# IEEE 1977 RUBBER AND PLASTICS INDUSTRIES

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*Not available for publication

# TIME-OF-DAY ELECTRIC RATE DESIGN IN CALIFORNIA

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During recent years, public utility commissions in the United States have become especially interested in applying marginal cost pricing principles to electric utility rate structures. Generic hearings on electricity pricing have been held in a number of states including New York and California. Several states have gone so far as to either strongly suggest or require that electric utilities submit "peak-load" - or, more generally, variable load - price structures based on marginalist principles. Considerable controversy has emerged in many jurisdictions regarding exactly how the basic theory of marginal cost pricing should be applied to construct time-of-day and seasonal rates in the special case of electricity, given the available information on demand, production costs, and taking into consideration the costs of metering and administering a complex pricing system.

## California is Unique in Rate Design

"We have concluded then, to make conservation in the sense of efficient allocation of electricity the keystone of the rate structure." (California Public Utilities Commission, Decision No. 85559, March 16, 1976)

The basic form of electric rate tariffs has remained unchanged for nearly three quarters of a century. During this period, costs generally declined as electric systems grew and new customers were added. The era of economies of scale justified declining block rate structures and a "cheaper by the dozen" approach to rate design.

The concept of alternative rate designs to promote efficient resource allocation is not new. The intensity of the onslaught of rate reform is. The environmental movement linked with the increasing scarcity and price of fossil fuel has accelerated the cost pendulum in the direction of utilities becoming increasing cost industries. The paramount need for efficient use of fossil fuel has become a focal point for reviewing electric rate design.

In California, the state legislature has been a leading catalyst in orienting the State Public Utilities Commission into considering monumental rate design changes. In August of 1974, the legislature took note of criticism of electric rate structures and urged the California Public Utilities Commission to make a thorough investigation of proposed alternatives to electric rate structures existing at the time. The intent of the alternative designs was to attempt to discourage rather than encourage increased consumption of electricity.

During much of 1975 and culminating in the order cited above, a substantial body of testimony dealing with the social, political and economic ramifications of electric rate design changes was gathered. This generic rate proceeding parallelled additional legislative efforts to codify a "lifeline" gas and electric rate for low use electric and natural gas customers. This "lifeline" legislation was successful in 1975 and the CPUC was required by law to determine basic minimum allowances of natural gas and electricity for essential residential appliances. These allowances were determined on an interim basis during 1976 and have been implemented for residential gas and electric consumption.

## Decision No. 85559

The conclusion of the California electric rate proceeding occurred in March of 1976 with the issuance of CPUC Decision No. 85559. This decision was unique in character. Contrary to what many had hoped, it did not call for a sweeping revision of traditional cost considerations in electric ratemaking. It did order the widespread implementation of time-of-day electric rates on a staggered basis through all customer groups down to the 500 kilowatt level. To give you an indication of the typical type of 500 kilowatt customer, the larger local department stores all tend to cluster around this level of kilowatt demand.

On the subject of marginal cost pricing, little was said about translation into time-of-day rates. California ratemakers were ordered to develop time-of-day rates under a hybrid costing approach of marginal and average costs. No clear cut delineation of priorities was specified nor was an appropriate methodology for determining overall marginal costs included in the Decision.

The crux of the Decision was energy conservation and rate designs which encourage energy conservation. The California Commission appears to be "burning a candle at both ends" in its approach to implementing conservation-oriented rate designs. With prescribed lifeline rates for small users of electricity and mandated time-of-day rates for the largest electric customers at the other extreme, the major uncertainty that remains to be resolved is what happens when the flames meet.

## PGandE Schedule No. A-17

In December of 1975 as an outgrowth of Pacific Gas and Electric Company's 1974 test year general rate case and with the concern and interest of a diversity of public interest groups and the CPUC staff, PGandE filed its first of the new wave of time-of-day rates for consideration and adoption by the California Public Utilities Commission. The design of this rate was a product of a series of public workshops intended to serve as a vehicle for thrashing out alternative forms for a time-of-day electric rate. Schedule No. A-17 is described on the following page.

PACIFIC GAS AND ELECTRIC COMPANY

Schedule No. A-17

General Service - Time Metered

| RATES | Per Meter Per Month | |
|---|---|---|
| Customer Charge .............................. | $715 | |
| $ Per Maximum Kw Demand in Each Time Interval: | Period A | Period B |
| On Peak ............................ | $3.45 | $2.30 |
| Plus Partial Peak .............. | 0.28 | 0.28 |
| Plus Off Peak ..................... | - | - |
| $ Per Kwhr in Each Time Interval: | | |
| On Peak ............................ | .01218 | .01218 |
| Plus Partial Peak .............. | .01018 | .01018 |
| Plus Off Peak ..................... | .00818 | .00818 |

Time Periods:

Period A would be applicable to meter readings from May 1 to September 30 inclusive for the following hours:

| | | |
|---|---|---|
| On Peak | 12:30 p.m. to 6:30 p.m. | Monday through Friday, except holidays. |
| Partial Peak | 8:30 a.m. to 12:30 p.m.<br>6:30 p.m. to 10:30 p.m. | Monday through Friday, except holidays. |
| | 8:30 a.m. to 10:30 p.m. | Saturday, except holidays. |
| Off Peak | 10:30 p.m. to 8:30 a.m. | Monday through Saturday, except holidays. |
| | All day Sunday and holidays | |

Period B would be applicable to meter readings from October 1 to April 30 inclusive for the following hours:

| | | |
|---|---|---|
| On Peak | 4:30 p.m. to 8:30 p.m. | Monday through Friday, except holidays. |
| Partial Peak | 8:30 p.m. to 4:30 p.m.<br>8:30 p.m. to 10:30 p.m. | Monday through Friday, except holidays. |
| | 8:30 a.m. to 10:30 p.m. | Saturday, except holidays. |
| Off Peak | 10:30 p.m. to 8:30 a.m. | Monday through Saturday, except holidays. |
| | All day Sunday and holidays | |

The rate form is a three time period rate form which varies seasonally. It is more precisely labeled a "time-of-use" tariff. The weekday daily periods are outlined for the Pacific Gas and Electric Company rate in Figures 1 and 2 following. The general form of PGandE's Schedule No. A-17 is both very new and very old. For a number of years many utilities including PGandE have had tariff provisions which ignored high demands created in an off-peak time period. Special metering was available for customers which had the potential to control the timing of their loads. This concept is indicative of the early involvement of utilities in the planning strategy which has only more recently been glamorized under the label "load management".

The new element which PGandE has introduced is the introduction of a partial peak time period. The partial peak period is defined as that period in the system daily load cycle where there is a lesser probability of the system peak occurring. This third time period was created to send "price signals" to customers in order to indicate to consumers that costs of energy and demand by time-of-day can vary, and that there would be a benefit to the utility if the customer shifted a portion or all of his load away from on-peak hours. The best way to accomplish this goal is through a direct price incentive built into the rates which evokes at minimum a tacit recognition of the cost-of-service by time periods. The time-of-day rates which flow from these considerations can give appropriate signals to consumers in guiding the timing of their consumption and also offer tremendous opportunities for customer savings on their electric bill.

On-peak, Off-peak, and Partial peak

Schedule No. A-17 defines 13% of the annual hours as on-peak hours. The Schedule collects a great portion of its revenues through its on-peak demand charge. If a customer can manage his load in such a manner as to minimize the level of his operations during only 13% of all annual hours, this customer could maximize the pricing incentives in the Schedule.

There are a variety of popularly debated techniques for calculating on-peak hours for a utility system. These methodologies run the spectrum from technically sophisticated loss-of-load probabilities to a visual scanning of typical monthly load shapes. There is no commonly accepted method for determining on-peak hours. At Pacific Gas and Electric Company, the abundance of hydroelectric capacity is tantamount to stored electricity. PGandE is able to dispatch hydroelectric plants as needed to supplement thermal generation during peaking periods. This obviates the need for detailed precision in specifying on-peak hours. Instead, on-peak hours have been selected to optimize the ability of customers to shift from them.

The winter rating period running from October 1 to April 30 defines the on-peak period as the 4-hour period on weekdays between 4:30 pm and 8:30 pm. These are the fringe hours of a typical 8:00 am to 5:00 pm workday. A mere half-hour shift in load can assist a customer in obtaining a substantial savings in his electric bill.

