**ANALYSIS OF FUEL SAVINGS ASSOCIATED WITH FUEL COMPUTERS
IN MULTIFAMILY BUILDINGS**

Final Report

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ABSTRACT

This research was undertaken to quantify the energy savings associated with the installation of a direct monitoring control system (DMC) on steam heating plants in multi-family buildings located in the New York City metropolitan area. The primary objective was to determine whether fuel consumption was lower in buildings employing a DMC relative to those using the more common indirect monitoring control system (IMC) and if so, to what extent.

The analysis compares the fuel consumption of 442 building over 12 months. The type of control system installed in these buildings was either a Heat-Timer (identified as IMC equipment) or a computer-based unit (identified as DMC equipment).

IMC provides control by running the boiler for longer or shorter periods depending on outdoor temperature. This system is termed indirect because there is no feedback from indoor (apartment) temperatures to the control. DMC provides control by sensing apartment temperatures. In a typical multifamily building, sensors are hard wired to between 5 and 10 apartments sensors.

The annual savings and simple payback were computed for the DMC buildings by comparing annual fuel consumption among the building groupings. The comparison is based on mean BTUs per degree day consumed annually and normalized for building characteristics, such as, equipment maintenance and boiler steady state efficiency as well as weather conditions. The average annual energy consumption for the DMC buildings was 14.1 percent less than the annual energy consumption for the IMC buildings. This represents 3,826 gallons of No.6 fuel oil or \$2,295 at a price of \$0.60 per gallon.

A base DMC system costs from \$8,400 to \$10,000 installed depending on the number of sensors and complexity of the system. The standard IMC system costs from \$2,000 to \$3,000 installed. Based on this analysis the average simple payback is 2. or 4.0 years depending on either an upgrade from IMC to DMC (4.0 years) or a new installation (2.9) years.

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SUMMARY

"Fuel computer" manufacturers claim that 25 to 30 percent savings in fuel costs can be realized through the installation of direct monitoring control equipment on boilers serving multifamily buildings. The purpose of this research was to determine whether fuel consumption was lower among multifamily buildings that have installed the fuel computer control system, and if so, to what extent.

This analysis compares the 12 month fuel consumption of 442 buildings gathered between 1987 and 1992. One group of buildings (204) employed DMC during the study; the remainder (238) used IMC. The average annual fuel consumption for DMC buildings was 14.1 percent less than that of the IMC buildings. This represents 3,826 gallons of No.6 fuel oil or \$2,295 at a price of \$0.60 per gallon.

Each building's fuel history was entered into a database after having been energy audited, either privately, or as part of programs funded by the New York State Energy Office. Fuel consumption for a previous twelve-month period was recorded at the time of the audit and provided the basic data for this study.

IMC is the predominant means of controlling boilers in New York City multifamily buildings. When the outdoor temperature drops below a preset level the IMC starts the boiler. The IMC runs the boiler until it obtains indirect confirmation that steam has reached every radiator in the building either from a dedicated pressuretrol on the boiler or a reverse acting aquastat on a distant dry return line. When a predetermined pressure setting or condensate return temperature is reached, the controller assumes that heat has been established throughout the building and now begins a 60-minute cycle. Run-time during the cycle is determined by outdoor temperature and a trim control. Following the completion of the allocated run-time, the boiler remains off until the start of the next 60-minute cycle. This system is called "indirect" because the feedback between indoor (apartment) temperatures and the control is indirect, i.e. boiler pressure or condensate temperature.

DMC is essentially a thermostat with multiple sensors. In a typical multifamily building installation, depending on the manufacturer, 5 to 10 apartments are hard-wired with temperature sensors. A sensor is usually located along an interior wall far enough from the radiators so that a "representative" room temperature is recorded. The sensor relays the apartment temperature to a central microprocessor, which then runs the boiler.

Although the DMC and IMC buildings were not selected randomly, simple statistical procedures confirm that direct monitor control is associated with significantly lower fuel consumption when other building and environmental factors are held constant. It is believed that since the sample population is comprised of 442 buildings, a replication of this investigation using data from different buildings would almost certainly yield similar results.

Section 1

INTRODUCTION

Research Objectives

This research was undertaken by the Energy Authority to quantify the energy savings associated with the installation of a direct monitoring control system (DMC) on steam heating plants in multi-family buildings located in the New York City metropolitan area. The primary objective was to determine whether fuel consumption was lower in buildings employing a DMC relative to those using the more common indirect monitoring control system (IMC) and if so, to what extent.

The annual savings and simple payback were computed for the DMC buildings by comparing annual fuel consumption among the building groupings. The comparison is based on mean BTUs per degree day consumed annually and normalized for building characteristics, such as, equipment maintenance and boiler steady state efficiency as well as weather conditions. The average annual energy consumption for the DMC buildings was 14.1 percent less than the annual energy consumption for the IMC buildings. This represents 3,826 gallons of No.6 fuel oil or \$2,295 at a price of \$0.60 per gallon.

Many factors influence a multifamily building's energy use. These include, the condition of the boiler and burner; upkeep and maintenance of the boiler and steam distribution systems; and the building's domestic hot water load. It is the opinion of the researchers, however, that if a multifamily building has a well maintained heating plant and if it does not have a comparably large domestic hot water load, lower annual fuel use is predicted for those buildings employing a DMC system.

Less than 10 percent of the eligible multifamily buildings in New York City employ DMC control. The results of this research indicate that a significant reduction in fuel consumption for multifamily buildings in the New York City area is possible by employing DMC equipment.

Overview of The Control Systems

Indirect Monitoring Control (IMC)

Heating plants in the vast majority of multifamily buildings in New York City are controlled by a system that monitors outside temperature in conjunction with boiler pressure or condensate return temperature. The control tends to overheat buildings because there is no direct feedback between actual apartment temperatures and the boiler. For the purposes of this report we have designated this an indirect monitor control system or IMC. We estimate that, of the approximately 125,000 multifamily buildings in New York City over 97 percent employ an IMC control.

IMC equipment is tailored to the New York City Multiple Dwelling Law requirement to maintain an indoor temperature by day of 68°F when the outside temperature drops below 55°F, and by night an indoor temperature of 55°F when the outside temperature drops below 40°F.¹ The most prevalent models of this type of control equipment in the New York City metropolitan area are made by Heat-Timer; other manufacturers include Fuel Watchman and American Steam Timer.

Figure 1-1, illustrates an IMC system. When there is a call for heat, the burner fires for an extended period until heat is established. This is done indirectly, either by a signal from a dedicated pressuretrol mounted on the boiler or a reverse-acting aquastat mounted on a dry return. The premise is that elevated pressure in the boiler or elevated condensate temperature is an indicator of a full distribution system.

1. Section 79(1) of the Multiple Dwelling Law as amended by Chapter 485 and the Laws of 1966.

Figure 1-1

TYPICAL IMC SYSTEM

Figure 1-2 illustrates the typical Heat-Timer² cycle. Once circulation is established, a 60-minute cycle clock begins. The burner will fire for a fixed amount of time during the 60 minute cycle, depending on two inputs: the outdoor temperature and the setting of a "Heat Adjustment". The heat adjustment varies the on-cycle by a factor of approximately 5 to 1.

Figure 1-2
HEAT-TIMER CYCLE

Heat Adjustment		Outdoor Temperature (°F)						
		20	25	30	35	40	45	50
A-		21	17	15	12	10	8	6
B-		25	20	17	15	13	11	8
C-		34	29	24	20	17	15	13
D-		42	35	30	26	22	19	16
E-		52	43	35	30	26	23	20
F-		58	54	47	40	34	29	25
G-		60	60	49	44	39	34	29
H-		60	60	56	50	44	38	53
I-		60	60	60	54	47	41	36
J-		60	60	60	60	52	46	40

Once the on-time period has passed, the boiler remains off until the 60 minute cycle is complete. If there is still a call for heat, the cycle begins again.

