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STOFEAS: A Personal Computer Program for Estimating the Economic Feasibility of Storage Cooling Systems

by
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Utility companies often increase electric rates for hours associated with high demand. For Army installations, this high demand charge can increase electrical utility bills from 30 to 60 percent. Storage cooling systems (SCSs) have become an important tool in reducing onpeak electric demand by shifting electric power use to offpeak periods. Before implementing an SCS, an economic feasibility study must be done. This study developed STOFEAS, a personal computer (PC) program that helps estimate the economic feasibility of SCSs. STOFEAS offers the following advantages:

1. STOFEAS will run on any IBM PC or compatible with 640K RAM.
2. Most required economic parameters are built into STOFEAS as default input. However, users can incorporate local information into an input data file.
3. The program does an initial economic feasibility analysis of SCSs, and outputs payback periods, differential system first costs, and rough sizes of SCSs sized to shift 1 to 25 percent of the total peak electric demand.
4. STOFEAS does a preliminary feasibility analysis for new construction, replacement, or retrofit with SCSs. This analysis must be followed by a separate, detailed design of the selected SCS before beginning actual construction of an SCS.

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FOREWORD

This work was performed for the U.S. Army Engineering and Housing Support Center (USAEHSC), Fort Belvoir, VA, under project 4A162784AT45, "Energy and Energy Conservation"; Work Unit EB-X41, "Energy Storage for Army Facilities and Installations." The technical monitor was Bernard Wasserman, CEHSC-FU.

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STOFEAS: A PERSONAL COMPUTER PROGRAM FOR ESTIMATING THE ECONOMIC FEASIBILITY OF STORAGE COOLING SYSTEMS

1 INTRODUCTION

Background

Since the oil crisis of 1973, environmental concerns over the byproducts from power plants (both nuclear- and fossil fuel-powered plants) have slowed the growth of power-generating capacity associated with the rapid economic expansion of the 1980s. "Demand side management" became an important option used by U.S. electric utility companies to forestall the addition of new power plants while still meeting an increasing electric demand. One way electric utilities controlled electric demand from the users was to escalate the demand charge. Since the U.S. Army is a large user of electricity, its energy costs rose dramatically during that time; higher electric demand charges during the 1970s and 1980s raised the demand portion of most Army installations' electrical utility bills from 30 to 60 percent of the total cost (\$658 million in FY90) (Department of the Army 1990).

In the private sector, storage cooling systems (SCSs) have become an important tool to reduce onpeak electric demand. During the past 8 years, most Army installations became familiar with SCSs as an effective way to cut onpeak electric demand for facility air conditioning through demonstrations done by the U.S. Army Construction Engineering Research Laboratories (USACERL), and funded by the Facility Engineering Application Program (FEAP). The first step to implement SCSs in Army installations is to do an economic feasibility study. Variations in the peak-day hourly electric demand profiles and demand charge rate schedules from one installation to another, make it unrealistic to devise a single uniform procedure to calculate the economic feasibility of an SCS. However, a recent study developed an algorithm to evaluate the economic feasibility of SCSs by calculating the payback period of an SCS based on the system first cost and the expected annual savings in the demand charge (Sohn and Cler 1990). This algorithm has been coded into a personal computer (PC) program that estimates the economic feasibility of SCSs—STOFEAS.

Objective

The objective of this study was to develop a fully documented computer program that does a quick, simple, and inexpensive initial assessment of the cost-effectiveness of installing and using an SCS on a particular Army installation.

Approach

A generalized model was developed to estimate the annual specific savings in demand charges for each kilowatt shifted from onpeak to offpeak hours, based on a number of typical electric demand rate schedules. SCS first-cost models were developed for new/replacement, retrofit, and theoretical highest cost applications. A default conversion constant between the electric power input and the mechanical refrigeration output was determined, and default economic parameters such as study life, discount rate, factors for economy of scale, demand charge escalation rates, and differential SCS operation and maintenance costs were selected. A programming language (PC BASIC) that meets the needs of the generalized and first-cost models, and that is easily accessible to program users was chosen. The

algorithm for the economic feasibility analysis of SCS was derived and coded into programming language, and a prototype version of STOFEAS was developed. The program was field tested and debugged. The draft STOFEAS was tested by a number of Army engineers in Army installations and District offices. Comments from these tests were incorporated into the final version of STOFEAS.

Scope

STOFEAS can project a number of measures of economic performance for an SCS (based on either chilled water or ice storage, including eutectic salt systems), and can handle most electric demand rate schedules (either the straight demand charge or the demand charge in tandem with the time-of-use [TOU] rates). For a special demand rate schedule, the user may need to precondition STOFEAS' utility rate model. STOFEAS is a tool for economic performance analysis only. While a rough system size of an SCS can be obtained from the STOFEAS output, it is important to note that STOFEAS is *not* a design tool for accurate sizing of an SCS or for determining the capacity of SCS components. If an SCS turns out to be feasible, the actual design should be conducted following the appropriate design guidelines. Discussion of SCS technology can be found elsewhere. (The References section of this report includes sources of that information.)

Mode of Technology Transfer

It is anticipated that the STOFEAS Program will be forwarded to the U.S. Army Engineering and Housing Support Center (USAEHSC) at Fort Belvoir, VA, for program maintenance, support, and distribution.

2 FEASIBILITY ANALYSIS OF STORAGE COOLING SYSTEMS

Parameters for Feasibility Analysis

The economic feasibility of an SCS is a function of a number of parameters, including the annual savings in electrical demand cost, system first cost, study life, projected escalation rate of demand cost, discount rate during the study life, differential system operation and maintenance cost from the conventional system, incentive program from the local electric utility company if available, and assumed final salvage value. Of these, annual savings in electric demand and system first cost are the most important parameters in determining the economic feasibility of an SCS.

Savings in Electrical Demand Cost

Electric Demand Charge:

There are more than 3000 electric utilities in the United States (*Electrical World—Directory of Electric Utilities* 1989). Each company has its own rate structure for a number of different categories such as residential, commercial, or industrial. While this makes it difficult to generalize the electric demand savings from one Army installation to another, most rate structures are based on two quantities: energy consumed (in kWh), and peak power demand (in kW).

The rationale behind using a demand charge is to pass the cost of the generating capacity to the user. A demand charge is typically levied in two forms: the TOU rate and/or the straight demand (\$/kW) based on the peak level of power drawn by the user. Most of the electric companies define a day in terms of onpeak and offpeak periods. Typically, an onpeak period would fall between 10:00 a.m. and 8:00 p.m., with the remaining hours being the offpeak period. The exact time interval may vary depending on the local environment. In the TOU rate structure, the cost of energy (\$/kWh) is cheaper during the offpeak period. In the straight demand structure, the charge is based on either the highest level of power demand during a billing period (typically a month) or a fixed fraction of the highest level established during the preceding 11-month period, whichever is greater, or the pre-arranged contract demand. If the billing demand depends upon a fixed fraction of the highest demand during the preceding 11 months, it is called a "ratchet schedule."

A case study with Fort Jackson for the calendar year of 1989 illustrates the concept of the electrical demand charge. The South Carolina Electric and Gas Company (SCE&G) provides electricity to Fort Jackson based on Rate 23 (included in the Appendix to this report). This rate has a straight 80 percent ratchet clause for determining the monthly demand charge of \$9.34/kW. Table 1 lists a breakdown of monthly electric utility costs for calendar year 1989. Note that the monthly demand charges from January to June 1989 are fixed at \$168,038.20/month. The monthly demand charges were determined by the billing demand for each month (80 percent of the highest peak established in 1988), rather than the actual monthly peak, during the period. The yearly peak for 1989 was 23,088 kW established at 1530, 12 July 1989. The billing demand from November 1989 to June 1990 would be 18,470kW (80 percent of 23,088 kW). The monthly demand charges for November and December 1989 reflect the billing demand, shown as the fixed amount, \$173,209.80.

Hourly Electric Demand Profile for the Peaking Day of a Year

The savings in electrical demand cost through reduction in billing demand (either the monthly peak or a specified portion, i.e., ratchet, of the yearly peak) requires a careful study of the characteristics of the

Table 1
Monthly Electric Utility Bill for CY89

Month	Total Bill	Demand Cost	Energy Cost
January	312,316.60	168,038.20	144,278.40
February	309,740.20	168,038.20	141,702.00
March	328,805.60	168,038.20	160,767.40
April	316,438.80	168,038.20	148,400.60
May	311,801.30	168,038.20	143,763.10
June	333,443.10	168,038.20	165,404.90
July	461,878.50	198,570.40	263,308.10
August	498,005.50	216,341.90	218,664.60
September	496,923.50	216,341.90	280,581.60
October	412,432.00	211,410.40	201,021.60
November	405,525.00	173,209.80	232,315.20
December	346,650.60	173,209.80	173,440.80
Total	4,533,960.70	2,197,313.40	2,336,647.30

hourly electrical demand profile of a peaking day. Figure 1 shows the hourly electric demand profile for the yearly peaking day for Fort Jackson in 1989, which is typical for most of the Army installations. Note that all the electric power supplied to Fort Jackson (as for most Army installations) is measured by a master meter. This measure gives Army installations an important advantage in implementing SCSs. Even though the typical utility onpeak period occurs during the hours of 1000-2000, the SCSs do not need to entirely shift 10 hrs of the onpeak period to reduce billing demand, as shown by Figure 1.