The summer on-peak rating period is somewhat longer. It also is for weekdays only and is six hours in duration from 12:30 pm to 6:30 pm. PGandE's summer peak is much broader than PGandE's winter peak as is evidenced by Figures No. 1 and 2. The summer period is in effect from May 1 through September 30.

PGandE's off-peak period is ten hours in length on weekdays and is in effect all day on Sundays and holi-

# PACIFIC GAS AND ELECTRIC COMPANY

## SUMMER RATE PERIODS

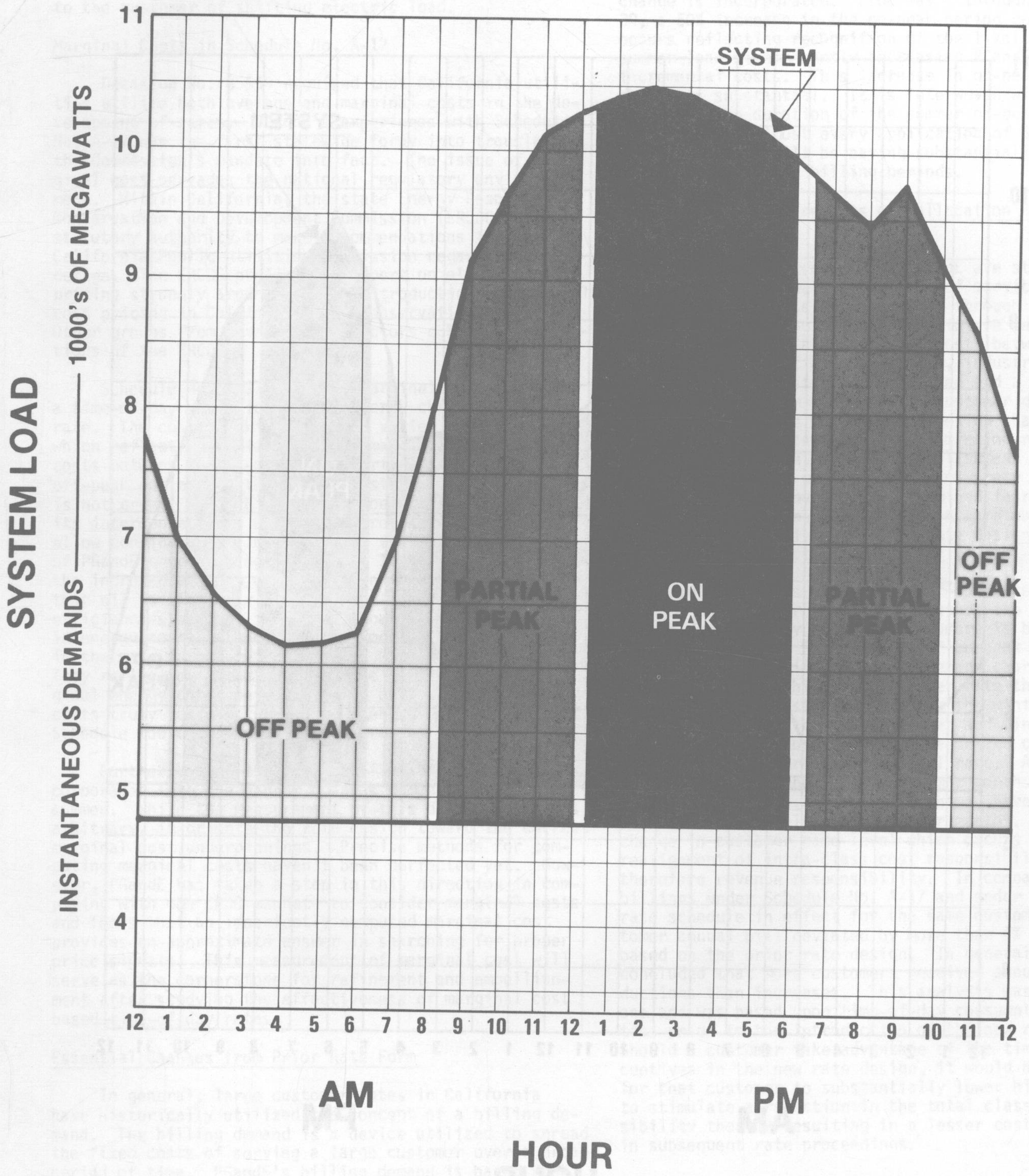
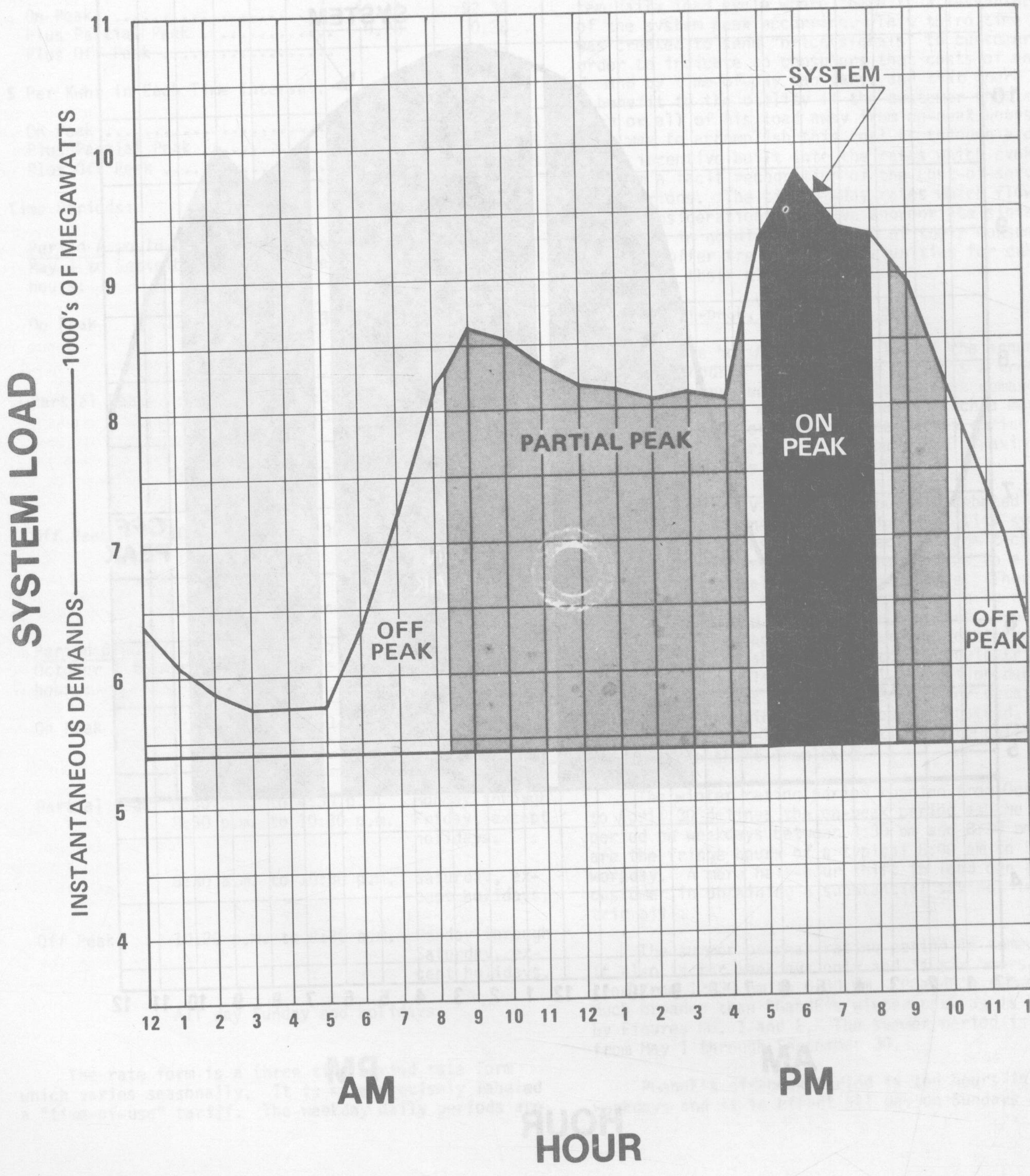





FIGURE 1

# PACIFIC GAS AND ELECTRIC COMPANY

## WINTER RATE PERIODS






FIGURE

days. It runs from 10:30 pm at night until 8:30 am the next morning. This provides substantial opportunity for lengthening third shift operations where practical and for testing and evaluating equipment late into the morning.

