A STUDY OF THE PRE-PROGRAMMED THERMOSTAT TIMER AS A LOAD CONTROL DEVICE

Mary L. Wallace
Energy Application Engineer
Texas Power & Light Company
Dallas, Texas

Marvin Thedford
Supervisor of Technical Services Research
Texas Power & Light Company
Dallas, Texas

ABSTRACT

Monitoring equipment was installed on a residential air conditioning unit to test the effects of a pre-programmed thermostat timer. This was done to determine its effect on the utility's load shape for the purpose of avoiding peak generation capacity. This report measured the temperature and energy changes as a result of the test.

PURPOSE:

The purpose of this research was to determine if a pre-programmed thermostat timing device can operate similarly to a dispatcher controlled load management device to reduce peak generation demands without adversely affecting energy (kWh) sales.

SCOPE:

The scope of this research is: (1) to determine if the device can be used as a viable means of load reduction, (2) to determine the parameters for equipment and programming for more extensive research involving dispatcher control of distribution load, and (3) to determine if the device can serve as a low cost substitute for a dispatcher load control system.

LIMITATION:

The test was limited to one residence with one central air conditioning compressor. The time period of the research was from August 25 to September 17, 1982. The test did not run through the complete summer cycle and did not run the cycle involving heating equipment.

BACKGROUND:

Demand leveling procedures are necessary if the Company is to make the best use of its generating capacity. A study of Chart I, "Average System Demand vs. Temperature for 1980-1982", indicates that a great potential for saving generating capacity (MW) occurs when the temperature exceeds 90°F. The slope of the curve from 80° to 100°F closely follows the heat gain coefficient (kW/Degree) curve of a typical residential structure with a nominal 3 ton, 7.5 EER central air conditioner. This indicates that above 80° a thermal sensitive load such as air conditioning is causing the upper part of the summer generating demand.

PROGRAMMABLE THERMOSTAT TIMER LOAD CONTROL DEVICE:

The energy management system utilized in this experiment is a pre-programmed system which allows certain functions to be programmed in the field. It employs solid state switching and is wired in series with the thermostat. The device functions by "duty-cycling" the air conditioning compressor.

According to the manufacturer:

"The addition of the management system to the present controls of a typical heating and air conditioning unit increase the energy efficiency and may decrease energy consumption by 20% or more annually. This means added room comfort and saved energy dollars for the residential or light commercial property owner."

Proceedings of the Second Symposium on Improving Building Systems in Hot and Humid Climates, College Station, TX, September 24-26, 1985

There is some concern by air conditioning equipment manufacturers that "duty cycling" of air conditioning compressors will shorten the life of the compressors. Some manufacturers imply that adding the device would be grounds to void the warranty.

An Article in the "Energy User News" dated November 8, 1982 states:

> "Compressor manufacturers say that all types of duty cycling whether excessive or not will shorten compressor life, although they couldn't pin down the exact consequences."

Obviously, the potential for shortened life of the compressor needs to be addressed. Compressors turned on by any means after being off for short periods of time are of great concern to compressor manufacturers. An off period of 4 to 5 minutes normally allows the time needed for the compressor's refrigerant circuit to "equalize" and thus elleviate the problem.

The load control device employed in this experiment has a "protective restart" feature. When the thermostat calls for cooling, the device delays compressor start-up in order to avoid short cycling. This delay protects the compressor from thermostat mis-use. It also protects the utility's interest by delaying re-start after a power interruption.

TEST SET-UP AND PROCEDURES:

The test site selected for the research project was a house in Allen, Texas. The house had 1802 sq. ft. of living space and meets TP&L's E-OK energy standards. Calculations indicated a 27,459 Btuh cooling requirement at 25°F dry bulb temperature difference. The compressor used in the house under test had a General Electric condenser BTN736A100 and a First Company evaporator #H36C. The system has an SEER of 8.6 with a 33,800 Btuh rating at 95°F. Thus, the unit was approximately 23% oversized, based on the 27,459 Btuh calculation requirement.