In Figure 1, the profile shows a sharp peak in the early afternoon that tops at 23,088 kW at 1530. If the shift "window" is defined as a period of time during which the electric demand is shifted to the offpeak period, then for a shift of the first 3 percent of the total electrical demand ($23,088 \times 0.03 = 692$ kW), a 4-h window (spanning from 1215 to 1615) would meet the requirement. For the next 3 percent (total 6 percent, 1385 kW) and the next 3 percent (total 9 percent, 2078 kW), a 6-h window and an 8-h window, respectively, would satisfy the shift requirements. Recall that the storage capacity (in ton-hour [T-h]) is a product of the load shifted (in tons) and the shift window (in hours). For example, assume an SCS with 2768 ton-hr capacity was installed at Fort Jackson. If a shift window of 4 h is selected, the storage can deliver 692 tons of cooling (roughly equivalent to 692 KW), thereby shaving 692 KW of peak electric demand. By selecting an 8-hr shift window, the storage will discharge at a rate of 346 tons, shaving 346 KW of peak demand. In this example, for the first 3 percent of the total demand (692 KW), a 4-hr window would be enough. Extending the shift window (i.e., increasing the discharge period and decreasing the discharge rate) by a factor of two (to 8 h) will result in a decrease of peak shaving by a factor of two. This would be equivalent to decreasing the savings by a factor of two. Therefore, for a fixed storage capacity (i.e., at fixed storage cost), the shorter the window, the more demand could be shifted to offpeak period (resulting in more savings in demand cost).

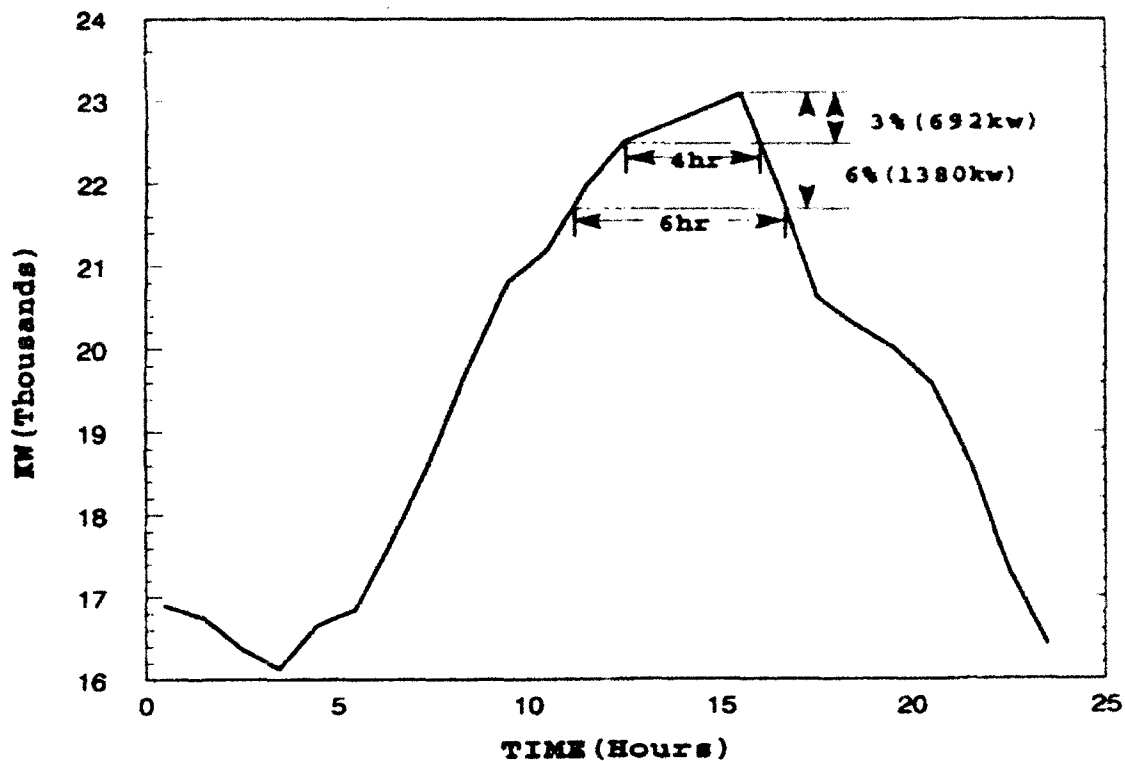


Figure 1. Peak Day Hourly Demand Profile for Fort Jackson, 12 July 1989.

System First Cost Model

The cost of an SCS is another important factor in determining its economic performance. STOFEAS measures the economic performance in terms of the payback period. The cost of an SCS is typically expressed in terms of dollar per storage capacity (\$/T-h). Due to its relatively early stage of development, the cost of an SCS is not yet firmly established. A significant gap between projected and actual cost is not uncommon (Sohn and Taylor, 1991). SCS costs will vary depending on whether the system consists of a new construction, a replacement application, or a retrofit application requiring only a new condensing unit. Another factor affecting the SCS costs is the cost associated with the additional physical space to place the storage tank. Typically, the size of the tanks are so large that they are installed outdoors without extra construction to house them. In most Army installations, the cost of land space is assumed to be free. This differs from the commercial sector, where cost of land is a prime concern, especially where the real estate cost is prime. For this reason, STOFEAS does not include the costs associated with the physical space to house the tanks.

New Construction

The cost of an SCS in STOFEAS is the differential cost between a conventional cooling system and an SCS serving the same building. For a new construction, the total cost of an SCS using a low-temperature air system is projected to be the same as or even lower than that of a new conventional cooling system (Duffy 1992). In this case, the payback period (PBP) of the SCS is zero, meaning that the system pays back from the first year.

However, for a typical new construction with 40 to 42 °F chilled water supply,* the differential cost is due to the storage tank and the associated labor. The situation is similar when a cooling plant is replaced due to expiration of its service life. In both cases, the cost of equipment for ice making/chilled water production is offset by the cost for a conventional chiller. A general rule of thumb for estimating the SCS system cost breakdown is one third for the condensing unit, one third for the storage tank, and one third for installation. For example, an EPRI report breaks the cost of an ice SCS into 65 percent major equipment and 35 percent installation cost (24 percent material, 7 percent labor, and 4 percent miscellaneous) (Reeves 1985).

Figure 2 shows the cost of the storage tank as a function of the storage capacity for an ice-on-coil system. It is based on an actual quote of the cost of tank from a manufacturer. The cost versus storage capacity relationship in Figure 2 can be approximated by:

$$P = 40T + 5300 \quad [\text{Eq 1}]$$

where P is the price of tank in dollars and T the storage capacity in T-h.

Most electrical utility companies are interested in SCSs as a means of load management by the end users. Figure 3 shows a comparison of costs between an ice storage SCS and a conventional cooling system, used by San Diego Gas and Electric Company (SDG&E) to estimate the amount of rebate (*Thermal Energy Storage, Inducement Program for Commercial Space Cooling* 1983). The SDG&E curve

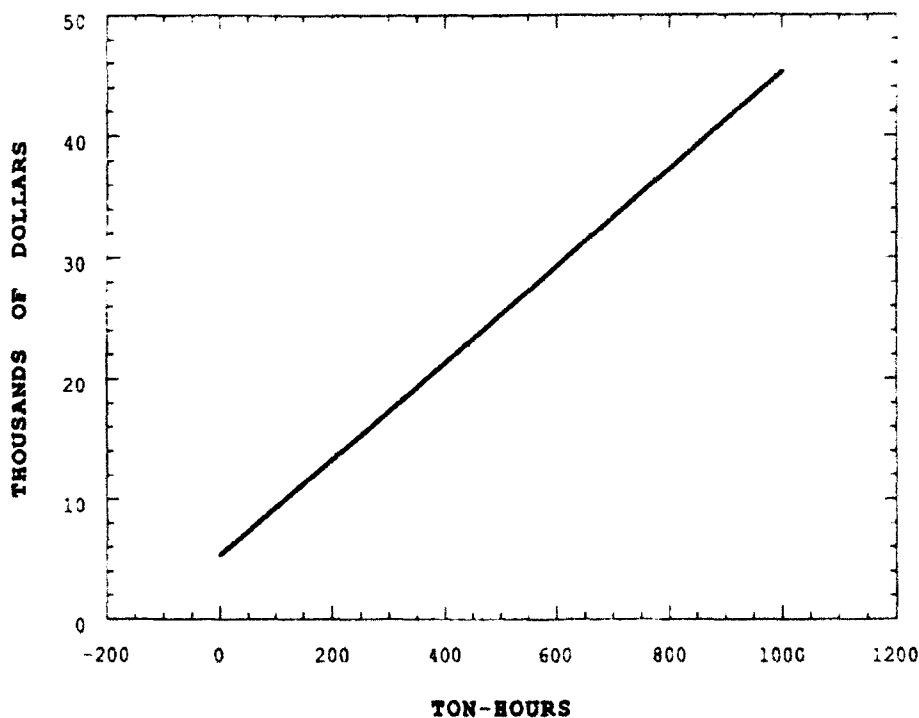


Figure 2 Cost of Storage Tanks as a Function of Storage Capacity for Ice-on-Coil Diurnal Ice Storage Cooling System.

*°F = (°C x 1.8) + 32.

represents the maximum allowance per T-h of storage used in their rebate program. It shows the installed costs of the storage tank, condensing units, and associated piping. According to the SDG&E estimate, the differential cost (excluding a smaller system affected by the economy of scale) is about \$70/T-h.