PGandE's rating periods were selected to offer incentives. Longer peaking periods would eliminate any potential for shifting load. The former schedule's on-peak period is telescoped into a much briefer on-peak. This specifies for customers the costs created by customer demands on or near an on-peak time period, thereby publicizing in tariff form the opportunity cost to the customer of shifting electric load.

Marginal Costs in Schedule No. A-17

Decision No. 85559 required that California utilities utilize both average and marginal costs in the development of rates. PGandE's experience with Schedule No. A-17 was the first statewide foray into translating the Commission's mandate into fact. The issue of marginal cost pervades the national regulatory environment. Within California, the state Energy Resources Conservation and Development Commission (ERCDC) has statutory authority to make recommendations to the California Public Utilities Commission regarding rate design. The ERCDC preliminary report on electricity pricing strongly argues for the introduction of marginal cost pricing in California as a conservation tool. Other groups from a variety of sectors echo the inclinations of the ERCDC.

Schedule No. A-17 utilizes marginal costs through a time-of-day variation in the energy charge within the rate. The cost per kilowatt hour varies by an amount which reflects the difference in marginal plant running costs between the on-peak, the partial peak and the off-peak periods on the PGandE system. This variation is not great. PGandE's vast hydroelectric network and its interconnections with the hydro-based northwest allow considerable flexibility in the routine dispatch of PGandE's generating capacity. In all time periods, the incremental form of generation is oil. The cost of that oil is virtually constant by time-of-day. Plant efficiencies account for the nominal 2 mill difference in energy costs between time periods. The energy costs in the rate do not reflect actual marginal energy costs. They reflect only the level of the difference in marginal energy costs between rating periods. If the costs truly represented marginal energy costs, the Schedule would collect excessive revenues.

Further use of the concept of marginal cost is incorporated into the higher on-peak demand charge in the summer. While the measurement of this demand charge is arbitrary, it orients the rate design toward the correct marginal cost underpinnings. Precise methods for computing marginal costs haven't been perfected yet. However, PGandE has taken a step in this direction in complying with the CPUC mandate to consider marginal costs and feels that an imperfectly computed marginal cost provides an approximate answer in searching for proper price signals. This measurement of marginal cost will serve as the cornerstone for refinement and embellishment after studying the effectiveness of marginal cost based time-of-day rates.

Essential Changes from Prior Rate Form

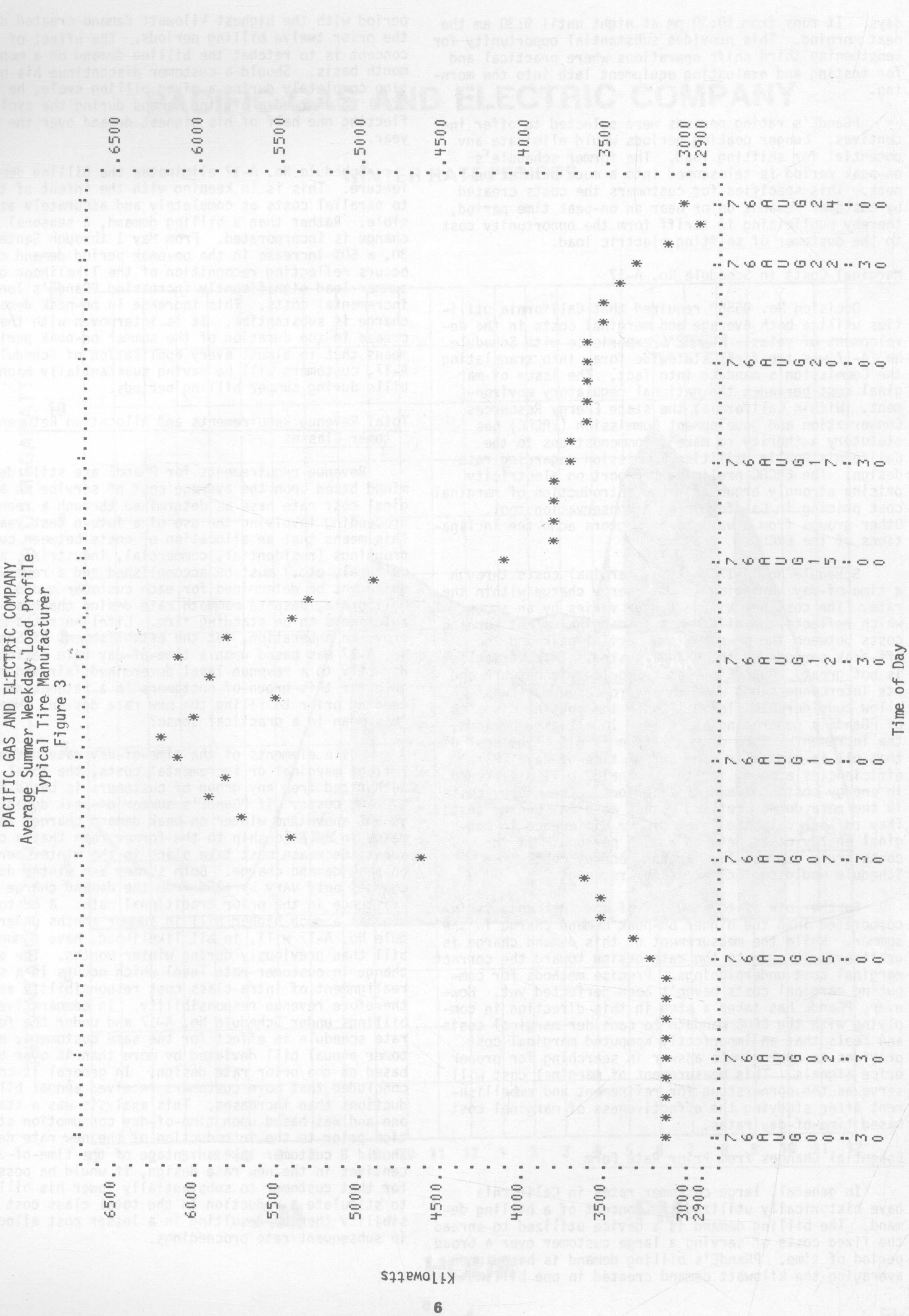
In general, large customer rates in California have historically utilized the concept of a billing demand. The billing demand is a device utilized to spread the fixed costs of serving a large customer over a broad period of time. PGandE's billing demand is based upon averaging the kilowatt demand created in one billing period with the highest kilowatt demand created during the prior twelve billing periods. The effect of this concept is to ratchet the billing demand on a month-by-month basis. Should a customer discontinue his operation completely during a given billing cycle, he would still be charged a billing demand during the cycle reflecting one half of his highest demand over the past year.

Schedule No. A-17 eliminates the billing demand feature. This is in keeping with the intent of the rate to parallel costs as completely and accurately as possible. Rather than a billing demand, a seasonal rate change is incorporated. From May 1 through September 30, a 50% increase in the on-peak period demand charge occurs reflecting recognition of the likelihood of summer load significantly increasing PGandE's long run incremental costs. This increase in on-peak demand charge is substantial. It is interwoven with the increase in the duration of the summer on-peak period and means that in almost every application of Schedule No. A-17, customers will be paying substantially higher bills during summer billing periods.

