) British Thermal Units.
Source Energy:	The energy consumed to produce a given effect at the point of usage. It includes the inefficiencies within the energy conversion plant and the losses throughout the distribution systems.
Primary Energy Systems:	Centralized heating, cooling and electrical power generation systems in a single central plant.
Secondary Energy Systems:	Heating, cooling, plumbing and electrical systems other than a central plant

within the building.

Semi-Automatic Plant: An on-site electrical generating plant that requires the continuous presence of less skilled operators than required for manually controlled plants. These operators usually initiate operational functions by remote controls. They press buttons to start a generator set, to stop it, and to begin the sequence of automatic synchronizing in parallel and load sharing between generators. The load shedding is usually initiated by the operators by remote control and/or automatically. In the event the equipment malfunction, the operators are alerted and if they take no action the units will shut down automatically.

Automatic Plant: An on-site electrical generating plant that does not require the presence of any operators. The automatic plant is capable of operating continuously according to a pre-programed schedule. All starting and stopping of generating units are initiated automatically by sensing the load as demanded by the distribution system. Although the plant is fully automated, it is good practice on military bases to provide an attendant trained to perform housekeeping duties and to maintain strict security. Because the attendant is not a qualified operator, the skill level will not have to be as high as required for manual or semi-automated plants. In the event of any malfunctioning, the respective piece of equipment will automatically be shut down and secured.

Differential Cost Growth Rate: The differential cost growth rate is the difference between the actual cost growth rate for a particular commodity (e.g. No. 2 Fuel Oil) and the general cost growth rate the economy as a whole.

INSTRUCTIONS FOR THE PREPARATION AND USE OF TABLES AND GRAPHS

LOAD PROFILE TABLES. Tables 1 through 8 are typical sample tables to be used by the A/E for the preparation of electrical and thermal load profiles, as required. These tables should be modified for the type of computer program selected.

EXAMPLES 1 and 2 demonstrate simple methods by which typical daily load factors may be established. Daily electrical load factor helps to establish average fuel consumption of prime movers. It also determines the annual equipment utilization factor.

FIGURES 1 and 2 have been based on the hourly demand columns found in Examples 1 and 2. The graphic presentation of daily load profiles is an aid to optimize the sizing of on-site generating modules.

FIGURES 3 and 4 represent typical working day heating and cooling load profiles for an office building.

TABLE 9 indicates the levels of temperatures and pressures at which waste heat is recoverable, as well as the quantities of heat available from various prime movers.

TABLES 10 through 14 are typical sample tables to be utilized by the A/E for compiling results of the TE/SE and HTP studies.

TABLE - 1

INTERNAL HEAT GAIN PROFILES - PEOPLE

DAY	PERCENTAGE OF DESIGN VALUES (0-100)																							
TYPE	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 NOON	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	MID NIGHT
1																								
2																								
3																								
4																								
5																								

DAY TYPE

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Others
5. "

PERCENTAGE OF DESIGN VALUES (0-100)

Hourly heat gains from people (sensible & latent), expressed in percentage of design load for each day type.

TABLE - 2

INTERNAL HEAT GAIN PROFILES - LIGHTS (MBTU & KW)

DAY TYPE	PERCENTAGE OF DESIGN VALUES (0-100)																							
	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 NOON	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	MID NIGHT
1																								
2																								
3																								
4																								
5																								

DAY TYPE

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Others
5. "

PERCENTAGE OF DESIGN VALUES (0-100)

Hourly heat gains from lights and electrical KW for lights, expressed as a percentage of maximum load for each day type.

TABLE - 3

MISCELLANEOUS ELECTRICAL LOAD PROFILES - (KW)

DAY TYPE	PERCENTAGE OF DESIGN VALUES (0-100)																							
	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 NOON	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	MID NIGHT
1																								
2																								
3																								
4																								
5																								

DAY TYPE

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Others
5. "

PERCENTAGE OF DESIGN VALUES (0-100)

Hourly miscellaneous electrical load, expressed as percentage of maximum load for each day type.

TABLE - 4

PROCESS LOAD PROFILES - (MBTU)

DAY TYPE	PERCENTAGE OF DESIGN VALUES (0-100)																							
	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 NOON	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	MID NIGHT
1																								
2																								
3																								
4																								
5																								

DAY TYPE

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Other
5. "

PERCENTAGE OF DESIGN VALUES (0-100)

Hourly process (domestic hot water) loads, expressed as a percentage of maximum load for each day type.

TABLE - 5

COOLING SYSTEM SHUTOFF HOURS

DAY	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
TYPE	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1																								
2																								
3																								
4																								
5																								

DAY TYPES

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Other
5. "

AM = no. of hours shutoff from midnight till noon.
PM = no. of hours shutoff from noon till midnight.

