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EVALUATION OF THE CONSERVATION POTENTIAL
OF A REFIT ENERGY MANAGEMENT SYSTEM
(USING A POWER LINE SUBCARRIER)
IN A LARGE, HIGH-RISE APARTMENT COMPLEX—
PHASE II

MASTER

September 1981

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Prepared by
Herbert E. Hirschfeld, P.E.

For
NEW YORK STATE ENERGY RESEARCH
AND DEVELOPMENT AUTHORITY
ROCKEFELLER PLAZA
ALBANY, NEW YORK 12223
and
BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, LONG ISLAND, NEW YORK 11973
UNDER CONTRACT NO. DE-AC02-76CH00016
with the

U.S. DEPARTMENT OF ENERGY

Office of Building Energy Research
and Development

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**Prepared for
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Rockefeller Plaza
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Associated Universities, Inc.
Upton, Long Island, New York 11973**

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ABSTRACT

An energy conservation study of the application of an energy management system (EMS) utilizing power line subcarrier communication equipment was made in a large apartment building in New York, New York. The building utilized individual cooling and resistance heating units in each apartment. The EMS turned the individual units on and off (with override by tenants) on a schedule determined by the building operator. Summer savings were found to be 11%; winter savings were 20%. Annual savings were projected to be 19%.

The study demonstrated the conservation value of power line subcarrier technology as an alternative to submetering. It also developed and evaluated control strategies for the system and served as a field test to accelerate commercialization of the technology.

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TABLE OF CONTENTS

	<u>PAGE</u>
I. Executive Summary.....	1
II. Analysis.....	9
A. Operational Considerations.....	9
B. Computer Graph Studies.....	11
C. Peak Winter Operation Analysis Update.....	62
D. Potential Energy Savings Analysis Update.....	65
III. Conclusions.....	73
IV. Planned Future Work.....	77
V. Recommendations.....	77

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LIST OF FIGURES

	<u>PAGE</u>
1. Two switch receiver control of heating/air conditioning unit.....	2
2. Energy management system schematic.....	3
3. Daily apartment electrical energy usage versus heating degree days--Tower "A".....	6
4. Daily apartment electrical energy usage versus heating degree days--Tower "B".....	7
5. Daily average partial apartment electrical energy usage versus billing heating degree days per day--Tower "B".....	8

LIST OF TABLES

1. Building Description.....	2
2. Mean Frequency of Occurrence of Dry Bulb Temperature (AFM-88-29).....	68
3. Computation of Peak Winter kWh Energy Savings-- (November to March)--Tower "A".....	69
4. Computation of Peak Winter kWh Energy Savings-- (November to March)--Tower "B".....	69

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LIST OF COMPUTER GRAPHS

<u>GRAPH NO.</u>	<u>PAGE</u>
1. Electrical Consumption--1980--Tower "A" versus Tower "B".....	20
2. Electrical Consumption--1981--Tower "A" versus Tower "B".....	21
3A, 3B. Average Daily Electrical Consumption--1979 to 1981-- Tower "A" only.....	22, 23
4A, 4B. Average Daily Electrical Consumption--1979 to 1981-- Tower "B" only.....	24, 25
5A, 5B. Heating Degree Days and Heating Degree Days per Day-- 1978 to 1981.....	26, 27
6. Electrical Demand--1980--Tower "A" versus Tower "B".....	28
7. Electrical Demand--1981--Tower "A" versus Tower "B".....	29
8. Total Apartment Electrical Consumption--1980-- Tower "A" versus Tower "B".....	30
9. Total Apartment Electrical Consumption--1981-- Tower "A" versus Tower "B".....	31
10A, 10B. Partial Apartment Electrical Consumption-- Meter S3--1978 to 1981--Tower "A" only.....	32, 33
11A, 11B. Partial Apartment Average Electrical Consumption-- Meter S3--1978 to 1981--Tower "A" only.....	34, 35
12A, 12B. Partial Apartment Specific Electrical Consumption-- Meter S3--1978 to 1981--Tower "A" only.....	36, 37
13A, 13B. Partial Apartment Electrical Consumption-- Meter S2--1978 to 1981--Tower "B" only	38, 39
14A, 14B. Partial Apartment Average Electrical Consumption-- Meter S2--1978 to 1981--Tower "B" only.....	40, 41
15A, 15B. Partial Apartment Specific Electrical Consumption-- Meter S2--1978 to 1981--Tower "B" only.....	42, 43

LIST OF COMPUTER GRAPHS (cont.)

<u>GRAPH NO.</u>		<u>PAGE</u>
16A, 16B.	Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--1978 to 1981-- Tower "A" only.....	44, 45
17A, 17B.	Average Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--1978 to 1981-- Tower "A" only.....	46, 47
18A, 18B.	Specific Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--1978 to 1981-- Tower "A" only.....	48, 49
19A, 19B.	Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981-- Tower "B" only.....	50, 51
20A, 20B.	Average Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981-- Tower "B" only.....	52, 53
21A, 21B.	Specific Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981-- Tower "B" only.....	54, 55
22.	Electrical Cost--1980--Tower "A" versus Tower "B".....	56
23.	Electrical Cost--1981--Tower "A" versus Tower "B".....	57
24A, 24B.	Unit Electrical Costs--1978 to 1981.....	58, 59
25.	Apartment Electrical Cost--1980--Tower "A" versus Tower "B"....	60
26.	Apartment Electrical Cost--1981--Tower "A" versus Tower "B"....	61

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Manhattan Plaza Complex

I. EXECUTIVE SUMMARY

An innovative energy management system was originally installed in one of two almost identical apartment towers at Manhattan Plaza in New York City during the summer of 1978. The system was expanded to include the other tower in January 1980. Phase I of this program included the evaluation of the work which was conducted during the time period up to December 31, 1979. This evaluation was prepared in April 1980 by Herbert E. Hirschfeld, P. E. under a contract with the Brookhaven National Laboratory (BNL) and under the sponsorship of the United States Department of Energy, Office of Building Energy Research and Development, and in cooperation with the New York State Energy Research and Development Authority.

This Phase II evaluation considers the work on the conservation program subsequent to January 1, 1980 and up to March 31, 1981. It is prepared with the understanding that all program background particulars, including a detailed description of the energy management system and instrumentation/data acquisition equipment operation, is included in the Phase I report (BNL 51299) and will not be repeated here. A description of the building, a diagram of the unit controls, and a schematic of the EMS are given in Table 1, Figure 1, and Figure 2, respectively.

The energy management system selected was a carrier wave (power line subcarrier or "ripple control") type which utilizes the existing electrical wiring network within the tower to transmit control signals from a central station to electrical loads (heating/air conditioning units) located in the apartments. The system was provided with such design features as receiver override switches and two-address receivers to facilitate use of both time dependent and temperature dependent operating modes. It operated daily unit shutdowns as a function of time and thermostatic lockouts as a function of outside air temperature.

The project objectives were:

1. Investigation of an energy management system presenting an alternative to submetering for energy conservation in large apartment buildings.
2. Demonstration of a new application of existing technology (power line subcarrier) to implement energy conservation in large apartment buildings.
3. Development of various control strategies required to successfully implement energy conservation in large apartment buildings.
4. Development of a market field test (and associated commercialization efforts) of this innovative energy management system to encourage market acceptance of energy conservation controls for large apartment buildings.

Table 1
Building Description

Section of Building	Tower A	Tower B	C	Total
Floor Space Square Feet				
Residential	882,356	883,014	19,400	1,784,770
Commercial	29,470	25,119	3,000	57,589
Total	911,826	908,133	22,400	1,842,359
Number of Apartments				
Studio	306	304	16	626
One Bedroom	398	392	8	798
Two Bedroom	134	132	0	266
Total	838	828	24	1,690
Number of Rooms	2,759	2,726	68	5,553
Number of Heating/Cooling Units	1,504	1,484	32	3,020

Figure 1. Two switch receiver control of heating/air conditioning unit.

Figure 2. Energy management system schematic.

This program, to date, has been, for the most part, successful although with numerous difficulties. These difficulties included several intermittent component failures; programming and operational errors; and interruption of data acquisition. These problems are more fully described in this report.