A family of four occupied the house and kept the thermostat set at 78°F although design conditions were for 75°F. During the test a typical pre-programmed load control timing device was used to turn the circuit to the compressor off for a period of 4 minutes out of each 15 minutes the thermostat was calling for compressor operation. Each time the compressor started, the 15 minute cycle (4 minutes off, 11 minutes on) was reset. A time clock turned the load control device on-and-off on alternate days. The air handler was allowed to run continuously during the experiment.

The electrical circuits to the air conditioning compressor and the air handler were both isolated from the other circuits and kWh meters with pulse generators were attached to monitor them. The measured demand (kW) and energy consumption (kWh) were recorded in 15 minute intervals on data loggers using magnetic tape. During this same period, the temperature of the return air was monitored by a temperature probe interfaced with a magnetic tape recorder.

For a short period of time, the relative humidity and inside temperature were measured by a recorder having a paper strip chart.

TEST RESULTS:

The research, though brief, indicates that a load control device can be used to reduce average hourly demand (kW) without significantly decreasing comfort. A summary of results with charts and data follow.

Average Temperature Defference vs. Outside Temperature with Duty Cycling

In Chart II, the average temperature difference between the inside and outside of the house was plotted against temperature in degrees Fahrenheit.

At 100°F, the temperature difference between the "on" mode and "off" mode of the compressor control device was found to be 1.5°F (20.5-19.0).

The temperature rise of the structure as a result of the timer operation was not noticeable to the occupants. Apparently this was due to three conditions: (1) the "ramping effect", (2) the length of the "off period", and (3) the frequency of duty cycle.

The "ramping effect" can be described as the temperature rise and fall in steps created by the duty cycle rate. For each "off" interval the temperature rises and for each "on" interval the temperature lowers. However, the "on" cycle does not reduce the temperature below the first "off" temperature and sometimes it is higher. This condition exists until the temperature outside the structure starts falling.

Average Compressor Demand vs. Time of Day- From August 25 to September 17, 1982

The average kW required by the compressor during normal operation is compared to the kW required with the duty cycling device in the system. From this curve, the duty cycling device appears to be saving kW from about 12:00 noon to about 8:00 p.m. This indicates that duty cycling for load control at other times would not be advantageous to the Company. The peak kW savings appears to be at 6:00 p.m., which compares favorably to the TP&L system generation peak. The average hourly demand differences at 6:00 p.m. for the days tested is 0.7 kW (3.05-2.35).

Average Compressor Demand In
Kilowatts vs. Temperature

Chart IV shows the average compressor demand in kW charted against outside temperature in both "off" and "on" modes of the timing device. The maximum average savings on average demand shown on the chart is 1.2 kW (3.6-2.4) at about 98°F.

On Chart IV for the 24-day test, the maximum savings between consecutive days appeared to be a little over 1 kW at temperature above 95°F. Below 90°F, the device produced no savings since the normal cycle rate of the thermostat controlled compressor either met or exceeded the programmed "off" period of the device.

Data for the 24-Day Test Period

Chart V shows 24 observations of test data. Along with averages calculated for kWh and for inside and outside temperatures during "on" and "off" periods of the load leveling device operation.

To summarize the data from Chart V:

Mode	Daily (kWh)	Demand (kW)	Daily L.F. %
Off	33.5	3.7	38
On	28.0	2.7	43
Avg. Saving	5.5	1.0	

The average reduction in energy was $\frac{5.5}{33.5} = 16.4\%$ during the test period.

The average reduction in demand was $\frac{1.0}{3.7} = 27\%$ at the time of coincident maximum demand.

Typical Day Comparison Summary-
For August 26 and August 27, 1983

Based on data from the 24 day test period, a typical set of weekdays, August 26 and August 27, were chosen. The load leveling device was in the "on" mode on August 26, and the "off" mode on August 27. Chart V identifies the data for August 26 and August 27.

Humidity strip charts (not included) show 60% to 65% relative humidity on August 26 and 60% on August 27. Chart V identifies the data for August 26 and August 27.

Charts VI through X are charts showing performance at various times during the day for August 26 and August 27. That data is summarized in Chart XI.