Direct Monitoring Control (DMC)

More than a decade ago a new type of boiler control system was introduced to multifamily buildings. The spur to its development was the need for hourly temperature recordings by building owners and managers of multifamily buildings to combat heat complaints filed with the City. Manufacturers include Optimum Applied Systems (OAS), US Energy Controls and Compusave.

2. Heat-Timer Corporation Literature - Approximate number of minutes of heat per hour after heat circulation has been established.

In recent years these early units have been upgraded and redesigned to provide full control of the boiler system and specific data on the operation of the heating system.

As illustrated in Figure 1-3, a typical base system will include a central processing unit, 5 to 10 apartment temperature sensors, boiler aquastat, flue gas temperature thermistors, modem and software.

The boiler starts when either a majority of, or the average of temperatures reported by the sensors fall below the building setpoint, usually 68°F. The controller shuts off the boiler when the majority (or average) rises above another setpoint, usually 72°. Since the controller is monitoring apartment temperatures, the control system responds directly to space conditions.

Figure 1-3

TYPICAL DMC SYSTEM

Section 2

DESIGN OF THE STUDY

Building Selection Process

Names and addresses of multifamily building owners and management firms were obtained from a number of sources. The IMC building data was obtained primarily from EME's extensive files of previously performed energy audits. The DMC building listing was obtained primarily from two manufacturers, OAS and US Energy Systems.

The building owners with DMC equipment were contacted by EME and asked to participate in the project. To encourage their participation, EME provided, at no cost, a complete survey of their boiler including a steady state efficiency test and summary report, a value of approximately \$750. With this incentive, 204 building owners participated.

The building owners were required to provide EME with the building's most recent 12 months of fuel consumption data, and permission to survey the building. Once permission was obtained, the surveys were scheduled and performed.

Variables for Analysis and Rationale for Their Selection

The purpose of the survey was to obtain heating plant and envelope characteristics of the buildings. Building parameters collected were: number of apartments, window glazing, i.e. single-glazed wooden windows vs. aluminum framed, occupancy and building area.

Heating plant parameters collected were: boiler capacity, fuel type, steady-state efficiency, boiler model, and boiler age, and description; boiler insulation condition, and the field technician's opinion of the upkeep and maintenance of the boiler. Much of the information on boiler maintenance was obtained by interviewing the superintendent. The maintenance questions included whether the boiler has water treatment; the frequency of boiler tune-ups and cleaning; and the occurrence of mechanical problems.

Similar building-specific information for the IMC buildings was collected. IMC building data were collected through a number of sources: contractor's files, building owner interviews and site visits, and through the New York City Building Department. Data were

collected for a total of 238 IMC buildings.

The rationale for collecting the physical and boiler characteristics of each building was to identify the variables which might affect fuel consumption. Once pinpointed, these variables could be normalized such that the comparison of fuel consumption between building groups could be accomplished with a greater degree of confidence.

Building Specific Variables

Once the database of IMC and DMC buildings was developed, buildings were grouped according to number of units: less than 20; 20 to 49; 50 to 74; 75 to 99; 100 to 149; and more than 150. There were too few buildings of 250 units or more to present them separately. Although the frequency of the number of apartments per building group varies between IMC and DMC, the mean number of apartments per building group are similar. These building classification characteristics, the frequency presented as a percentage and average number of apartments per group, are represented in Tables 2-1 and 2-2.

Table 2-1:
PERCENT DISTRIBUTION BY BUILDING SIZE

No. of Arts.	DMC	IMC
Less than 20	13.7%	20.6%
20 - 49	40.7	47.9
50 - 74	29.9	17.6
75 - 99	7.4	5.5
100 - 149	6.9	3.4
150 or more	1.5	5.0
Total	100.0%	100.0%
Number of Buildings	(204)	(238)

Table 2-2:
MEAN NUMBER OF APARTMENTS PER BUILDING BY BUILDING SIZE

No. of Arts	DMC	IMC
Less than 20	12.0	11.6
20 - 49	37.5	34.2
50 - 74	60.9	61.2
75 - 99	85.1	86.3
100 - 149	111.9	116.6
150 or more	186.3	183.1
All buildings combined	51.8	47.4

Number of rooms was another variable used to compare DMC and IMC buildings. Measuring fuel consumption as a function of the number of rooms, not including kitchens and bathrooms, is a common practice in the real estate industry. Therefore an attempt to analyze the effect of DMC by number of rooms was performed. However, as discussed in detail in Section 3, sufficient data on the number of rooms for IMC buildings was not available to perform much of the analysis.

Table 2-3 and 2-4 show the percent distribution and mean number of rooms per building for IMC and DMC buildings.

Table 2-3:
PERCENT DISTRIBUTION BY NUMBER OF ROOMS IN BUILDING

No. of Rooms	DMC	IMC
Less than 100	25.5%	37.1%
100 - 149	16.2	18.6
150 - 199	25.0	21.6
200 or more	33.3	22.8
Total	100.0%	100.0%

Table 2-4:
MEAN NUMBER OF ROOMS PER BUILDING BY BUILDING SIZE

No. of Arts.	DMC	IMC
Less than 20	48.3	38.0
20 - 49	132.2	123.8
50 - 74	201.5	200.6
75 - 99	271.7	282.4
100 - 149	396.7	358.9
150 or more	597.3	614.3
All buildings combined	176.6	165.1

A building configuration variable was also used to compare DMC and IMC buildings. Within size classes, IMC buildings consistently had more floors, especially when the number of units exceeded 99 as illustrated in Table 2-5.

It is worth noting, however, that DMC buildings had more units per floor than IMC buildings as expressed in Table 2-6. The net result, however, is that there was little difference between DMC and IMC in terms of number of units and number of rooms.

Table 2-5:**MEAN NUMBER OF FLOORS PER BUILDING BY BUILDING SIZE**

No. of Apts.	DMC	IMC
Less than 20	3.8	4.6
20 - 49	5.3	5.9
50 - 74	5.7	6.1
75 - 99	6.2	7.2
100 - 149	6.4	9.1
150 or more	6.3	10.1
All buildings combined	5.4	6.1

Table 2-6:**MEAN NUMBER OF APARTMENTS PER FLOOR BY BUILDING SIZE**

No. of Apts.	DMC	IMC
Less than 20	3.2	2.8
20 - 49	7.1	6.4
50 - 74	10.9	10.3
75 - 99	13.8	13.5
100 - 149	18.4	15.9
150 or more	29.4	20.4
All buildings combined	9.3	7.7

Heating Plant Specific Variables

For a given building grouping, DMC and IMC buildings differed in heating plant characteristics such as boiler efficiency and general maintenance. There was little difference, however, in capacity of boilers.

Boilers in DMC buildings tested at a higher steady state efficiency than IMC boilers, particularly in buildings with 100 or more units. One explanation maybe that DMC buildings were, in general, better maintained. Tables 2-7 and 2-8 summarize boiler capacity and steady state efficiency.

Table 2-7:**MEAN CAPACITY OF BOILER (Hp) BY BUILDING SIZE**

No. of Apts.	DMC	IMC
Less than 20	27.4	27.1
20 - 49	76.8	76.5
50 - 74	116.8	128.9
75 - 99	157.3	167.5
100 - 149	212.4	210.1
150 or more	263.0	266.1
All buildings combined	100.7	93.8

Table 2-8:**MEAN STEADY STATE EFFICIENCY RATING OF BOILER BY BUILDING SIZE**

No. of Apts.	DMC	IMC
Less than 20	75.6%	75.2%
20 - 49	77.6	74.4
50 - 74	79.0	72.7
75 - 99	78.5	75.8
100 - 149	79.4	70.9
150 or more	83.0	73.9
All buildings combined	78.0	74.2

Ratings of boiler maintenance also distinguished the two sets of buildings. Maintenance of the boiler was rated as good, average or poor depending on a number of factors, including the physical condition of the boiler, steady-state efficiency and interview with the superintendent. In general, the maintenance of boilers in the DMC buildings was more likely to be rated good, 90%, 8% were rated average and 2% rated poor; whereas, the maintenance of boilers in IMC buildings was rated 63% good, 26% fair and 11% poor. Participation in the study was voluntary for all owners, but for the DMC building owners it presupposed purchase of DMC equipment. Unfortunately, while reduced fuel consumption is associated with better maintenance, there were not enough buildings in both sets to determine how much the maintenance level, apart from all the other building variables, affected differences in fuel consumption.