Note that SDG&E's estimated differential cost, \$70/T-h, is roughly twice the cost of the storage tank, \$40/T-h, shown in Equation 1 since the SDG&E cost includes installation charges. Note also that this case roughly corroborates the one-third rule of thumb in SCS cost estimate (1/3 for tank, 1/3 for condensing unit, and 1/3 for installation costs) at \$40/T-h for tank and \$30/T-h for installation. In STOFEAS, the default value for the differential cost for SCS in new construction is set at \$80/T-h, which should be a conservative estimate. The currency of the cost data has been checked against a more recent cost study (Sohn and Taylor 1991), which revealed little difference. In the STOFEAS program, users are allowed to update the cost information if better data are available.

Replacement Applications

When an existing cooling system needs to be replaced for reasons such as expiration of its service life, a new condensing unit should be purchased. In this case, the cost differential between an SCS and a conventional unit will be the same as the one considered in a new construction because a new condensing unit must be purchased and installed regardless of its type. The only extra cost for the SCS will be for the storage tanks and their associated installation. The cost of a storage tank may be estimated by Equation 1, as discussed in the previous section. The differential cost for SCS in replacement application is also set at \$80/T-h.

Retrofit Application

Suppose an SCS is added to an existing cooling system that does not require replacement service except for regular maintenance, e.g., adding an SCS to a central cooling plant. Such an SCS can provide cooling during a short period (say 2 to 4 h) when the installation is experiencing a peak demand. For a retrofit application, the purchase of a new condensing unit as well as storage tanks is required, and system installation labor charges must be paid for. This will be the most expensive application as far as system first cost is concerned.

Although the total system cost has not yet been firmly established, reports of actual paid-for system costs range from \$100 to \$300/T-h. In STOFEAS, the default values for retrofit applications are assumed for two models: one at a cost of \$150/T-h (realistic scenario), and \$300/T-h (upper limit scenario). Note that the cost model for the upper limit scenario is an extreme value for demonstration of the impact of the system first cost on the economic feasibility of an SCS.

Other Economic Parameters

All the input parameters for the STOFEAS program may be customized by the user. For the convenience of running the program, realistic values for these parameters were built into the STOFEAS program as default inputs. Users are encouraged to take these default input values if no more accurate data are available.

Study Life

The default study life is 25 years.

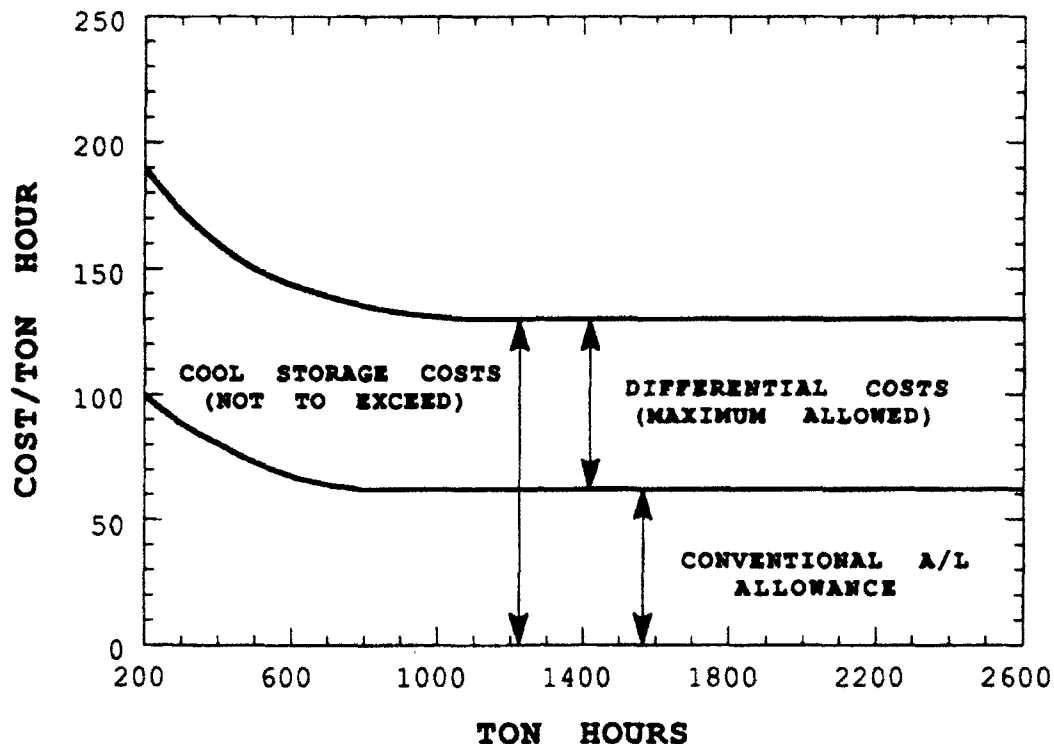


Figure 3. SCS System Costs as a Function of Capacity.

Demand Charge Escalation Rate

U.S. Department of Energy (DOE) data do not differentiate the increase of the energy cost based on kWh from that of the demand based on kW (10 CFR 346A, cited in TM 5-802-1, *Economic Studies for Military Construction Design-Applications* [31 December 1986]). Since this data does not show demand charge escalation rates separately, STOFEAS sets the default for that parameter to zero. However, for a more realistic calculation, assume the escalation rate of demand charge to be equal to the rate of the cost of electricity. Users can access these values from STOFEAS and specify the region of interest through the menu item, "DEMAND CHARGE ESCALATION RATE."

Discount Rate

The default discount rate is 4 percent.

Differential System Operation and Maintenance Cost

The storage tank is a passive component that requires no special maintenance. The operation and maintenance of a chiller, for a chilled water storage, or an ice maker, for an ice SCS is same as that for a conventional cooling plant. STOFEAS does not account for the difference in O&M cost of various types of storage cooling systems. O&M cost would be a strong function of type of system, mode of operation, and local maintenance activities, and as such, generalization of the O&M cost model is not realistic. Therefore, the default value for the differential system O&M cost was set to zero. Users may, however, enter the annual differential cost as a certain percentage of the total system first cost. Therefore, the default value for the differential system operation and maintenance cost was set to zero. If desired, the annual differential cost may be entered as a certain percentage of the total system first cost.

Final Salvage Value

The default final system salvage value is zero.

Incentive Award From Electric Utility Company

The default value of the incentive is zero.

Economy of Scale for the System First Cost

Due to the economies of scale, the specific system first cost (\$/T-h) for a large system is lower than that of a smaller system. STOFEAS assumes a system is small when the system storage capacity is below 1000 T-h, and large when the capacity is over 10,000 T-h. A system whose storage capacity falls in between is assumed to be medium-sized. For the medium and large capacity SCS, the reduction in specific system first cost due to the economy of scale is assumed to be 13 and 23 percent, respectively. This implies the values in the system first-cost models for medium- or large-size systems are reduced by 13 and 23 percent, respectively.

Feasibility Analysis

In STOFEAS, the economic feasibility of SCS is measured by payback period and saving-to-investment ratio (SIR). The payback period is calculated by:

$$Y = C/S \quad [\text{Eq 2}]$$

where, Y = payback period (yrs)
 S = annual savings (\$/yr)
 C = initial differential system cost (\$).

Annual Savings

The specific annual savings is defined as the annual savings in dollars realized by shifting 1 kW of demand from onpeak to offpeak periods. The specific annual savings (S/P) by SCS in a straight demand schedule can be calculated by:

$$S/P = D_1 \times F_1 \quad [\text{Eq 3}]$$

where S = annual savings in demand charge by SCS (\$/yr)
 P = peak power reduced by SCS (kW)
 D_1 = demand charge (\$/kW)
 F_1 = annual ratchet factor (1/year).

The annual ratchet factor (F_1) is a number that accounts for the ratchet clause in the electrical rate structure. For example, "A demand charge will be \$10/kW. The billing demand shall be the greater between the maximum demand during the billing month and 80 percent of the highest demand occurring during the 11 preceding months." During the 4 summer months (June through September), the typical

billing month demand exceeds 80 percent of the highest demand among the preceding 11 months. Thus the annual ratchet factor is

$$\begin{aligned} F &= 1 \times 4 \text{ (summer months)} + 0.8 \times 8 \text{ (nonsummer months)} \\ &= 10.4 \end{aligned} \quad [\text{Eq 4}]$$

For the example, the specific annual savings (for each shifted kW of peak power) is calculated to be:

$$\begin{aligned} S/P &= D_1 \times F_1 \\ &= \$10/\text{kW} \times 10.4/\text{yr} \\ &= \$104/\text{yr} - \text{kW} \end{aligned} \quad [\text{Eq 5}]$$

Note that the annual ratchet factor (F_1) in a straight demand schedule is a function of the ratchet percentage and the number of months the ratchet is in effect.

For a rate schedule other than the straight demand, calculation of specific annual savings (S/P) is not so simple. It should be calculated case by case following the given rate structure. For example, in the following case, with a time-of-use (TOU) rate along with demand charges and a demand charge of \$15/kW and no ratchet, the energy charge is \$0.05/kWh during onpeak period, and \$0.03/kWh during offpeak periods.

An examination of total installation power demand profile (Figure 1) shows that a 4-h window can capture the demand peak effectively. Reduction of the demand portion due to TOU rate per each kW for a period of N days is given by:

$$D_2 = d \times W \times N \quad [\text{Eq 6}]$$

where D_2 = monthly savings by SCS due to TOU rate (\$/kW)
 d = cost differential per kWh between on-peak and off-peak periods (\$/kWh)
 N = number of days in a month benefited by demand shift (day)
 W = width of window for a day during which the demand is shifted (hr/day).