On August 26th the load leveling device caused a reduction of approximately 1 kW which changed the load factor for the day from 55.4% to 63.7%. The loss in kWh was 7.6 or approximately 15% for the day.

CONCLUSIONS:

This experiment verified that a pre-programmed thermostat timer can be used to shut-off an air-conditioning compressor at pre-set intervals during peak and near peak generating periods with minimum interference to operations at other times. It identified the daily effective load control time period and the effective temperature.

From the results of this experiment, duty cycling of an average central residential air conditioning unit may be expected to provide about 1 kW saving with a consumption reduction of 5.5 kWh per day during peak air conditioning days. The total summer reduction in energy (kWh) consumption was not determined because the test period was not long enough.

During the test, it was determined that the timing mechanism in the pre-programmed load control device was accurate and operated according to settings.

RECOMMENDATIONS:

Since the ordinary operational kWh savings may not be an adequate incentive to a customer, TP&L may need to furnish the device to the customer as well as provide rate incentives. With modification, the device could be installed in or near the power meter and the control wire interfaced with the compressor controls. By using a solid state billing meter, the control function could be de-activated during weekends and holidays.

Since this test was limited to the compressor in one house for a period of only 24 days, it is desirable to run further tests for more complete answers. It does appear, however, that pre-programmed thermostat timers offer a viable means to achieve peak reduction.

Also, for reducing peaks caused by residential air conditioning, the use of these devices is expected to be a low cost substitute for the more expensive dispatcher controlled peak reduction devices which have the site/substation/feeder specific limitations.

The device can be used to control air conditioning equipment in small commercial buildings as well as in residence.