Weather Related Variables

Another difference between the two sets of buildings is that more IMC buildings were studied in 1987-1989, while all DMC buildings entered the study after 1989. The timing of entry to the study would not make much difference except 1987, 1988, and to some extent 1989 were much colder years than 1990, 1991, and 1992. Consequently, the average number of degree days during the observation periods for IMC buildings is higher than the average for DMC buildings, which may affect total fuel consumption. This may be due to the fact that the boilers were operating at a slightly higher seasonal efficiency because they were closer to full capacity. Boiler operating efficiency drops off significantly when operating below full capacity.³ Table 2-9 summarizes the degree days for each building group.

Table 2-9:

MEAN DEGREE DAYS IN OBSERVATION PERIOD BY BUILDING SIZE

No. of Apts.	DMC	IMC
Less than 20	4335	4505
20 - 49	4271	4469
50 - 74	4270	4321
75 - 99	4194	4485
100 - 149	4366	4251
150 or more	4103	4193
All buildings combined	4278	4430

3. Direct Measurement of The Overall Efficiency and Annual Fuel Consumption of Residential Oil-Fired Boilers, January 1978, Brookhaven National Laboratory.

Section 3

RESULTS OF THE ANALYSIS

Assumptions Regarding Annual Fuel Use and Domestic Hot Water

To identify annual heating energy consumption associated with IMC and DMC buildings two basic measures of fuel consumption were used: total consumption (including space heating and domestic hot water (DHW)) for the twelve-month period, and estimated consumption for space heating (extracting fuel use for generating DHW).

Fuel use for space heating was desired due to the uncertainty of the effect that DHW fuel use would have on the results. Currently there is a paucity of data on domestic hot water consumption for multifamily buildings in New York City and generally accepted estimates were made based on professional experience⁴.

In the absence of direct measurement of DHW consumption, estimates of annual DHW fuel use was based on the non heating season fuel use as recorded in fuel and natural gas deliveries. Since all of the heating systems for both the IMC and DMC building groups generated DHW through immersion coils, a correction for estimated system efficiency during the non-heating and heating seasons was made.

Based on figures published by American Society of Heating Refrigeration and Air conditioning Engineers (ASHRAE)⁵. Interpolation was used to arrive at consumption for buildings falling between the sizes used by ASHRAE 20 or less, 50, 75, 100, and 200 or more. In the first estimate, the ASHRAE figures per apartment per day were converted to BTUs, assuming 60% system efficiency in summer and 80% system efficiency in winter. The results were then multiplied by 122 days (non heating season) or 243 days (heating season)

4. There is an on-going jointly sponsored research program sponsored by the Energy Authority and Consolidated Edison Company "Consumption of Domestic Hot Water in Multifamily Buildings" being performed by EME Group, with a planned completion date in early 1994. The results of this project will provide consumption rates of DHW in multifamily buildings throughout New York City.
5. American Society of Heating, Refrigeration, Air Conditioning Engineers, (ASHRAE) Handbook, 1987 HVAC Systems and Applications Handbook, Chapter 54; Service Hot Water.

and adjusted for the number of units in the building.

However, there were differences between the IMC and the DMC buildings in number of occupants per apartment, even within building size categories. Also, as the distribution of buildings by size was somewhat different in the two sets of buildings, it could not be assumed that linear interpolation (which posits even distribution of buildings within size classes) would be realistic for either. Alternatively, another estimate was made which took the number of occupants into account.

This additional estimate was necessary since occupant information was lacking for because for 120 buildings (115 IMC and 5 DMC), performed under the State Energy Office's Multifamily Steam System Technical Survey (MSSTS)⁶. When these buildings were excluded, the only building size class with appreciable numbers of buildings remaining was the 20-49 class. (The next building group, 50-74 units, IMC data was available on 8 buildings and only three other buildings in the remaining building groups). For these buildings, a DHW per occupant figure was computed by dividing the first estimate by the number of occupants. Although this might not have been ASHRAE's estimate, it is not likely to introduce additional bias. The overall mean fuel consumption per person for DHW was then multiplied by the number of occupants in the building, and this figure was subtracted from total BTU consumed. The result, adjusted for number of degree days, then served as an estimate of heating fuel use.

Building Size

From the outset, installing a DMC system in smaller buildings was not expected to be as cost effective as larger buildings. However, the analysis showed an apparent disadvantage of DMC for buildings with less than 20 units. At first, it was hypothesized that fuel consumption for DHW had been underestimated because DHW fuel use can be a larger proportion of total annual fuel consumption in smaller buildings. It was also considered that among smaller IMC buildings there may have been an unusual number of breakdowns in boilers during cold spells, resulting in an understatement of fuel consumption in the observation periods. However, the number of breakdowns was not specified and therefore

6. Multifamily Steam System Technical Survey - A 3 year program sponsored by the New York State Energy Office which provided detailed surveys of steam plants in multifamily buildings in New York City.

not recorded in the audits. Because of this anomaly in the less than 20 apartments per building group, fuel and cost savings comparisons were not included in the overall results.

Energy Savings

Energy savings as a function of BTU per degree day, normalized for the number of apartments in each building group are presented graphically in Figure 3-1. Apparent fuel savings increase linearly with building size; the anomalous behavior of the 75 to 99 group is explained, we believe, by the small number of buildings in the group.

Figure 3-1

There is a negative difference among buildings with less than 20 units, and a small positive difference in buildings with less than 75 units. Buildings with 75 to 99 units showed the widest difference of all, as noted previously. Overall, however, apparent fuel savings in increase linearly with building size as noted above in Figure 3-1.

If buildings with less than 20 units are included in the analysis, there is only a 3.9% difference between IMC and DMC buildings in annual fuel use and only a 6.4% difference between IMC buildings and all DMC buildings during the heating season fuel use. However, it is clear that the difference is a function of building size in terms of number of units.

Tables 3-1 and 3-2 summarize the fuel consumption in mean BTUs per degree day per between IMC and DMC buildings, first annually and then during the heating season.

Table 3-1:

ANNUAL MEAN BTU PER DEGREE DAY PER APARTMENT BY BUILDING SIZE

No. of Apts.	DMC	IMC	Difference
Less than 20	353,218	306,884	*
20 - 49	876,198	918,681	4.6
50 - 74	1,330,622	1,442,668	7.8
75 - 99	1,599,157	2,223,565	28.1
100 - 149	2,273,532	2,686,449	15.4
150 or more	3,220,819	3,965,238	18.8
All buildings	1,123,832	1,169,495	3.9%
Bldgs over 20 units	1,246,429	1,393,135	10.5

* There is a negative difference of 1.51% in energy use in this building category which has a large effect on total energy savings.

Table 3-2:

**HEATING SEASON MEAN BTU PER DEGREE DAY PER APARTMENT
BY BUILDING SIZE**

No. of Apts.	DMC	IMC	Difference
Less than 20	307,734	264,445	*
20 - 49	736,690	795,241	7.4%
50 - 74	1,113,665	1,226,196	9.2
75 - 99	1,302,206	1,940,084	32.9
100 - 149	1,903,213	2,290,534	16.9
150 or more	2,596,091	3,353,838	22.6
All buildings	939,518	1,003,811	6.4%
Bldgs over 20 units	1,040,029	1,195,498	13.0

The percent difference in fuel use increases to 10.5% annually and 13.0% during the heating season for buildings with 20 units or more. This difference among larger buildings in heating fuel cost is significant. However, the difference is much less among smaller buildings than among the larger ones. In buildings of 20-49 units, heating fuel use in DMC buildings is only 7.4% less than in IMC buildings, but among buildings of 150 units or more, the difference is 22.6%. Moreover, the fuel savings is even greater (32.9%) in buildings of 75-99 units.