TABLE - 6

OUTSIDE AIR & HEATING SYSTEM SHUTOFF

DAY TYPE	HOURS/DAY O.A.SHUTOFF		JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1																										
2																										
3																										
4																										
5																										

DAY TYPES

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Other
5. "

AM = no. of hours system shutoff from midnight till noon
PM = no. of hours system shutoff from noon till midnight

TABLE - 7

NUMBER OF HOURS & DEGREES OF SETBACK TEMPERATURE

NUMBER OF DEGREES THERMOSTAT SETBACK (NEGATIVE OR POSITIVE)

DAY TYPE	HOURS/DAY O.A.SHUTOFF		JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1																										
2																										
3																										
4																										
5																										

DAY TYPE

1. Weekdays
2. Saturday
3. Sunday & Holiday
4. Other
5. "

Negative values indicate winter setback of thermostat.
Positive values indicate summer setup of thermostat.

TABLE - 8

DISTRIBUTION OF DAY TYPE

MONTH	DAY TYPE					TOTAL * NUMBER OF DAYS
	1	2	3	4	5	
JAN						31
FEB						28
MAR						31
APR						30
MAY						31
JUN						30
JUL						31
AUG						31
SEP						30
OCT						31
NOV						30
DEC						31

* Total number of day types per month should equal the total number of days in the month.

EXAMPLE - 1

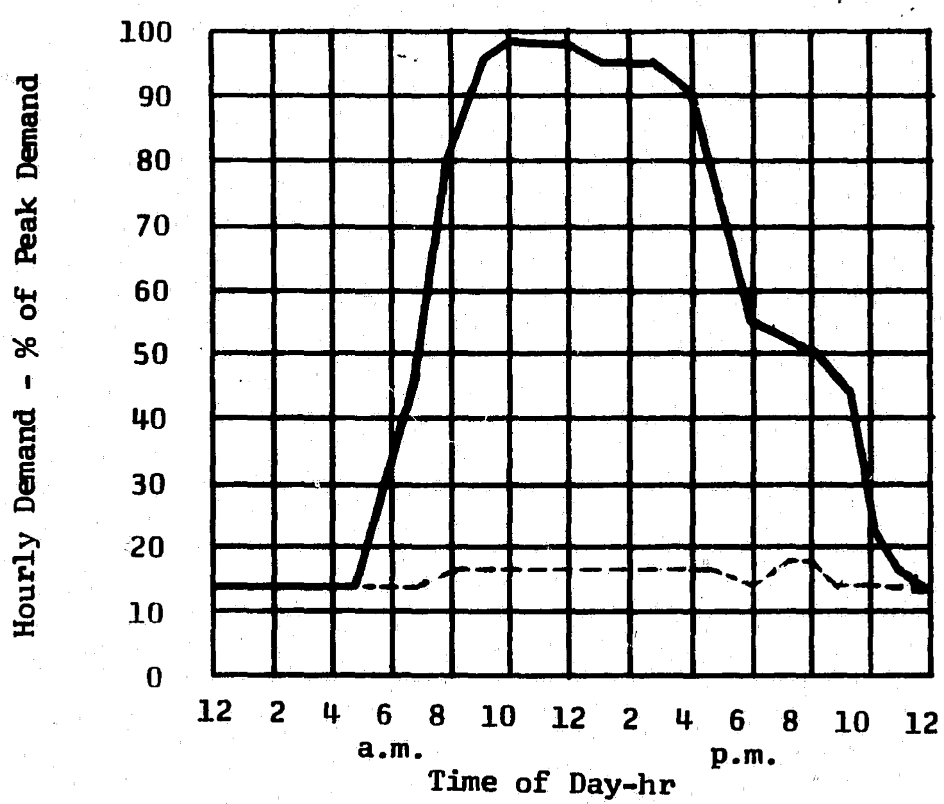
TYPICAL OFFICE BUILDING
DAILY LOAD FACTOR CALCULATIONS

Time	Normal Operating Demand as % of Peak Demand	Reduced Operating Demand as % of Peak Demand
Midnight	14.5	14.5
1 a.m.	14.5	14.5
2 a.m.	14.5	14.5
3 a.m.	14.5	14.5
4 a.m.	14.5	14.5
5 a.m.	14.5	14.5
6 a.m.	30.0	14.5
7 a.m.	48.4	14.7
8 a.m.	79.1	16.1
9 a.m.	96.7	16.1
10 a.m.	98.4	16.1
11 a.m.	98.4	16.1
Noon	98.4	16.1
1 p.m.	96.7	16.1
2 p.m.	96.7	16.1
3 p.m.	96.7	16.1
4 p.m.	93.6	16.1
5 p.m.	74.2	16.1
6 p.m.	56.4	14.7
7 p.m.	53.2	17.6
8 p.m.	50.0	17.9
9 p.m.	45.2	14.7
10 p.m.	24.2	14.7
11 p.m.	17.7	14.5
	1,341.0	371.3

Daily Load Factor = 1,341.0 ÷ 24 = 371.3 ÷ 24

= 55.9% =15.5%

FIG - 1



ELECTRICAL USE FOR A TYPICAL OPERATING DAY AND A TYPICAL REDUCED LOAD DAY FOR OFFICE BUILDINGS

<u>NOTES</u>:

Demand <u>for day</u> type - 1
Demand <u>for day</u> type - 2 or 3

The above load profile graph is based on the "Hourly Demand" columns shown in Example - I

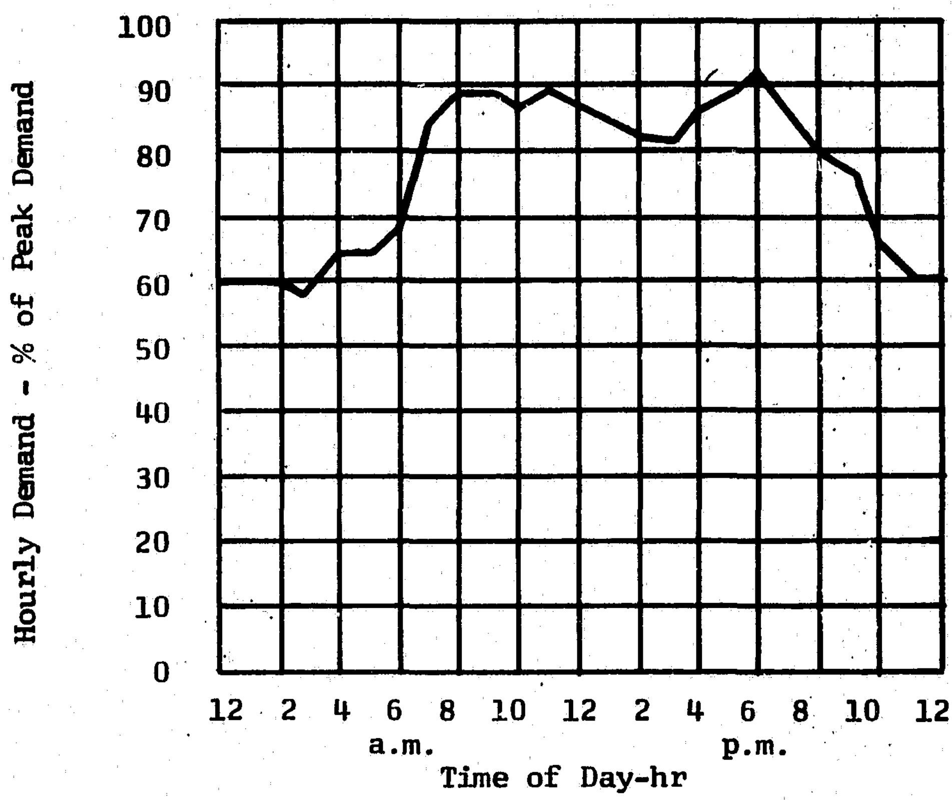
EXAMPLE - 2

TYPICAL HOSPITAL DAILY LOAD FACTOR CALCULATIONS

Time	Normal Operating Demand as % of Peak Demand	Reduced Operating Demand as % of Peak Demand
Midnight	60.0	Same as Normal Operating
1 a.m.	60.0	
2.a.m.	60.0	
3 a.m.	57.7	
4 a.m.	64.4	
5 a.m.	64.4	
6 a.m.	66.7	
7 a.m.	84.4	
8 a.m.	89.0	
9 a.m.	89.0	
10 a.m.	86.0	
11 a.m.	89.0	
Noon	86.5	
1 p.m.	84.5	
2 p.m.	82.2	
3 p.m.	82.2	
4 p.m.	86.5	
5 p.m.	89.0	
6 p.m.	93.3	
7 p.m.	86.5	
8 p.m.	79.8	
9 p.m.	77.8	
10 p.m.	66.6	
11 p.m.	60.0	
	1,845.5	

