LOW TEMPERATURE AIR DISTRIBUTION WITH ICE STORAGE SYSTEM
A CASE STUDY

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Abstract. This paper discusses the performance of an off peak ice storage air conditioning system installed on an office warehouse building in Dallas, Texas. The system also incorporates a low temperature (45 degree) air distribution system utilized with parallel fan-powered VAV boxes. The entire system is controlled by a microprocessor based Building Automation System (BAS) incorporating state-of-the-art direct digital controls (DDC). The economic performance of the system will be discussed by comparing utility bills, and the system performance will be observed through the use of actual trend logs taken from the BAS on a typical summer day. The reduced space relative humidity levels, resulting from the low temperature distribution system, will be shown in actual trend logs also. The method of distributing low temp air without causing occupant discomfort (cold air dumping) will also be discussed.

Introduction. The Trane Company, Dallas, Texas in late 1988, made a decision to consolidate its Commercial Sales Office, Dealers Sales Office, and Warehouse into one building and entered into a lease agreement for an existing unfinished 60,000 square foot office/warehouse located in the northwest section of Dallas, Texas. The building was constructed of concrete tilt wall with steel pan/3 ply roof. It incorporated single pane glass windows with some very large sections (nine feet tall) on the bottom floor. The building is two stories tall and we decided to use 30,000 square feet as an equipment warehouse and the remaining 29,000 square feet as general office space for sales and service operations. The final lease agreement was reached on January 15, 1989. We had two and a half months to select, install, and commission the system and interior for a move-in date of April 1.

System Selection. The lowest cost system available to condition the 29,000 square feet of office space was multiple mid-range rooftops. We also evaluated commercial rooftops with DDC/VAV, and a chilled water system incorporating ice storage and low temperature air distribution with DDC/VAV. We selected the ice storage system based on life cycle cost and performance. The specifics of the installed system are as follows:

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AIR CONDITIONING SYSTEM (OFFICE AREA)

CHILLERS

QUANTITY	NOMINAL SIZE	TYPE	COMPRESSORS	MFGR.
2	60 TON	Air Cooled	1 w/2 Recips 1 w/4 Scrolls	Trane

AIR UNITS

QUANTITY	TYPE	COIL SIZE	LEAVING AIR TEMP	ENTERING WATER TEMP	TOTAL CFM	MFGR.
2	Draw-Thru	8 Row	45°	38°	22838	Trane

VAV BOXES

QUANTITY	TYPE	TOTAL CFM	MFGR.
24	Parallel-Fan Powered w/DDC Controls	2500	Trane

ICE TANKS

QUANTITY	NOMINAL CAPACITY	MFGR
4	190 Ton-Hr	Cal-Mac

AUTOMATION SYSTEM

TYPE	MFGR
Tracer 100	Trane

SYSTEM OPERATION (FULL STORAGE)

TIME	CHILLERS	ICE TANKS	OCCUPANCY
6:30 am - 11:50 am	On	Stand by	Full
11:50 am - 8:10 pm	Off	Melt	Full
8:10 pm - 6:30 am	On	Freeze	Partial (Timed-Override)

Mechanical Contractor - H & G Systems

Mechanical Engineer - Patton Engineers Inc.

System Justification. TU Electric, the local power company, offers a two part incentive for thermal storage systems, so we were very interested in seeing how the life cycle cost of the ice system compared to the small rooftop and large rooftop VAV alternatives. The incentive is essentially a front-end cash incentive that amounts to approximately $350 per KW, shifted away from "on peak" operating hours (12:00 noon to 8:00 pm weekdays). The second part of the incentive is a "time of day" rate structure that bases the demand charge in June, July, August, and September on the electrical demand registered during the "on peak" time (12:00 noon to 8:00 pm). This allows an owner to run a higher demand during "off peak" hours without paying a penalty. Dallas also has an 80% ratchet clause so that any peak demands you incur during June through September will penalize you for at least a full year. These incentives, of course, promote thermal storage systems and really captured our interest. We also realized that an ice storage system would enable us to utilize 38 degree chilled water. This leans very favorably to low temperature air distribution systems. Low temperature air distribution was attractive because it reduced the CFM by 33% and corresponding operating cost of the fans; it also increased the front-end cash incentive payment, as TU Electric would include the KW reduction of the fans in their cash incentive program. We additionally wanted to experiment with introducing cold air directly into the occupied spaces without running the VAV mixing fans. We were unable to find any information on installations that had done this, however, so we opted to utilized parallel fan-powered boxes on all of the zones (interior and perimeter) so we could run the fan and mix return air with the low temp (45 degree) air from the ductwork, should it be necessary. To promote mixing at the diffuser, this system incorporated induction slot diffusers that utilized the coanda effect to promote natural mixing at the ceiling and prevent dumping of cold air on occupants at reduced part load air flows.

