COTTON GIN SIMULATION/MANAGEMENT

A Thesis

by

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ABSTRACT

Cotton Gin Simulation/Management

(May, 1985)

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A subroutine involving utility rate structures has been added to ESIM, an energy-based cotton gin sumulator (Williams, 1982). This addition provides an enhanced tool for energy management in cotton gins.

In 1970, gins were paying about $.02 per kilowatt-hour for electricity. The cost has risen to over $.10 per kilowatt-hour in 1985. With such a drastic increase, gins must be as efficient as possible to survive. ESIM, in its modified form, has a lot of potential to improve that efficiency.

The modified version will allow a gin operator to analyze various options to make better energy management decisions. Such analysis include comparison of utility rate schedules of different power companies, planning of a ginning season before it starts; thus avoiding an unnecessary demand charge, and a dollar savings from reducing energy comsumption.

ACKNOWLEDGEMENTS

I wish to thank Dr. Calvin B. Parnell Jr. for his help, encouragment, and patience. His guidance and experience exposed me to the world of research. Thank you.

I thank the people involved in the Undergraduate Fellows Program and Texas A & M University for the education and opportunities you have given me.

I dedicate this thesis to the 1984-85 Texas A & M University Mechanized Agriculture Club. You have given me more than I will ever be able to repay.

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INTRODUCTION

"Farm Recession Spurs Radical Restructuring of Agriculture in the U. S." was a headline in the Wall Street Journal on Friday, November 9, 1984. Agriculture in the United States is undoubtedly in the midst of a major reorganization process. Agricultural products have been overproduced and underpriced for many years. In past years, government subsidies provided the crutch. However, the government support is now being substantially trimmed as a means of reducing the federal deficit. As a result, agriculture as a whole must restructure.

Cotton gins are no exception to the overall reorganization. Cotton farms going bankrupt, changing ownership, and/or consolidating will have both temporary and long term effects on the volume of cotton supplied to gins. This factor, combined with the cost/price squeeze prevalent in agriculture, requires cotton gins to improve efficiency in every possible area.

To further complicate the situation, electrical energy costs for cotton gins have increased substantially in the past 14 years. In 1970, gins paid about $.02 per kilowatt-hour of electricity. Today, in 1985 gins are paying $.10 - .13 per kilowatt-hour. Utility rate schedules are separated into different divisions including demand charge, energy charge, fuel cost charge, and service availability charge. A substantial portion of the high current costs are attributed to the demand charge which is based on the peak consumption rate of electricity covering a 15 - minute period during that month.

The number of cotton gins in the United States has decreased from 18,400 in 1920 to 2200 in 1981 while overall production has remained relatively constant. More production per gin indicates that gins are becoming larger and requiring more and more power. Cotton gins consume large quantities of electricity on a seasonal basis. Gins normally have a connected load between 500 and 2500 horsepower but operate only 2 or 3 months per year. Huge amounts of electricity flow into the gin during this 2 to 3 month operating season. Power companies must have the generating capacity to meet those large seasonal demands. The gin is idle in the rest of the year so the large generating capacity of the power company must be used elsewhere or remain idle. Thus, one can better understand the power company's point of view in having a high demand charge (Pollard, 1980).

The Texas Cotton Ginners Association has its own point of view. The Association feels that cotton gins are being discriminated against through an excessive demand charge. Gin numbers have decreased from 135 gins in 1979 to 83 gins in 1984 in the area served by Texas Power and Light. While some new gins are larger, the overall energy requirements have decreased substantially. Utility companies have based their increases in the demand charge on the need to increase generating capacity. However, overall energy needs of the ginning industry has declined. Thus, cotton gins are subsidizing other utility customers who are using the same rate schedule. (Price, 1984).

A major controversy has arisen on the subject of electrical energy use in cotton gins. An effective energy management program would ease the tension as well as save both sides a lot of money. The primary objective of this project is the development of such an energy management program.

Many businesses have energy management programs which have proven successful in reducing energy costs. Foley's Department Stores, a division of Federated Department Stores Inc., is a prime example. According to Chuck Pearce, Group Manager of Operations, Foley's reduced energy costs by $450,000 in the first year after an energy management program was begun (Pearce, 1985). The primary area of attack in such a program is on the demand charge through energy load management. The main concept is to spread the loads out across time which reduces the peak demand and thus, the required generating capacity of the utility company.