Daily Load Factor = 1,845.5 ÷ 24
= 77.0%

FIG - 2

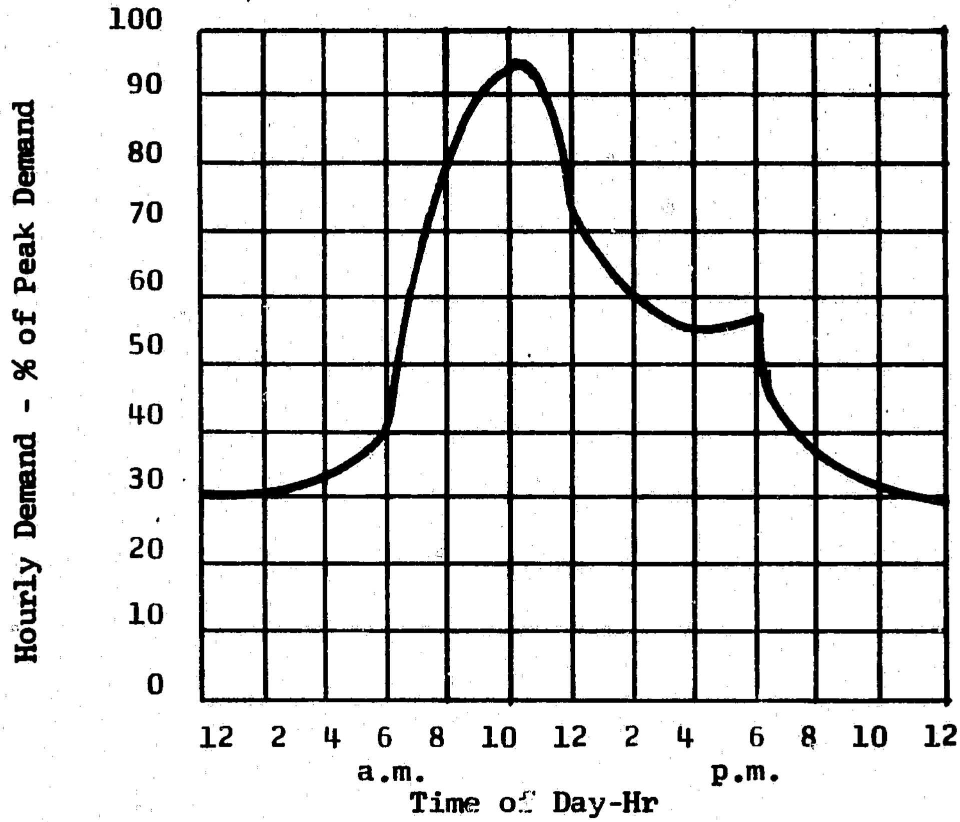


ELECTRICAL USE FOR A TYPICAL OPERATING DAY
FOR A HOSPITAL

NOTES:
Demand for day type - 1

The above load profile graph is based on the "Hourly Demand" columns shown in Example - 2

FIG - 3

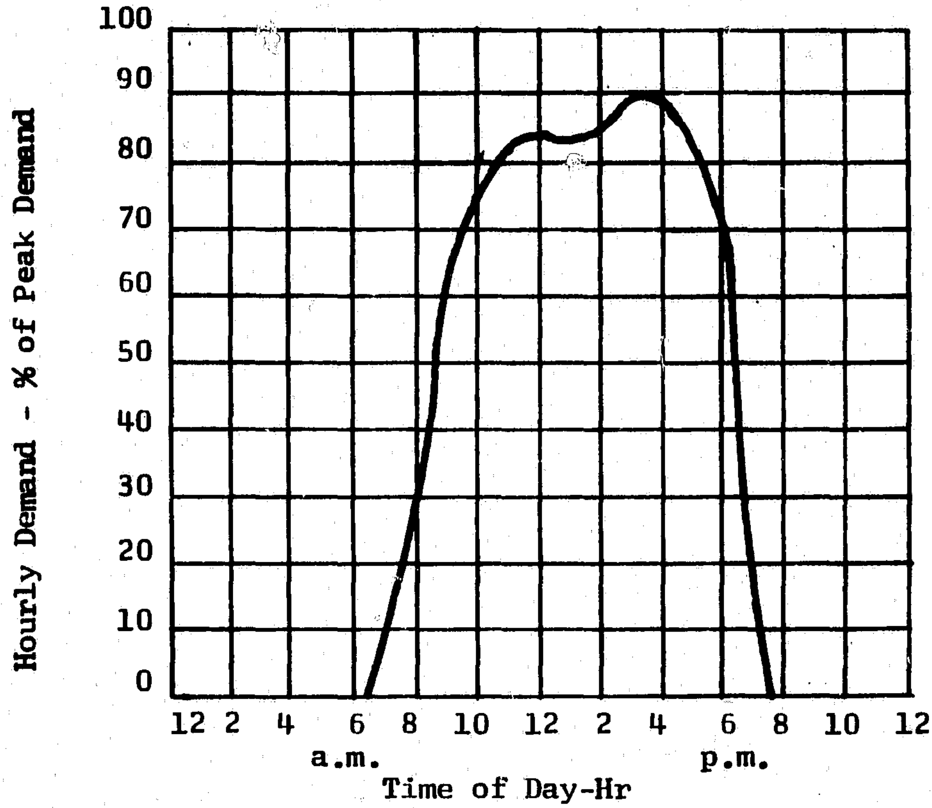


OFFICE BUILDING

HEATING LOAD PROFILE

FOR A TYPICAL WORKING DAY

FIG - 4



<u>OFFICE BUILDING</u>

<u>COOLING LOAD PROFILE FOR</u>

<u>A TYPICAL WORKING DAY</u>

TABLE - 9

HEAT RECOVERY CHARACTERISTICS OF TURBINES & ENGINES

EQUIPMENT			* QUALITY & QUANTITIES OF RECOVERABLE HEAT: MAXIMUM TEMPERATURE & PRESSURE	* QUALITY & QUANTITIES OF RECOVERABLE HEAT: HEAT RECOVERABLE BTU/HP
GAS TURBINE	UNFIRED HEAT RECOVERY UNIT		950° F	5000 to 9000
GAS TURBINE	FULLY FIRED HEAT RECOVERY UNIT		3000° F	8000 to 11000
STEAM TURBINE	CONDENSING AUTOMATIC EXTRACTION		VARIES ACCORDING TO EXHAUST CONDITION	6000 to 12000
STEAM TURBINE	NON CONDENSING		VARIES ACCORDING TO EXHAUST CONDITION	12000 & Higher
RECIPROCATING ENGINES	DIESEL	JACKET	250°F & 30 PSIA HOT WATER & 15 PSIG STEAM	1000 to 2000
RECIPROCATING ENGINES	DIESEL	EXHAUST	700° F	750 to 1000
RECIPROCATING ENGINES	GAS	JACKET	250°F & 30 PSIA HOT WATER & 15 PSIG STEAM	1500 to 3000
RECIPROCATING ENGINES	GAS	EXHAUST	1000° F	1000 to 1500