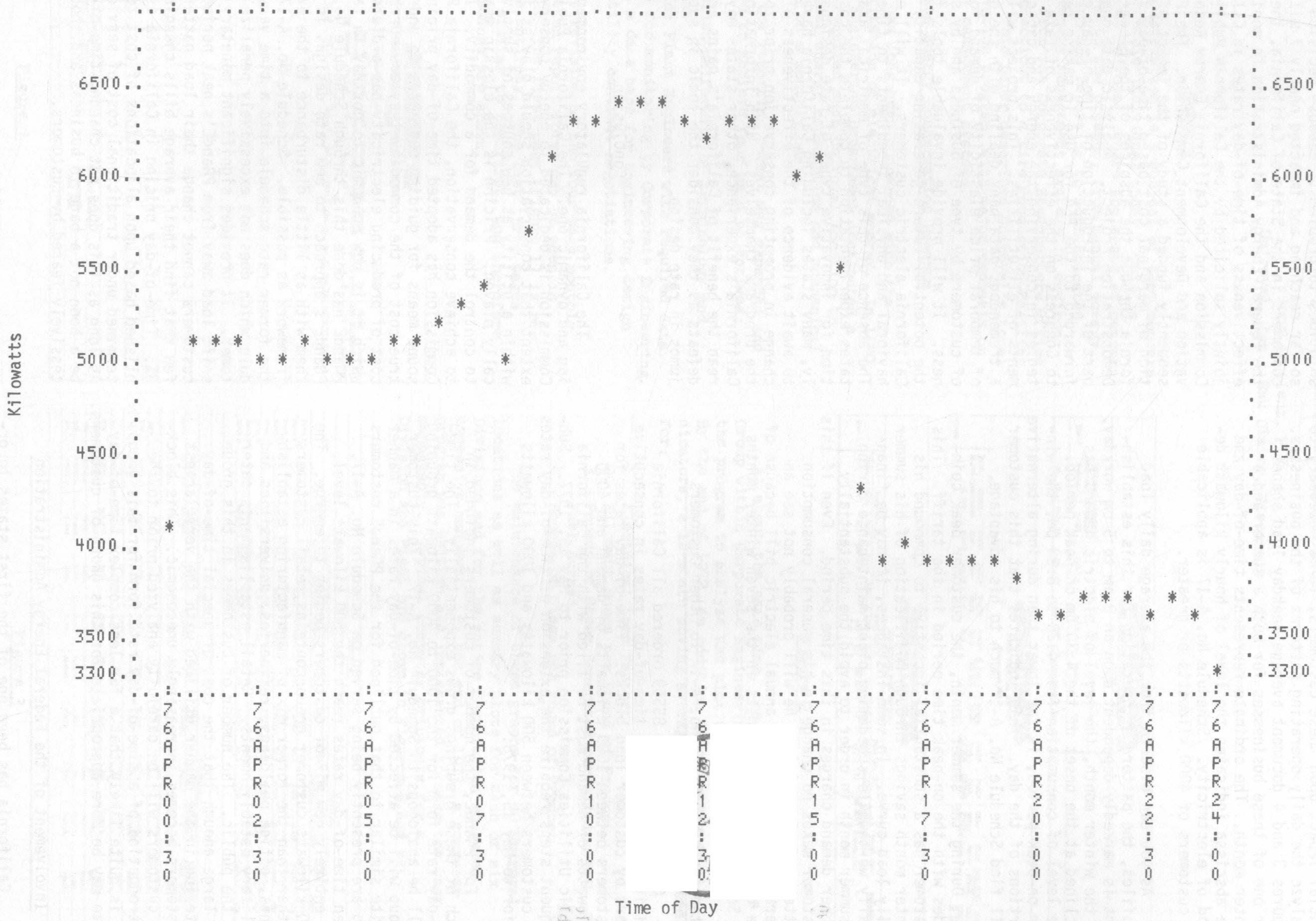
Total Revenue Requirements and Allocation Between Customer Classes

Revenue requirements for PGandE are still determined based upon the average cost of service on an original cost rate base as determined through a regulatory proceeding involving the use of a future test year. This means that an allocation of costs between customer groupings (residential, commercial, industrial, agricultural, etc.) must be accomplished and a revenue requirement be determined for each customer group. In California, despite mammoth rate design changes, this rule seems to be standing firm. Lifeline rates may prove an abberation, yet the establishment of Schedule No. A-17 was based upon a time-of-day rate design linked directly to a revenue level determined fair and reasonable for this group of customers in a ratemaking proceeding prior to filing the new rate design. What does this mean in a practical sense?

While elements of the time-of-day rate design may reflect marginal or incremental costs, the total revenue authorized from any group of customers is based upon average costs. If PGandE's summer on-peak demand charge is 50% above the winter on-peak demand charge, this means in relationship to the former rate that a commensurate decrease must take place in the winter period on-peak demand charge. Both summer and winter demand charges only vary by $\pm$25% from the demand charge in existence in the prior traditional rate. A customer who has a much higher bill in summer months under Schedule No. A-17 will, in all likelihood, have a much lower bill than previously during winter months. The only change in customer rate level which occurs is a slight realignment of intra-class cost responsibility and therefore revenue responsibility. In comparative annual billings under Schedule No. A-17 and under the former rate schedule in effect for the same customers, no customer annual bill deviated by more than 4% over billings based on the prior rate design. In general it could be concluded that more customers received annual bill reductions than increases. This analysis was a static one and was based upon time-of-day consumption statistics prior to the introduction of the new rate design. Should a customer take advantage of the time-of-day incentives in the new rate design, it would be possible for that customer to substantially lower his bill and to stimulate a reduction in the total class cost responsibility thereby resulting in a lesser cost allocation in subsequent rate proceedings.


PACIFIC GAS AND ELECTRIC COMPANY
Average Summer Weekday Load Profile
Typical Tire Manufacturer
Figure 3
Kilowatts
2900
3000
3500
4000
4500
5000
5500
6000
6500
Time of Day

PACIFIC GAS AND ELECTRIC COMPANY
Average Winter Weekday Load Profile
Typical Tire Manufacturer
Figure 4



## Application of Schedule No. A-17 to the Rubber Industry

Within the PGandE service territory, there are at least two major rubber industry operations. The plant operations at these locales will be served under PGandE's Schedule No. A-17. In order to view the potential impact upon these customers, it is necessary to analyze the daily operating patterns of the businesses. Figures 3 and 4 document average weekday load shapes for one of these businesses for both a summer and a winter month. The ordinate represents time-of-day and the abscissa indicates the level of hourly kilowatt demand of electricity. Schedule No. A-17 is applicable to customers of 4000 kilowatts or greater.

As you can discern from the average daily load profiles, the pattern of operation for this establishment is markedly dependent upon an 8 am to 5 pm workday. In the winter month, the level of electric demand has declined at the onset of the 4:30 pm on-peak period. The level of consumption from 4:30 to 8:30 pm, the winter on-peak period, is far lower than during alternative portions of the day. This indicates that this customer will find Schedule No. A-17 much to his advantage.

During the summer month, the customer peak coincides with the on-peak time period in the tariff. This customer has a substantial incentive to compound his winter month savings through modification of his summer daily load curve. In some instances, it may be financially worthwhile scheduling plant maintenance during a summer month in order to avoid the substantially higher demand charges in this time period. Even if this customer makes no change in his general consumption pattern of electricity, he will probably not see an overall increase in his annual electric bill because of the diminution of his costs in the seven winter months of Schedule No. A-17.

## Extension of Schedule No. A-17 To Other Customers

CPUC Decision No. 85559 ordered all California Utilities to introduce time-of-day rates in consecutive years by customer load blocks. Time-of-day rates for customers between 1000 kilowatts of demand and 4000 kilowatts of demand must be filed with the California Public Utilities Commission prior to May 15, 1977. Subsequent steps require the extension of time-of-day rates to customers between 500 kilowatts and 1000 kilowatts prior to May 15, 1978.

For PGandE, the number of customers included in each of these groupings grows exponentially. The time-of-day rate form for the 1000 to 4000 kilowatt grouping will be analogous to Schedule No. A-17. This customer group will be affected by time-of-day rates in a manner quite similar to that outlined for the PGandE customers who are presently being served on Schedule No. A-17. When time-of-day rates reach the 500 kilowatt level, an entirely new mix of customers begins to emerge. The 500 kilowatt customer group contains retail customers rather than the former mix of manufacturing establishments, office buildings, refineries, universities and military establishments. Retail establishments cater to the public. The number of customers in this group is large enough that the cost of special time-of-day metering in the manner utilized with the very largest customers becomes increasingly uneconomic. This block of customers will be carefully analyzed prior to the introduction of a time-of-day rate form for this group. It is quite likely that a far less complex time-of-day rate may be more appropriate for this group of customers.