The significant effects of these project difficulties were:

1. System "down time" during winter months of operation was 30%.
2. Intermediate season thermostatic lockout operation has not been implemented to date. This mode of operation represents 25% of the total potential annual savings in electrical energy by the apartments.
3. Control strategies have not been optimized to date. Each 1% improvement in system efficiency represents approximately an additional \$30,000.00 savings based on 1980 dollars.

In spite of these shortcomings there have been very encouraging, positive results to date:

1. Savings in electrical energy by the apartments during the winter operation has been demonstrated to be 11.5% of the total complex usage and 20.6% of the apartment-only usage. The savings during the winter operation represents 65% of the annual savings.
2. Savings in electrical energy by the apartments during the summer operation has been demonstrated to be 7.2% of the total complex usage and 11.5% of the apartment-only usage. The savings during the summer operation represents 10% of the annual savings.
3. Total annual savings by controlling the apartment heating/air conditioning units only with existing summer and winter strategies and with employing the thermostatic lockout mode during the spring and fall are projected to be 3,285,000 kWh. This represents 10.2% of the total complex usage and 19.5% of the apartment-only usage. This is equivalent to a savings of 5,563 barrels of oil.
4. System performance operating curves for both towers have been developed. Figures 3 and 4 depict daily electrical energy usage in the apartments as a function of outside air temperature (in heating degree days) for both "controlled" and "uncontrolled" modes of operation. Figure 5 is presented to depict the daily average partial apartment electrical energy usage by the 32 metered apartments in the "B" Tower as a function of the average degree day per billing period (heating degree days per day). These curves clearly demonstrate substantial energy savings over long periods of time, utilizing data from 1978 to 1981.

To conclude this study on a positive note is to state that Consolidated Edison Company of New York has engaged Herbert E. Hirschfeld, P. E. to continue this study for the time period October 1, 1981 to March 31, 1982. Objectives established during this additional time period include:

1. The development of a Load Management Plan applicable to Manhattan Plaza.
2. The evaluation of the microprocessor equipment.
3. The expansion of the data collection from March 31, 1981 to December 31, 1981.
4. The initiation of a tenant attitude/behavior study.

A report including these additional findings will be prepared in 1982.

Figure 3. Daily apartment electrical energy usage versus heating degree days--Tower "A".

Figure 4. Daily apartment electrical energy usage versus heating degree days--Tower "B".

Figure 5. Daily average partial* apartment electrical energy usage versus billing heating degree days per day-- Tower "B".

*Metered by S2 for apartments B, C, D, E, F, G, H, K, L, M, N, O, P, and Q--14 of 19 typical.

II. ANALYSIS

A. Operational Considerations

In order to analyze the data collected as part of this evaluation of the energy management system operation, the system "on" time and corresponding mode of operation must be considered.

From January 1, 1980 to March 31, 1981, which is the time period covered by this Phase II report, there were numerous difficulties with equipment and operations which resulted in various periods of uncontrolled building operation. To compare energy usage during time periods, consideration as to whether the building was running in a "controlled" or "uncontrolled" mode must be incorporated into the analysis.

The reasons for uncontrolled operations included:

1. Various microprocessor failures, which included drift in the teletype communications frequency and electrical interference with other monitoring, instrumentation, and interface equipment.
2. Installation wiring deficiencies.
3. Operational and procedural errors in microprocessor programming and in equipment start-up after a microprocessor failure. The incorrect start-up of the motor-generator in the "A" Tower resulted in burning out the motor starter and the subsequent loss of system operation in that tower for almost all of March 1980.
4. Building management elected to run both towers in an uncontrolled mode during various periods of severe cold weather as the Temperature Interface Unit was not operational and, as a result, the automatic low temperature override was not available.
5. Building management elected to run in an uncontrolled mode to collect data and to facilitate tests for the DOE/BNL sponsored study.

These difficulties in the design, installation, and operation of the system were shared by the equipment manufacturer, installation subcontractor, and building operation personnel. The difficulties contributed to an overall reduction in system operation time during the peak winter months in this reporting period by ~30%. Accordingly, data for each tower was reviewed and analyzed on a month-by-month basis to determine if sufficient system "on" time was provided.

Because the energy management system became operational in the "B" Tower in January 1980, all previous data for this tower will pertain to an "uncontrolled" mode of operation. March, November, and December 1980 and February and March 1981 had sufficient control to be considered operation in a "controlled" mode for winter savings analysis.

Both July and August 1980 can also be considered operational in a "controlled" mode for summer savings analysis.

Use of the "A" Tower data was more difficult as the energy management system became operational in this tower in August 1978, and the subsequent metering modification, which isolated the apartment energy usage from the total tower energy usage, was not completed by Con Edison until December 1978. Accordingly, there is no total apartment energy usage data available before this modification.

Additionally, numerous operational changes and associated problems make it more difficult to make meaningful comparisons for specific billing periods in the "A" Tower. It will be shown that the system operating curves depicting daily apartment energy usage as a function of heating degree days for both "controlled" and "uncontrolled" modes of operation, which were generated for the Phase I report, still represent the most meaningful presentation of the system performance. These curves have been subsequently generated for the "B" Tower as well and updated to incorporate data from the winters of 1979 to 1980 and 1980 to 1981.

For the purposes of this evaluation, February and March 1980 and January 1981 were uncontrolled for the "A" Tower.

The winter program, which went into operation during the winter of 1980 to 1981, includes shutdowns at 9 a.m., 11 a.m., 8 p.m., 12 a.m., 2:30 a.m., and a turn on at 7 a.m. The changes from previous winter programs include the deletion of the 4 p.m. to 5 p.m. staged turn on; the deletion of the 5 a.m. to 6 a.m. staged turn on and substitution of the 7 a.m. turn on instead; and the addition of the 8 p.m. shutdown.

The summer program, which was in effect during July and August 1981, included shutdowns at 9 a.m., 11 a.m., and 8 p.m. Management still elected to eliminate the nighttime shutdown during the summer months of operation.

The intermediate program, which was planned for the Spring and Fall of 1980, including the thermostatic lockout during outside air temperatures between 60° and 76°F was not implemented. Failure of the Temperature Interface Unit during Phase I of this program reduced the reliability and confidence in this equipment. Although it was repaired in April 1980, it could not be simultaneously wired into both microprocessors, which are parallel connected, until a Relay Interface Unit was installed during March 1981. Additionally, program modifications requested by building management required preparation of new computer program tapes by the equipment manufacturer. Interim program tapes that were prepared did not provide for interface with

the Temperature Interface Unit. This precluded control of both towers by a single microprocessor interconnected with the Temperature Interface Unit.

During this reporting period, the use of the winter program was extended and the summer program was advanced to provide control for the intermediate spring and fall seasons. Calculations in this report are included to determine potential energy savings by incorporating the thermostatic lockout mode of operation.

Comparisons of winter operations become less precise because of modifications to the program, but on an overall basis have sufficient merit for consideration. Use of both winter and summer data for the "B" Tower is more meaningful because previous to this reporting period there was no "controlled" mode of operation.

B. Computer Graph Studies (1 to 26)

1. Computer Graph 1. Electrical Consumption--1980--Tower "A" versus Tower "B", (p. 20). Tower "A" consumed 16,569,500 kWh or 6.5% more energy than Tower "B" which consumed 15,557,700 kWh. The total electrical consumption for the complex was 32,127,200 kWh.

	<u>"A" Tower</u>	<u>"B" Tower</u>	<u>Total</u>
1980	16,569,500	15,557,700	32,127,200
1979	15,156,000	*15,264,000	30,421,000
1978	14,800,000	*14,469,000	29,270,000

You will note that the increase in the "A" Tower in 1980 over 1979 is 9.33% as compared to the corresponding increase of 1.92% in the "B" Tower during 1980. The significant overall increase of commercial area energy usage is demonstrated here and in subsequent computer graphs.

2. Computer Graph 2. Electrical Consumption--1981--Tower "A" versus Tower "B", (p. 21). Data for January 1981 to March 1981 is presented. Energy usage in the "A" Tower is running 21.5% higher than in the "B" Tower because of significant increase in commercial and health club activities.