The quantity D_2 corresponds to the monthly demand charge in a straight demand charge rate schedule. The effective annual ratchet factor for this case is the number of months the SCS is in service. According to the Army regulation, this would typically be the 5 months between mid-May and mid-October:

$$\begin{aligned} F_1 &= 5/\text{yr} \\ F_2 &= 5/\text{yr} \end{aligned} \quad [\text{Eq 7}]$$

where F_1 = annual ratchet factor due to straight demand,
 F_2 = annual ratchet factor due to TOU rate.

Therefore, the specific annual saving, (S/P), will be given by:

$$\begin{aligned} S/P &= D \times F \\ &= D_1 \times F_1 + D_2 \times F_2 \end{aligned} \quad [\text{Eq 8}]$$

where D_1 = demand charge (\$/kW) due to straight demand
 D_2 = implicit demand charge (\$/kW) due to TOU schedule.

For the above example

$$D_1 = 15 (\$/\text{kW}) \quad [\text{Eq 9}]$$

and

$$\begin{aligned} D_2 &= d \times W \times N \\ &= \$0.02/\text{kWh} \times 4 \text{ hr/day} \times 22 \text{ day} \\ &= \$1.76/\text{kW} \end{aligned} \quad [\text{Eq 10}]$$

therefore

$$\begin{aligned} S/P &= 15 \times 5 + 1.76 \times 5 \\ &= \$83.80/\text{kW} \end{aligned} \quad [\text{Eq 11}]$$

Annual Ratchet Factor

The critical factors determining the annual savings by SCS are the monthly demand charge and the ratchet schedule. The method of calculating the annual ratchet factor for the cases of straight demand and straight demand with time-of-use rate schedule was discussed in the previous section. For a more complicated rate structure, derivation of the factor may have to be customized. However, the basic idea of the annual ratchet factor is to normalize the explicit and/or implicit ratchet charge schedule in terms of the straight demand charge and the number of months when the demand charge clause stays in effect.

Differential System First Cost

To calculate the payback period, the differential system first cost is taken from previous sections. For a new construction or replacement application, STOFEAS calculates C, the differential system first cost, as:

$$C = 80 (\$/T - H) \quad [\text{Eq 12}]$$

for a retrofit application,

$$C = 150 (\$/T - H) \quad [\text{realistic scenario}] \quad [\text{Eq 13}]$$

and

$$C = 300 (\$/T - H) \quad [\text{upper limit scenario}] \quad [\text{Eq 14}]$$

Recall that these values are default values. If more accurate data become available, they can be easily updated for actual calculations.

System Sizing for Demand Shifting

The size of SCS (in T-H) to achieve a given percentage of reduction in peak demand is calculated as follows. Let Q be the annual peak power demand for an installation. The intent is to shift r_1 percent of the peak demand to offpeak periods. The amount of shifted energy in kWh (K) for this application is always less than $(r_1/100) \times Q \times W_1$, where W_1 is the window of shift (in hr) (Figure 4), so that:

$$K \leq (r_1/100) \times Q \times W_1 \quad [\text{Eq 15}]$$

In an extreme case when the demand profile over the window W_1 is a perfect rectangular shape, the shifted energy in kWh will be equal to $(r_1/100) \times Q \times W_1$.

To reduce the peak by another r_2 percent, the time window required would be W_2 , which will probably be longer than W_1 . As the reduction of peak demand increases, the time window also increases. This increases the size of the storage capacity, which in turn increases the cost of shifting power from the onpeak period. The storage size can be summarized as:

$$K = Q \times \left(\sum_i \right) [r_i/100 \times W_i] \quad [\text{Eq 16}]$$

For two equal reductions in the demand, the above equation reduces to:

$$K \leq Q \times (r_1/100 \times W_1 + r_2/100 \times W_2) \quad [\text{Eq 17}]$$

The equal sign applies to an extreme case when the demand profile over W_1 and W_2 is two perfect rectangles (Figure 4).

Examination of peak demand profiles from a number of installations shows that a 4-h window will generally be sufficient enough to cover the first 3 percent of peak demand. In Figure 1, 4 h of W_1 covers 692 kW of peak demand. Similarly, an 6-h window is sufficient to cover the next 3 percent of demand (6 percent of the total demand). In STOFEAS, the window size for the shifted power in terms of percentage of the total peak demand can be designed to match the local characteristics of the demand profile for an installation of interest. The default window design in STOFEAS is 4 h up to 3 percent, 6 h for the next 3 percent, and 8 h for over 7 percent of the total peak demand of the installation.

Note that the unit of the amount of shifted energy (K) is in kWh, not in T-h, which is the accepted unit of storage capacity (T) of SCS. Both the quantities of K and T are energy measures, which have the same physical dimension. The conversion between K and T is given by following analysis.

For a conventional cooling system, the power consumption factor of a typical centrifugal chiller is about 0.7 kW per ton of cooling. If a chilled water SCS is used, the evaporator temperature of the chilled water generator (typically a centrifugal chiller) will be the same as that for a conventional cooling system. However, if an ice SCS is used, the evaporator temperature must be about 20 °F lower than that of a conventional chiller. The lower evaporator temperature implies the suction temperature of the ice maker must be about 20 °F. Due to the lower suction temperature, the volumetric efficiency of the compressor

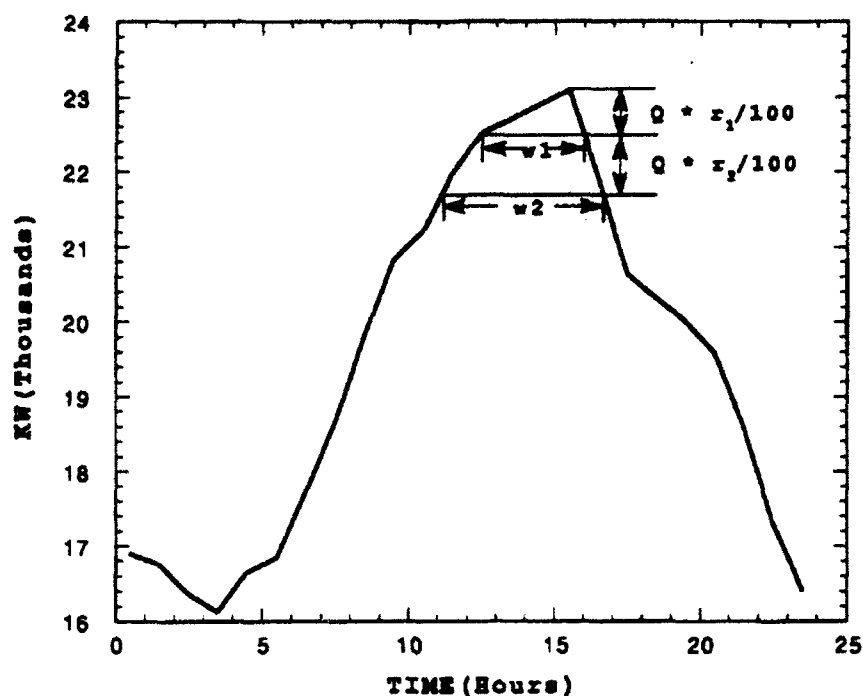


Figure 4. Shift Window Analysis.

will be reduced, thereby resulting in a derating of the compressor. Also, due to the thermodynamic characteristics of the enthalpy-pressure relationship of the refrigerant, the lower suction temperature yields a lower coefficient of performance (COP) in the refrigeration cycle. The reported power consumption factor for ice storage SCS is a little over 1.0 kW/ton (ASHRAE Handbook—HVAC Systems and Applications 1987). In STOFEAS, the power consumption factor for an SCS is set at 1.0 kW/ton. Therefore, a conversion factor (f) for the required storage capacity (T) of an SCS from the amount of shifted energy (K) is:

$$f = 1.0(\text{ton/kW}) \quad [\text{Eq 18}]$$

Thus

$$T = f \times K(T-h) \quad [\text{Eq 19}]$$

Incentives for Demand Shifting

A number of electrical utility companies offer incentives to customers to install SCSs as a way to shift electrical demand from onpeak to offpeak periods. The incentive program is intended to improve the utility load factor thereby achieving higher power generation efficiency and reducing the requirement for additional power plants to meet the short-period peak power demand. As of February 1992, at least 38 U.S. electric utility companies offer such incentives, and the number is increasing (ITSAC Technical Bulletin 1992). The incentive ranges from \$60 to \$500 per kW shifted from onpeak to offpeak periods. Typically, electric utilities require the power to be shifted at least 8 h from the onpeak period.

Such incentives can reduce the initial construction cost and shorten the payback period significantly. However, the incentive may not be available for an SCS that shifts demand less than 8 h. This may create a conflict in choosing an SCS storage capacity. For a given amount of power to be shifted, a shorter period of shift (i.e., less than 8 h) would require less storage capacity. Although a smaller system has the advantage of a lower initial construction cost, it may also have the disadvantage of not qualifying for the incentive program requirement. It may be advantageous to increase the window of shift at the expense of increased storage capacity to qualify for the incentive rebate. Whether this approach is cost-effective depends on the demands of individual project and the specifications of the given incentive program. In STOFEAS, the incentive rebate was included only for the windows of 8 h or longer.

3 STOFEAS Program

Program Overview

STOFEAS is a simple, interactive, PC-version computer program written in Quick-BASIC for the economic feasibility analysis of SCSs based on a USACERL developed algorithm (Sohn and Cler 1989).