## Involvement of the Federal Energy Administration

California has been one of the first states to order statewide time-of-day electric rates. In this paper I have highlighted the detail of PGandE's time-of-day rate. The rates which other utilities will put into effect in California will probably be somewhat different than Schedule No. A-17. This is in keeping with California's tradition for diversity of ideas, locales, and solutions to problems. Because Decision No. 85559 was so far reaching and impacted nearly 7 million electric customers in the State of California, the interest of the Federal Energy Administration in monitoring the effectiveness of time-of-day rates in California was jointly solicited by the California Public Utilities Commission and the California Energy Resources Conservation and Development Commission. The F.E.A. has subsequently funded a study of the impact of the introduction of marginal cost based time-of-day rates in California through the auspices of the Electric Utilities Demonstration Project. Analytic data generated as a part of the introduction of time-of-day rates will be forwarded to the FEA for use in making recommendations to Congress on the effectiveness of rate design strategies in conserving the energy and capacity requirements of all utilities. This project will initiate a tremendous data bank dealing with the quantification of temporal price elasticity of demand for aggregations of customers by type of business and by size of business. It will provide invaluable tools for estimating the potential future generating capacity needed to serve California electric customers. It will categorize behavioral and physical impediments to time-of-day pricing. The absence of this type of empirical analysis necessitates experimentation to complete the cost/benefit equation for innovative types of rate designs. Unfortunately, many states including California have been reluctant to await evidence of the effectiveness of rate design change in promoting conservation prior to embarking upon the programs themselves. With information supplied by California's experience, other states may be able to reap the benefit of California's gains and avoid its defeats as they consider the logic in support of quantum jumps in rate design.

## Conclusion

The California regulatory environment is an exciting and dynamic one. The California Public Utilities Commission is dedicated to energy conservation to the extent that conservation should play as important a role within a utility as new sources of supply have historically played. Pricing is the classic means through which to control the demand for a commodity. In its fervor to achieve conservation, the California Public Utilities Commission has adopted time-of-day pricing as the most sound means for guiding customers to understand the true cost of the commodity they are purchasing. The cost of producing electricity has a diurnal variation which it is now economic to portray in tariff form. PGandE has done this through Schedule No. A-17. PGandE's approach to new rate designs is to introduce them with as little disturbance to the existing rate framework as possible. Schedule No. A-17 telescopes the former rate schedule into a time varying rate schedule which does not excessively penalize any one customer. It provides significant monetary incentive to shift load away from PGandE's peak periods. Even if customers cannot change their load pattern, there are few that find their average bills changing by more than 3%. Time-of-day pricing in California is being accomplished based upon allocations of cost to customers determined under traditional cost of service principles. As long as this does not change, time-of-day rates can be a boon not a bane to business and should not be excessively feared by customers.

# ENERGY MANAGEMENT BY COMPUTER CONTROL AT UNIROYAL

By

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## Summary

Energy conservation is a subject of deep concern to every responsible individual today. This is especially so at Uniroyal, where the scope of concern spans from 1940 to the present, from manual energy data acquisition and reporting to sophisticated computerized energy management systems in environments ranging from the Corporate Headquarters Office Complex in Connecticut to a Tire Production Facility in Wisconsin. This paper describes Uniroyal's total energy conservation program, with major emphasis on the two energy management systems.

## Corporate Energy Conservation Program

Uniroyal has long been concerned with the efficient utilization of electrical energy. In 1940, the Corporate Engineering Department instituted a program which required each Uniroyal location to report electrical energy consumption and mechanical power services on a monthly basis.

In 1971, the reporting format was expanded and further refined to achieve four main objectives:

1. Establish uniformity of terminology and system.
2. Provide Plant Engineers with required data.
3. Allow for monitoring by Corporate Engineering.
4. Build a data base for engineering design and utility contract negotiations.

The latest revision of the four-page monthly energy consumption report forms may be seen in Figures 1 and 2. The first page (Figure 1) is reproduced in its entirety. The last three pages (Figure 2) are similar to the first, and therefore only column headings are shown.

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OXFORD MANAGEMENT & RESEARCH CENTER
PLANT ELECTRIC POWER CONSUMPTION DATA
SHEET 1

| Month | Billing Period Ending | Maximum Demand: Metered KW | Maximum Demand: Billing | Energy M-KWH | Comparative Use: Hrs. of Metered Demand | Comparative Use: Hours/ Billing Period | Comparative Use: Load Factor % | Power Factor % | Billing: Demand Charge $ | Billing: Energy Charge $ | Billing: Fuel Adjust. $ | Billing: Dis-count $ | Billing: Total Net Bill $ | Billing: Average Rate Mills Per KWH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Col. 1 | Col. 2 | Col. 3 | Col.4 | Col.5 | Col.6 | Col. 7 | Col.8 | Col.9 | Col.10 | Col.11 | Col.12 | Col.13 | Col. 14 |
| Jan. | | | | | | | | | | | | | | |
| Feb. | | | | | | | | | | | | | | |
| Mar. | | | | | | | | | | | | | | |
| Apr. | | | | | | | | | | | | | | |
| May | | | | | | | | | | | | | | |
| June | | | | | | | | | | | | | | |
| July | | | | | | | | | | | | | | |
| Aug. | | | | | | | | | | | | | | |
| Sept. | | | | | | | | | | | | | | |
| Oct. | | | | | | | | | | | | | | |
| Nov. | | | | | | | | | | | | | | |
| Dec. | | | | | | | | | | | | | | |
| Annual | | | | | | | | | | | | | | |

| Rate Schedules: | Start of Year | Revision |
|---|---|---|
| Designation | | |
| Effective Date | | |

Utility Name: ____
Account No.: ____
Plant Name: ____
Year: ____

Figure 1

CORPORATE ENGINEERING DEPARTMENT
OXFORD MANAGEMENT & RESEARCH CENTER
PLANT ELECTRIC POWER CONSUMPTION DATA
SHEET 2

| Month | Billing Period Ending | Finished Goods M-LBS | Unit Cost: KWH/LB | Unit Cost: $/LB | Production: Hours | Production: LF-% |
|---|---|---|---|---|---|---|
| | Col. 15 | Col. 16 | Col. 17 | Col. 18 | Col. 19 | Col. 20 |

CORPORATE ENGINEERING DEPARTMENT
OXFORD MANAGEMENT & RESEARCH CENTER
POWER SERVICES REPORT
Steam and Water

| Month | Prod. M lbs. | Steam Generated M lbs. | Fuel* Con-sumed | Fuel* Con-sumed | Fuel* Cost M $ | Fuel* Cost M $ | # Steam / MM BTU | # Steam / # Prod. | Fuel* Cost / MM BTU | Fuel* Cost / MM BTU | City Water M Gals | City Water Cost $ | Gal.C.W. / #Prod. | City Water Cost($) / M gal. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

CORPORATE ENGINEERING DEPARTMENT
OXFORD MANAGEMENT & RESEARCH CENTER
NON-BOILER FUEL REPORT

| Month | Fuel No. 1: Type (1) | Fuel No. 1: Qnty. (2) | Fuel No. 1: Cost (3) | Fuel No. 1: Cost / MM BTU | Fuel No. 2: Type (1) | Fuel No. 2: Qnty. (2) | Fuel No. 2: Cost (3) | Fuel No. 2: Cost / MM BTU | Fuel No. 3: Type (1) | Fuel No. 3: Qnty. (2) | Fuel No. 3: Cost (3) | Fuel No. 3: Cost / MM BTU | Total Cost Boiler and Non-Boiler Fuel | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Figure 2

At about the same time, the Operations Analysis Group within Corporate Engineering, was assigned to the program to analyze and plot the reported data. By the end of 1972, in addition to other key indicators, a 12-month moving average was being plotted for:

1. Electrical Load Factor.
2. Kilowatt Hours per Pound of Product.
3. Pounds of Steam Generated per Million BTU Fuel Burned.
4. Pounds of Steam per Pound of Product.

The maintenance of these graphs for 80 Uniroyal locations as well as summary plots for each of six Divisions and for the entire Corporation consumed excessive manpower. By the end of 1973, a computer program was written and implemented to make the task manageable. Typical computer printouts for a Division and Plant are shown in Figures 3 and 4.