3. Computer Graphs 3A and 3B. Average Daily Electrical Consumption--1979 through 1981--Tower "A" Only, (p. 22 and 23). Data previously compiled for 1979 to 1981 in both Phase I and Phase II are further reduced by considering number of days in each billing period to determine average daily usage in "A" Tower. The corresponding days per billing period used throughout this evaluation areas follows:

*EMS not operating.

NUMBER OF DAYS PER BILLING PERIOD

<u>Billing Period</u>	<u>YEAR</u>			
	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>
January	31	31	29	29
February	31	31	31	33
March	29	29	31	29
April	31	31	29	29
May	30	30	30	32
June	30	30	32	30
July	31	31	29	29
August	30	30	30	29
September	29	29	29	32
October	29	32	31	30
November	33	31	32	32
December	30	32	33	31

4. Computer Graphs 4A and 4B. Average Daily Electrical Consumption--1979 through 1981--Tower "B" Only, (p. 24 and 25). Data previously compiled for 1979 to 1981 in both Phase I and Phase II are further reduced by considering number of days in each billing period to determine average daily usage in "B" Tower. Use schedule in Item 3 above.

5. Computer Graphs 5A and 5B. Heating Degree Days and Heating Degree Days Per Day--1978 through 1981, (p. 26 and 27). Total heating degree days for peak winter billing periods (November, December, January, February and March) are presented and factored by number of days per billing period to determine the average heating degree day for period or heating degree day per day. These data permit adjusting winter energy usage data to incorporate the effect of varying outside temperatures in a year-to-year (or month-to-month) energy usage comparison.

This weather data will have a significant effect on the apartment energy usage because the apartments are electrically heated. This weather data, on the other hand, will have limited effect on commercial area energy usage, which has substantial base loads independent of weather.

It should be noted that pertinent cooling degree data have also been collected but is not sufficient to provide separate presentation on computer graphs. These data will be used later in this report to analyze system performance during summer operation and are as follows:

	<u>Cooling Degree Days</u>	<u>CDD/Day</u>
July 1978	316	10.2
July 1979	446	14.4
July 1980	451	15.6
August 1978	337	11.2
August 1979	340	11.3
August 1980	472	15.7

6. Computer Graph 6. Electrical Demand--1980--Tower "A" versus Tower "B", (p. 28). The Tower "A" demand in 1980 was 2.4% above that of Tower "B", a smaller difference than in previous years:

	<u>"A" Tower</u>	<u>"B" Tower</u>
1980	37,880	37,008
1979	36,320	34,440
1978	32,512	30,228

The increase in demand over 1978 in the "A" Tower is 16.5% and in the "B" Tower is 22.4%.

7. Computer Graph 7. Electrical Demand--1981--Tower "A" versus Tower "B", (p. 29). Data for January 1981 to March 1981 are presented.

8. Computer Graph 8. Total Apartment Electrical Consumption--1980--Tower "A" versus Tower "B", (p. 30). The total 1980 electrical consumption by the apartments only in Tower "A" was 8,758,000 kWh. This represents an increase of 4.06% over the 8,416,000 kWh consumed during 1979. This apartment load is measured by the sum of meters S3 and S4 in the "A" Tower. The apartment load represents 52.86% of the total "A" Tower load (1980) as compared with the 55.53% it represented in 1979. This decrease is attributed to the increase in commercial and health club usage.

The apartment load is measured by the sum of meters S2 and S4 in the "B" Tower. The defective S4 meter in the "B" Tower invalidated total apartment energy usage data for August 1979 to January 1980. Data collection was resumed in February 1980.

9. Computer Graph 9. Total Apartment Electrical Consumption--1981--Tower "A" versus Tower "B", (p. 31). Data for January 1981 to March 1981 are presented.

10. Computer Graph 10A and 10B. Partial Apartment Electrical Consumption--Meter S3--1978 to 1981--Tower "A" Only, (p. 32 and 33). Meter S3 monitors the electrical energy usage by the following apartments in the "A" Tower: A, B, C, D, E, F, G, H, J, R, S, and T (12 apartments out of 19 typical).

The apartments metered by S3 in the "A" Tower consumed 5,908,100 kWh in 1980, which represented 35.66% of the total energy consumed in this tower. Comparisons with previous years are as follows:

<u>Year</u>	<u>S3 Consumption</u>	<u>Heating Degree Days</u>	<u>kWh/HDD</u>
1980	5,908,100 kWh	4,408	1,340
1979	5,699,000	3,867	1,474
1978*	6,364,000	4,293	1,482

*EMS became operational in August.

11. Computer Graphs 11A and 11B. Partial Apartment Average Electrical Consumption--1978 through 1981--Meter S3--Tower "A" Only, (p. 34 and 35). Data previously compiled for 1978 to 1981 in both Phase I and Phase II are further reduced by considering number of days in each billing period to determine average daily usage by the S3 metered apartments in the "A" Tower.

12. Computer Graphs 12A and 12B. Partial Apartment Specific Electrical Consumption--1978 through 1981--Meter S3--Tower "A" Only, (p. 36 and 37). The electrical consumption by the S3 apartments in the "A" Tower is adjusted to incorporate the heating degree days for the peak winter months of November, December, January, February, and March, 1978 through 1981.

All data prior to August 1978 pertain to uncontrolled time period, January to March 1978. The winter months where there was a controlled mode of operation in the "A" Tower are March, November, and December 1979; January, November, and December 1980; and February to March 1981.

<u>Uncontrolled</u>	<u>kWh/HDD</u>
January, 1978	943
February, 1978	916
March, 1978	1,002

Average = 953.66 kWh/HDD

<u>Controlled</u>	<u>kWh/HDD</u>
March, 1979	883
November, 1979	970
December, 1979	868
January, 1980	813
November, 1980	823
December, 1980	717
February, 1981	790
March, 1981	899

Average = 845.38 kWh/HDD

The difference between controlled and uncontrolled mode of operation during peak winter months for the "A" Tower is 12.81%. This is substantial proof of the effectiveness of the energy management system operation in the "A" Tower. It should also be noted that in many of the controlled months there were several uncontrolled days which would tend to reduce the overall savings achieved.

13. Computer Graphs 13A and 13B. Partial Apartment Electrical Consumption--Meter S2--1978 to 1981--Tower "B" Only, (p. 38 and 39). Meter S2 monitors the electrical energy usage by the following apartments in the "B" Tower: B, C, D, E, F, G, H, K, L, M, N, O, P, and Q (14 apartments out of 19 typical).

The apartments metered by S2 in the "B" Tower consumed 5,840,400 kWh in 1980, which represented 37.54% of the total energy consumed in this tower. Comparisons with previous years are as follows:

<u>S2 Consumption</u>	
1980	5,840,400
1979*	6,016,000
1978*	6,460,000

*EMS not operating.

14. Computer Graphs 14A and 14B. Partial Apartment Average Electrical Consumption--Meter S2--1978 to 1981--Tower "B" Only, (p. 40 and 41). Data previously compiled for 1978 to 1981 in both Phase I and Phase II are further reduced by considering number of days in each billing period to determine average daily usage by the S2 metered apartments in the "B" Tower.

15. Computer Graphs 15A and 15B. Partial Apartment Specific Electrical Consumption--Meter S2--1978 to 1981--Tower "B" Only, (p. 42 and 43). The electrical consumption by the S2 apartments in the "B" Tower is adjusted to incorporate the heating degree days of the peak winter months of November, December, January, February, and March, 1978 to 1981.

All data prior to January 1980 pertain to the uncontrolled time period, January to March, 1978 and 1979 and November and December 1978 and 1979. The winter months where there were a controlled mode of operation in the "B" Tower are March, November, December, 1980 and February and March, 1981.

<u>Uncontrolled</u>	<u>kWh/HDD</u>
January, 1978	933
February, 1978	883
March, 1978	919
January, 1979	975
February, 1979	871
March, 1979	924

<u>Uncontrolled</u>	<u>kWh/HDD</u>
November, 1978	911
December, 1978	1,040
November, 1979	1,029
December, 1979	899

Average = 938.4 kWh/HDD

<u>Controlled</u>	<u>kWh/HDD</u>
March, 1980	792
November, 1980	782
December, 1980	715
February, 1981	775
March, 1981	870

Average = 786.8 kWh/HDD

The difference between the controlled and uncontrolled mode of operation during peak winter months for the "B" Tower is 19.27%. This is substantial proof of the effectiveness of the energy management system operation in the "B" Tower. This result is probably more indicative of the overall system performance than the calculation for the "A" Tower in Item 12, due to the fact that it is predicated on more recent data.