Before discussing differences in BTU per degree day per room, introduced earlier, it should be pointed out that this difference will be slightly exaggerated because IMC buildings, with a known number of rooms, used more fuel (other factors being equal), even when only buildings with 20 or more units are counted. Number of rooms data are missing for 53 IMC buildings with 20 or more units.

When using number of rooms as an indicator of size and comparing only buildings with 20 or more units, there is a gradual increase with size in the percent difference in fuel use with an increase in building size. Where there are less than 100 rooms, the difference is only 1.8% annually and 5.6% during the heating season. During the heating season the percent difference is 16.9% for buildings with 100 to 149 rooms. It declines to 13.2% for those with 150 to 199 rooms, and then rises to 33.3% for buildings with 200 or more rooms.

Table 3-3 is a summary of mean BTUs per degree day used annually by building for DMC and IMC buildings.

Table 3-3:

**ANNUAL MEAN BTU PER DEGREE DAY PER BUILDING IN BUILDINGS
COMPRISED OF THE FOLLOWING ROOM GROUPINGS
(Buildings with 20 or more units)**

No. of Rooms	DMC	IMC	Difference
Less than 100	656,746	668,698	1.8%
100 - 149	826,771	953,161	13.3%
150 - 199	1,220,951	1,382,273	11.7%
200 or more	1,679,820	2,436,409	31.1%
All buildings	1,246,429	1,416,346	12.0%

Table 3-4 is a summary of the mean BTUs per degree day used during the heating season by building for DMC and IMC buildings grouped according to the number of rooms.

Table 3-4:

**HEATING SEASON MEAN BTU PER DEGREE DAY PER BUILDING IN BUILDINGS
COMPRISED OF THE FOLLOWING ROOM GROUPINGS
(Buildings with 20 or more units)**

No. of Rooms	DMC	IMC	Difference
Less than 100	535,775	567,436	5.6%
100 - 149	683,868	823,207	16.9%
150 - 199	1,036,784	1,193,918	13.2%
200 or more	1,395,457	2,092,080	33.3%
All buildings	1,040,029	1,217,574	14.6%

To illustrate the effect of this on apparent fuel savings, we can compare the percent differences normalized for number of apartments for all buildings and for those where room data are available. The percent difference in annual BTU per degree day per apartment is 14.1% for all buildings of 20 units or more, it is 14.6% for buildings where the number of rooms is known. The difference in fuel consumption is about the same during the heating season: 16.7% for all buildings per apartment, and 17.1% for those building with room

data. Therefore comparisons of BTU per degree day per room and per apartment during the heating period for buildings with 20 or more units generally agree.

General Findings for All Buildings

Figures normalized for number of rooms and number of apartments are widely accepted than average figures per building size. Normalizing is a way of minimizing the effects of differences in building size on average fuel consumption. In this step, each building's fuel consumption per degree day was divided by the number of apartments (or rooms) in the building. Normalized figures were then averaged over all buildings in the monitor control class (DMC or IMC).

Tables 3-5 and 3-6 show succinctly the average difference in fuel consumption associated with direct monitor control for all building sizes. Normalized for the number of units in the building, the figures show a difference of 14.1% annually and 16.7% during the heating period.

Table 3-5:

**ANNUAL MEAN BTU PER DEGREE DAY
NORMALIZED FOR VARIOUS BUILDING CHARACTERISTICS
(Buildings with 20 or more units)**

Characteristic	DMC	IMC	Difference
Number of units	21,992	25,597	14.1%
Number of rooms*	6,667	7,840	15.0%

*Note: Information on the number of rooms was unavailable for 53 IMC buildings with 20 or more units. However, there was little variation from the mean of 3.3 rooms per unit in the larger IMC buildings for which information was available.

Table 3-6:

**Heating Season Mean BTU PER Degree Day
Normalized for Various Building Characteristics
(Buildings with 20 or more units)**

Characteristic	DMC	IMC	Difference
Number of units	18,377	22,054	16.7%
Number of rooms*	5,556	6,703	17.1%

When normalizing BTU per degree day by number of rooms, the difference between IMC and DMC buildings with 20 or more units was 15% on annual basis, and 17.1% during the heating season.

The analysis shows that among the largest buildings of 200 units or more, the fuel savings from the use of DMC equipment approached one third annually. Overall, a fuel saving of 14% to 15% annually was associated with DMC among the buildings studied (not including the less than 20 unit buildings); savings were 16% to 17% during the heating season.

Correcting For Building And Heating Plant Factors

Before concluding that these differences are due to the type of monitor control, the possible influence of additional factors must be evaluated. Additional factors that might have produced an exaggerated estimate of fuel savings associated with DMC were: differences boiler efficiencies; differences in windows; and differences in the occupancy rate.

As for buildings with double glazed windows: information on window type and time of installation in many of the IMC buildings was not available. Thus, it was not possible to make an accurate analysis of the effect that new windows have on a building's fuel consumption, or in particular, the effect new windows would have had on the results of this

*Note: Information on the number of rooms was unavailable for 53 IMC buildings with 20 or more units. However, there was little variation from the mean of 3.3 rooms per unit in the larger IMC buildings for which information was available.

analysis. However, it is theorized that double-glazed windows would result in greater energy savings in DMC buildings because of the feedback control will inform the boiler that the apartment is satisfied. Further analysis at this level of detail would focus on fuel consumption in buildings before and after new windows were installed in both DMC and IMC buildings.

Controlling for differences in number of occupants in the IMC and DMC buildings is more difficult, because the occupancy data was unavailable for 120 of the buildings. It was possible to compare only buildings with 20 to 49 units, where the number of occupants was known for 63 IMC buildings and 80 DMC buildings. The occupancy figures permitted EME to calculate fuel use for DHW on a per person basis, which is believed to be more accurate. This resulted in a difference in heating space BTU per degree day of only 4.1%, compared to a difference of 7.6% before adjusting for occupancy. However, since there was very little difference in the average number of occupants per unit in the two sets of buildings (2.97 in DMC buildings vs. 2.67 in IMC buildings) the results of this adjustment are difficult to interpret. Further analysis at this level of detail will depend on more accurate measurement of occupant DHW use patterns.

Section 4

COST EFFECTIVENESS

Based on the preceding analysis, the cost effectiveness of installing a DMC system to control boiler operation in a multifamily building is a function of the number of apartments in the building. The findings show that, on average, the greater the number of apartments in a building the more cost effective the measure.

The standard DMC system costs between \$8,400 and \$10,000, installed. Depending on building size, the base system includes 10 apartment temperature sensors, outdoor air sensor, aquastat control, hot water sensor, software and modem.

The standard IMC system costs from \$2,000 to \$3,000 installed and includes a condensate temperature sensor, outdoor air bulb and time clock.

Annual savings and a simple payback were computed for a standard building based on the analysis. The building is based on 47.4 apartments, which is the mean number of units per building in the analysis; an average savings of 14.1 percent; mean number of degree days of 4,430 and no. 6 fuel oil at \$0.60 per gallon. The results of this comparison are summarized in Table 4-1.

Table 4-1:

**PROJECTED ENERGY SAVINGS AND COST
BASED ON MEAN NUMBER OF APARTMENTS WITH SAVINGS NORMALIZED TO
VARIOUS BUILDING CHARACTERISTICS
(Buildings with 20 or more units)**

Mean No. of Apts.	Difference in Annual Energy Use		Projected DMC Installation Cost (\$)		Projected Payback (Years)	
	Gallons	Dollars	Replace*	New	Replace	New
47.4	3,826	2,295	9,200	6,700	4.0	2.9

* Replacement cost refers to the cost associated with replacement of an existing IMC system with a DMC unit. New refers to the cost-differential between each system in a retrofit or new system installation.