Agriculture has been slow in adopting new technology such as energy load management. With the current reorganization of agriculture, the present seems to be the time to take advantage of what energy management has to offer. The nature of cotton gins and the ginning season make gins a prime candidate. To explain the "nature of cotton gins," I have enclosed an exerpt from "Public Statement on Docket #5640" by J. H. Tony Price, Executive Vice President of The Texas Cotton Ginners Association:

> "Cotton gins are a service business tied directly to the harvest of cotton. Cotton is not marketable until it is ginned. The scheduling of operations, from

start to close, is dictated by the harvest of cotton. The harvesting season, in turn, is dictated by weather conditions and the physiology of the cotton plant. Any delay in harvest after the cotton reaches maturity produces a deterioration in quality and results in lower revenue to the farmer-gin customers. Since the cotton reaches maturity all at the same time in a given general area, gins must operate at maximum capacity at the maximum time available to process the cotton into a baled product for the market."

Clearly, the "nature of cotton gins" relates to the relatively short, intense ginning season. Thus, one can better understand the large power requirements for 3 months of the year in relation to almost no power requirements the remaining 9 months.

OBJECTIVES

Cotton gins are caught in a cost price squeeze characteristic of many agricultural industries. A rapidly growing area on the cost side is energy. Electricity prices have increased from $.02 per kilowatt-hour in 1972 to $.10 - .13 per kilowatt-hour in 1985. To counter these rising energy costs, an energy management program has been developed. Our initial objectives included:

(1) To analyze utility rate schedules and their effect on cotton gins.

(2) Analyze potential savings by running an energy efficient gin.

(3) Develop an energy management program for cotton gins.

(4) Demonstrate that different utility rate structures have different effects on total energy costs.

REVIEW OF LITERATURE

ESIM

ESIM is an energy based cotton gin simulator developed by Gordon F. Williams and Dr. Calvin B. Parnell Jr. in 1982. The simulation was developed to accurately predict the per bale kilowatt-hour consumption of cotton gins over a typical ginning season. Energy consumption of the ginning equipment was modelled using equations relating to operational factors such as horsepower requirements, processing rate, and downtime.

In construction of ESIM, the ginning process was divided into four basic subsystems: seed cotton unloading, seed cotton cleaning, conveying, and lint cotton handling. These divisions allowed for energy consumption output by subsystem and easy program modification of changes in ginning equipment. Inputs for the model included an equipment schedule for a particular gin, operational parameters of rated capacity, seasonal hours, percentage arrivals that are modules, mean time between gin failures, the amount of seed cotton per bale of lint, the initial and final moisture contents for drying, and the cost per kilowatt-hour of electrical energy. Using these inputs, ESIM developed energy consumption equations and simulated a "typical" ginning season for that particular gin.

Outputs from ESIM included specific energy consumption data, detailed gin operational characteristics, and a statistical analysis on each. The specific energy use data was displayed by subsystem and total. The gin operation report detailed processing results, electrical power costs, seasonal and facility utilizations, and operational inputs. Statistical results for the simulation were summarized and histograms of selected parameters were produced.

Cotton Gin Subsystems

A brief discussion of the four primary subsystems in a cotton gin follows. This review serves as a reminder of how energy is used in a gin and better defines the subsystems in ESIM. The subsystem analysis was obtained from the Cotton Ginners Handbook issued in July 1977.

Seed Cotton Unloading

The seed cotton unloading subsystem has 3 primary functions.

(1) getting the seed cotton into the gin.

(2) removing green bolls

(3) cotton moisture control

Each function is briefly discussed in the following paragraphs.

(1) A pneumatic air suction system is the most common method of moving seed cotton into the gin. A large suction pipe pulls the seed cotton out of a loaded trailer and into the gin. A new, more energy efficient method is the module unloading system. The module system requires substantially less energy than the con-

ventional unloading system. The module system also provides a more consistent feeding rate and requires less labor. Ethridge and Branson (1977) illustrated by testing that processing efficiency could be increased by 15% with a module unloading system. However, in 1980-81, two-thirds of the seed cotton was still delivered by trailer (USDA, 1981). This represents a big target area for energy management by adoption of a module unloading system.