The specific electrical consumption in the "B" Tower apartments is computed for both controlled and uncontrolled periods from the data in Graphs 5A, 8, and 9. For example, the specific electrical consumption by all apartments in the "B" Tower for March 1980 is 712,800 kWh (from Graph 8) divided by 609 heating degree days (from Graph 5A) yielding 1,170 kWh/HDD.

In similar fashion:

<u>Uncontrolled</u>	<u>kWh/HDD</u>
January, 1979	1,408
February, 1979	1,259
March, 1979	1,372

Average = 1,346.3

<u>Controlled</u>	<u>kWh/HDD</u>
March, 1980	1,170
November, 1980	1,165
December, 1980	1,044
February, 1981	1,145
March, 1981	1,279

Average = 1,160.6

The difference between the controlled and uncontrolled mode of operation during peak winter months for all the apartments in the "B" Tower is 16%.

It should be noted that the generation of Figure No. 5, Page 8, "Daily Average Partial Apartment Electrical Energy Usage versus Billing Heating Degree Days per Day--Tower 'B'," was the result of plotting kWh/day versus HDD/day from Computer Graphs 5B, 14A, and 14B.

This curve, the results of Items 12 and 15 and the updating of the plots of "Daily Apartment Electrical Energy Usage versus Heating Degree Days" for both the towers (Figures 3 and 4, Pages 6 and 7), most strongly demonstrates the overall effectiveness of the energy management system in reducing the energy usage by the apartments.

16. Computer Graphs 16A and 16B. Electrical Consumption Commercial, Health Club, and some Common Areas--Meter S2--1978 to 1981--Tower "A" Only, (p. 44 and 45). The commercial areas, health club, and some of the common areas metered by S2 in Tower "A" consumed 5,158,100 kWh in 1980 compared to 4,441,000 kWh in 1979 and 3,496,000 kWh in 1978, an increase of 16.1% and 47.5%, respectively. These areas represented 31.1% of the total tower consumption in 1980 as compared to only 23.6% in 1978. This significant increase in energy usage by these commercial and public areas has more than offset the reduction in apartment usage. Expansion of the energy management system operation or other conservation techniques would be appropriate for incorporation in these commercial and public areas. The savings achieved may certainly be interpreted at least as a cost avoidance.

17. Computer Graphs 17A and 17B. Average Electrical Consumption--Commercial, Health Club, and some Common Areas--Meter S2--1978 to 1981--Tower "A" Only, (p. 46 and 47). Data previously compiled for 1978 to 1981 in both Phase I and Phase II are further reduced by considering number of days in each billing period to determine average daily usage by the commercial and public areas metered by S2 in the "A" Tower.

18. Computer Graphs 18A and 18B. Specific Electrical Consumption--Commercial, Health Club, and some Common Areas--Meter S2--1978 to 1981--Tower "A" Only, (p. 48 and 49). Since there are substantial base loads in the commercial and public areas which are not temperature dependent, and since these areas are for the most part not under the control of the energy management system, there is no significant value in analyzing these data. These data are presented as shown.

19. Computer Graphs 19A and 19B. Electrical Consumption--Commercial, Building "C", and some Common Areas--Meter S3--1978 to 1981--Tower "B" Only, (p. 50 and 51). The commercial areas, Building "C", and some common areas metered by S3 in Tower "B" consumed 4,144,300 kWh in 1980 compared to 3,988,000 kWh in 1979 and 3,103,000 kWh in 1978, an increase of 3.9% and 33.6%, respectively. These areas represented 26.6% of the total tower consumption in 1980 as compared to 21.4% in 1978.

20. Computer Graphs 20A and 20B. Average Electrical Consumption--Commercial, Building "C", and some Common Areas--Meter S3--1978 to 1981--Tower "B" Only, (p. 52 and 53). Data previously compiled for 1978 to 1981 in both Phase I and Phase II are further reduced by considering number of days in each billing period to determine average daily usage by the commercial areas, Building "C", and public areas metered by S3 in the "B" Tower.

21. Computer Graphs 21A and 21B. Specific Electrical Consumption--Commercial, Building "C", and some Common Areas--Meter S3--1978 to 1981--Tower "B" Only, (p. 54 and 55). Since there are substantial base loads in the commercial and public areas which are not temperature dependent, and since these areas are for the most part not under the control of the energy management system, there is no significant value in analyzing this data. These data are presented as shown.

22. Computer Graph 22. Electrical Cost--1980--Tower "A" versus Tower "B", (p. 56). The cost of electricity for Tower "A" was \$1,223,723.00 or 5.8% more than Tower "B", which was \$1,156,433.00. The total cost for the complex was \$2,380,156.00 or 7.4¢ per kWh in 1980. The overall increase in the electrical cost for the complex was 29.6% over 1979 and 55.2% over 1978, although the increase in energy usage was only 5.6% and 9.8%, respectively. A summary of total complex electrical costs is as follows:

1980	\$2,380,156.00
1979	\$1,836,581.00
1978	\$1,533,938.00

Projected costs for 1981 exceed \$3,000,000.00.

23. Computer Graph 23. Electrical Cost--1981--Tower "A" versus Tower "B", (p. 57). Data for January 1981 to March 1981 are presented.

24. Computer Graph 24A and 24B. Unit Electrical Costs--1978 to 1981, (p. 58 and 59). Cost data for 1978 to 1980 were as follows:

1980	7.40¢ per kWh
1979	6.04
1978	5.24

The average cost of energy in 1980 was 41.2% higher in 1980 than 1978. Costs for the first three months in 1981 averaged at 9.17¢/kWh which is running at 75% higher than 1978. A major factor has been the increase in fuel adjustments during this time period.

25. Computer Graph 25. Apartment Electrical Costs--1980--Tower "A" versus Tower "B", (p. 60). The average monthly electrical cost per apartment (excluding electric consumption not in apartments) in the "A" Tower during 1980 was \$64.36 as compared to \$50.47 for 1979, an increase of 27.52%.

The annual cost of electricity per apartment in the "A" Tower was \$772.32 for 1980 as compared to \$605.60 for 1979.

Monthly data for the "B" Tower apartments are available for all of 1980 except January when the S4 meter was defective.

The increases shown above are almost entirely the result of rate increases.

26. Computer Graph 26. Apartment Electrical Cost--1981--Tower "A" versus Tower "B", (p. 61). The electrical cost data (excluding the commercial and public areas) for January 1981 to March 1981 are presented.

LEGEND INFORMATION

Bar A = MWHR TOWER A
Bar B = MWHR TOWER B

SCALE INFORMATION

Each A = 30.00 MWHR
Each B = 30.00 MWHR

TOTAL A = 16569.50 MWHR
TOTAL B = 15527.70 MWHR

AVERAGE A = 1380.79 MWHR
AVERAGE B = 1296.47 MWHR

Computer Graph 1. Electrical Consumption--1980--Tower "A"
versus Tower "B".