Section 5

STATISTICAL PROCEDURES

The statistical analysis in this study had several objectives:

- o To test the validity of the data by examining relationships expected and not expected to be found;
- o To identify if the two sets of buildings differed in characteristics other than type of monitor control that might contribute to or mask differences in fuel consumption;
- o To ascertain if differences can be observed in average fuel consumption between DMC and IMC buildings irrespective of differences in building size;
- o To determine the role of other factors including boiler characteristics, other building characteristics or occupancy; and
- o To test if the patterns of differences net of other factors are large enough to be statistically significant so it can be stated with confidence that they did not occur by chance.

All the differences reported in this study were statistically significant (R^2 of 0.75 or better) unless stated otherwise.

The first procedure was to verify that significant correlations actually existed between variables that could be expected to be related (for example, fuel consumption and building size, and fuel consumption and number of degree days). These correlations were all acceptable high, R^2 of 0.832 and 0.826 respectively.

Second, a test was made for correlations that were **not** expected (for example, number of degree days during the observation period and building size and number of occupants.). All these correlation coefficients were extremely close to zero, with one exception: among IMC buildings, fuel consumption per degree day correlated **slightly negatively** with number of degree days in the observation period.

When the nature of the buildings and the basic variables were described, the exploration of differences in fuel consumption could begin. A simple statistical tool for testing the differences between means is the t-test, but since it was expected that other differences between the two sets of buildings would always have to be considered, a more versatile statistical model selected was analysis of variance. Regression analysis was used, but only to test the scatter within the data.

Analysis of variance is well suited to situations when one or more of the variables is nominal. It permits consideration of several independent variables simultaneously. The effect of each variable net of all the others in the analysis was tested for significance. Thus, it was possible to determine the effect of building size as well as type of monitor control. Additional factors such as boiler efficiency and level of maintenance were included in the analysis.

A test for R^2 correlation was also employed by the researchers. R^2 is interpreted as the proportion of the total variance in the dependent variable that is explained by the other variables. In every test in this study, R^2 was at least .75, indicating that the multiple correlation coefficients were at least .86 to .87. By far the greatest contribution to R^2 in this study was building size.

From the beginning, it was apparent that the amount of variance, the summed squares of the differences of individual buildings from their mean or average, was high no matter which building characteristic was considered. Furthermore, the variances among IMC buildings were greater than among DMC buildings. At first glance, this should not be surprising in view of the wider variation in the observation periods for IMC buildings, the markedly wide range in types of heating equipment, and the larger number of small buildings in the IMC set. However, since variances were also wider among larger IMC buildings which were more likely to have been built in recent decades, to have more uniform equipment, to be better maintained, and generally to be somewhat more like DMC buildings of comparable size, questions still remain. The research did show that the level of maintenance is related to the variance in fuel consumption. The variance in fuel consumption within the (few) IMC buildings where maintenance was rated "good" is much less.

Section 6

CONCLUSIONS

As a result of this research, multifamily buildings that employ DMC which are comprised of more than 20 apartments or which have more than 100 rooms, on average, have energy savings which are significant enough to justify investment. However, this research did not show savings in energy for multifamily buildings employing DMC which are comprised of less than 20 apartments. In fact, the findings suggested a net increase in energy use for this DMC building group: however this is not conclusive.

Many factors influence a multifamily building's energy use. These include, the condition of the boiler and burner; upkeep and maintenance of the boiler and steam distribution systems; and the building's domestic hot water load. It is the opinion of the researchers, however, that if a multifamily building has a well maintained heating plant and if it does not have a comparably large domestic hot water load, lower annual fuel use is predicted for those buildings employing a DMC system.

Less than 10 percent of the eligible multifamily buildings in New York City employ DMC control. The results of this research indicate that a significant reduction in fuel consumption for multifamily buildings in the New York City area is possible by employing DMC equipment.

Recommendations for Future Research

As a result of this study there were a number of issues which this research did not address. First, more definitive information is needed in reference to domestic hot water (DHW) consumption. It is the researchers' opinion that assuming DHW fuel consumption from the existing means, i.e. ASHRAE and summer fuel records, does not accurately reflect DHW fuel use.

Second, the researchers recommend a similar research project which will quantify energy savings in (realized or unrealized) in multifamily buildings which have had either single pane, or wood framed windows replaced with aluminum frame double pane windows.

Third, the researchers recommend investigating the feasibility of upgrading the DMC equipment to include other multifamily building energy systems, such as, control of common space lighting, control of building exhaust fans, control and monitor of domestic hot water use and consumption, and more precise control of the boiler through a demand based heating and domestic hot water control feature.

APPENDIX A

BUILDING CHARACTERISTICS FOR DMC AND IMC BUILDINGS

ID#	UNITS	FLS	RHS	AGE (YRS)	BOILER EFF (%)	CAP (HP)	REPL	FUEL	COMS H/SEAS (MMBTU)	DEG/DYS	TOTAL H/SEAS (MMBTU)	FUEL COMS FRD W/TRMT	INS REC (PIPE)	MTN	POP	SQ. FT	S/DATE	BUILDING ADDRESS	BOR
001	12	5	10	10	80	12	MO	2	1.17	4386	0.27	0.05	YES	A	6	12	90	313 WEST 100TH STREET	MM
002	16	4	6	5	77	39	MO	G	0.24	4726	0.48	0.06	YES	G	32	12	90	427 15TH STREET	BK
003	24	5	6	6	82	50	YES	G	0.36	4561	0.59	0.05	YES	A	100	12	90	46-50 RIVINGTON STREET	MM
004	19	6	5	6	71	32	MO	G	0.56	4661	0.72	0.05	YES	P	16	12	90	255 WEST 22ND STREET	MM
005	23	5	5	4	81	50	MO	G	0.34	4756	0.42	0.03	NO	G	23	12	90	214 EAST 11TH AVENUE	BK
006	27	5	5	4	75	32	MO	G	0.54	4505	0.72	0.03	NO	G	81	12	90	222 ANDREWS AVENUE	BK
007	20	5	5	4	72	50	MO	G	0.24	4574	0.42	0.03	NO	G	20	12	90	538 EAST 85TH STREET	BK
008	11	5	5	3	77	60	YES	G	0.24	4584	0.42	0.03	YES	A	10	01	91	1124 STRATFORD STREET	MM
009	24	5	5	3	77	20	MO	G	0.13	4463	0.15	0.04	YES	A	10	01	91	304 WEST 78TH STREET	MM
010	11	5	5	6	75	80	MO	G	0.25	4427	0.29	0.03	NO	A	11	01	91	36 EAST 69TH STREET	MM
011	24	5	5	7	76	50	MO	G	0.42	4481	0.41	0.03	YES	A	86	02	91	585 WEST 214TH STREET	MM
012	13	5	5	2	77	37	MO	G	0.34	4308	0.41	0.03	YES	A	70	02	91	203 WEST 94TH STREET	BK
013	14	5	5	5	74	15	MO	G	0.08	4376	0.08	0.03	YES	A	51	03	91	2312/1618 BEDFORD AVE	MM
014	15	5	5	10	81	125	MO	G	0.40	4399	1.03	0.05	YES	A	8	03	91	313 EAST 10TH STREET	MM
015	15	5	5	10	82	15	MO	G	0.40	4389	1.03	0.05	YES	G	105	03	91	70 EAST 77TH STREET	MM
016	18	5	5	30	75	90	MO	G	0.69	4390	0.88	0.05	YES	G	8	02	91	2061 BROADWAY	MM
017	18	5	5	30	75	90	MO	G	1.13	4390	1.88	0.05	YES	A	110	03	91	302 WEST 79TH STREET	MM
018	18	5	5	30	75	90	MO	G	1.13	4390	1.88	0.05	YES	A	37	03	91	681 RIVERSIDE DRIVE	MM
019	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	902 OCEAN PARKWAY	BK
020	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	1860 OCEAN PARKWAY	BK
021	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	73 FIFTH AVENUE	MM
022	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	555 WEST 170TH STREET	MM
023	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	624 WEST 176TH STREET	MM
024	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	506 WEST 176TH STREET	MM
025	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	580 WEST 176TH STREET	MM
026	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	600 WEST 176TH STREET	MM
027	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	134 MANOR AVENUE	MM
028	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	178 BEACH AVENUE	BK
029	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	111 FATHER ZEISER PLACE	BK
030	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	138 MANOR AVENUE	BK
031	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	138 MANOR AVENUE	BK
032	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	241 WEST 23RD STREET	MM
033	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	47-07 41ST STREET	MM
034	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	55 EAST 76TH STREET	MM
035	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	510 WEST 123RD STREET	MM
036	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	82 ELLWOOD STREET	MM
037	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	72 ELLWOOD STREET	MM
038	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	650 WEST 162ND STREET	MM
039	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	666 WEST 162ND STREET	MM
040	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	29 WEST 10TH STREET	MM
041	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	47-43 43RD STREET	MM
042	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	561 WEST 175TH STREET	MM
043	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	1780 EASTBURN AVENUE	MM
044	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	610 WEST 140TH STREET	BK
045	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	87 ELLWOOD AVENUE	MM
046	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	53-57 VERMILION AVENUE	MM
047	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	520 WEST 180TH STREET	MM
048	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	520 WEST 180TH STREET	MM
049	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
050	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
051	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
052	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
053	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
054	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
055	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
056	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
057	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
058	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
059	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
060	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
061	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
062	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
063	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
064	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
065	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
066	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
067	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
068	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
069	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM
070	18	5	5	30	75	90	MO	G	0.83	4380	1.52	0.05	YES	A	115	03	91	522 WEST 131RD STREET	MM