* Based on Manufacturer's data at rated load.

PRIME MOVER INFORMATION REQUIRED FOR THE STUDY

1. ENGINE (Reciprocating Piston Type)

Service purpose: Continuous heavy duty

Location: Indoor

Drive characteristics: Direct/Indirect

Fuel: Type

Engine: Type

Engine aspiration: Turbo-charged/Naturally aspirated

Continuous net full-load rating: BHP (to include power required to drive all engine auxiliaries)

Exhaust temperature at rated load: °F

Exhaust flow at rated load

Permissible maximum exhaust back pressure

Heat radiation to engine room atmosphere: BTU/Hour

Heat rejection rate to cooling water

Fuel consumption at various loadings and rated RPM

Operating weight of engine

Overall dimensions: Height, Width, Length

Normal noise level of engine at full load: Decibels

Site elevation

Ambient temperature: °F

2. GAS TURBINE

Service purpose: Continuous

Location: Indoor

Drive characteristics: Direct

Fuel: Gas/Fuel oil

Ambient temperature: °F

Gas Turbine output: KW
Gas Turbine exhaust flow: LBS/HR

Gas Turbine exhaust temperature: °F

Permissible maximum back pressure

Fuel consumption at various loads

Noise level of turbine at full load: Decibels

Operating weight of turbine

Overall dimensions: Height, Width, Length

3. STEAM TURBINE

Service purpose: Continuous

Drive characteristics: Direct/Indirect

Steam flow rates: LBS/HR

Supply steam temperature: °F

Supply steam press: PSIG

Exhaust condition: PSIG/In of HG and temperature

Turbine output: KW/HP

Steam input at various loads LBS/HR

Operating weight of turbine

Overall dimensions: Height, Width, Length

TABLE - 10

BUILDING ENERGY PEAK DEMAND AND CONSUMPTION

NO.	DESCRIPTION	PEAK DEMAND	YEARLY CONSUMPTION	REMARKS
1.	HEATING		BTU	
2.	COOLING		BTU	
3.	ELECTRICAL		KWH	
4.	PROCESS LOAD (DHW & Others)		BTU	

TABLE - 11

ANNUAL ENERGY CONSUMPTION

NO.	SCHEMES	STEAM LBS	GAS MCF	FUEL OIL GALLONS	PURCHASED ELECTRICITY CONSUMPTION KWH
1.	SCHEME 1 (Conventional System)				
2.	SCHEME 2 (Total Energy)				
3.	SCHEME 3 (Total Energy)				
4.	SCHEME 4 (Total Energy)				
5.	SCHEME 5 (Selective Energy)				
6.	SCHEME 6 (Selective Energy)				
7.	SCHEME 7 (Selective Energy)				

TABLE - 12

ANNUAL SOURCE ENERGY CONSUMPTION - MMBTUS (10^6 BTU)

SCHEME NO.	PURCHASED ELECTRICITY MMBTU	STEAM MMBTU	PURCHASED GAS MMBTU	PURCHASED FUEL OIL MMBTU	TOTAL SOURCE ENERGY MMBTU
1.					
2.					
3.					
4.					
5.					
6.					
7.					

TABLE - 13

ANNUAL COST OF ENERGY (FUELS, STEAM & ELECTRICITY)

SCHEME NO.	PURCHASED ELECTRICITY DOLLARS	STEAM DOLLARS	PURCHASED GAS DOLLARS	PURCHASED FUEL OIL DOLLARS	TOTAL COST OF ENERGY DOLLARS
1.					
2.					
3.					
4.					
5.					
6.					
7.					

TABLE - 14

SCHEME NO.

ANNUAL OPERATING COST - DOLLARS

ITEM		COST
1.	COST OF FUEL OIL AND GAS	
2.	COST OF STEAM	
3.	COST OF ELECTRICITY	
4.	COST OF MAINTENANCE (LABOR & MATERIALS)	
5.	SALARIES OF OPERATING PERSONNEL	
6.	TOTAL	

TABLE 15

SUMMARY OF ENERGY CONSUMPTION AND ECONOMIC ANALYSIS

System Description	Initial Total Cost BOD	Total LCC	Percent Base LCC	LCC Energy Consumption Million BTU	Percent Base Energy Consumption
Conventional Heating Cooling Plant (Base)					
Selective Energy Systems					
System 1					
System 2					
System 3					
etc.					
Total Energy Systems					
System 1					
System 2					
System 3					
etc.					