(Units are 1,000 kWh or 1 MWhr)

LEGEND INFORMATION

Bar A = MWHR TOWER A
Bar B = MWHR TOWER B

SCALE INFORMATION

Each A = 30.00 MWHR
Each B = 30.00 MWHR

TOTAL A = 5493.60 MWHR
TOTAL B = 4521.60 MWHR

AVERAGE A = 1831.20 MWHR
AVERAGE B = 1507.20 MWHR

Computer Graph 2. Electrical Consumption--1981--Tower "A"
versus Tower "B".
(Units are 1,000 kWh or 1 MWh)

Computer Graph 3A. Average Daily Electrical Consumption--
1979 to 1981--Tower "A" Only.
(Units are kWh/day in billing period)

LEGEND INFORMATION

Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980

SCALE INFORMATION

Each X = 1250.00 KWHR/DAY
Each Y = 1250.00 KWHR/DAY

AVERAGE X = 35999.34 KWHR/DAY
AVERAGE Y = 44976.00 KWHR/DAY

Computer Graph 3B. Average Daily Electrical Consumption--
1979 to 1981--Tower "A" Only.
(Units are kWh/day in billing period)

LEGEND INFORMATION

Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980
Bar Z = KWHR/DAY 1981

SCALE INFORMATION

Each X = 1250.00 KWHR/DAY
Each Y = 1250.00 KWHR/DAY
Each Z = 1250.00 KWHR/DAY

TOTAL X = 273615.00 KWHR/DAY
TOTAL Y = 268460.00 KWHR/DAY
TOTAL Z = 149582.00 KWHR/DAY
AVERAGE X = 45602.50 KWHR/DAY
AVERAGE Y = 44743.34 KWHR/DAY
AVERAGE Z = 49862.34 KWHR/DAY

Computer Graph 4A. Average Daily Electrical Consumption--
1979 to 1981--Tower "B" Only.
(Units are kWh/day in billing period)

LEGEND INFORMATION

Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980

SCALE INFORMATION

Each X = 1250.00 KWHR/DAY
Each Y = 1250.00 KWHR/DAY

TOTAL X = 223139.00 KWHR/DAY
TOTAL Y = 239829.00 KWHR/DAY

AVERAGE X = 37189.84 KWHR/DAY
AVERAGE Y = 39971.50 KWHR/DAY

Computer Graph 4B. Average Daily Electrical Consumption--
1979 to 1981--Tower "B" Only.
(Units are kWh/day in billing period)

Computer Graph 5A. Heating Degree Days and Heating Degree Days per Day--1978 to 1981.

LEGEND INFORMATION

Bar A = HDD/DAY 1978
Bar B = HDD/DAY 1979
Bar C = HDD/DAY 1980
Bar D = HDD/DAY 1981

SCALE INFORMATION

Each A = 1.00 HDD/DAY
Each B = 1.00 HDD/DAY
Each C = 1.00 HDD/DAY
Each D = 1.00 HDD/DAY

AVERAGE A = 27.90 HDD/DAY
AVERAGE B = 25.02 HDD/DAY
AVERAGE C = 28.02 HDD/DAY
AVERAGE D = 26.00 HDD/DAY

Computer Graph 5B. Heating Degree Days and Heating Degree Days per Day--1978 to 1981.

LEGEND INFORMATION

Bar A = KW TOWER A
Bar B = KW TOWER B

SCALE INFORMATION

Each A = 60.00 KW
Each B = 60.00 KW

TOTAL A = 37880.00 KW
TOTAL B = 37008.00 KW

AVERAGE A = 3156.67 KW
AVERAGE B = 3084.00 KW

Computer Graph 6. Electrical Demand--1980--Tower "A" versus Tower "B".
(Units are in kW)

Computer Graph 7. Electrical Demand--1981--Tower "A" versus
Tower "B".
(Units are in kW)

LEGEND INFORMATION

Bar A = MWHR TOWER A
Bar B = MWHR TOWER B

SCALE INFORMATION

Each A = 15.00 MWHR
Each B = 15.00 MWHR

Computer Graph 8. Total Apartment Electrical Consumption--
1930--Tower "A" versus Tower "B".
(Units are 1,000 kWh or 1MWh)

Computer Graph 9. Total Apartment Electrical Consumption--
1981--Tower "A" versus Tower "B".
(Units are 1,000 kWh or 1MWh)

LEGEND INFORMATION

Bar W = MWHR 1978
 Bar X = MWHR 1979
 Bar Y = MWHR 1980
 Bar Z = MWHR 1981

SCALE INFORMATION

Each W = 15.00 MWHR
 Each X = 15.00 MWHR
 Each Y = 15.00 MWHR
 Each Z = 15.00 MWHR

Computer Graph 10A. Partial Apartment Electrical Consumption--
 Meter S3--1978 to 1981--Tower "A" Only.
 (Units are 1,000 kWh or 1 MWh)

Computer Graph 10B. Partial Apartment Electrical Consumption--
Meter S3--1978 to 1981--Tower "A" Only.
(Units are 1,000 kWh or 1 MWh)

LEGEND INFORMATION

Bar W =	KWHR/DAY	1978
Bar X =	KWHR/DAY	1979
Bar Y =	KWHR/DAY	1980
Bar Z =	KWHR/DAY	1981

SCALE INFORMATION

```
Each W = 750.00 KWHR/DAY
Each X = 750.00 KWHR/DAY
Each Y = 750.00 KWHR/DAY
Each Z = 750.00 KWHR/DAY
```

Computer Graph 11A. Partial Apartment Average Electrical Consumption.--Meter S3--1978 to 1981--Tower "A" Only.
(Units are kWh/day in billing period)

LEGEND INFORMATION

Bar W = KWHR/DAY 1978
Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980

SCALE INFORMATION

Each W = 750.00 KWHR/DAY
Each X = 750.00 KWHR/DAY
Each Y = 750.00 KWHR/DAY

Computer Graph 11B. Partial Apartment Average Electrical
Consumption--Meter S3--1978 to 1981--Tower "A" Only.
(Units are kWh/day in billing period)

Computer Graph 12A. Partial Apartment Specific Electrical Consumption--Meter S3--1978 to 1981--Tower "A" Only.
 (Units are kWh/heating-degree day)

Computer Graph 12B. Partial Apartment Specific Electrical
Consumption--Meter S3--1978 to 1981--Tower "A" Only.
(Units are kWh/heating-degree day)

LEGEND INFORMATION

Bar W = MWHR 1978
Bar X = MWHR 1979
Bar Y = MWHR 1980
Bar Z = MWHR 1981

SCALE INFORMATION

Each W = 15.00 MWHR
Each X = 15.00 MWHR
Each Y = 15.00 MWHR
Each Z = 15.00 MWHR

TOTAL W =	3637.00 MWHR	AVERAGE W =	606.17 MWHR
TOTAL X =	3246.00 MWHR	AVERAGE X =	541.00 MWHR
TOTAL Y =	2839.20 MWHR	AVERAGE Y =	473.20 MWHR
TOTAL Z =	1850.40 MWHR	AVERAGE Z =	616.80 MWHR

Computer Graph 13A. Partial Apartment Electrical Consumption--
Meter S2--1978 to 1981--Tower "B" Only.
(Units are 1,000 kWh or 1 MWh)

LEGEND INFORMATION

Bar W = MWHR 1978
Bar X = MWHR 1979
Bar Y = MWHR 1980

SCALE INFORMATION

Each W = 15.00 MWHR
Each X = 15.00 MWHR
Each Y = 15.00 MWHR

Computer Graph 13B. Partial Apartment Electrical Consumption--
Meter S2--1978 to 1981--Tower "B" Only.
(Units are 1,000 kWh or 1 MWh)

Computer Graph 14A. Partial Apartment Average Electrical Consumption--Meter S2--1978 to 1981--Tower "B" Only.
 (Units are kWh/day in billing period)

LEGEND INFORMATION

Bar W = KWHR/DAY 1978
Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980

SCALE INFORMATION

Each W = 500.00 KWHR/DAY
Each X = 500.00 KWHR/DAY
Each Y = 500.00 KWHR/DAY

Computer Graph 14B. Partial Apartment Average Electrical Consumption--Meter S2--1978 to 1981--Tower "B" Only.
(Units are kWh/day in billing period)

LEGEND INFORMATION

Bar W = KWHR/HDB 1978
Bar X = KWHR/HDB 1979
Bar Y = KWHR/HDB 1980
Bar Z = KWHR/HDB 1981

SCALE INFORMATION

```

EACH W =      15.00 KWHR/HDD
EACH X =      15.00 KWHR/HDD
EACH Y =      15.00 KWHR/HDD
EACH Z =      15.00 KWHR/HDD

```

Computer Graph 15A. Partial Apartment Specific Electrical
Consumption--Meter S2--1978 to 1981--Tower "B" Only.
(Units are kWh/heating-degree day)

Computer Graph 15B. Partial Apartment Specific Electrical
 Consumption--Meter S2--1978 to 1981--Tower "B" Only.
 (Units are kWh/heating-degree day)

Computer Graph 16A. Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--
1978 to 1981--Tower "A" Only.
(Units are 1,000 kWh or 1 MWh)

Computer Graph 16B. Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--
1978 to 1981--Tower "A" Only.
(Units are 1,000 kWh or 1 MWh)