The main source program "STOFEAS.BAS" contains several subprograms that perform specific functions for the economic feasibility study. The subprogram "ANALYSIS" calculates several economic parameters to be used as a basis for the feasibility study; the subprogram "DATAWIND" modifies the default input data from the screen interactively; and the subprogram "OUTFORM" controls the format of the output data.

Figure 5 gives an overview of the program execution. Once the program begins execution, the user has two options in preparing an input file: to use the default input data file built into STOFEAS, or to retrieve a preconditioned input file saved from an earlier run of STOFEAS. In either case, the user would customize the input file by modifying the data for the specific applications. The output of STOFEAS consists of four pages of printout. The first page echoes back the inputs employed. The other three pages show the results of the STOFEAS run: the feasibility of SCS for new/replacement applications, retrofit applications, and upper limit cases with an extreme system first cost scenario. Before exiting STOFEAS, the user is prompted whether to save the output results.

Program Requirement

System Environment

The required system is an IBM PC/XT/AT or a compatible with at least 640K random access memory (RAM). The execution file is STOFEAS.EXE.

System Installation

The installation of the program is simple and explained below. The program may be executed from either a floppy disk or a hard disk. It is recommended that a backup copy be made before running the program. If a hard disk is available, make a directory named "STOFEAS" or another name of your choice. Copy all the files in the distributed diskette to the new directory. The distributed diskette contains the following three files: (1) STOFEAS.BAS, a source file of the program in Quick-Basic language; (2) STOFEAS.EXE, an executable file of the program; and (3) BRUN45.EXE, a library file for Quick-BASIC application program.

Input Management

Default Input

To simplify the input procedures, the program assumes default input data for a particular site according to current economic parameters and the most frequently occurring data of the required information for SCS performance. For a different site, the data can be modified or based on the information in another default data bank.

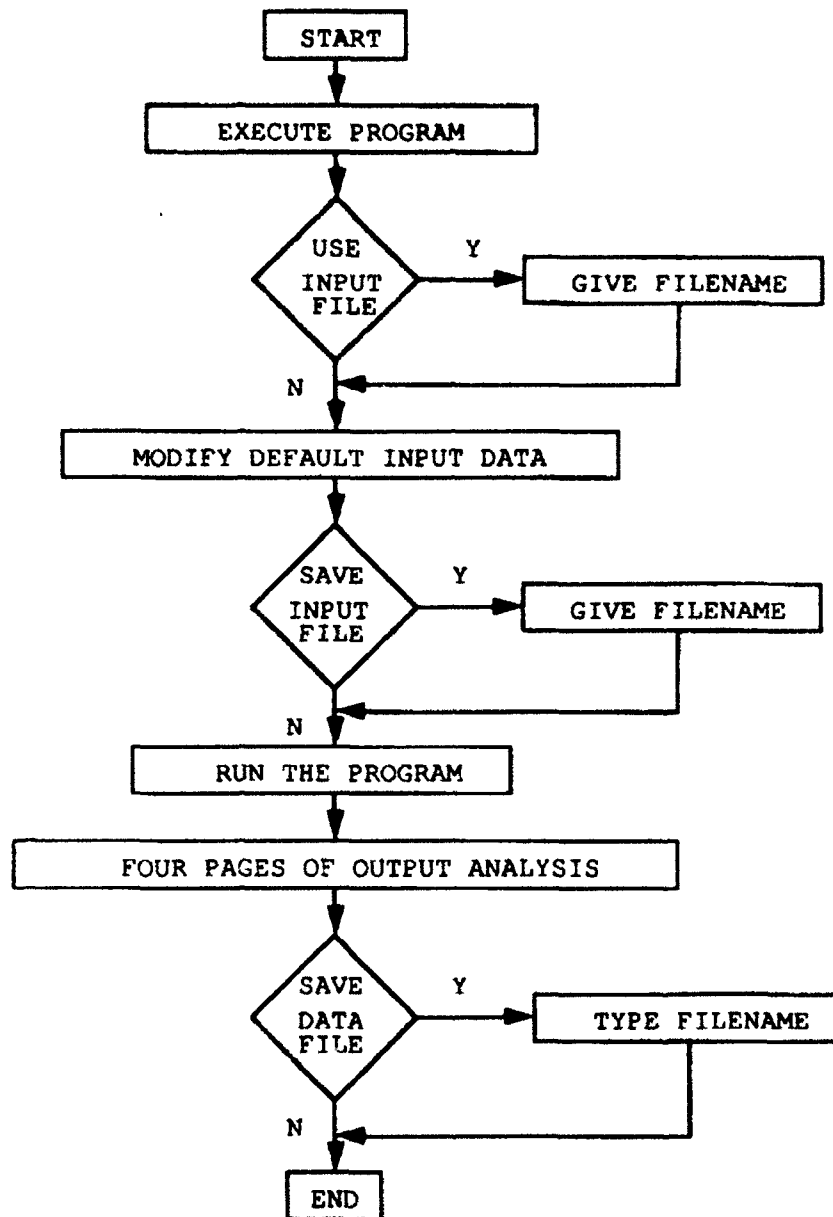


Figure 5. STOFEAS Flowchart.

Input Modification

Data based on the default input or a preconditioned data file can be modified from the screen of each data entry interactively. After all of the data has been modified, it is strongly recommended that the user save the data for further analysis. (The data file is small.) The program will request a filename for the conditioned data. If the file already exists, the contents within the existing file will be overwritten and replaced by the new data.

Data saved for a project can be retrieved for use as the required input information of running STOFEAS. STOFEAS will ask for the filename of the input data, and the user can provide the previously defined filename.

Running the Program

Getting Started

There are no login procedures necessary to run STOFEAS. The first step in running this program is to change the STOFEAS subdirectory and then to type the execution filename (STOFEAS). The USACERL logo and window for input data will appear (Figure 6).

Entering Input

Figure 7 shows the main menu, which lists the input data to be entered. Data can be entered either from a preconditioned data file or from the screen interactively, which should be self-explanatory. Default data has been built into the program. Modification of input data can be done by changing the information of the corresponding data entry on the screen. There are nine data arrays for the main information input. The following discussion describes each of the data arrays in more detail.

ARRAY 1. The seven elements of this PROJECT DESCRIPTION array are: "PROJECT TITLE," "PROJECT LOCATION," "PROJECT YEAR," "PROJECT NUMBER," "CAT CODE," "DESIGNER," and "DATE." This descriptive information identifies the project when the program generates its output. The date is automatically set by the computer but it can also be modified by entering a new date.

ARRAY 2. The ECONOMIC PARAMETERS array contains two elements: "STUDY LIFE" and "INTEREST RATE (or DISCOUNT RATE)." The first element, the study life of a project, is necessary information to calculate the SIR (Savings and Investment Ratio) in the case where the discounted rate is being considered. To be consistent with current design guidance, the default value for this parameter is given as 25 years. The second element, the interest rate, is required to compute the compensated rate of actual saving. In accordance with 10 USC 2857, the value required to compute this factor at the present time is 7 percent/year.

ARRAY 3. The information in the ELECTRIC UTILITY RATE array is provided to calculate the annual demand charge savings per kW shifted, which will depend on the choice between Straight Demand or TOU Rate Demand.

In the case of Straight Demand, the array contains four elements: "DEMAND CHARGE" (in \$/kW), "ENERGY COST" (in \$/kWh), "RATCHET PERCENTAGE" (in percent), and "NUMBER OF MONTHS OUT OF RATCHET" (i.e., "NUMBER OF ONPEAK MONTHS"). The data for the first and second elements are based on information from the previous fiscal year. The data in the third element is based on the electric utility rate structure. The data for the last element is based on the 12 monthly peak demand records.

In the case of TOU rate demand structure, there are two options: "ON/OFF" Peaks- and "ON/MID/OFF" Peaks-based structures. The data in the first option contain five elements: "DEMAND CHARGE," "ONPEAK ELECTRICITY CHARGE," "OFFPEAK ELECTRICITY CHARGE," "RATCHET PERCENTAGE" and "ONPEAK INTERVAL" (in hours). The information for the first three elements can be obtained from the electricity utility bill. The data for the fourth element can be obtained from the utility rate structure. The data for the last element can be obtained from the daily demand profile. The data for the second option will be similar to that of the first option, except two more elements are needed. They are: "MID-PEAK ELECTRICITY CHARGE" and "MID-PEAK INTERVAL." The corresponding data can be obtained from sources similar to those described above.