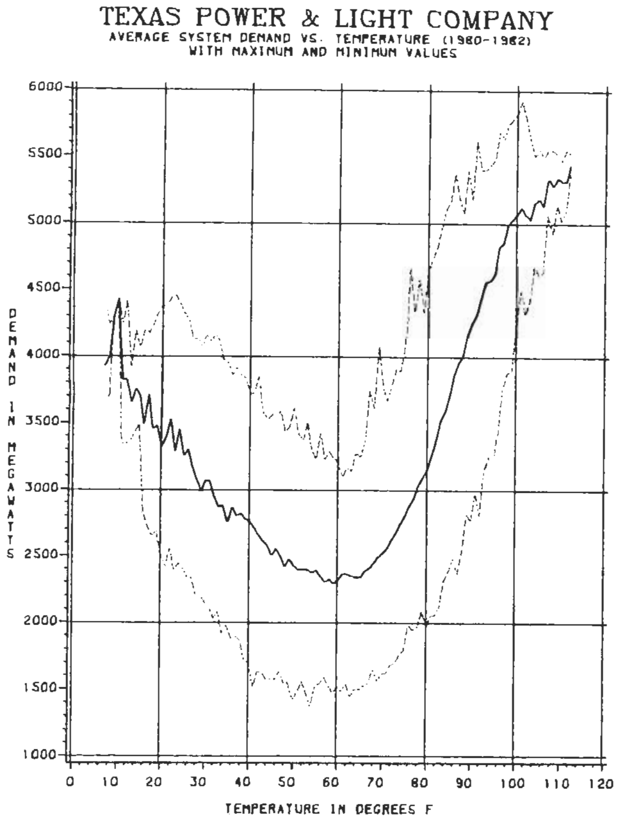

CHART I

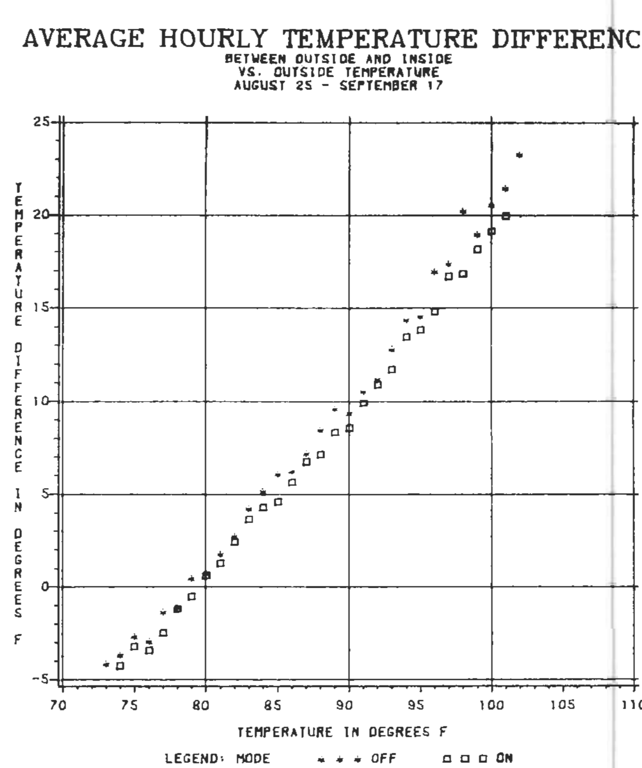

CHART II

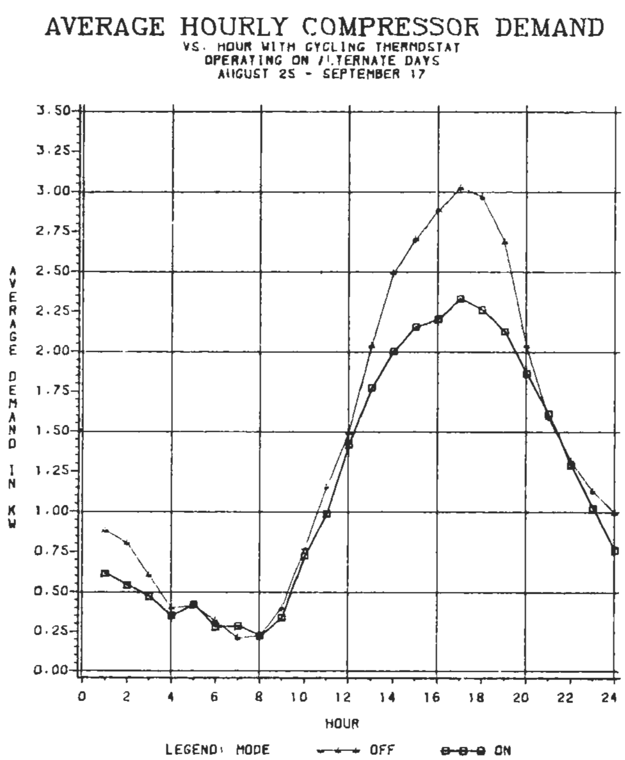

CHART III

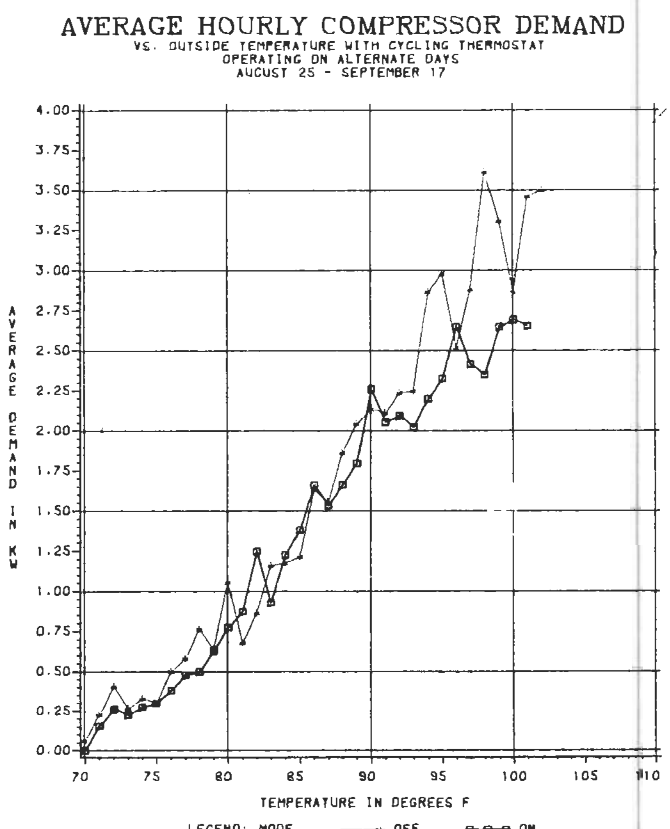

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CHART IV

DAILY SUMMARY OF DATA FOR TEST PERIOD

DATE	MODE	TOTAL DAILY COMPRESSOR KWH	MAXIMUM HOURLY DEMAND	LOAD FACTOR (%)	AVERAGE OUTSIDE TEMP (F)	AVERAGE OUTSIDE TEMP (4-6 PM)	AVERAGE INSIDE TEMP (F)	AVERAGE INSIDE TEMP (4-6 PM)
WED, AUG 25, 1982	OFF	43.0	3.70	48.4	91.0	101.7	78.4	79.0
THU, AUG 26, 1982	ON	41.6	2.72	63.7	91.9	100.2	79.9	81.9
FRI, AUG 27, 1982	OFF	49.2	3.70	55.4	91.5	100.7	79.3	79.7
SAT, AUG 28, 1982	ON	24.3	2.08	48.6	78.7	85.4	79.8	80.6
SUN, AUG 29, 1982	OFF	36.7	3.57	42.9	84.9	94.9	80.2	80.2
MON, AUG 30, 1982	ON	32.8	2.70	50.7	87.7	95.6	80.7	81.4
TUE, AUG 31, 1982	OFF	40.2	3.52	46.2	87.8	95.7	80.3	80.1
WED, SEP 1, 1982	ON	36.6	2.67	57.1	88.5	96.0	81.0	82.6
THU, SEP 2, 1982	OFF	38.5	[illegible]	43.9	88.5	99.5	80.6	81.2