Computer Graph. 17A. Average Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--1978 to 1981--Tower "A" Only.
 (Units are kWh/day in billing period)

LEGEND INFORMATION

Bar W = KWHR/DAY 1978
Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980

SCALE INFORMATION

Each W = 400.00 KWHR/DAY
Each X = 400.00 KWHR/DAY
Each Y = 400.00 KWHR/DAY

Computer Graph 17B. Average Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2-- 1978 to 1981--Tower "A" Only.
(Units are kWh/day in billing period)

Computer Graph 13A. Specific Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--1978 to 1981--Tower "A" Only.
(Units are kWh/heating-degree day)

Computer Graph 18B. Specific Electrical Consumption--Commercial, Health Club, and Some Common Areas--Meter S2--1978 to 1981--Tower "A" Only.
 (Units are kWh/heating-degree day)

Computer Graph 15A. Electrical Consumption--Commercial,
Building "C", and Some Common Areas--
Meter S3--1978 to 1981--Tower "B" Only.
(Units are 1,000 kWh or 1 MWh)

Computer Graph 19B. Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981--Tower "B" Only. (Units are 1,000 kWh or 1 MWh)

LEGEND INFORMATION

Bar U = KWHR/DAY 1978
Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980
Bar Z = KWHR/DAY 1981

SCALE INFORMATION

Each U = 150.00 KWHR/DAY
Each X = 150.00 KWHR/DAY
Each Y = 150.00 KWHR/DAY
Each Z = 150.00 KWHR/DAY

AVERAGE U = 8103.50 KWHR/DAY
AVERAGE X = 11205.67 KWHR/DAY
AVERAGE Y = 11385.67 KWHR/DAY
AVERAGE Z = 12120.33 KWHR/DAY

Computer Graph 2CA. Average Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981--Tower "B" Only.
(Units are kWh/day in billing period)

LEGEND INFORMATION

Bar W = KWHR/DAY 1978
Bar X = KWHR/DAY 1979
Bar Y = KWHR/DAY 1980

SCALE INFORMATION

Each W = 150.00 KWHR/DAY
Each X = 150.00 KWHR/DAY
Each Y = 150.00 KWHR/DAY

AVERAGE W = 8804.33 KWHR/DAY
AVERAGE X = 10466.50 KWHR/DAY
AVERAGE Y = 11156.67 KWHR/DAY

Computer Graph 20B. Average Electrical Consumption--Commercial,
Building "C", and Some Common Areas--Meter S3--
1978 to 1981--Tower "B" Only.
(Units are kWh/day in billing period)

Computer Graph 21A. Specific Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981--Tower "B" Only.
(Units are kWh/heating-degree day)

Computer Graph 21B. Specific Electrical Consumption--Commercial, Building "C", and Some Common Areas--Meter S3--1978 to 1981--Tower "B" Only.
 (Units are kWh/heating-degree day)

Computer Graph 22. Electrical Cost--1980--Tower "A" versus Tower "B".
(Units are dollars)

Computer Graph 23. Electrical Cost--1981--Tower "A" versus
Tower "B".
(Units are dollars)

Computer Graph. 24A. Unit Electrical Costs--1978 to 1981.
 (Units are cents/kWh)

LEGEND INFORMATION

Ear W = CTS/KWHR 1978
 Ear X = CTS/KWHR 1979
 Ear Y = CTS/KWHR 1980

SCALE INFORMATION

Each W = 0.20 CTS/KWHR
 Each X = 0.20 CTS/KWHR
 Each Y = 0.20 CTS/KWHR

AVERAGE W = 5.75 CTS/KWHR
 AVERAGE X = 7.13 CTS/KWHR
 AVERAGE Y = 7.58 CTS/KWHR

Computer Graph 24B. Unit Electrical Costs--1978 to 1981.
 (Units are cents/kWh)

Computer Graph 25. Apartment Electrical Cost--1980--Tower "A"
versus Tower "B".
(Units are dollars/apartment)

Computer Graph 26. Apartment Electrical Cost--1981--Tower "A"
versus Tower "B".
(Units are dollars/apartment)

C. Peak Winter Operation Analysis Update

During Phase I of this evaluation, system performance curves depicting the "A" Tower "controlled" versus "uncontrolled" modes of operation were generated as a function of heating degree days. Additionally, after the Con Edison pulse dump data were analyzed and the computer printouts were corrected to account for different channel pulse multipliers, performance curves depicting the "A" Tower operation versus the "B" Tower operation were also generated. Since there was no energy management system installed in the "B" Tower during this phase, the "B" Tower curves are representative of "uncontrolled" operation.

These curves demonstrated a significant energy savings potential which approximated 1,350,000 kWh for the months of December through February for each tower. Subsequent calculations expanded these savings to approximately 1,693,000 kWh per tower for the time period November through March.

These curves and subsequent calculations, as presented in the Phase I report, were also analyzed by Cosentini Associates, Consulting Engineer to HRJ, and determined to be in fair agreement with their findings. A valid criticism made by Cosentini was that these curves were predicated on a limited amount of data.

Accordingly, it became incumbent to expand this analysis to incorporate winter data accumulated during the winters of 1979-1980 and 1980-1981, largely covered by the Phase II report.

Substantially more data points were available and the performance curves for the "A" Tower were redrawn to incorporate this additional input. Figure 3 presents the revised system performance curves depicting both "uncontrolled" and "controlled" modes of operation as a function of the heating degree days for winter operation.

Since the energy management system became operational in the "B" Tower in January 1980, sufficient data points became available to generate a similar set of curves for the "B" Tower; refer to Figure 4.

The potential energy savings have been revised in this report to reflect these curves and other operating data collected during this phase. Comparison of Figures 3 and 4 will show that they are in fair agreement with each other, which would be expected, and present somewhat more conservative estimates than the data collected during Phase I.

In an effort to examine the system performance over longer periods of time rather than the daily approach depicted by Figures 3 and 4, all the data as presented by the computer graphs were analyzed.

Examination of Computer Graphs 5B and 14A and 14B yield the following data from the S2 metered apartments in the "B" tower:

Figure 3. Daily apartment electrical energy usage versus heating degree days--Tower "A".

Figure 4. Daily apartment electrical energy usage versus heating degree days--Tower "B".

<u>Uncontrolled</u>	<u>kWh/day</u>	<u>HDD/day</u>
January, 1978	35,225	37.8
February, 1978	32,516	36.8
March, 1978	18,448	20.1
January, 1979	31,581	32.4
February, 1979	30,322	34.8
March, 1979	16,448	17.8
November, 1978	16,211	17.8
December, 1978	28,133	27.0
November, 1979	16,612	15.2
December, 1979	22,437	24.9

<u>Controlled</u>	<u>kWh/day</u>	<u>HDD/day</u>
March, 1980	15,561	19.6
November, 1980	16,012	20.5
December, 1980	26,326	35.7
February, 1981	18,327	23.6
March, 1981	14,979	17.2

When kWh/day is plotted as a function of HDD/day, Figure 5 curves for both "controlled" and "uncontrolled" mode of operation are generated.

Both Figures 4 and 5 can be used to check each other. Note that the S2 meter in the "B" Tower monitors 14 and 19 typical apartments or 74% of the apartment energy usage.

From Figure 4 at 30 HDD:

Total apartment energy (uncontrolled) = 38,000 kWh
Total apartment energy (controlled) = 30,000 kWh

74% of 38,000 kWh = 28,120 kWh

74% of 30,000 kWh = 22,000 kWh

From Figure 5 at 30 HDD:

S2 Apartment energy (uncontrolled) = 28,000 kWh
S2 Apartment energy (controlled) = 23,000 kWh

Note the fair agreement with the points on both Figures 4 and 5.

D. Potential Energy Savings Analysis Update

1. Peak Winter Savings Analysis. Figures 3 and 4 and the Weather Data presented by AFM-88-29 are used to determine the potential energy savings in both the "A" and "B" Towers by controlling the apartment heating units during the winter months of November to March by the ASHRAE bin method.

Figure 5. Daily average partial* apartment electrical energy usage versus billing heating degree days per day-- Tower "B".

*Metered by S2 for apartments B, C, D, E, F, G, H, K, L, M, N, O, P, and Q--14 of 19 typical.