ID#	UNITS	FLS	RHS	AGE (YRS)	BOILER EFF (%)	CAP (HP)	REPL	FUEL	TOTAL W/SEAS (MMBTU)	DEG/DYS	TOTAL H/SEAS (MMBTU/DO)	FUEL CONS PRO	W/TRMT	INS REC (PIPE)	HTM	POP	SO.FT	S/DATE	BUILDING ADDRESS	BOR
071	27	3	10	20	75	75	7	G	376	4593	0.07	10.88	NO	YES	P	9	2508	01 90	2109 FIFTH AVENUE	MN
072	29	3	20	1	61	61	14	G	1750	4860	0.17	02.88	NO	YES	G	30	3200	02 99	60 MOOSTER STREET	MN
073	151	3	30	1	76	76	123	G	3612	4609	0.14	02.88	NO	YES	A	50	7400	07 99	74 WEST 103th STREET	MN
074	123	3	25	25	65	65	123	G	3961	4623	0.04	11.88	NO	YES	A	60	21900	03 90	68 EAST 97th STREET	MN
075	48	3	60	60	80	80	13	G	3592	4610	0.04	11.88	NO	YES	A	60	45744	03 90	1391 MADISON AVENUE	MN
076	149	3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
077		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
078		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
079		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
080		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
081		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
082		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
083		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
084		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
085		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
086		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
087		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
088		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
089		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
090		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
091		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
092		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
093		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
094		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
095		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
096		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
097		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
098		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
099		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
100		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
101		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
102		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
103		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
104		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
105		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
106		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
107		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
108		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
109		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
110		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
111		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
112		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
113		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
114		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
115		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
116		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
117		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
118		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
119		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
120		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
121		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN
122		3	60	60	81	81	13	G	3591	4611	0.04	11.88	NO	YES	A	60	45744	03 90	1411 MADISON AVENUE	MN

ID#	UNITS	FLS	RHS	AGE (YRS)	EFF (%)	BOTTLER	CAP (HP)	REPL	FUEL	TOTAL INSEAS (MMBTU)	DEG/DYS	TOTAL W/SEAS (MMBTU/DD)	FUEL CONS PRD W/TRMT	INS REC (PIPE)	MTN	POP	SQ.FT	S/DATE	BUILDING ADDRESS	BOR
301	120	5	430	40	75	265	500	YES	6	15564	3008	3.98	01 90	NO	A	480	140450	02 92	4761-4779 BROADWAY	MM
302	120	21	505	50	80	500	500	NO	6	20374	3108	6.50	12 90	YES	G	768		08 91	400 EAST 85th STREET	MM
303	172	16		27	80	500	500	NO	6	16611	3134	0.89	12 91	NO	G	688		01 92	100 OVERLOOK TERRACE	MM
304	140	12	390	27	70	500	500	YES	6	13596	4024	2.04	01 90	YES	A	560	120000	12 91	227-233 EAST 21st STREET	MM
305	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	210 WEST 89th STREET	MM
306	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	3950 BLACKSTONE AVENUE	MM
307	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	144-35/45 SANFORD AVENUE	MM
308	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	25 MEPTUNE BOULEVARD	MM
309	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	777 WEST END AVENUE	MM
310	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	420 NORTH BROADWAY	MM
311	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	95-117 RAVINE AVENUE	MM
312	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	95-117 RAVINE AVENUE	MM
313	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	105 EAST 198th STREET	MM
314	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	150 EAST 165th STREET	MM
315	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	430 WEST 34th STREET	MM
316	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	37-15 72nd STREET	MM
317	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	1407 SHERIDAN AVENUE	MM
318	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	6325 SAUNDERS STREET	MM
319	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	263 PALISADE AVENUE	MM
320	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	507 PARK PLACE	MM
321	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	507 PARK PLACE	MM
322	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	41-08 PARSONS BOULEVARD	MM
323	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	3001 HENRY HUDSON PKWY	MM
324	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	600 EAST 18th STREET	MM
325	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	17 VAN SICLEN AVENUE	MM
326	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	134 WEST 58th STREET	MM
327	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	915 WEST END AVENUE	MM
328	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	127 EAST 117th STREET	MM
329	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	3405 KOSSUTH AVENUE	MM
330	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	175 WEST 76th STREET	MM
331	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	15 BEACH ROAD	MM
332	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	219 SAINT ANNS AVENUE	MM
333	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	249-51 E KINGSBRIDGE RD	MM
334	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	176-20 WEXFORD TERRACE	MM
335	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	543 OCEAN AVENUE	MM
336	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	667 OCEAN AVENUE	MM
337	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	32-21/51 77th STREET	MM
338	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	2195 GRAND CONCOURSE	MM
339	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	1166 PACIFIC STREET	MM
340	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	84-07 SHORE PARKWAY	MM
341	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	32-30 70th STREET	MM
342	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	32-50 70th STREET	MM
343	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	6901 NORTHERN BOULEVARD	MM
344	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	25 GUN HILL ROAD	MM
345	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	2700 HENRY HUDSON PKWY	MM
346	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	308 EAST 85th STREET	MM
347	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	2601 HENRY HUDSON PKWY	MM
348	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	201 CROWN STREET	MM
349	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	266 SOUTH FULTON AVENUE	MM
350	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	311 FRANKLIN AVENUE	MM
351	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	517 FRANKLIN AVENUE	MM
352	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	517 EAST 21st STREET	MM
353	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	8820 FORT HAMILTON PKWY	MM
354	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
355	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
356	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
357	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
358	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
359	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
360	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
361	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
362	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
363	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
364	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
365	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
366	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
367	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
368	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
369	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM
370	180	6	594	20	70	500	500	YES	6	16271	3677	0.83	01 90	YES	A	560		09 91	515/21/51 CASTLETON AVE	MM

APPENDIX B

STATISTICAL TESTS ON ALL VARIABLES

```

SET LISTING='TESTREV3.LST'.
GET FILE='CONTROL8.SYS'.
The SPSS/PC+ system file is read from
file CONTROL8.SYS
The file was created on 11/23/92 at 8:11:19
and is titled SPSS/PC+
The SPSS/PC+ system file contains
442 cases, each consisting of
62 variables (including system variables).
62 variables will be used in this session.