FRI, SEP 3, 1982	ON	[illegible]	2.53	38.6	82.7	88.5	80.9	81.1
SAT, SEP 4, 1982	OFF	20.3	2.25	37.5	78.6	86.3	80.3	80.7
SUN, SEP 5, 1982	ON	13.5	1.71	32.9	77.9	86.2	80.7	81.5
MON, SEP 6, 1982	OFF	26.4	2.88	38.2	80.5	90.2	77.4	80.8
TUE, SEP 7, 1982	ON	26.2	2.58	42.4	82.6	91.3	78.6	81.6
WED, SEP 8, 1982	OFF	27.7	2.66	43.4	82.6	90.7	79.7	82.0
THU, SEP 9, 1982	ON	26.2	2.55	42.8	81.8	90.1	80.0	82.5
FRI, SEP 10, 1982	OFF	26.0	2.64	41.1	82.9	91.6	79.3	81.9
SAT, SEP 11, 1982	ON	29.8	2.59	48.0	83.9	92.5	80.1	82.4
SUN, SEP 12, 1982	OFF	37.3	3.49	44.6	84.8	93.9	79.2	80.0
MON, SEP 13, 1982	ON	30.2	1.83	68.9	84.2	87.8	80.5	81.2
TUE, SEP 14, 1982	OFF	36.2	3.25	46.4	84.2	93.9	80.1	81.7
WED, SEP 15, 1982	ON	25.8	2.07	52.0	81.1	85.6	80.8	81.6
THU, SEP 16, 1982	OFF	21.0	2.00	43.9	77.7	87.4	79.6	81.6
FRI, SEP 17, 1982	ON	25.9	2.58	41.8	82.2	91.1	80.3	82.9
12 Day Average	OFF	33.5 kWh			84.6°F		79.5°F	
12 Day Average	ON	28.0 kWh			83.6°F		80.3°F	