Table 2 presents the mean frequency of occurrence of dry bulb temperature for the New York City area. These data are used to compute the total days during these winter months at specific temperature levels.

Figures 3 and 4 are employed to determine the daily energy savings at the mean of the various temperature intervals depicted. The savings are determined by subtracting the daily energy usage in the controlled mode of operation from the daily energy usage in the uncontrolled mode of operation.

Tables 3 and 4 present the calculation of energy savings by taking the sum of the individual products of total days times daily energy savings.

The results are as follows:

"A" Tower - 1,028,262 kWh
 "B" Tower - 1,115,524
 Average - 1,071,893 kWh

2. Summer Savings Analysis. Computer Graph 13B and weather data from the National Oceanic Atmospheric Administration are used to determine the energy savings in both the "A" and "B" Towers obtained by controlling the apartment air conditioning units during the months of July and August.

Computer Graph 13B presents the S2 metered apartment energy usage in the "B" Tower both during the "controlled" and "uncontrolled" modes of operation.

The weather data provide the cooling degree days during the appropriate billing period.

<u>Controlled</u>	<u>kWh</u>	<u>CDD</u>
July, 1980	506,400	451
August, 1980	508,800	472
Totals:	1,015,200	923
kWh/CDD =	1,100.0	

<u>Uncontrolled</u>	<u>kWh</u>	<u>CDD</u>
July, 1978	432,000	316
August, 1978	456,000	337
July, 1979	523,000	446
August, 1979	391,000	340
Totals:	1,802,000	1,439
kWh/CDD =	1,252.3	

Table 2
Mean Frequency of Occurrence of Dry Bulb Temperature
(Based on Engineering Weather Data--AFM 88-29)

Temperature	Month					Total Hours	Total Days
	November	December	January	February	March		
60/64	63	5	3	3	22	96	4.0
55/59	89	21	6	8	29	153	6.4
50/54	124	29	18	20	59	250	10.4
45/49	126	58	41	45	98	368	15.3
40/44	130	111	93	99	157	590	24.6
35/39	111	160	155	162	187	775	32.3
30/34	58	143	161	140	111	613	25.5
25/29	13	99	118	86	48	364	15.2
20/24	5	64	75	53	25	222	9.3
15/19	1	38	44	29	5	117	4.8
10/14	0	13	19	17	2	51	2.1
5/9	0	3	7	7	0	17	0.7
0/4	0	0	1	1	0	2	0.1
	720	744	741	670	743	3,618	150.7

Table 3
Computation of Peak Winter kWh Energy Savings
(November to March) Tower "A"

Temperature	Total Days	X	Daily kWh Savings *	=	Total kWh Savings
60/64	4.0		750		3,000
55/59	6.4		1,875		12,000
50/54	10.4		2,500		26,000
45/49	15.3		3,750		57,375
40/44	24.6		5,000		123,000
35/39	32.3		7,500		242,250
30/34	25.5		8,750		223,125
25/29	15.2		10,000		152,000
20/24	9.3		10,625		98,812
15/19	4.8		11,250		54,000
10/14	2.1		12,500		26,250
5/9	0.7		13,000		9,100
0/4	0.1		13,500		1,350
			TOTAL	=	1,028,262 kWh

*From Figure 3.

Table 4
Computation of Peak Winter kWh Energy Savings
(November to March) Tower "B"

Temperature	Total Days	X	Daily kWh Savings *	=	Total kWh Savings
60/64	4.0		750		3,000
55/60	6.4		1,875		12,000
50/54	10.4		2,500		26,000
45/49	15.3		3,750		57,375
40/44	24.6		5,000		123,000
35/39	32.3		7,500		242,250
30/34	25.5		9,375		239,062
25/29	15.2		11,250		171,000
20/24	9.3		13,125		122,062
15/19	4.8		15,000		72,000
10/14	2.1		16,250		34,125
5/9	0.7		17,000		11,900
0/4	0.1		17,500		1,750
			TOTAL	=	1,115,524 kWh

*From Figure 4.

The kWh/CDD for the "uncontrolled" mode of operation is 13.85% greater than the kWh/CDD for the "controlled" mode of operation.

The savings is the difference of 152.3 kWh per CDD. Since the S2 meter monitors ~74% of the apartments, this factor is adjusted to 205.8 kWh/CDD.

During the past three summers (1978-1980) the average CDD per July through August season has been 787.3.

$$\text{Savings} = 787.3 \times 205.8 = 162,033 \text{ kWh per tower.}$$

3. Intermediate Season Savings Analysis. Weather data presented by AFM-88-29 were used to determine the potential energy savings achieved by utilizing the thermostatic lockout strategy at outside air temperatures between 60 and 76°F.

The number of hours during the intermediate season when the temperature is in the 60 to 76° range is:

<u>Month</u>	<u>Number of Hours</u>
April	129
May	346
June	442
September	437
October	282
	<hr/>
	1,636 hours

Observation of the system during the past three years when shutdowns have occurred during an intermediate season indicates that a conservative reduction of 250 kW can be accomplished in each tower.

$$\text{Savings} = 250 \times 1,636 = 409,000 \text{ kWh per tower.}$$

Since this strategy has not been employed to date, a significant portion of potential savings has not yet been accomplished.

4. Summary of Savings Analysis. A summary of real and projected apartment annual energy savings is:

- a. Winter (November to March).....1,071,893 kWh
- b. Summer (July and August)..... 162,033
- c. Intermediate (April, May, June, Sept., and Oct.)..... 409,000

Total.....1,642,926 kWh
per tower

or 3,285,852 kWh for both towers.

The above compares to 4,347,092 kWh projected at the end of Phase I.

This total savings of 3,285,852 kWh represents 10.2% of the total complex electrical energy usage during 1980 and also represents approximately 19.5% of the total apartment electrical energy usage during 1980.

The above figures are converted to equivalent barrels of oil by these factors:

- a. plant fuel to electrical conversion efficiency = .33
- b. Btu/gallon of fuel = 144,000
- c. gallons per barrel of fuel = 42
- d. Btu/kWh = 3,413

$$\text{Equivalent barrels} = \frac{3,413 \times 3,285,852}{144,000 \times .33 \times 42} = 5,563$$

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III. CONCLUSIONS

1. The application of the energy management system in both towers at Manhattan Plaza has clearly demonstrated the potential for significant electrical energy savings during the peak winter months of operation. Savings which represent 11.5% of the total complex electrical energy usage and 20.6% of the apartment only electrical energy usage are projected (based on results achieved to date and presented in this report) for the winter months of operation (November to March). Approximately 65% of the total annual savings achieved are accomplished during these winter months of operation.

2. The application of the energy management system in both towers at Manhattan Plaza has demonstrated potential electrical energy savings during the summer months of July and August. Savings, which represent 7.2% of the total complex electrical energy usage and 11.5% of the apartment only electrical energy usage, are projected (based on results achieved to date and presented in this report) for the summer months of July and August. Approximately 9.9% of the total annual savings achieved are accomplished during these summer months of operation. Further work with the program strategies employed during the summer season operation should improve these savings statistics.

3. Analyses are presented in this report to demonstrate significant potential savings during the intermediate (Spring and Fall) seasons by employing the thermostatic lockout during moderate outside air temperature periods. Savings, which represent 9.2% of the total complex electrical energy usage and 19.9% of the apartment only electrical energy usage, are projected by employing the thermostatic lockout during the months of April, May, June, September, and October. Approximately 24.9% of the total annual savings can be achieved during these intermediate season months of operation.

Intermittent failures of the Temperature Interface Unit, need for the incorporation of relay Interface Unit between the parallel connected micro-processors and the Temperature Interface Unit, and program modifications requiring new program tapes have largely precluded the use of the thermostatic lockout mode of operation to date. Although the technical problems described have been subsequently overcome, longer periods of reliable system operation are required before this mode of operation will be employed.

4. Total annual savings by controlling the apartment heating/air conditioning units only are projected to be approximately 3,285,000 kWh, which represents ~10.2% of the total complex electrical energy usage and 19.5% of the apartment only electrical energy usage. This is equivalent to 5,563 barrels of oil saved.