```

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```

This procedure was completed at 7:44:46
COMPUTE BTUDDMIN=BTUDD/1000000.
COMPUTE BTUD2MIN=BTUDD2/1000000.
IF (MC EQ 0) BTUIMC=BTUDDMIN.
IF (MC EQ 0) BTU2IMC=BTUD2MIN.
IF (MC EQ 1) BTUDMC=BTUDDMIN.
IF (MC EQ 1) BTU2DMC=BTUD2MIN.
REGRESSION VARIABLES=BTUDDMIN,UNITS MC
The raw data or transformation pass is proceeding
442 cases are written to the uncompressed active file.
/DEPENDENT=BTUDDMIN
/METHOD=STEPWISE.

```

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
1.. UNITS

Multiple R	.90885
R Square	.82601
Adjusted R Square	.82561
Standard Error	.35097

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	257.30024	257.30024
Residual	440	54.19774	.12318

F = 2088.87120 Signif F = .0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
UNITS	.02040	4.46387E-04	.90885	45.704	.0000
(Constant)	.13955	.02768		5.042	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	-.08046	-.19256	.99659	-4.112	.0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
2.. MC

Multiple R	.91239
R Square	.83246
Adjusted R Square	.83170
Standard Error	.34479

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	259.30986	129.65493
Residual	439	52.18812	.11888

F = 1090.64120 Signif F = .0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
UNITS	.02051	4.39281E-04	.91355	46.684	.0000
MC	-.13549	.03295	-.08046	-4.112	.0000
(Constant)	.19687	.03055		6.443	.0000

End Block Number 1 POUT = .100 Limits reached.

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This procedure was completed at 7:45:15
REGRESSION VARIABLES=BTUD2MIN,UNITS MC
/DEPENDENT=BTUD2MIN
/METHOD=STEPWISE.

* * * * MULTIPLE REGRESSION * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

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2/23/9

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number

1.. UNITS

Multiple R .90382
 R Square .81688
 Adjusted R Square .81647
 Standard Error .27377

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	147.11740	147.11740
Residual	440	32.97836	.07495

F = 1962.85255 Signif F = .0000

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* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
UNITS	.01543	3.48205E-04	.90382	44.304	.0000
(Constant)	.16494	.02159		7.640	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	-.08516	-.19868	.99659	-4.247	.0000

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* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number

2.. MC

Multiple R .90781
 R Square .82411
 Adjusted R Square .82331
 Standard Error .26862

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	148.41917	74.20958
Residual	439	31.67659	.07216

F = 1028.45679 Signif F = .0000

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***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
UNITS	.01551	3.42236E-04	.90879	45.325	.0000
MC	-.10905	.02567	-.08516	-4.247	.0000
(Constant)	.21108	.02380		8.867	.0000

End Block Number 1 POUT = .100 Limits reached.

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This procedure was completed at 7:45:31
 REGRESSION VARIABLES=BTUDDMIN,ROOMS MC
 /DEPENDENT=BTUDDMIN
 /METHOD=STEPWISE.

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***** MULTIPLE REGRESSION *****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
 1.. ROOMS

Multiple R .89024
 R Square .79252
 Adjusted R Square .79196
 Standard Error .38274

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	206.48380	206.48380
Residual	369	54.05576	.14649

F = 1409.51717 Signif F = .0000

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2/23/

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
ROOMS	5.809450E-03	1.54739E-04	.89024	37.544	.0000
(Constant)	.16885	.03315		5.094	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	-.09415	-.20649	.99799	-4.048	.0001

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2/23/

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
2.. MC

Multiple R	.89519
R Square	.80137
Adjusted R Square	.80029
Standard Error	.37500

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	208.78868	104.39434
Residual	368	51.75088	.14063

F = 742.34713 Signif F = .0000

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2/23/9

* * * * MULTIPLE REGRESSION * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
ROOMS	5.836988E-03	1.51762E-04	.89446	38.461	.0000
MC	-.15859	.03917	-.09415	-4.048	.0001
(Constant)	.25133	.03834		6.556	.0000

B-5

End Block Number 1 POUT = .100 Limits reached.

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2/23/9

This procedure was completed at 7:45:45

REGRESSION VARIABLES=BTUD2MIN,ROOMS MC

/DEPENDENT=BTUD2MIN

/METHOD=STEPWISE.

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2/23/9

***** MULTIPLE REGRESSION *****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number

1.. ROOMS

Multiple R .88874
R Square .78986
Adjusted R Square .78929
Standard Error .28896

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	115.81378	115.81378
Residual	369	30.81164	.08350

F = 1386.98497 Signif F = .0000

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
ROOMS	4.350830E-03	1.16825E-04	.88874	37.242	.0000
(Constant)	.19277	.02502		7.703	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	-.09804	-.21365	B-6	-4.195	.0000

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number
2.. MC

Multiple R .89412
R Square .79945
Adjusted R Square .79836
Standard Error .28268

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	117.22018	58.61009
Residual	368	29.40524	.07991

F = 733.49230 Signif F = .0000

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
ROOMS	4.372341E-03	1.14398E-04	.89314	38.221	.0000
MC	-.12388	.02953	-.09804	-4.195	.0000
(Constant)	.25720	.02890		8.900	.0000

End Block Number 1 POUT = .100 Limits reached.

This procedure was completed at 7:46:06
REGRESSION VARIABLES=BTUDDMIN,TMMBTUDD MC
/DEPENDENT=BTUDDMIN
/METHOD=STEPWISE.

***** MULTIPLE REGRESSION *****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent BTUDDMIN

Variable(s) Entered on Step Number
1.. TMMBTUDD

Multiple R .99999
R Square .99999
Adjusted R Square .99999
Standard Error 3.016906E-03

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	311.49397	311.49397
Residual	440	.00400	.00001

F = 34223625.5584 Signif F = .0000

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
TMMBTUDD	.99996	1.70931E-04	.99999	5850.096	.0000
(Constant)	4.849413E-05	2.43158E-04		.199	.8420

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	2.2079E-04	.06155	.99925	1.292	.1970

End Block Number 1 PIN = .050 Limits reached.

Page 30 BUILDING CONTROLS ANALYSIS

2/23/9

This procedure was completed at 7:46:15
REGRESSION VARIABLES=BTUD2MIN,TMMBTUDD MC
/DEPENDENT=BTUD2MIN
/METHOD=STEPWISE.

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2/23/9

***** MULTIPLE REGRESSION *****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number
1.. TMMBTUDD

Multiple R .97396
R Square .94859
Adjusted R Square .94847
Standard Error .14506

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	170.83701	170.83701
Residual	440	9.25875	.02104

F = 8118.62219 Signif F = .0000

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***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
TMMBTUDD	.74054	8.21879E-03	.97396	90.103	.0000
(Constant)	.07736	.01169		6.617	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	-5.479E-03	-.02415	.99925	-.506	.6129

End Block Number 1 PIN = .050 Limits reached.

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This procedure was completed at 7:46:25
REGRESSION VARIABLES=BTUDDMIN,HMMBTUDD MC
/DEPENDENT=BTUDDMIN
/METHOD=STEPWISE.

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***** MULTIPLE REGRESSION *****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

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***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUDDMIN
B-9

Variable(s) Entered on Step Number
1.. HMMBTUDD

Multiple R .97394
R Square .94856
Adjusted R Square .94844
Standard Error .19084

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	295.47342	295.47342
Residual	440	16.02456	.03642

F = 8113.06429 Signif F = .0000

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2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
HMMBTUDD	1.28156	.01423	.97394	90.073	.0000
(Constant)	-.04080	.01602		-2.546	.0112

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	3.9261E-03	.01730	.99898	.363	.7171

End Block Number 1 PIN = .050 Limits reached.

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2/23/

This procedure was completed at 7:46:40