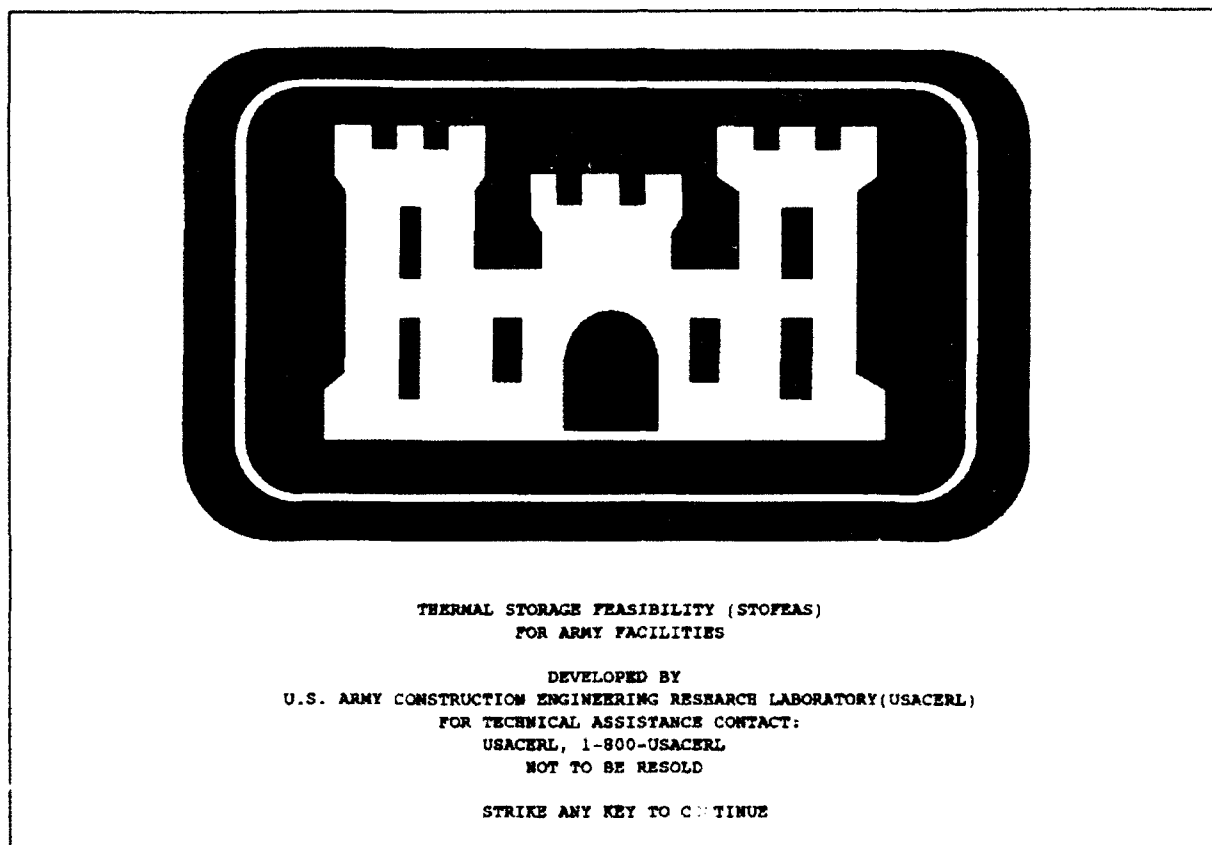


Figure 6. The STOFEAS Introductory Screen.

STOFEAS can also handle those cases with two different demand charges, i.e., one for the summer and the other for the winter months. Inputs can be entered in a way similar to the case of a single demand charge. The screen will prompt the user to enter the two demand charges.

For demand charge structures different from the cases above, the structure should be normalized before entering into STOFEAS. The normalizing procedures were discussed in *Annual Savings* (p 13).

ARRAY 4. The data for this array contain the "WINDOW SIZE" information for the shifted power percentage and are used to calculate the cost of demand shifting. Two options are available for designing the corresponding window size for a specified percentage of the shifted peak power. One is based on the default design, and the other is based on the daily peak power consumption history.

For the first option of default design obtained by entering the "ESC" key, the window for designing the (lower and upper) shifted power percentages for a specified window size appears. The user can define eight different windows sizes by specifying lower and upper shift percentages for each window size with desired length of period in hours. Note that the maximum length of the window is set to be 8 h in STOFEAS.

The second option is based on the power consumption history, and requires information that can be determined from the hourly demand profile of the peaking day of a year. The demand of each hour should be entered into the table shown on the screen. Otherwise, the default option will be requested.

MAIN MENU
ENTER PROJECT DESCRIPTION
ENTER ECONOMIC PARAMETERS
ENTER ELECTRIC UTILITY RATE AND WINDOW DESIGN
ENTER ELECTRIC UTILITY DATA
ENTER SYSTEM FIRST COST MODEL
ENTER SYSTEM OPERATION AND MAINTENANCE COST MODEL
ENTER SCALES OF ECONOMY FOR FIRST COST
ENTER DEMAND CHARGE ESCALATION RATES
SAVE CONDITIONED DATA
RETRIEVE PRE-CONDITIONED DATA FILE
RUN
QUIT

USE CURSOR ARROWS TO MOVE, RETURN TO SELECT

Figure 7. The STOFEAS Main Menu.

ARRAY 5. The data in this array contain the information on "ELECTRIC UTILITY DATA." The first element of this array is "PEAK DEMAND" (in kW). The second element of this array is "UTILITY INCENTIVE" (\$/kW). The information for the first element can be obtained from the site's utility bill. For the incentive, check the local electric utility company.

ARRAY 6. The data in this array supply the information for the "SYSTEM FIRST COST" model. The cost of an SCS is one of the critical factors in determining the payback period (PBP). The first cost of concern is the differential cost between a conventional air-conditioning system and an SCS that would meet the same cooling requirements represented in terms of dollars amount per storage capacity. The default differential system first costs were set at \$80, \$150, and \$300/T-h for new/replacement, retrofit, and upper limit applications, respectively.

ARRAY 7. The information in this array concerns the "SCALE OF ECONOMY FOR FIRST COST". The costs of installment for the three different types of application (new/replacement, retrofit, and upper limit) described in Array 6 have been specified. The system capacity is also an important factor in the installment cost. Three different sizes are categorized into SMALL (< 1000 T-h), MEDIUM (1 KT-h < 10 KT-h), and LARGE (> 10 KT-h), and the corresponding scale factors are requested. Default values were set to 1, 0.87, and 0.77, for small, medium, and large systems, respectively.

ARRAY 8. The data in this array are required by the "SYSTEM OPERATION" and "MAINTENANCE COST" model. The costs for system operation and maintenance can be interpreted as the extra differential cost for a new SCS. The default is set at zero percent since an existing system also needs to account for the system operation and maintenance cost.

ARRAY 9. The information in this array supplies data for the "ANNUAL DEMAND CHARGE ESCALATION RATE." This option allows specification of the projected escalation rate of the demand charge in the coming years. The data may be obtained from the utility company. The default rate was set at zero percent annually. STOFEAS also provides electricity cost escalation rates forecast by the DOE.

Execution of Program

The procedure for running the program is described in the following steps.

1. Insert the distributed diskette into a disk drive, or change the directory to STOFEAS.
2. Type "STOFEAS", and the USACERL logo will appear on the screen.
3. Type any key to proceed, and the "MAIN MENU" will be displayed.
4. Move the highlighted cursor to any desired menu, using the up or down arrow on the number key pad. (Deactivate the NUM LOCK key.)
5. Enter the input data according to the menu. (The menu should be self-explanatory.) Input the data as requested by the menu. Every input should be entered with the "RETURN" key. Modification of the data will not be completed until the "RETURN" key is typed.
6. Return to the main menu by pressing the Escape key. Repeat steps 4 and 5, until all of the input procedures are completed, return to the Main Menu window, and move the cursor to "RUN", then press the "ENTER" key. The program will now execute.
7. Move the cursor to the QUIT menu and press the "RETURN" key to end the program.
8. Type "Y" in response to "Are you sure?" to return to DOS.

Output Management

After the program has been executed, the window will display a screen of input data and will temporarily stop before displaying more. Once all of the input data has been checked, press any key to proceed to the next screen. Output information appears after all of the input data has been reviewed. The user will be asked whether to save the output data. To save, type "YES" and give the file name; otherwise, type "NO". STOFEAS will also ask whether the user wants to print the output. To print, type "YES"; otherwise, type "NO" and press "ENTER". (Note that if a file exists with the same name, it will be overwritten with the current output file.)

When the analysis is complete, the user may save the input data file from that specific site for future use by specifying a filename for the data. If several designs of an SCS are likely to be performed at the same installation, the user can use this option to customize data for later runs at that site.

Discussion of Output

Output Structure

Once run, STOFEAS produces four pages of output: (1) a summary of the data entered for the information requested; (2) the economic analysis results for the case of New/Replacement; (3) the economic analysis results for the case of Retrofit; and (4) the economic analysis results for the case of Upper Limit. Based on these outputs, the user can determine the feasibility of a prospective SCS.

Economic Feasibility

The second page of output contains an economic analysis of the performance of a new storage cooling or replacement system. This page will contain nine columns of data. The first column shows the percentage peak power shifted by the SCS. The second column shows the corresponding shifted power (in kW) by SCS with respect to the percentage given in the first column. The third column contains the required storage capacity (or size) in terms of T-h for the specified shifted power in column two. The fourth column shows the System First Cost (in terms of thousands of dollars) for the corresponding storage capacity shown in column three. The fifth column displays First Year Savings in terms of thousands of dollars for the corresponding shifted power in column two. The sixth column shows the simple payback period based on the nondiscounted interest rate for the corresponding shifted power. The seventh column shows a discounted payback period based on the specified discounted interest rate (similar to column 6). The eighth column shows the Savings and Investment Ratio (SIR), a valuable economic parameter for the feasibility study. The ninth (last) column shows the Net Savings (in thousands of dollars) under the specified percentage peak power shifted, the input Electric Demand Charge, and the System First Cost Model.

The third and the fourth page show output information similar to that shown on page two except that the third page of the output is for the case of Retrofit, and the last page is for the case of the Upper Limit (the "worst case" from a feasibility standpoint).

This program output can help evaluate the feasibility of an SCS system with a specific anticipated life-span. Also, the program can be re-run with different economic parameter combinations to account for a variety of real-life situations, making the application of this program both flexible and realistic.