POWER SERVICE REPORT
DIVISION A
12 MONTH MOVING AVERAGES

| | PRODUC-TION 1000 LB | FUEL: LB.STEAM / MM-BTU | FUEL: LB.STEAM / LB.PROD. | FUEL: BTU / LB.PROD. | FUEL: CENTS / LB.PROD. | FUEL: FUEL COST $ | ELECTRICAL: LOAD FACTOR | ELECTRICAL: KWH / LB.PROD. | ELECTRICAL: CENTS / LB.PROD. | ELECTRICAL: ELECTRIC COST $ | @ MONTH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant 1 | 13897.2 | 829. | 2.633 | 3421. | 0.196 | 27235. | 70.6 | 0.599 | 0.572 | 75274. | MAY |
| Plant 2 | 10424.3 | 869. | 6.510 | 7497. | 1.655 | 172516. | 54.7 | 0.526 | 1.452 | 151324. | MAY |
| Plant 3 | 10654.6 | 807. | 8.693 | 11017. | 0.935 | 99584. | 58.9 | 0.819 | 1.943 | 190629. | APR |
| Plant 4 | 12206.9 | 774. | 6.225 | 8057. | 1.053 | 128573. | 50.9 | 0.514 | 0.574 | 118862. | MAY |
| Plant 5 | 4193.4 | 760. | 5.998 | 7650. | 0.853 | 35778. | 56.2 | 0.464 | 0.621 | 26050. | MAY |
| Plant 6 | 1165.3 | 0. | 0.0 | 194. | 0.022 | 259. | 51.3 | 0.242 | 0.609 | 7095. | MAY |
| Plant 7 | 5017.2 | 753. | 6.483 | 9047. | 0.635 | 31870. | 48.4 | 0.744 | 1.778 | 86994. | APR |
| Plant 8 | 9855.9 | 817. | 3.343 | 4771. | 0.330 | 32487. | 61.7 | 0.774 | 1.304 | 128502. | APR |

DIVISION TREND SUMMARY

| MONTH | PRODUC-TION 1000 LB | FUEL: LB.STEAM / LB.PROD. | FUEL: BTU / LB.PROD. | FUEL: CENTS / LB.PROD. | FUEL: FUEL COST $ | ELECTRICAL: KWH / LB.PROD. | ELECTRICAL: CENTS / LB.PROD. | ELECTRICAL: ELECTRIC COST $ | TOTAL ENERGY BTU/LB.PROD. GOAL 12206 |
|---|---|---|---|---|---|---|---|---|---|
| MAY | 88464.8 | 5.080 | 6440. | 0.486 | 429572. | 0.562 | 0.783 | 692299. | 12064. |
| JUNE | 88374.0 | 5.056 | 6423. | 0.501 | 443045. | 0.561 | 0.802 | 708604. | 12032. |
| JULY | 87349.0 | 5.051 | 6364. | 0.511 | 446066. | 0.562 | 0.822 | 717914. | 12009. |
| AUG | 86606.3 | 5.057 | 6403. | 0.529 | 458339. | 0.564 | 0.848 | 734827. | 12038. |
| SEPT | 85301.2 | 5.114 | 6488. | 0.552 | 470620. | 0.568 | 0.882 | 752049. | 12166. |
| OCT | 83816.4 | 5.169 | 6564. | 0.579 | 485335. | 0.573 | 0.919 | 770127. | 12297. |
| NOV | 82588.4 | 5.166 | 6568. | 0.601 | 496177. | 0.576 | 0.949 | 783714. | 12324. |
| DEC | 78595.4 | 5.243 | 6694. | 0.635 | 501945. | 0.589 | 1.000 | 789750. | 12584. |
| JAN | 76727.6 | 5.248 | 6716. | 0.683 | 524359. | 0.594 | 1.037 | 795991. | 12654. |
| FEB | 73304.6 | 5.321 | 6824. | 0.714 | 523715. | 0.606 | 1.088 | 798228. | 12883. |
| MAR | 69358.3 | 5.419 | 6574. | 0.762 | 528618. | 0.621 | 1.146 | 794573. | 13188. |
| APR | 67672.2 | 5.402 | 6555. | 0.780 | 527582. | 0.625 | 1.176 | 795829. | 13205. |

Figure 3

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DIVISION A | | | | | | | | | | | |
| PLANT 1 | | | | | | | | | | | |
| MONTH | FINISHED GOODS FUEL 1000 LBS | COST FUEL $ | STEAM GENERATED 1000 LBS | #STEAM /MMBTU | TOTAL FUEL MM BTU | CITY WATER 1000 GAL | COST CITY WATER $ | LOAD FACTOR | ENERGY 1000 KWH | FINISHED GOODS ELECT 1000 LBS | COST ELECT $ |
| MAY | 12993.0 | 21735.0 | 35705.0 | 813.0 | 45388.0 | 15832.0 | 2238.0 | 71.4 | 9040.0 | 13441.0 | 78C84.0 |
| JUNE | 11759.0 | 26467.C | 40912.0 | 820.0 | 51003.0 | 17680.0 | 2450.0 | 69.8 | 8760.0 | 12322.0 | 76505.0 |
| JULY | 12770.C | 26521.0 | 43528.C | 863.0 | 52C09.0 | 19319.0 | 2639.0 | 72.5 | 9248.0 | 12466.0 | 84C88.0 |
| AUG | 12190.0 | 27306.0 | 40690.0 | 8C4.0 | 51527.0 | 20147.0 | 3304.0 | 73.7 | 8704.0 | 11722.C | 76815.0 |
| SEPT | 12976.C | 25542.0 | 36891.0 | 794.0 | 47570.0 | 16C77.0 | 2734.0 | 74.0 | 8976.0 | 12406.C | 81719.0 |
| OCT | 16229.0 | 28345.0 | 39226.0 | 824.0 | 48540.0 | 17741.0 | 2967.0 | 75.0 | 8680.0 | 14336.0 | 86527.0 |
| NOV | 13902.0 | 28052.0 | 35538.0 | 813.0 | 48692.0 | 12942.0 | 2295.0 | 75.1 | 9C80.0 | 16176.C | 86547.0 |
| DEC | 13991.0 | 32015.0 | 41067.0 | 876.0 | 55920.0 | 12733.0 | 2266.0 | 69.7 | 8064.0 | 15378.0 | 8CC55.0 |
| JAN | 159C5.0 | 30824.0 | 39590.0 | 861.0 | 53648.0 | 12303.0 | 2205.0 | 67.0 | 7880.0 | 146CC.C | 76433.0 |
| FEB | 13198.0 | 29197.0 | 34996.0 | 841.0 | 48143.0 | 10893.0 | 2008.0 | 69.0 | 7280.0 | 13882.0 | 72975.0 |
| MAR | 11728.0 | 22295.0 | 25704.0 | 813.0 | 36703.0 | 8919.0 | 1732.0 | 63.5 | 6736.0 | 13261.0 | 66125.0 |
| APR | 16318.0 | 25365.0 | 30744.0 | 816.0 | 39830.0 | 11841.0 | 2141.0 | 64.5 | 6864.0 | 13256.C | 67565.0 |
| MAY | 15800.0 | 24889.0 | 29489.0 | 827.0 | 26880.0 | 13920.0 | 2432.0 | 73.6 | 9328.C | 16292.C | 53089.0 |