LIFE CYCLE COSTING INSTRUCTIONS FOR TOTAL ENERGY SYSTEMS

1. General: The life cycle cost analyses of the total energy, selective energy and heat pump systems will consider maintenance and operating costs over the life (assumed to be 25 years for these analysis) of each system in addition to the initial construction costs.

a. Costs:

(1) Initial Costs include all expenses associated with the construction of the facility, exclusive of Government costs and contingencies.

(2) Maintenance Costs are related to the repair, replacement, etc., of building components and/or equipment and in the case of a total energy plant the labor necessary for the operation of the plant.

(3) Operating Costs are those related to consumption or conversion of energy, i.e. electricity, fuel oil, gas, and coal.

b. Study Planning Dates: The following dates (rounded off to years and months) are to be listed in the economics section of each total energy system study. The need for each of these dates is explained in the Philosophy paragraph below.

Dates of Estimate for Project Costs (Initial, Maintenance and Operating (M&O))

Project Anticipated Midpoint of Construction Date

Project Anticipated Beneficial Occupancy Date (BOD)

Midpoint of First Year of Facility Use (Six Months After BOD)

c. Philosophy:

(1) The middle of the year convention is being used (as opposed to the end-of-year-convention) whereby all costs incurred during the year are assumed to be incurred, at the middle of the year.

(2) For the purposes of these studies, initial construction/procurement/construction related costs are escalated to the anticipated midpoint of construction date of the project, using the differential cost growth rate.

(3) Project M&O costs will commence as of the project BOD and the period for the study shall be 25 years. M&O costs will reflect a

differential cost growth rate from the date of the project cost estimate to the time in which thev occur. Thus. the first year's cost will be calculated as of six months after BOD, the second year's cost as of eighteen months after BOD. etc. (reflecting the middle-of-the-year convention). The present worth of all the M&O costs will then be determined.

(4) For reasons of economic comparison all costs have to be compared at the same point in time. The selected point in time is the date of the anticipated midpoint of construction. This point in time will coincide with the date that is used for budgetary estimates used for congressional appropriations. However, the cost estimates developed in the life cycle cost analysis will not correspond to the cost estimates developed for budgetary purposes, since the former are based on differential rates of cost growth and the latter on absolute rates of cost growth. The use of differential cost growth for the life cycle cost analysis is required for compatibility with the ten percent discount rate. Cost estimates based on differential cost growth are proper and appropriate for the economic comparison of alternates and only for that purpose. Cost estimates for budgetary purposes must be based on absolute rates of cost growth. Consequently, the two types of cost estimates should not be expected to be the same.

2. Cost Data: The validity of the life cycle cost analysis is dependent upon the accuracy of the cost data, which in turn, depends upon the methods used to obtain the data. Initial costs will be determined in the conventional manner (without any provision for inflation). Operating costs will be based upon the results of the energy analysis. Maintenance cost data will be an important factor in determining the life cycle cost of the plant. Maintenance costs may be determined by consulting with electrical and heating contractors, facilities engineers, power plant operators, maintenance magazines, and manufacturers. Manufacturers may be able to give good data on preventive maintenance but their data on corrective maintenance have not been realistic. Information on corrective maintenance would probably be best obtained from an examination of records and consultation with operators of active plants.

3. Determination of Life-Cycle Costs: Life cycle costs are determined by adding the present worth of all the maintenance and operating costs to the initial cost. The life cycle cost for M&O costs may be calculated by multiplying the basic annual cost by a suitable factor based on a 25 year life, a discount rate of ten percent and a constant growth rate. The multiplying factors given hereinafter incorporate the appropriate growth rate due to inflation, applicable. Multiplying factors and the method for determining each type of cost are explained below:

a. Inflation: All project costs exclusive of energy costs should ordinarily be assumed to inflate (full cost growth) at the same rate as the overall general inflation rate of the economy as a whole, unless there is good reason to believe otherwise. Energy costs are inflated as noted in paragraph 12.3, "Fuel Cost Escalation."

b. Initial Costs: Initial costs are calculated as described in paragraph 11, "Development of Initial Construction Costs." If the cost of a particular project is expected to inflate at a rate higher than the general inflation rate a differential factor shall be applied. The specific reasons for the application of this differential factor must be given in the study. Normally a differential factor of 1.0 shall be applied to initial costs.

c. Maintenance Costs:

(1) Annual Costs The maintenance cost multiplying factor for annual costs is equal to 9.524 for the purposes of these studies. This factor is the sum of the annual present worth discount factors over the 25 year life of the project. These studies will assume a discount rate of ten percent per year, thus, the discount factor for the second year is 0.867, for the third, 0.788, for the fourth 0.717 and so on. (See AR 11-28 for the development of these factors). The sum of these discount factors for 25 years is the maintenance cost multiplying factor and is equal to 9.524.