4 SAMPLE ILLUSTRATION

Sample Run of STOFEAS

This chapter shows how STOFEAS was applied in an actual case study for Fort Belvoir, VA. This case study considers a new shopping center to be built at Fort Belvoir in the near future. A preliminary cooling load estimate has been completed. Since the demand charge of the Virginia Power and Electric is relatively high, the engineer at Fort Belvoir would like to consider an SCS as an option to avoid the additional electrical demand cost expected for the new shopping center.

Preliminary input data available for the STOFEAS analysis for this sample problem are:

1. The yearly peak demand for Fort Belvoir in 1991 is 25,148 kW, which was established at 1430, 23 July 1991. (This information is easily available from the local electric utility). The current demand charge schedule is \$12.90/kW. There is a 90 percent ratchet clause. There are 4 months with a monthly demand higher than the ratchet demand. (These data are readily obtained from the past year's billing records or from the local electric utility.)
2. The estimated cooling load for the new shopping center is 321.6 tons. Assuming 1 kW/ton power consumption factor for a new cooling plant, the expected growth of electric demand due to a new cooling plant is 1.3 percent of the total electric demand at Fort Belvoir. For such a small percentage, the window size should be much less than 8 h. Therefore, no incentive from the local electric utility will be considered in the STOFEAS analysis.
3. For a quick feasibility analysis, the other parameters assume the default values.

Based on these inputs, STOFEAS runs as follows:

- a. After a routine PC power on, either insert a floppy disk containing the STOFEAS program or change the current directory to that containing the STOFEAS program. Type "STOFEAS" and press Return.
- b. The logo screen appears (Figure 6). Press any key to proceed to the "Main Menu." The screen will display Main Menu (Figure 7).
- c. Make sure the "Number Lock" key is off, so the number pad keys can move the flashing cursor. The cursor is now at "ENTER PROJECT DESCRIPTION"; press Return to select a menu item. Information in this block is for project documentation only. (It is not used for calculation.) After completion of inputs, press Escape. The screen reverts back to the Main Menu.
- d. Select the next menu "ENTER ELECTRIC UTILITY RATE AND WINDOW DESIGN" by pressing Return. Select the "STRAIGHT DEMAND" option, and update the demand charge to a value of 12.90, and the ratchet to 90. For "WINDOW SIZE FOR SHIFTED PERCENTAGE," use the default table.
- e. Select "ENTER ELECTRIC UTILITY DATA" in the main menu, and replace the default value of the "YEARLY PEAK DEMAND (kW)" with 25,148 (kW).
- f. Select "ENTER DEMAND CHARGE ESCALATION RATES" from the main menu. Select the "DOE ESCALATION RATES" option, and enter "3" for the DOE region number of Virginia.

g. STOFEAS should now be ready to run. Before running, move the cursor to "SAVE CONDITIONED DATA" in the Main Menu, and save the customized data file into an appropriate directory. Move the cursor to "RUN," and press Enter. STOFEAS will first list the inputs used for calculation (Figure 8), and will then show three pages of output: New/Replacement, Retrofit Case, and Upper Case results (Figures 9 to 11).

h. When the output is done printing, you will be prompted whether to save the output. If you respond with a "Y", the screen will guide you through the steps to save the output. The STOFEAS program can then be terminated by moving the cursor to "QUIT", and pressing Return.

Discussion of Sample Output

The Fort Belvoir example is a case of new construction, so the first page of output (Figure 9) is applicable. The shifting of 321.6 kW (for a 321.6 tons of cooling load) falls between 1 (251 kW) and 2 percent (503 kW) of the total demand of Fort Belvoir (25,148 kW). An interpolation shows that 321.6 kW will be 1.3 percent of the total demand. The output table (Figure 9) shows that the SCS will pay back in 3 years with a saving-to-investment ratio of 8.5. An SCS for this application will be highly cost effective, and is recommended for installation.

A rough estimate of size and differential construction cost of the system can also be obtained from the output. For a system with a 1.3 percent of shift, an interpolation between 1 and 2 percent for these values yields the storage capacity of 1308 T-h and \$91K of extra construction cost for an SCS over the construction cost of a conventional cooling system. Note that these results are for the determination of the feasibility of an SCS and not design values for the system. If the program shows that the installation of an SCS is feasible, and a managerial decision is made to include it, a detailed design of an SCS should follow as the next step of the project.

FEASIBILITY REPORT ON STORAGE COOLING SYSTEMS

***** PROJECT DESCRIPTION *****

PROJECT TITLE: New Shopping Center
PROJECT LOCATION: Fort Belvoir, VA
PROJECT YEAR: FY93
PROJECT NUMBER: N/A
CAT CODE: N/A
DESIGNER: C. Sohn
DATE: 10-15-1992

***** ECONOMIC PARAMETERS *****

STUDY LIFE : 25yrs DISCOUNT RATE : 4%

type enter to continue?

***** ELECTRIC UTILITY RATE STRUCTURE *****

--- STRAIGHT DEMAND ---

DEMAND CHARGE (\$/kW): 12.90000
RATCHET PERCENTAGE (%): 90
NUMBER OF MONTHS (ACTUAL>RATCHET): 4
ENERGY COST (\$/kWh): 0.00000

***** WINDOW SIZE FOR SHIFTED POWER PERCENTAGE *****

1- 3%	4- 6%	7- 9%	10- 12%	13- 15%	16- 18%	19- 21%	22- 24%
4 hr	6 hr	8 hr	8 hr	8 hr	8 hr	8 hr	8 hr

***** ELECTRIC UTILITY DATA *****

YEARLY PEAK DEMAND (kW): 25,148.00
UTILITY INCENTIVE (\$/kW): 0.00

type enter to continue?

Figure 8. List of Input.


```

***** SYSTEM FIRST COST MODEL *****
NEW/REPLACEMENT      RETROFIT      UPPER LIMIT
($/ton-hr)           ($/ton-hr)    ($/ton-hr)
      80              150          300

```

```

***** ECONOMY OF SCALE FOR FIRST COST *****
Small(<1000 t-h)    Medium    Large(>10kt-h)
      1              .87        .77

```

```

***** SYSTEM O&M COST MODEL *****
PERCENT OF SYSTEM FIRST COST(%)
      0

```

type enter to continue?

```

***** EXPECTED ANNUAL DEMAND CHARGE ESCALATION RATE *****
      1          2          3          4          5    (YEAR)
-1.081      1.4567      .575      .0713      .2138  (%)
      6          7          8          9          10   (YEAR)
.7824      .9184      2.2389      1.3006      1.2164  (%)
      11         12         13         14         15   (YEAR)
1.135      1.0564      1.437      .3861      .7692  (%)
      16         17         18         19         20   (YEAR)
.5098      .5696      .819      .6103      .6136  (%)
      21         22         23         24         25   (YEAR)
.6166      .6197      .6234      .6264      .6291  (%)

```

type enter to continue?

Figure 8. (Cont'd).

***** New/Replacement *****

Shift (%)	Shifted (kW)	Storage Sz(ton-hr)	System 1st Cst(1000\$)	1st yr Svns(1000\$)	Payback Smpl Dsct	SIR	Net Svng (1000\$)
1	251	1,006	70	36	1.9	3.0	528
2	503	2,012	140	73	1.9	3.0	1,057
3	754	3,018	210	109	1.9	3.0	1,585
4	1,006	6,036	420	145	2.9	4.0	1,973
5	1,257	7,544	525	182	2.9	4.0	2,466
6	1,509	9,053	630	218	2.9	4.0	2,960
7	1,760	14,083	868	254	3.4	4.0	3,321
8	2,012	16,095	991	291	3.4	4.0	3,795
9	2,263	18,107	1,115	327	3.4	4.0	4,269
10	2,515	20,118	1,239	363	3.4	4.0	4,744
11	2,766	22,130	1,363	400	3.4	4.0	5,218
12	3,018	24,142	1,487	436	3.4	4.0	5,692
13	3,269	26,154	1,611	472	3.4	4.0	6,167
14	3,521	28,166	1,735	509	3.4	4.0	6,641
15	3,772	30,178	1,859	545	3.4	4.0	7,115

type enter to continue?

9	2,263	18,107	1,115	327	3.4	4.0	4,269
10	2,515	20,118	1,239	363	3.4	4.0	4,744
11	2,766	22,130	1,363	400	3.4	4.0	5,218
12	3,018	24,142	1,487	436	3.4	4.0	5,692
13	3,269	26,154	1,611	472	3.4	4.0	6,167
14	3,521	28,166	1,735	509	3.4	4.0	6,641
15	3,772	30,178	1,859	545	3.4	4.0	7,115

type enter to continue?

16	4,024	32,189	1,983	581	3.4	4.0	7,590
17	4,275	34,201	2,107	618	3.4	4.0	8,064
18	4,527	36,213	2,231	654	3.4	4.0	8,539
19	4,778	38,225	2,355	690	3.4	4.0	9,013
20	5,030	40,237	2,479	727	3.4	4.0	9,487
21	5,281	42,249	2,603	763	3.4	4.0	9,962
22	5,533	44,260	2,726	799	3.4	4.0	10,436
23	5,784	46,272	2,850	836	3.4	4.0	10,910
24	6,036	48,284	2,974	872	3.4	4.0	11,385
25	6,287	50,296	3,098	908	3.4	4.0	11,859

* Annual O&M Cost is assumed to be 0% of system cost.

type enter to continue?