CHART V

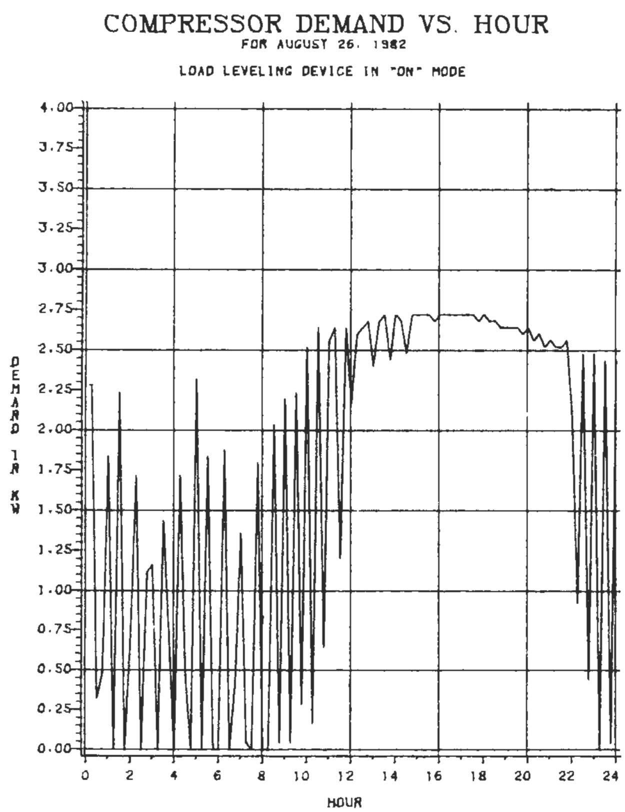

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CHART VI

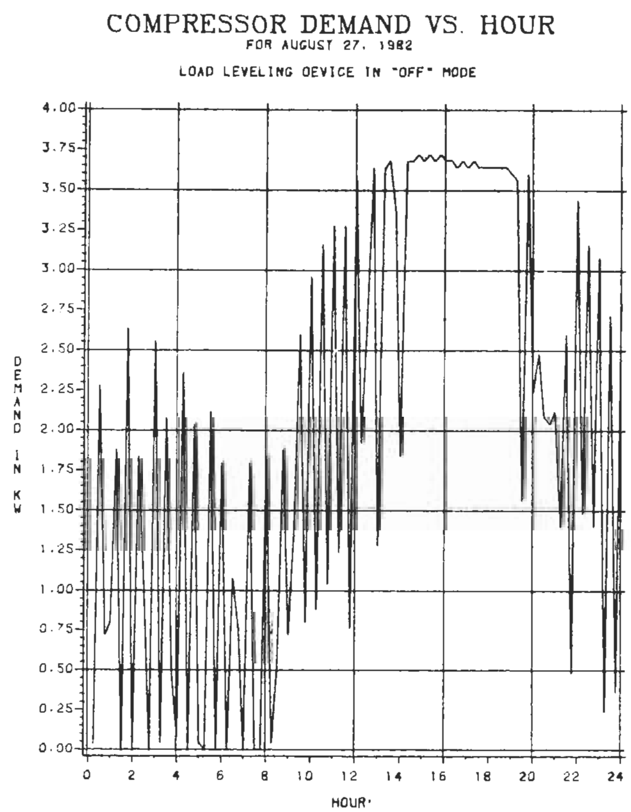

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CHART VII

AMBIENT AIR TEMPERATURE VS. HOUR

FOR AUGUST 26 & 27, 1982

LOAD LEVELING DEVICE "ON" AUG.26
LOAD LEVELING DEVICE "OFF" AUG.27

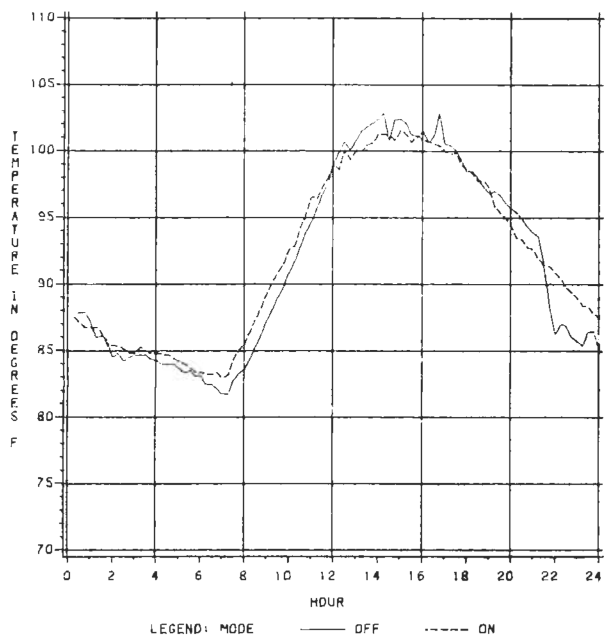

CHART VIII

RETURN AIR TEMPERATURE VS. HOUR

FOR AUGUST 26, 1982