(2) Cyclical Costs are costs which occur only at intervals other than annual. Cyclical costs are influenced by present worth discount factor, which as in the case of annual costs, is also ten percent. The discount rate factor for any year in the life of the energy system is shown in Table I below:

YR	FACTOR	YR	FACTOR	YR	FACTOR
1	0.954	10	0.405	18	0.189
2	0.867	11	0.368	19	0.172
3	0.788	12	0.334	20	0.156
4	0.717	13	0.304	21	0.142
5	0.652	14	0.276	22	0.129
6	0.592	15	0.251	23	0.117
7	0.538	16	0.228	24	0.107
8	0.489	17	0.208	25	0.097
9	0.445				

TABLE I - DISCOUNT FACTOR vs FACILITY AGE

The life cycle cost for the cyclical costs is the sum of the present worth values of all of the individual cyclical costs. The prorated discount factor for the last cyclical cost should be calculated from the equation,

$$F = N \times \frac{R}{P}$$

where

F = Prorated discount factor

N = Discount factor for last cyclical cost

R = Remaining years between last cyclical event and end of building life.

P = Period of cyclical cost

See the example problem herein for an application using the above formula.

(3) Maintenance Differential Growth If the cost of maintenance for a particular project is expected to inflate at a rate higher than the general rate a differential factor shall be applied. The specific reasons for the application of this differential factor must be given in the study. Normally a differential factor of 1.0 shall be applied to maintenance costs.

d. Operating Costs: Operating costs will reflect the differential cost growth rate from the date of the project cost estimate to the time in which they occur. These differential cost growth rates (taken from a DoD source) vary for each energy source (see paragraph 12.3 herein). These costs are also influenced by the annual present worth discount factors (see Table I). In order to simplify the calculations, Table II has been created. Table II lists the differential cost growth-present worth (DCG-PW) factor in terms of the differential rates expressed as a percent as applied to a ten percent present worth discount rate over a 25 year time period. After the present worth of the 25 year costs at the time of BOD is determined from the factor in Table II, this cost should be recalculated back to the anticipated midpoint of construction date. (See paragraph 4c(3)(a) below).

DIFFERENTIAL COST GROWTH RATE-PERCENT	DCG-PW FACTOR
0	9.524
1.0	10.325
2.0	11.236
3.0	12.268
4.0	13.440

DIFFERENTIAL COST GROWTH RATE-PERCENT	DCG-PW FACTOR	
5.0	14,776	---- (Coal)
6.0	16.302	
7.0	18.048	---- (Electricity)
8.0	20.050	---- (Fuel Oil) (NG & LPG)
9.0	22.351	
10.0	25.000	
11.0	28.054	
12.0	31.580	
13.0	35.658	
14.0	40.379	
15.0	45.850	

TABLE II

4. Life Cycle Cost Sample Problem:

a. Basic Information:

(1) Project Name: Andrezej Kosciusko Army Medical Centre

(2) Project Costs (Initial, Maintenance, and Operating are Estimated To-- March 1977

(3) Project Anticipated Midpoint of Construction Date----- October 1980

(4) Project Anticipated Beneficial Occupancy Date (BOD)--- January 1983

(5) Midpoint of First Year of Facility Use--------------- July 1983

b. Alternates Under Consideration:

Alternates	MARCH 1977 COSTS					
	Initial Costs	MAINTENANCE		OPERATING		
		Annual	Cyclical	Coal	Fuel Oil	Electricity
A	5,000,000	300,000	1,000,000 occurring in years 6, 12, 18 and 24	800,000	-	2,500,000
B	7,000,000	400,000	850,000 occurring in years 6, 12, 18 and 24	-	1,000,000	2,000,000
C	12,000,000	450,000	750,000 occurring in years 8, 16, and 24	2,400,000	500,000	-

c. Calculation Rationale:

(1) Planning Date - Time Calculations

(a) Time from project cost estimate (March 1977) to the midpoint of first year of facility use (July 1983) is six years-four months (6.33 years).

(b) Time from anticipated midpoint of construction (Oct 1980) to the project BOD (Jan 1983) is two years-3months (2.25 years).

(2) Initial Costs Initial cost differential cost growth factor for this Army medical centre is 1.0, as it is anticipated that its cost will inflate at the same rate as the general inflation rate. Hence, the initial cost estimate dated March 1977 will be the same dollar value as the anticipated midpoint of construction date estimate for all three alternates.

(3) Maintenance Costs Maintenance cost differential cost growth factor is 1.0, for same reason as the initial cost factor. Hence, the maintenance cost estimates dated 1 March 1977 will be the same dollar value as the BOD year cost estimates for all three alternates.

(a) Annual Costs. The annual cost multiplying factor is 9.524, which when multiplied by each alternate's annual maintenance cost will determine the present worth of the 25 year cost at BOD (1 Jan 83). These 25 year costs at

BOD must then be recalculated (present worth) back to the anticipated midpoint of construction. To find the present worth of these maintenance costs, the following formula, using the "single payment present worth factor" is to be used.

$$P = S\left[\frac{1}{(1+i)^n}\right]$$

P = Present worth of maintenance costs at the anticipated midpoint of construction.