Figure 9. Feasibility Results for New/Replacement Applications.

***** Retrofit Case *****

Shift (%)	Shifted (kW)	Storage Sz(ton-hr)	System 1st Cst(1000\$)	1st yr Svns(1000\$)	Payback Smpl Dsct	SIR	Net Svng (1000\$)
1	251	1,006	131	36	3.6	4.0	4.6
2	503	2,012	263	73	3.6	4.0	4.6
3	754	3,018	394	109	3.6	4.0	4.6
4	1,006	6,036	788	145	5.4	7.0	3.0
5	1,257	7,544	985	182	5.4	7.0	3.0
6	1,509	9,053	1,181	218	5.4	7.0	3.0
7	1,760	14,083	1,627	254	6.4	8.0	2.6
8	2,012	16,095	1,859	291	6.4	8.0	2.6
9	2,263	18,107	2,091	327	6.4	8.0	2.6
10	2,515	20,118	2,324	363	6.4	8.0	2.6
11	2,766	22,130	2,556	400	6.4	8.0	2.6
12	3,018	24,142	2,788	436	6.4	8.0	2.6
13	3,269	26,154	3,021	472	6.4	8.0	2.6
14	3,521	28,166	3,253	509	6.4	8.0	2.6
15	3,772	30,178	3,486	545	6.4	8.0	2.6

type enter to continue?

9	2,263	18,107	2,091	327	6.4	8.0	2.6	3,293
10	2,515	20,118	2,324	363	6.4	8.0	2.6	3,659
11	2,766	22,130	2,556	400	6.4	8.0	2.6	4,025
12	3,018	24,142	2,788	436	6.4	8.0	2.6	4,391
13	3,269	26,154	3,021	472	6.4	8.0	2.6	4,757
14	3,521	28,166	3,253	509	6.4	8.0	2.6	5,123
15	3,772	30,178	3,486	545	6.4	8.0	2.6	5,489

type enter to continue?

16	4,024	32,189	3,718	581	6.4	8.0	2.6	5,855
17	4,275	34,201	3,950	618	6.4	8.0	2.6	6,221
18	4,527	36,213	4,183	654	6.4	8.0	2.6	6,587
19	4,778	38,225	4,415	690	6.4	8.0	2.6	6,953
20	5,030	40,237	4,647	727	6.4	8.0	2.6	7,318
21	5,281	42,249	4,880	763	6.4	8.0	2.6	7,684
22	5,533	44,260	5,112	799	6.4	8.0	2.6	8,050
23	5,784	46,272	5,344	836	6.4	8.0	2.6	8,416
24	6,036	48,284	5,577	872	6.4	8.0	2.6	8,782
25	6,287	50,296	5,809	908	6.4	8.0	2.6	9,148

* Annual O&M Cost is assumed to be 0% of system cost.

type enter to continue?

Figure 10. Feasibility Results for Typical Retrofit Applications.

***** Upper Limit Case *****

Shift (%)	Shifted (kW)	Storage Sz(ton-hr)	System 1st Cst(1000\$)	1st yr Svns(1000\$)	Payback Smpl Dset	SIR	Net Svng (1000\$)
1	251	1,006	263	36	7.2 9.0	2.3	336
2	503	2,012	525	73	7.2 9.0	2.3	671
3	754	3,018	788	109	7.2 9.0	2.3	1,007
4	1,006	6,036	1,575	145	10.8 14.0	1.5	818
5	1,257	7,544	1,969	182	10.8 14.0	1.5	1,022
6	1,509	9,053	2,363	218	10.8 14.0	1.5	1,227
7	1,760	14,083	3,253	254	12.8 17.0	1.3	935
8	2,012	16,095	3,718	291	12.8 17.0	1.3	1,068
9	2,263	18,107	4,183	327	12.8 17.0	1.3	1,202
10	2,515	20,118	4,647	363	12.8 17.0	1.3	1,336
11	2,766	22,130	5,112	400	12.8 17.0	1.3	1,469
12	3,018	24,142	5,577	436	12.8 17.0	1.3	1,603
13	3,269	26,154	6,042	472	12.8 17.0	1.3	1,736
14	3,521	28,166	6,506	509	12.8 17.0	1.3	1,870
15	3,772	30,178	6,971	545	12.8 17.0	1.3	2,003

type enter to continue?

9	2,263	18,107	4,183	327	12.8 17.0	1.3	1,202
10	2,515	20,118	4,647	363	12.8 17.0	1.3	1,336
11	2,766	22,130	5,112	400	12.8 17.0	1.3	1,469
12	3,018	24,142	5,577	436	12.8 17.0	1.3	1,603
13	3,269	26,154	6,042	472	12.8 17.0	1.3	1,736
14	3,521	28,166	6,506	509	12.8 17.0	1.3	1,870
15	3,772	30,178	6,971	545	12.8 17.0	1.3	2,003

type enter to continue?

16	4,024	32,189	7,436	581	12.8 17.0	1.3	2,137
17	4,275	34,201	7,900	618	12.8 17.0	1.3	2,270
18	4,527	36,213	8,365	654	12.8 17.0	1.3	2,404
19	4,778	38,225	8,830	690	12.8 17.0	1.3	2,538
20	5,030	40,237	9,295	727	12.8 17.0	1.3	2,671
21	5,281	42,249	9,759	763	12.8 17.0	1.3	2,805
22	5,533	44,260	10,224	799	12.8 17.0	1.3	2,938
23	5,784	46,272	10,689	836	12.8 17.0	1.3	3,072
24	6,036	48,284	11,154	872	12.8 17.0	1.3	3,205
25	6,287	50,296	11,618	908	12.8 17.0	1.3	3,339

* Annual O&M Cost is assumed to be 0% of system cost.

Do you want to print the output (yes/no)?

Figure 11. Feasibility Results for Upper Extreme Construction Cost Applications.

5 CONCLUSION

This study has developed STOFEAS, a menu-driven, screen-input PC program that helps estimate the economic feasibility of SCSs. STOFEAS offers the following advantages:

1. It will run on any IBM PC or compatible with at least 640K RAM..
2. The program requires minimum user input; most of the required economic parameters were built into STOFEAS as default input derived from current market conditions. However, users can easily incorporate more detailed local information into an input data file. The most critical user-supplied inputs are the installation's total peak electric demand and the demand charge rate schedule. These are available through the previous year's billing records, which are generally available from the installation DEH office or the local electric utility. In this way, STOFEAS can account for future variations in factors impacting the economic feasibility.
3. STOFEAS is accurate enough to perform an initial economic feasibility analysis of SCSs. STOFEAS outputs payback periods, differential system first costs, and rough sizes of SCSs suited to shift 1 to 25 percent of the total peak electric demand. This preliminary analysis can help determine the economic feasibility of an SCS under consideration.
4. STOFEAS performs a preliminary feasibility analysis for new construction, replacement, or retrofit with SCSs. It is important to note that the STOFEAS analysis must be followed by a separate, detailed design of the selected storage cooling system before actual construction of an SCS can begin.

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APPENDIX: South Carolina Electric & Gas Company Billing Policy, Rate 23

RATE 23

LARGE GENERAL SERVICE

AVAILABILITY

This rate is available to any customer using the Company's standard service for power and light requirements and having a contract demand of 1,000 KW or over. It is not available for resale service.

CHARACTER OF SERVICE

Alternating current, 60 hertz, three phase, metering at the delivery voltage which shall be standard to the Company's operation.

RATE PER MONTH

Demand Charge

First

1,000 KW of Billing Demand for \$10,040.00

Excess over

1,000 KW of Billing Demand @ \$9.34 per KW

The billing demand (to the nearest whole KW) shall be the greatest of: (1) the maximum integrated fifteen minute demand measured (which may be on a rolling time interval) during the current month; (2) eighty per cent (80%) of the highest demand occurring during the eleven preceding months; (3) the contract demand; or (4) 1,000 KW.

The customer shall maintain a power factor of as near unity as is practicable. If the power factor of the customer's installation falls below 85%, the Company will adjust the billing demand to a basis of 85% power factor.

Plus Energy Charge

All Kwhrs @

\$ 0.2153 per Kwhr

DISCOUNT

A discount of 5% per KW of billing demand will be allowed when the service is supplied at a delivery voltage of 46,000 volts or higher.

MINIMUM CHARGE

The monthly minimum charge is the demand charge as determined above. The Company may allow a buildup period not to exceed six months for new and expanding accounts during which time the contract demand and/or the minimum demand specified in the rate schedule may be waived. The Company shall not commit itself to a buildup period exceeding six months without prior approval of the Commission for the specific account involved.

ADJUSTMENT FOR FUEL COSTS

Fuel costs of \$ 0.1475 per Kwhr. are included in the energy charge and subject to adjustment by order of the Public Service Commission of South Carolina.

SALES AND FRANCHISE TAX

To the above will be added any applicable sales tax, franchise fee or business license tax which may be assessed by any state or local governmental body.

PAYMENT TERMS

All bills are net and payable when rendered.

SPECIAL PROVISIONS

The Company will furnish service in accordance with its standard specifications. Non-standard service will be furnished only when the customer pays the difference in costs between non standard service and standard service or pays to the Company its normal monthly facility charge based on such difference in costs.

TERM OF CONTRACT

The contract terms will depend on the conditions of service. No contract shall be written for a period of less than five (5) years. A separate contract shall be written for each meter at each location.

GENERAL TERMS AND CONDITIONS

The Company's General Terms and Conditions are incorporated by reference and are a part of this rate schedule.

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