(2) Early season machine-stripped cotton often contains green immature bolls which cause ginning problems such as clogging of machinery. If the flow of green bolls becomes too bad, the gin must be shut down and the wet material removed by hand. The green bolls also transfer moisture to the dry mature cotton making it sticky and problematic. Most problems with the green bolls are encountered in the gin stand. Therefore, green boll traps are located to remove the green bolls as the seed cotton first enters the gin.

Most green boll traps are constructed on the principle that the green bolls have a much greater density than the dry open bolls. The air velocity is great enough in the air suction system to carry both the open dry and the green closed bolls into the gin. As the material moves through the conveying pipes, one of two methods can be used to remove the green bolls.

A. A chamber is set up in the pipe with a reduced air velocity. The lighter open bolls move on through the chamber while the heavier green bolls fall out.

B. Centrifugal force is another method. The heavier green bolls tend to move outward. Separation occurs by exposing the cotton to equal angular acceleration. The cotton is carried through a duct which abruptly changes direction. The lighter open bolls follow the air stream while the heavier bolls continue going straight and are expelled into a collection chamber.

A problem with these two systems is that a substantial amount of cotton is carried out with the green bolls. Therefore, a reclaiming airstream is needed to move the desirable open bolls back into the mainstream (Laird, 1977).

Green boll removal requires energy as does the other areas of a gin. However, it is necessary primarily in the stripper harvested areas as opposed to picker harvested. The different harvesting techniques will be discussed below.

(3) The moisture content of cotton fibers must be controlled for two primary reasons: smooth operation of processing machinery and to obtain maximum fiber quality from the cotton.

The optimal fiber moisture content of 6.5% to 8% allows smooth gin operation, profitable lint grades, and minimal fiber breakage. Cotton ginned at high moisture levels will tend to not separate into single locks and will form wads which may clog ginning machinery. Cotton at low moisture levels stops the ginning process by clinging to machinery because of static electricity.

Before lint cleaners became popular, the seed cotton cleaning equipment was used to get the cotton as clean as possible.

Since dry cotton is easier to clean, overdrying became a problem. Fiber strength is directly proportional to fiber moisture content. As overdrying occurs, fiber length is endangered because of breakage.

Cotton is a hygroscopic material. Its moisture content varies directly with relative humidity. Cotton may be harvested at a moisture content of over 12% in high humidity conditions. Low humidity harvesting may produce cotton at less than 4% moisture. Therefore, to gin at a predetermined moisture level (6.5% to 8%), the gin must be able to add as well as remove moisture (Griffin, 1977).

The seed cotton unloading subsystem has an average connected horsepower of 3.4% of the total gin horsepower (Williams, 1982).

Seed Cotton Cleaning and Extracting

The need for seed cotton cleaning equipment has expanded over the years because of rougher harvesting methods. Hand picking methods evolved into machine picking which was somewhat rougher. Next came the stripper harvester which is used to harvest 90% of the cotton in Texas (Parnell, 1985). The stripper harvester has an extremely high level of foreign material compared to other harvesting methods. To illustrate this high level of foreign material, McArthur (1980) showed that it takes 2200 pounds of stripped cotton to make a 480 pound bale of line. In comparison, it takes 1500 pounds of picked cotton for the same 480 pound bale. Because of the excess foreign material, gins processing stripper harvested cotton have more seed cotton cleaning equipment than gins processing machine picked cotton (Parnell, Cotton Ginning Systems).

Cleaners consist of a series of beater cylinders and concave grid screens. The cylinders convey the cotton through the machine, scrubbing the cotton over the concave surfaces. This action allows the smaller trash particles such as broken leaves and dirt to fall out.

Extractors use a toothed cylinder which seizes the cotton and slings the trash off by centrifugal force. Extractors remove burrs and larger pieces of trash.

Trash removal improves gin stand performance and lint grades. Wear on the gin stand is reduced, and gin stand efficiency is improved by presenting clean cotton to it in small uniform units. Lint grade can also be improved by good cleaning. An economical limit exists as, at a point, benefits are offset by damage to the lint, seed, and bale weight loss.