S = Sum of money equal to the worth of maintenance costs at the BOD.

i = Interest rate (present worth discount factor), expressed as a decimal, normally ten percent.

n = Time in years between the anticipated midpoint of construction and the BOD.

(b) Cyclical Costs The present worth of each cyclical cost is determined by multiplying this cost by the discount factor, given Table I for the year the cost is incurred. If the current estimated cost of the cyclical maintenance remains constant the yearly factors are to be totalized then multiplied by this cost, to determine their present worth. However, the last cyclical maintenance cost is to be prorated so that only a total of 25 years of cyclical maintenance is considered in the analyses. The equation, $F = N \times \frac{R}{P}$ is used to determine the prorated discount factor for the last cyclical cost. Once the present worth of 25 years of cyclical maintenance is determined, these costs are recalculated back to the anticipated midpoint of construction as shown above.

(4) <u>Operating Costs</u>

Step by Step Calculation Procedure

(a) The March 1977 annual cost for each energy source is to be increased each year, by the differential cost growth rate (given in paragraph 12.3) to midpoint of the BOD year (July 1983).

(b) The inflated costs determined by Step 1 above are then multiplied by the DCG-PW factor given in Table II.

(c) The present worth of the 25 year costs, at the time of BOD, are then recalculated back to the anticipated midpoint of construction date using the formula presented in paragraph 4c(3)(a).

d. Calculations:

(1) Alternate "A"

(a) Initial Cost.

As per calculation rationale, the differential cost growth factor is 1.0, therefore the March 1977 initial cost of $5,000,000 is also the October 1980 initial cost.

(b) Maintenance Cost

1 Annual. The differential cost growth factor is 1.0, therefore only the annual cost multiplying factor (9.524) must be considered to determine the 25 year maintenance cost at BOD

$ 300,000 x 9.524 = $ 2,857,200

To find the October 1980 cost or present worth of these maintenance costs we use $P = S\left[\frac{1}{(1+i)^n}\right] = 2,857,200\left[\frac{1}{(1+.1)^{2.25}}\right]$

= 2,857,200 x 0.807 = 2,305,722
say 2,305,700

2 Cyclical.

$1,000,000 occurring in years 6, 12, 18 and 24.

The discount factors for years 6, 12, 18 and 24 are .592, .334, .189 and .107 respectively.

The prorated discount factor for the last cyclical maintenance cost is determined from the equation:

$$F = N \times \frac{R}{P} = .107 \times \frac{25-24}{6}$$

F = 0.018

The present worth of the total cyclical cost at BOD is:

$1,000,000 (.592 + .334 + .189 + .018)

$1,133,000

This BOD year cost is now recalculated to obtain the anticipated midpoint of construction cost therefore:

$$P = S\left[\frac{1}{(1+i)^n}\right] = 1,133,000 \times \frac{1}{(1.1)^{2.25}} = \$914,316$$

P = $914,300

(c) Operating Costs

1 Coal

Step 1 - The five percent differential cost growth rate must be applied to the \$800,000 annual cost, each year, to bring the March 1977 cost to the BOD year (1983) level. Therefore \$800,000 x $(1.05)^{6.33}$ = \$1,089,478

Step 2 - The BOD year cost is now multiplied by the DCG-PW factor of 14.776. Therefore \$1,089,478 x 14.776 = \$16,098,119.

Step 3 - Now the 25 year, BOD year cost must be recalculated to obtain the present worth at October 1980. Therefore

$$P = S\left[\frac{1}{(1+i)^n}\right] = 16{,}098{,}119 \times \frac{1}{(1.1)^{2.25}} = 12{,}990{,}970$$

P = \$ 12,991,000

2 Electricity

Step 1 - \$2,500,000 x $(1.07)^{6.33}$ = \$3,836,536

Step 2 - \$3,836,536 x 18.048 = \$69,241,809

Step 3 - \$69,241,809 x $\frac{1}{(1.1)^{2.25}}$ = \$55,877,239

\$55,877,200

(d) Alternate "A" Summary

Initial Cost--------------------------------------\$ 5,000,000

Maintenance

Annual -- 2,305,700

Cyclical-- 914,300

Operation

Coal -- 12,991,000

Electricity ------------------------------------ 55,877,200

Total Life Cycle Cost ---------------------------\$77,088,200

(2) No detailed calculation of alternates "B" or "C" are provided.

See summary below for cost figures.

e. Summary for sample problem.

	LIFE CYCLE COST (OCT 1980)						
		MAINTENANCE		OPERATING			
Alternates	Initial Cost	Annual	Cyclical	Coal	Fuel Oil	Electricity	Total
A	5,000,000	2,305,700	914,400	12,991,000	-	55,877,200	77,088,200
B	7,000,000	3,074,300	777,100	-	26,336,200	44,701,800	81,889,400
C	12,000,000	3,458,600	444,900	38,972,900	13,168,100	-	68,044,500