LOAD LEVELING DEVICE IN "ON" MODE

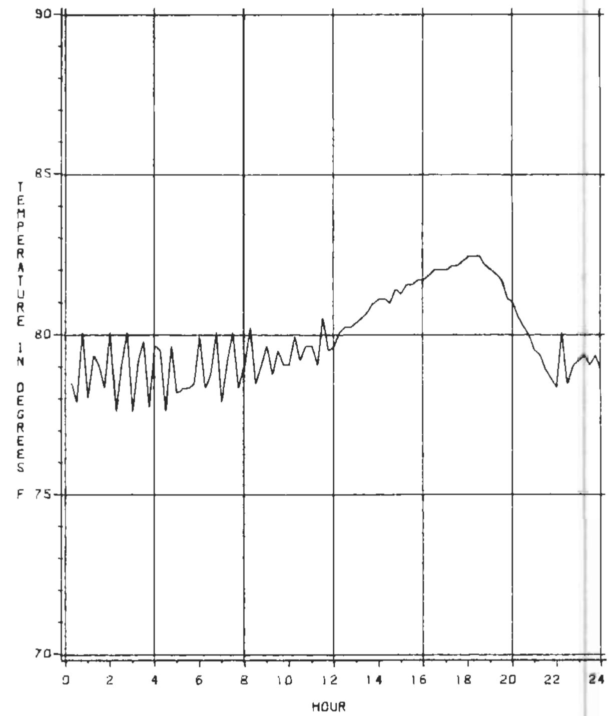

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CHART IX

RETURN AIR TEMPERATURE VS. HOUR

FOR AUGUST 27, 1982

LOAD LEVELING DEVICE IN "OFF" MODE

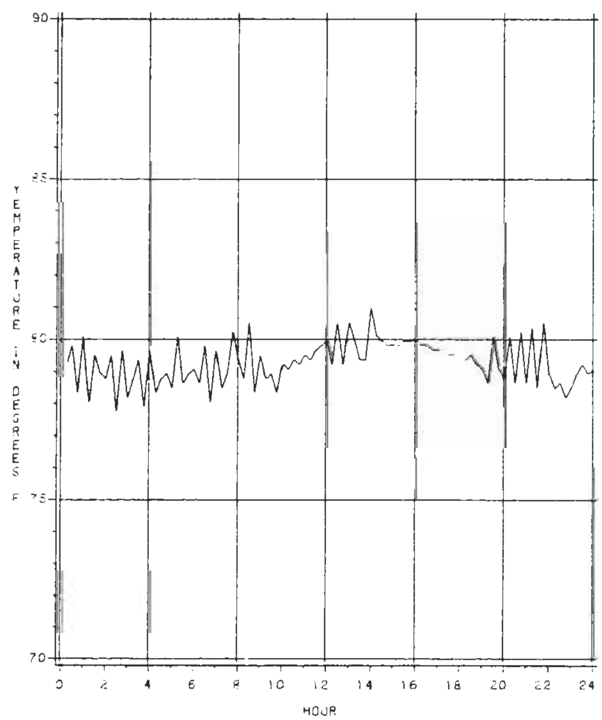

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CHART X

Typical Day Summary

Date	Mode	kWh	kW	Avg. Temp	R.H. (%)
Aug. 27	Off	49.2	3.70	91.5	60
Aug. 26	On	41.6	2.72	91.9	60-65
Difference		7.6	0.98	0.4	5

Chart XI