Cotton sometimes arrives at the gin cleaner than at other times. Bypass valves can be adjusted to allow the cleaner cotton to skip part of the cleaning and extracting processes. Trash removal should be restricted to what is necessary to produce the most economical grade and bale weight combination. Also, bypassing some steps saves time, energy, and wear.

The seed cotton cleaning and extracting subsystem has an average connected horsepower of 9.6% of the total gin horsepower.

Conveying

Pneumatic conveying acts as the primary transportation system of seed cotton and gin trash through a gin plant (Williams, 1982). Pneumatic conveying systems are only 50 percent as efficient as comparable mechanical conveying systems (Baker and Stedronsky, 1968). Consequently the conveying system also has a larger connected horsepower than any other subsystem. Power surveys of cotton gins have shown that 50 to 60 percent of the total power used in the ginning process is consumed by the conveying fans (USDA, 1977).

Since so much power is consumed by the conveying system, it is a primary target for energy management. Downtime has a big effect on the energy consumption of the conveying subsystem. Conveying fans may consume up to 125% as much energy when running empty than when they have cotton flowing through them. Therefore, shutting the system down during a breakdown would substantially decrease power consumption (Williams, 1982).

Lint Cotton Handling

This subsystem includes the processes of ginning, lint cleaning, and packaging.

Ginning, the separation of fibers from the seeds in the gin stand, is the primary processing operation of a cotton gin. The limited factor for overall gin capacity is normally the gin stand. Modern gins may employ several gin stands to achieve the

the desired capacity.

The lint cleaning system is the final cleaning step before packaging. This system is designed for the purpose of removing small trash particles still in the cotton lint after the lint/seed separation.

Packaging is the final process at a gin. Equipment includes a lint condenser, tramper, and bale press. The final result is a 480 pound bale of cotton.

The lint cotton handling subsystem has an average connected horsepower of 30.5% of the total gin horsepower.

METHODS

ESIM, an energy based cotton gin simular, was used in developing an energy management program for cotton gins. The simulator was developed at Texas A & M University as a master's thesis by Gordon Frederick Williams under the direction of Dr. Calvin B. Parnell Jr. in 1982. It is a computer simulation used to accurately predict the per bale kilowatt-hour consumption of cotton gins.

The Public Utility Commission in Austin, Texas supplied a number of utility rate schedules. Analysis of these schedules has led to the development of a subroutine which has been added to ESIM.

The new subroutine

(1) considers the structure of rate schedules

(2) breaks the structure down into component costs such as demand charge, energy charge, etc.

(3) consists of the rate structures of two separate utility companies.

The structure of utility rate schedules becomes rather complicated. A simplified version of a rate schedule is illustrated in the flowchart on the following page. The flowchart also shows the basic structure of the subroutine added to ESIM.