12 MONTH AVERAGES

| | | FUEL | | | | | WATER | | | ELECTRICAL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PRODUCTION 1000 LB | CENTS / LB.PROD | LB.STEAM / LB.PROD | LB.STEAM / MM-BTU | BTU / LB. | FUEL COST $ | GAL / LB.PROD | CENTS / LB.PROD | WATER COST $ | LOAD FACTOR | KWH / LB.PROD | ELEC COST $ | CENTS / LB.PROD |
| MAY | 12158.5 | 0.182 | 3.370 | 824. | 4354. | 22167. | 1.246 | 0.018 | 2159. | 70.9 | C.677 | 67330. | C.553 |
| JUNE | 12239.8 | 0.185 | 3.330 | 824. | 4307. | 22640. | 1.265 | 0.018 | 2198. | 70.5 | C.672 | 68485. | 0.554 |
| JULY | 12515.5 | 0.184 | 3.242 | 828. | 4178. | 22992. | 1.242 | 0.018 | 2204. | 70.4 | C.667 | 69955. | 0.558 |
| AUG | 12635.9 | 0.186 | 3.153 | 827. | 4123. | 23483. | 1.244 | 0.018 | 2272. | 70.4 | C.659 | 7C993. | 0.557 |
| SEPT | 12849.6 | 0.187 | 3.137 | 823. | 4066. | 23983. | 1.230 | 0.018 | 2322. | 70.4 | 0.656 | 72365. | 0.562 |
| OCT | 13073.1 | 0.187 | 3.C67 | 823. | 3978. | 24496. | 1.214 | 0.018 | 2372. | 70.8 | C.648 | 73583. | 0.566 |
| NOV | 13149.1 | 0.190 | 3.C20 | 822. | 3949. | 25043. | 1.199 | 0.018 | 2391. | 71.0 | 0.641 | 75278. | 0.569 |
| DEC | 13252.4 | 0.191 | 2.977 | 826. | 3848. | 25348. | 1.181 | 0.018 | 2410. | 71.1 | 0.633 | 76366. | C.571 |
| JAN | 13383.8 | 0.196 | 2.944 | 830. | 3789. | 2626C. | 1.159 | C.018 | 2426. | 71.4 | C.626 | 77283. | 0.571 |
| FEB | 13434.6 | 0.200 | 2.923 | 832. | 3756. | 26913. | 1.141 | 0.018 | 2433. | 71.4 | C.622 | 78030. | 0.575 |
| MAR | 13271.9 | 0.202 | 2.959 | 83C. | 3701. | 26841. | 1.120 | 0.018 | 2404. | 70.8 | 0.615 | 77552. | 0.575 |
| APR | 13663.3 | 0.197 | 2.716 | 828. | 3531. | 26972. | 1.C76 | 0.018 | 2415. | 70.4 | C.6C8 | 78C24. | 0.573 |
| MAY | 13897.2 | 0.196 | 2.633 | 829. | 3421. | 27235. | 1.046 | 0.017 | 2431. | 70.6 | C.599 | 79274. | 0.572 |

Figure 4

A graphic representation of the energy information flow within the Company may be seen in Figure 5. It is essentially self-explanatory.

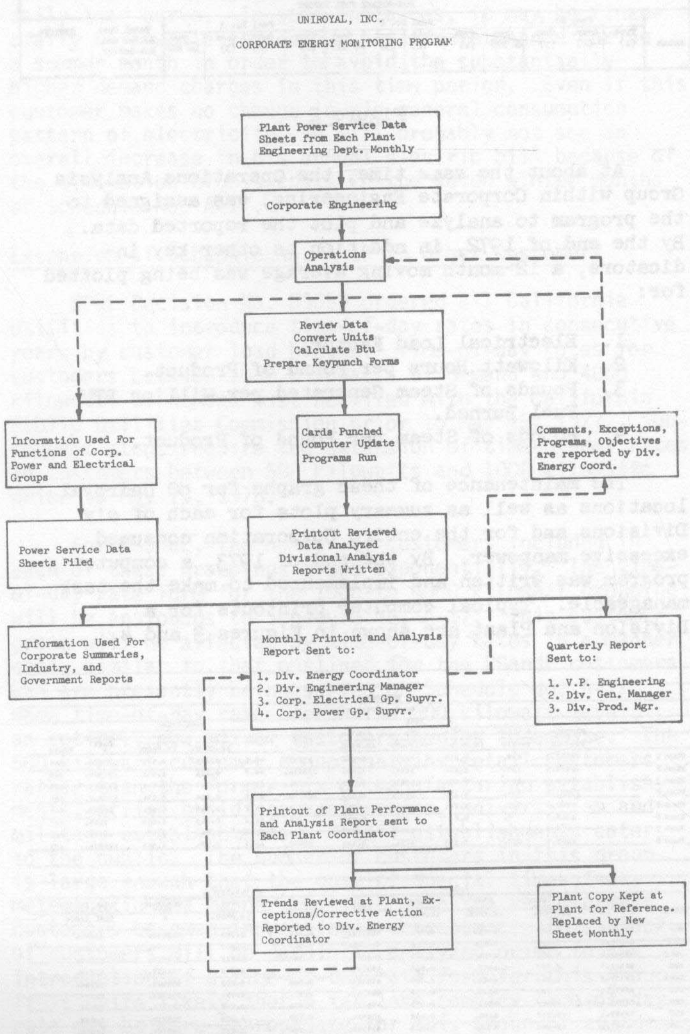


Figure 5

In conjunction with more extensive gathering, analysis and dissemination of energy consumption data, in July of 1971, Uniroyal instituted the first of what has become an annual energy conservation meeting, attended by Corporate, Division and Plant Engineering Personnel and Energy Coordinators. These meetings have served as an important vehicle to focus attention on the energy conservation program, facilitate the exchange of ideas and stimulate a healthy competitive results-oriented attitude within the Company. "Belt Tightening" is far easier to accept when you know others are making an equal contribution to the effort.

The effective result of this program on a Company-wide basis has been a 6% reduction in energy consumption per pound of product manufactured in 1975 as compared to 1972, in spite of adverse changes in product mix and operating level. These savings have been accomplished through conventional economy measures such as elimination of energy waste on weekends and holidays, improved maintenance to reduce energy wasting losses of air, steam and water, substitution of low-energy fluorescent lamps for standard tubes, reduction of air flow in buildings, relocation of air intakes, tuning boilers for maximum efficiency, installation of stack-gas heat recovery devices, conversion from area to spot lighting, replacement of broken glass windows with plastic, utilization of air-cleaning devices to allow increased recycling, recovery of flash steam, installation of automatic shutdown valves on major equipment, replacement of over-sized motors, installation or extension of condensate recovery systems, use of exhaust steam (e.g. from turbine pumps) to preheat raw make-up water, reduction of mixing and curing cycles, improvement in cooling water systems and heating coil arrangements, etc. In addition, although it only saves money and not energy, production has been rescheduled in many plants to increase the 24-hour load factor and reduce electrical billing demand.

Now that the "cream has been skimmed", further savings will not come easily. With this in mind, Uniroyal management approved the installation of two computerized energy management systems. One is located at the Company's Headquarters in Middlebury, Connecticut, and has been in operation for more than a year. The second, at a Tire Plant in Eau Claire, Wisconsin, has just been completed. These two systems are of primary interest and constitute the remainder of this paper.

## Corporate Headquarters Energy Management System

### Background

The Corporate Headquarters of Uniroyal, Inc., known as the Oxford Management and Research Center, is located on a 120-acre site in Middlebury, Connecticut. It was designed several years prior to its first occupancy in 1971, when energy conservation did not have the same significance it does today. The multi-building complex consists of the following four areas:

1. The Administration Building (228,000 sq.ft.) is a four-story structure which contains the Company's main computer center and extensive landscaped offices with vast expanses of glass.
2. The Guest House and Training Center (61,000 sq. ft.) include a 48-room motel, lounge, cafeteria, dining room, restaurant and conference center, all open to the public.

3. The Research Center (318,000 sq. ft.) houses 60 laboratories, pilot plant operations, library, auditorium and offices.
4. The Boiler House (20,000 sq. ft.) contains all major support equipment for the complex including:
   a. Two 50-million Btu/hour high-temperature hot-water boilers for space conditioning.
   b. Two 14,000-pound/hour high-pressure steam boilers for process requirements.
   c. Three 1100-ton absorption chillers.
   d. The environmental control center, which enables remote operation of all building service equipment through multiplexed satellite relay stations.

Shortly after the complex was completed, Uniroyal's first energy conservation meeting was held at "Oxford." It became imperative that Corporate Headquarters set a good example for the entire Company to follow, and a program of energy reduction for the facility was undertaken. Each of the four areas of the site presented special problems and had to be treated individually, but a significant overall reduction in both electrical energy and fuel oil consumption of 16% and 42%, respectively, was achieved by 1974, primarily through the following:

1. Removal of all non-essential fluorescent and incandenscent lamps (e.g. over unoccupied areas and walk-ways).
2. Relamping approximately 30,000 standard rapid-start fluorescent fixtures with low energy lamps.
3. Implementation of a mass cleaning technique which utilizes the entire cleaning force in one area at a time. This allows the reduction from 1/3 cleaning level lighting to darkness as each area is completed. Since cleaning begins at 5:00 P.M. and finishes at 11:00 P.M., this is significant.
4. Maintaining the complex in complete darkness from 1:00 A.M. to 6:00 A.M. daily and throughout weekends and holidays.
5. Installation of modulated dampers to control building temperature by regulating the amount of outside make-up air, and de-activation of re-heat coils in zone air-handling equipment.
6. Resetting thermostats to 40°F to minimize perimeter heat pump operation.
7. Removing unloaded rotating stand-by pumps from service.