Expansion of the energy management system capabilities by controlling equipment contained in common areas, commercial areas and the health club and garage facilities can offer attractive additional energy savings. Additional

work in this area is recommended to improve the overall effectiveness of the energy management system, especially when noting that the electrical energy usage by the apartments only is approximately 54% of the total complex usage, the balance of 46% being attributed to these common, public, and commercial areas.

5. The energy conservation program at Manhattan Plaza has successfully demonstrated the application of the power line subcarrier ("ripple control") as a communications vehicle to transmit control signals as an integral part of an energy management system for a large, high-rise apartment building application. The signals were consistently transmitted and received with sufficient strength to control the heating/air conditioning units located throughout each building network. The equipment associated with the transmission and reception of the "ripple control" signals has operated reliably throughout the time covered by the Phase I and Phase II (August 1978 to March 1981) evaluation. The reliability of the receivers exceeded the end user's expectations.

On the other hand, equipment difficulties have been experienced with sensor interface equipment, the microprocessors, and the instrumentation and data acquisition equipment.

The intermittent failures associated with the Temperature Interface Unit and the microprocessors have resulted in a reduction in the system "on" time and subsequent loss in energy savings, and have precluded the use of "temperature dependent" operating modes which would add substantially to the savings achieved.

The difficulties associated with the Temperature Interface Unit have been subsequently identified and corrected. The difficulties associated with the microprocessors appear to be related to a drift in the teletype communications frequency and electrical interference associated with the "B" microprocessor and its interconnection and/or proximity with instrumentation/data acquisition equipment subsequently added by BNL/DOE. The evaluation of the microprocessors is not covered within the Phase II time frame.

6. The scope of the tasks originally anticipated for this program were significantly underestimated. This has dramatic consequences on the pay-back period originally forecast for the energy management system.

The intermittent component failures, the length of time required for the computer program development and subsequent modifications, the addition of instrumentation/data acquisition equipment, and installation delays have increased the system start-up period from one- to an approximate three-year time period.

To stretch out a three year return-on-investment to almost five years seriously alters the economic viability of such an energy conservation program for this type application. The experience gained in this project can serve to reduce start-up times substantially in future related projects.

A major area which was underestimated was the technical support and man power required to successfully move this project through the program development stages. During the time period of May to August 1980, the equipment manufacturer was undergoing a major reorganization which led to the formation of a new joint venture (RTE-Zellweger) responsible for handling the Manhattan Plaza program. The lack of required support during this time period underscored the need for a strong field service capability to successfully support such a project as Manhattan Plaza.

The New York City Department of Housing Preservation and Development stated that without the support of the Brookhaven National Laboratory and the United States Department of Energy through the efforts of Herbert E. Hirschfeld, P.E., the energy conservation program at Manhattan Plaza may have had to be abandoned.

7. The energy conservation program at Manhattan Plaza had demonstrated itself to be an important part of the commercialization effort of energy conservation controls for large, high-rise apartment buildings. The establishment of a "show place" for builders to witness firsthand the operation of this system should accelerate the market acceptance of this type of conservation control equipment. The success and problems of this program can both be of great value to the commercialization efforts of other suppliers in this marketplace since they can learn from our experience.

During Phase II of this program there were certain events which have significant commercialization value. Some of these are listed below:

- a. A demonstration of the system operation for the New York State Energy Office on June 25, 1980; the New York City Energy Office on August 8, 1980; and the New York State Urban Development Corporation on September 30, 1980.
- b. A demonstration of the system operation for the delegation from Helsinki, Finland, on August 1, 1980.
- c. A presentation of the energy conservation program to the International Energy Agency at Princeton University on October 31, 1980. Attending were member nations of Annex III--Italy, Belgium, Switzerland, Sweden, Denmark, Netherlands, and the United States.
- d. Publication of a description of the energy conservation program at Manhattan Plaza in Energy User News, October 13, 1980 edition.
- e. A briefing of the system operation to the New York State Public Service Commission on November 20, 1980 and the United States Department of Energy on January 13, 1981.

8. Instrumentation/data acquisition equipment has demonstrated itself to be an important component of the energy management system. The kW (instantaneous demand) meters for both towers have been particularly useful in detecting system "down" periods due to microprocessor failures. These meters also verified improper use of the EPG device when attempts were made by building operating personnel to restore use of apartment heating/air conditioning units (which were thermostatically locked-out due to a stalling microprocessor in the middle of transmission periods). These kW meters showed, on several occasions, that the EPG device was used to "open" the switch in the thermostat circuit rather than "close" this switch.

The computer graphs depicting the system operational characteristics were generated as part of the instrumentation/data acquisition contract.

9. The tenant behavioral patterns and psychological considerations have demonstrated themselves to be significant factors in this energy conservation program. Attempts to educate the tenants and solicit their support were made throughout this phase of the program. Herbert E. Hirschfeld, P.E. wrote monthly articles in the Manhattan Plaza News which kept the tenants abreast on new developments regarding the energy conservation program. A presentation to the tenants committee on March 13, 1980 was made to answer questions regarding the operation of this system. Tenant education has improved their cooperation, but building management has been quite conservative in implementing program changes in order to minimize any disruption to the tenant. The maintenance of a good tenant-landlord relationship is an essential ingredient to a successful energy conservation program.

10. The failure of the Temperature Interface Unit and the subsequent loss of temperature dependent operating modes provided the opportunity for the further development of time dependent modes as effective control strategies. The time dependent mode of operation, such as the daily shut-downs, has demonstrated itself to be a more significant factor than originally anticipated.

11. Defective magnetic tapes and time shifted print-outs in 17 Con Edison tapes and the lack of data from J & C Lamb Corporation significantly complicated the analyses associated with evaluating the performance of the energy management system. To put this in proper perspective consider that a new tape is required every two weeks for each tower. This means that approximately one third (32.7%) of all data tapes were either defective or in error. Errors ranged from 6% to 212% per tape.

This program has been helpful to Con Edison in identifying various shortcomings in their data collection and computer programming procedures. Steps have been undertaken to correct these deficiencies.

IV. PLANNED FUTURE WORK

Con Edison has made a commitment to continue the work undertaken by this BNL/DOE sponsored study. Their commitment is to extend the data collection period from March 31, 1981 to December 31, 1981 and prepare a report incorporating this additional data. Herbert E. Hirschfeld, P.E. has been retained by Con Edison, effective October 1, 1981, to be the principal consultant and work with Con Edison until March 31, 1982. The major objective developed jointly by Con Edison and Mr. Hirschfeld are:

- a. The development of a load management plan applicable to Manhattan Plaza incorporating new time-of-day (TOD) billing.
- b. The evaluation of the microprocessor.
- c. The expansion of data collection to December 31, 1981.
- d. The initiation of a tenant attitude/behavior study.

V. RECOMMENDATIONS

1. The United States Department of Housing and Urban Development has a 40 year commitment at Manhattan Plaza under Section 8 and presently provides an annual subsidy of approximately \$10,000,000.00. This \$400,000,000.00 commitment may be substantially reduced by improving the effectiveness of the energy management system. This is put into proper perspective when noting that in 1980 approximately 25% of the annual subsidy was used to pay for electricity and that this cost for electricity in 1981 will be approximately double what it was in 1978.

An obvious recommendation is for the United States Government, through HUD or DOE or whatever appropriate agency, to continue this conservation program at Manhattan Plaza. An improvement in system operation of 5% will yield a savings to the United State Government of an additional \$150,000.00 in 1980 dollars.

2. The energy management system is presently controlling the apartment heating/air conditioning units. The apartments themselves represent only 54% of the total complex electrical energy usage. Expansion of the system to control equipment in the commercial, common, and public areas (including the health club and garage) is recommended. These additional areas represent 46% of the total complex electrical energy usage.

3. The new commitment by Con Edison to support this study until March 31, 1982 will yield these benefits:

- a. Increase data collection until December 31, 1981;
- b. development of a load management plan for Manhattan Plaza to reduce kW charges in addition to kWh charges;
- c. evaluation of microprocessor;
- d. initiation of a tenant attitude/behavior study.

Financial support and full cooperation by the building management to this additional study is strongly recommended.

The development of a subsequent follow-up program to maintain, monitor, and evaluate the energy management system by building management or designated consultants should be implemented. This program, to date, has demonstrated that program refinements and improvements are tedious and time consuming procedures. Continued work is required to maintain the system at peak operating efficiency.