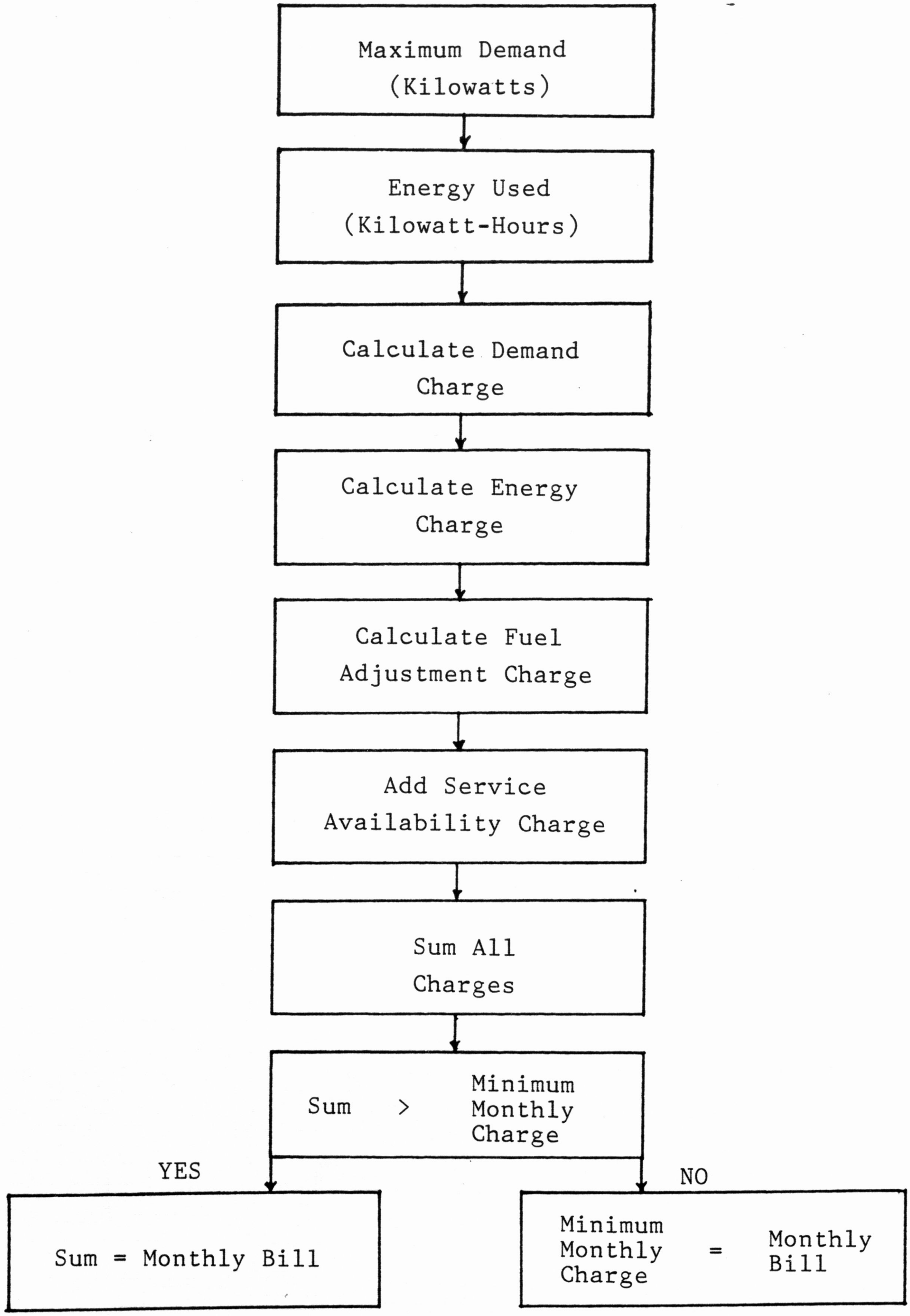


Figure 1. Flowchart of Utility Rate Schedule

Utility rate structures normally contain several component charges. Some common charges include the demand charge, energy charge, and service availability charge.

The demand charge is based on a kilowatt load established by a customer during the 15-minute period of maximum energy use during the month. The demand charge accounts for the fact that the utility company must have the generating capacity to meet this maximum demand no matter how much energy is used the rest of the month.

The energy charge is calculated on the basis of how much energy in kilowatt-hours is consumed over a specified time period such as a month. This charge is not as susceptible to energy management as the demand charge. However, one can still reduce the overall energy consumption by turning off unnecessary loads when possible.

The service availability charge is relatively inflexible. A monthly fee is charged to remain connected to the power lines. This fee remains constant throughout the year.

Utility rate schedules of two different utility companies are incorporated into the subroutine. The rate structure is different for each utility company. This illustrates the varying effects of rate structures on a given energy consumption situation. Thus, one can analyze various rate structures and see which is the most economical for a given situation.

In developing and testing the subroutine, data was used from the "Summary of 1983 Southern Division - All Electric Gin

Report." A typical gin season has 906 hours of actual processing time (Shaw, 1978). Gin efficiency was assumed to be 85 percent of the rated hourly capacity of the gin. Actual hours processing multiplied by the average hourly processing rate yielded the facility capacity estimate for a gin (Ethridge and Branson, 1977). Seasonal efficiency was found by the ratio of actual bales ginned in a season to computed gin capacity for a season. A seasonal efficiency of 100 percent is possible if gins operate longer than the "typical" 906 hours (Williams, 1982).