However, between 1973 and 1974, the skyrocketing costs of fuel oil and electrical energy, which were particularly severe in the Northeast, caused operating costs to continue to rise, in spite of the significant reduction in energy consumption.

Load Parameters

By the middle of 1974, an investigation was under way to determine the feasibility and economics of installing an energy management system to further reduce energy consumption as well as trim electrical demand. A survey of all rotating equipment revealed that 1730 KW of connected load could be cycled for short periods of time. Assuming an average load factor of 60%, the net shedable load represented approximately 1/4 of the total demand - an appreciable amount of potential energy reduction.

A profile of electrical usage for a typical working day was developed from utility revenue metering tapes of the 15-minute demand interval over a three-month period. That profile appears in Figure 6, and depicts a curve with peaks at 11:00 A.M. and 2:00 P.M. This suggested that it would seem reasonable to expect some reduction in demand under computer control.

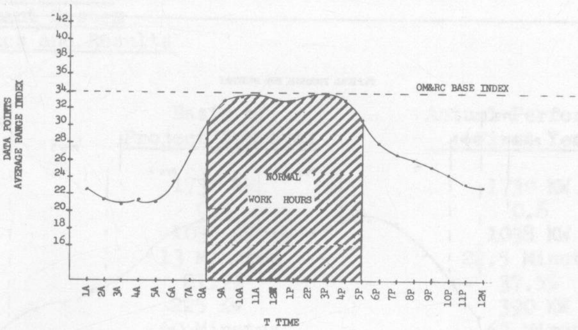


Figure 6

Having concluded that the potential for substantial additional savings existed (refer to the Economics/Results Section for details), a specification was written and quotations solicited from several vendors. After a comparative evaluation of each system proposal, a Model 808 Watt Shaver, manufactured by Solid State Systems, Inc., was selected for this particular application for the following reasons:

1. Ease of interfacing with an existing Honeywell environmental control system.
2. Free format English language computer addressing.
3. A perpetual calender, which allows special treatment of weekends, holidays, etc.
4. An installed cost of under $45,000.

Project approval was obtained by the end of 1974, and the energy management system was ordered. Uniroyal worked closely with Solid State, Inc. in the design stage of the system. All necessary access points internal to the Honeywell environmental control system were wired to external terminal strips in an interconnection/test panel and then to a 48-pin connector. Meanwhile, Solid State wired the mating half of the connector to corresponding points within the Model 808, and consequently, the installation essentially consisted of setting the console on the floor and literally plugging it in! The system was completely operational, controlling load, and saving energy within $2\frac{1}{2}$ days of delivery to the site in August of 1975.

System Description

The system configuration includes a digital computer with core storage capacity of 16K, interfacing hardware and two teletype operator consoles, located in the boiler house and Facilities Service Engineer's office, each with complete I/O capability. There are now 54 loads under direct computer control, slightly less than the system capacity of 64, which could easily be expanded to 128, in increments of 16, if ever required.

The software package can presently accommodate 15 load cycle/shed programs, of which 7 are now in use. Each program can be scheduled to control during specific intervals daily or only on selected days of the week, thus simplifying the handling of weekends and holidays. They can be mutually exclusive or overlap, in which case the higher order program takes precedent. Figure 7 shows typical program scheduling for a weekday.

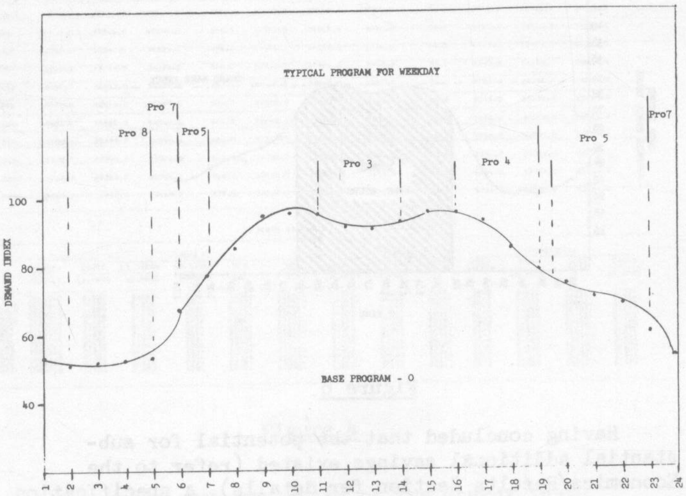


Figure 7

Each program can control any or all of the 64 loads and, for each load, can have individually set parameters such as: on time, off time, cycle/shed mode, priority level and group assignment. The mode determines whether the load will be cycled, shed or both. The priority level (1-63) establishes the sequence in which loads will be shed, if required to limit demand. There are 31 groups divided into three types as follows:

1. Fifteen groups force all loads in the same group to be cycled or shed simultaneously (e.g. supply and exhaust fans are paired to prevent pressure differentials).
2. Fifteen groups prevent more than one load in any group from being cycled or shed at a given time (e.g. at least one of three supply fans in the computer area is required to assure proper fire detector operation).
3. One group is non-restrictive. Each load in this group is completely independent of all other loads.

System status reports are automatically printed hourly, or on command if an update is desired. Each report gives complete information on actual energy usage and demand versus the preset limit for each demand interval, cumulative totals for the billing period, as well as a report of any equipment malfunctions.

Economics/Results

As stated previously, the installed cost of the energy management system was under $45,000, due to the existence of a centralized environmental control system. The data presented in Table 1 is a detailed comparison of the estimates on which the project approval was based and the actual system performance. The total energy savings for the first year amounted to double the invested cost - obviously a very successful project. However, it is particularly interesting to note that, although demand reduction was not anticipated to account for a major portion of the savings, in actuality, it represented a mere 11.8% of the total savings. This certainly does not justify the extent that demand savings are publicized by most manufacturers of energy management systems. It is probably a safe generalization to state that in most well run operations, the real savings potential for such a system is in energy reduction through load cycling - not demand control.

## Tire Plant
## Energy Management System

### Background

Uniroyal's second energy management system installation is in a Tire Production Facility at Eau Claire, Wisconsin. The plant is a large energy user, consuming approximately 1.2 trillion Btu/year. A typical monthly electrical load may be defined as 17,500 KW, 96.5% power factor, 18,130 KVA, 7,670,000 KWH and 65.1% load factor. The desire to limit this quantity of energy is the result of an interest in reducing costs and conserving our resources. In spite of the fact that this plant was originally constructed in 1916, and rebuilt in 1945, it is relatively efficient in terms of energy consumption per pound of product.

When the energy crisis of 1974 with its subsequent increases in energy prices hit, Eau Claire went through the crash conservation programs, as did almost all production facilities in the U.S.. Terms which had been in the English language for many years, such as load factor, demand curves, and base loads, suddenly became all important.

The people at Eau Claire were re-educated to turn off equipment when it was not needed, production loads were shifted to balance electrical demand, and buildings were insulated to save thermal energy. When mass concern for energy conservation dropped off in 1975, it became apparent that any successful energy conservation program could not depend entirely on people for implementation. In addition, very little research had been done on what makes up the base load (that which depends very little on the level of production) and what can be done about it. So early in 1975 a survey was begun at Eau Claire to determine the feasibility of some type of a machine-controlled energy management system. The first step of the survey was to find loads which could be controlled using the following criteria:

1. Load cycling: Non-production associated loads which run continuously but would not have to. Generally, these are heating and ventilating systems.
2. Process Line Down Time: process associated loads which continue to run when the process stops. Blowoffs on tread lines and exhausts on stock warmup mills would be examples.
3. Load Cycling: pumping, vacuum, or circulating systems which run continuously during production and are off during non-production hours, recognizing the fact that the output requirements of these systems is not that flat.
4. Demand Control: loads which can be shed for short periods of time on an irregular basis with no adverse effects. This can be, and often is, many of the same loads in the above categories. In addition, some production equipment, such as battery chargers, would be involved.