REGRESSION VARIABLES=BTUD2MIN,HMMBTUDD MC
/DEPENDENT=BTUD2MIN
/METHOD=STEPWISE.

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2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

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2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN
B-10

Variable(s) Entered on Step Number
1.. HMMBTUDD

Multiple R .99999
R Square .99998
Adjusted R Square .99993
Standard Error 3.000595E-03

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	180.09180	180.09180
Residual	440	.00396	.00001

F = 20002269.9020 Signif F = .0000

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
HMMBTUDD	1.00053	2.23712E-04	.99999	4472.390	.0000
(Constant)	-6.20791E-04	2.51921E-04		-2.464	.0141

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	-2.316E-04	-.04935	.99898	-1.035	.3012

End Block Number 1 PIN = .050 Limits reached.

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2/23/9

This procedure was completed at 7:46:59
REGRESSION VARIABLES=BTUDDMIN,TCONS MC
/DEPENDENT=BTUDDMIN
/METHOD=STEPWISE.

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2/23/9

***** MULTIPLE REGRESSION *****

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
1.. TCONS

Multiple R .99128
R Square .98264
Adjusted R Square .98260
Standard Error .11086

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	306.09060	306.09060
Residual	440	5.40738	.01229

F = 24906.67702 Signif F = .0000

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
TCONS	2.357524E-04	1.49382E-06	.99128	157.818	.0000
(Constant)	-.01892	9.08380E-03		-2.082	.0379

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	.01303	.09885	.99836	2.081	.0380

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2/23/9

***** MULTIPLE REGRESSION *****

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
2.. MC

Multiple R .99137
R Square .98281
Adjusted R Square .98273
Standard Error .11044

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	306.14344	153.07172
Residual	439	5.35454	.01220

F = 12549.81251 Signif F = .0000

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2/23/9

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
TCONS	2.358779E-04	1.48942E-06	.99181	158.369	.0000
MC	.02195	.01055	.01303	2.081	.0380
(Constant)	-.02967	.01042		-2.847	.0046

End Block Number 1 POUT = .100 Limits reached.

Page 48 BUILDING CONTROLS ANALYSIS 2/23/

This procedure was completed at 7:47:18
REGRESSION VARIABLES=BTUD2MIN,TCONS MC
/DEPENDENT=BTUD2MIN
/METHOD=STEPWISE.

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

Page 50 BUILDING CONTROLS ANALYSIS 2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number
1.. TCONS

Multiple R	.97370
R Square	.94809
Adjusted R Square	.94797
Standard Error	.14576

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	170.74750	170.74750
Residual	440	9.34826	.02125

F = 8036.66929 Signif F = .0000

Page 51 BUILDING CONTROLS ANALYSIS 2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
TCONS	1.760793E-04	1.96413E-06	.97370	89.647	.0000
(Constant)	.05595	.01194		4.684	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	7.3301E-03	.03215	.99836	.674	.5007

End Block Number 1 PIN = .050 Limits reached.

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2/23,

This procedure was completed at 7:47:41
 REGRESSION VARIABLES=BTUDDMIN,HCONS MC
 /DEPENDENT=BTUDDMIN
 /METHOD=STEPWISE.

Page 53 BUILDING CONTROLS ANALYSIS

2/23,

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

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2/23,

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
 1.. HCONS

Multiple R	.95750
R Square	.91681
Adjusted R Square	.91662
Standard Error	.24268

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	285.58485	285.58485
Residual	440	25.91313	.05889

F = 4849.17707 Signif F = .0000

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2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
HCONS	2.954933E-04	4.24340E-06	.95750	69.636	.0000
(Constant)	-.03555	.02055		-1.730	.0844

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	.01864	.06454	.99772	1.355	.1761

End Block Number 1 PIN = .050 Limits reached.

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This procedure was completed at 7:47:53
 REGRESSION VARIABLES=BTUD2MIN,HCONS MC
 /DEPENDENT=BTUD2MIN
 /METHOD=STEPWISE.

Page 57 BUILDING CONTROLS ANALYSIS 2/23/9

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number
 1.. HCONS

Multiple R	.98996
R Square	.98003
Adjusted R Square	.97998
Standard Error	.09042

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	176.49851	176.49851
Residual	440	3.59725	.00818

F = 21588.52706 Signif F = .0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
HCONS	2.323007E-04	1.58103E-06	.98996	146.930	.0000
(Constant)	-2.96261E-03	7.65677E-03		-.387	.6990

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	.01520	.10739	.99772	2.263	.0241

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number
2.. MC

Multiple R	.99008
R Square	.98026
Adjusted R Square	.98017
Standard Error	.09000

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	176.54000	88.27000
Residual	439	3.55576	.00810

F = 10897.95067 Signif F = .0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
HCONS	2.324710E-04	1.57547E-06	.99069	147.557	.0000
MC	.01946	8.59681E-03	.01520	2.263	.0241
(Constant)	-.01262	8.73541E-03		-1.445	.1491

End Block Number 1 POUT = .100 Limits reached.

Page 62 BUILDING CONTROLS ANALYSIS 2/23/

This procedure was completed at 7:48:07
REGRESSION VARIABLES=BTUDDMIN,POP MC
/DEPENDENT=BTUDDMIN
/METHOD=STEPWISE.

Page 63 BUILDING CONTROLS ANALYSIS 2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUDDMIN

Beginning Block Number 1. Method: Stepwise

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

Variable(s) Entered on Step Number
1.. POP

Multiple R .88071
R Square .77564
Adjusted R Square .77513
Standard Error .39854

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	241.61111	241.61111
Residual	440	69.88687	.15883

F = 1521.15687 Signif F = .0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUDDMIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
POP	5.158755E-03	1.32269E-04	.88071	39.002	.0000
(Constant)	.31285	.02861		10.936	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	.03801	.08004	.99457	1.682	.0932

End Block Number 1 PIN = .050 Limits reached.

Page 66 BUILDING CONTROLS ANALYSIS 2/23/

This procedure was completed at 7:48:18
REGRESSION VARIABLES=BTUD2MIN,POP MC
/DEPENDENT=BTUD2MIN
/METHOD=STEPWISE.

Page 67 BUILDING CONTROLS ANALYSIS 2/23/

* * * * M U L T I P L E R E G R E S S I O N * * * *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. BTUD2MIN

Beginning Block Number 1. Method: Stepwise

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

Variable(s) Entered on Step Number
1.. POP

Multiple R .87185
R Square .76013
Adjusted R Square .75958
Standard Error .31334

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	136.89604	136.89604
Residual	440	43.19972	.09818

F = 1394.32067 Signif F = .0000

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* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. BTUD2MIN

----- Variables in the Equation -----

Variable	B	SE B	Beta	T	Sig T
POP	3.883130E-03	1.03992E-04	.87185	37.341	.0000
(Constant)	.29886	.02249		13.288	.0000

----- Variables not in the Equation -----

Variable	Beta In	Partial	Min Toler	T	Sig T
MC	.03235	.06587	.99457	1.383	.1673

End Block Number 1 PIN = .050 Limits reached.

Page 70 BUILDING CONTROLS ANALYSIS 2/23/

This procedure was completed at 7:48:30
REGRESSION VARIABLES=BTUDDMIN,BTUDDUN MC
/DEPENDENT=BTUDDMIN
/METHOD=STEPWISE.

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* * * * M U L T I P L E R E G R E S S I O N * * * *

***** P L O T *****

Data Information

442 unweighted cases accepted.

Frequencies and symbols used (not applicable for control or overlay plots)

1 - .

Page 6

SPSS/PC+

11/10/92

PLOT OF BTUDDMIN WITH UNITS

442 cases plotted.

PLOT OF BTUD2MIN WITH UNITS

442 cases plotted.

This procedure was completed at 15:32:07

***** P L O T *****

Data Information

442 unweighted cases accepted.

Frequencies and symbols used (not applicable for control or overlay plots)

1 - +

04 cases plotted.

PLOT OF BTU2DMC WITH UNITS

204 cases plotted.

This procedure was completed at 15:34:54

***** P L O T *****

Data Information

442 unweighted cases accepted.

frequencies and symbols used (not applicable for control or overlay plots)

1 - -

PLOT OF BTUIMC WITH UNITS

Energy Use

Units in Building

8 cases plotted.

38 cases plotted.

**DATE
FILMED**

9/29/93