RESULTS AND DISCUSSION

In this section, some outputs of the modified ESIM will be discussed and analyzed. Four areas are considered. They include

(1) Management Potential

(2) Utility Rate Analysis

(3) Demand Charge Management

(4) Effect of Different Utility Companies

Management Potential

Using the calculation techniques discussed in the METHODS section, potential savings by good energy management was analyzed. It was assumed that an efficient gin consumed 60 kilowatt-hours per bale. The actual killowatt-hours consumed minus the "ideal" consumption yielded potential kilowatt-hour savings per bale. This potential energy savings was then multiplied by the actual bales ginned in a season to get the total potential energy savings in kilowatt-hours. The total was then multiplied by $.10 to get potential dollar savings by good energy management.

Table 1 illustrates the potential savings for small, medium, and large gins. Saving up to $20,000 per ginning season clearly illustrates the benefits of good energy management.

MANAGEMENT POTENTIAL
ASSUME 60 KWH/BALE IS EFFICIENT
SOURCE: 1983 GIN REPORT

BALES GINNED	CONNECTED HP	KWH/ SEASON	KWH/ BALE	KWH SAVINGS	POTENTIAL $ SAVINGS	$ SAVINGS PER BALE
3900	500	334,000	85	99,000	9,900	2.50
4200	1000	374,000	87	117,000	11,700	2.70
6800	2000	621,000	90	207,000	20,700	3.00

Table 1.

Utility Rate Analysis

Rated capacity is the maximum capacity of a gin in bales per hour. The modified ESIM allows the user to change the capacity rating (maximum bales per hour) and the percent of rated capacity (actual bales per hour). A distribution of related power charges is then produced as shown in Table 2. The same analysis on a percentage basis is shown in Table 3.

In this particular analysis, the fuel adjustment charge dominates with demand and energy costs following. However, from an energy management standpoint, the demand charge is the main focus as discussed in the next section.

UTILITY RATE ANALYSIS BY $
20 BPH GIN

% OF RATED CAPACITY	DEMAND	ENERGY	FUEL ADJUSTMENT
25	$12,000	$ 5,300	$17,100
50	24,300	11,000	35,100
75	24,500	16,700	53,400

Table 2.

UTILITY RATE ANALYSIS BY %
20 BPH GIN

% OF RATED CAPACITY	DEMAND %	ENERGY %	FUEL ADJUSTMENT
25	35	16	49
50	35	16	49
75	26	18	56

Table 3.

Demand Charge Management

The demand charge represents the primary focus of an energy management program. First, by spreading the energy loads across time, the peak demand will be at a lower point. This is illustrated by Figure 2. Curve 1 represents a typical demand curve while Curve 2 illustrates an ideal, modified demand curve. Assuming Point A to be the highest demand in the month for Curve 1, the demand charge would be calculated at this point. On the modified Curve 2, demand would be 0 calculated at Point B which is about 700 kilowatt of demand lower than Point A. At $7.00 per kilowatt of demand, this represents an ultimate potential savings of $4900 for this particular month.

A second method of decreasing the demand charge is illustrated by Figure 3. In the top graph, energy consumption is shown as constant through the first two months of the ginning season. Consumption drops off sharply about one week into the third month representing the end of the ginning season.

The bottom graph shows a cost per kilowatt-hour of $.086 through the first two months. However, due to the effects of the demand charge being calculated at Point C in the top graph, the cost per kilowatt hour for the third month rose to $.59.

By analyzing historical records, evaluating the present crop, and using ESIM, the cotton gin operator can predict how many bales of cotton he will gin in the upcoming season. Thus, in the example discussed above, the expensive energy costs of the third month could have been avoided by consolidating all ginning into the first two months. Consolidation would slightly increase the energy costs of the first two months but would totally omit the extremely expensive third month. Such a move may require actions like double work shifts, equipment modification, etc. ESIM allows the gin operator to analyze the situation and make the most economical decision.

DEMAND CURVE MODIFICATION

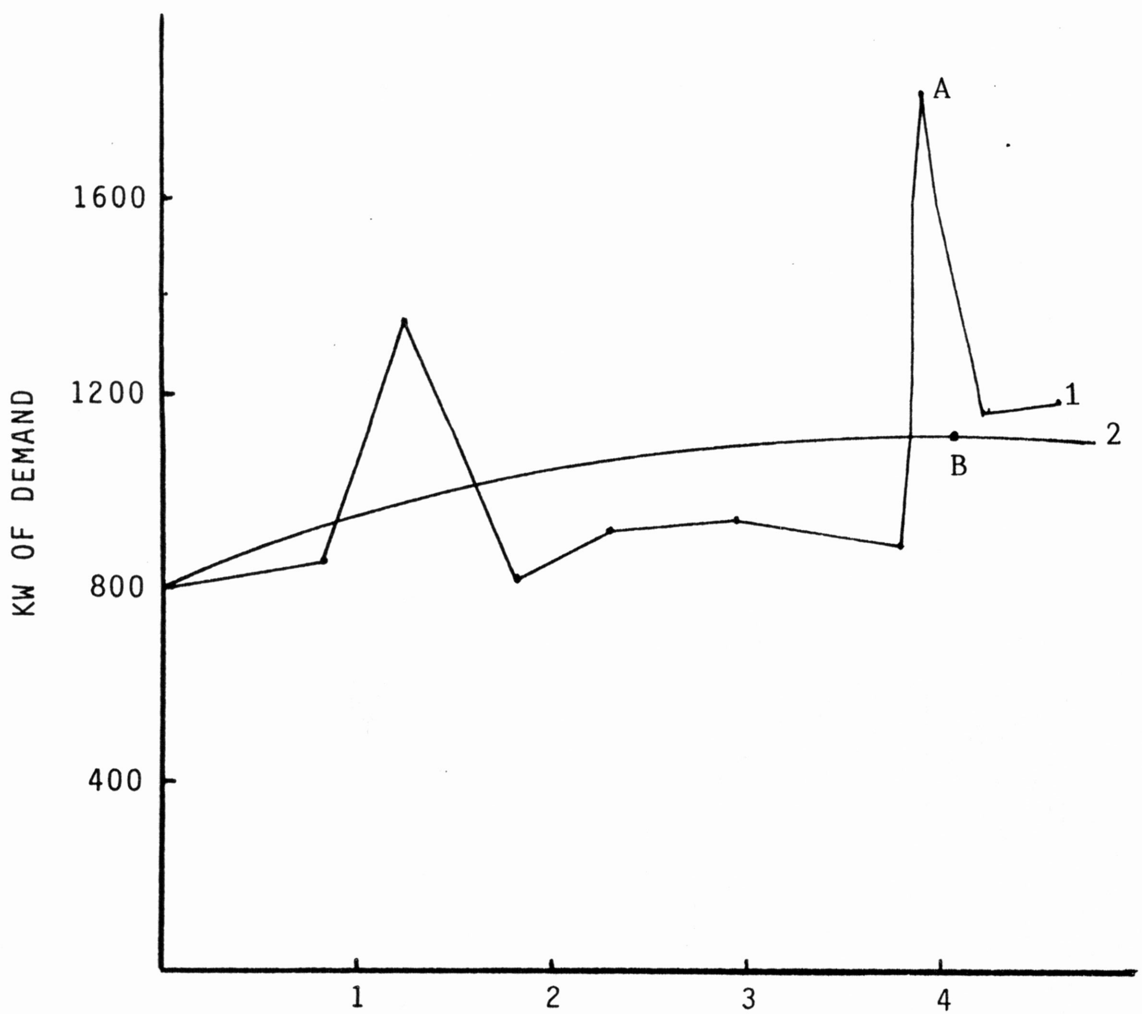
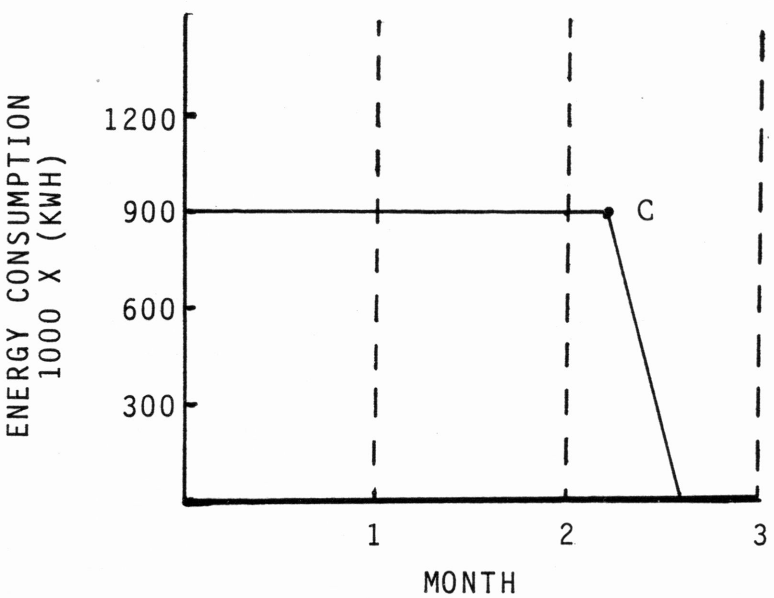


Figure 2.

MONTHLY DEMAND CURVE EFFECT



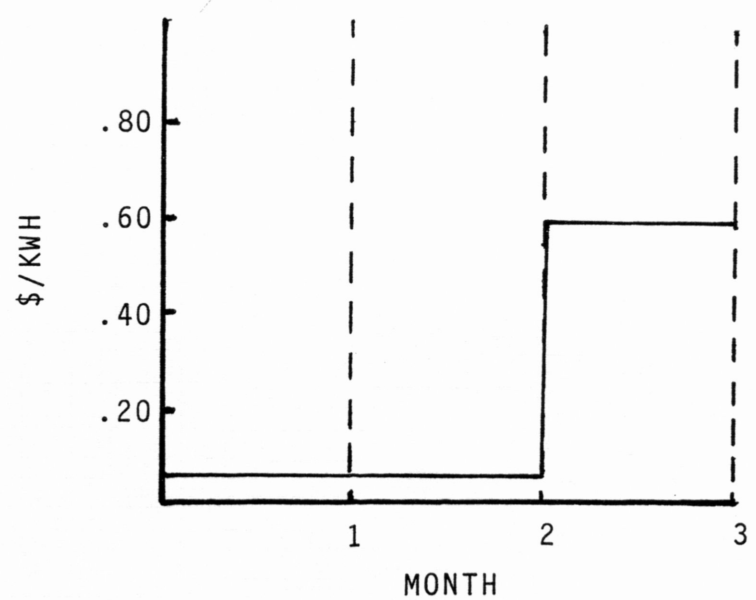


Figure 3.

Effect of Different Utility Companies

The new subroutine consists of rate structures from two different power companies serving cotton gins. Table 4, generated by the modified ESIM, illustrates how substantial the difference is between utility rate schedules. Everything was exactly the same for the two power companies except their rate schedule. The difference in total cost for the given season ranged from $25,000 at 50 percent of rated capacity to $40,000 at 100 percent of rated capacity. Thus, one can see how different rate schedules produce different energy costs in a given situation.

TOTAL ENERGY CHARGE/SEASON
POWER COMPANY 1 vs. POWER COMPANY 2
MAXIMUM GIN CAPACITY = 20 BPH

% OF RATED CAPACITY	POWER COMPANY 1	POWER COMPANY 2
50	$ 95,000	$ 70,000
75	123,000	95,000
100	167,000	127,000

Table 4.

SUMMARY AND CONCLUSIONS

Summary

An energy management program for cotton gins has been developed by adding a subroutine to ESIM, an energy based cotton gin simulator. The subroutine incorporates the effects of utility rate structures on energy costs for gins. The total cost is broken down into divisions such as demand charge, energy charge, and fuel adjustment charge to allow better analysis.

The new version of ESIM will allow a gin operator to consider various options and make energy management decisions accordingly. He will be able to plan the ginning season out and make the necessary preparations before the first cotton has even matured.

Conclusions

- A gin can save up to $3 per bale with good energy management. At 10,000 bales per season, the gin can save $30,000 per season in energy costs.

- ESIM is now running on a microcomputer (TI Professional). Thus, a gin operator can afford the necessary computer hardware.

- Different utility rate schedules produce different costs in a given situation.

- The demand charge portion of the rate schedule is the primary focus of energy management.

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