The stage was set to evaluate the three systems. The guiding light that our corporation gave us was that any additional first cost adds must be offset by a simple payback of three years or less. We had the mechanical contractor evaluate the three systems. In ascending first cost ratings they came in as follows:

1. Small Rooftops, Constant Volume
2. Commercial Rooftops with DDCVAV
3. Thermal Storage with Low Temp Air Distribution and DDCVAV

The rooftop VAV system was close enough in cost to the storage system that it was easy to justify the storage over the rooftop VAV. The constant volume, small rooftop system, however, offered first cost savings that made the thermal storage system a three and one-half year payback, even considering the first cost incentive from the power company. At that point, we began to evaluate performance and comfort. We decided that due to the increased number of control zones and the capability to monitor and maintain comfort with the automation system, we should be providing a much more comfortable environment for employees that should improve productivity and reduce complaints. This led us to select the thermal storage system with low temperature air distribution and DDC/VAV.

The system was commissioned in April of 1989 and in January of 1990 the power company announced a revenue increase that would be implemented in August of 1990. The effect of this revenue increase on commercial customers is essentially a 50% increase in the demand charge and very little change in the consumption (KWH) charge. Since the primary operating cost savings on ice storage systems is due to the shifting of demand to off peak times, our ice storage system will actually give us much better than a three year payback. This was not known when the analysis was made in January of 1989. In any case, the system was installed and commissioned in April of 1989 and the ice storage operation was started in late May.

Economic Performance. Our operating cost analysis in January 1989 projected approximately $8,000 to $10,000 operating cost savings per year utilizing the ice storage/low temp system vs. constant volume rooftops. This savings was primarily based on the demand shift of approximately 140 KW on the chillers and the demand reduction of approximately 7 KW on the air handlers. We reviewed our actual utility bills for the period of July 1989 through June 1990, and found that the cost of electrical utilities was approximately 87 cents per square foot for the office space in the building. This did not include the estimated portion of utilities consumed by the shop and warehouse. We compared these bills to our previous office space and found that we were utilizing approximately $1.25 per square foot with a large rooftop VAV system. The savings of 38 cents per square foot per year amounts to approximately an $11,000 savings total per year, which is slightly higher than our projection. As this savings is primarily due to demand shift, it should escalate to approximately $15,000 per year after the rate structure for Comanche Peak Phase I is implemented. The savings could be over $20,000 per year after Phase II of Comanche Peak is brought on-line. We are expecting the effective demand charge in Dallas to be approximately $14 per KW at this time.

We installed a pulse meter on our building electrical distribution panel to monitor both on peak and off peak demand as well as KWH consumption with our BAS. We run continuous trend logs on these figures and they can be reviewed in Attachment H and Attachment I. Please note that the on peak KW demand is listed as zero for weekend and holidays, as the utility company considers the entire day an off peak situation. The monitoring of electrical utility usage has proven to be fairly accurate and we have found them to be within 3 percent of the energy usage reported in our actual utility bills.

System Performance. The Tracer 100 Building Automation System allows us to monitor and keep trend logs on all of the binary and analog control functions performed. A few of these trend logs are included as Attachments A through I of this report. The chillers, air units, and VAV boxes are also shipped with factory installed microprocessors that allow us to monitor, control, and trend log all of their functions. Thanks to advanced microprocessor technology, we are able to closely scrutinize the buildings performance.

Low Temperature Distribution System. We had a lot of interest in evaluating the performance of the low temperature air distribution system, as it was not a commonly used system in comfort applications at the time it was implemented in 1989. We feel its performance has greatly exceeded its expectations and an unexpected bonus in comfort levels is achieved through reduced relative humidity during the summer months. Attachment E lists some of our temperature averages over a summer day and the corresponding relative humidity recorded by a sensor located near a hallway downstairs. We have also checked the humidity throughout the building and find that we average 34% to 36% RH throughout the day during the summer months. Most office buildings average 50% to 60% relative humidity in the summer and this 15% to 20% reduction in relative humidity levels has greatly enhanced the comfort on muggy summer days. I feel this is one of the primary advantages of a low temperature air distribution system, especially in hot and humid climates. We had some concerns about the performance of the low temperature air distribution system and I will discuss these individually.

1. Condensation. We were concerned that the low temperature air (45 degrees) might cause possible condensation problems on the diffusers or in the ductwork located above the ceiling. To-date we have had no condensation problems whatsoever and we attribute this to the fact that the building is drier with its relative humidity of approximately 35 percent. We are utilizing the ceiling plenum in which the ductwork is located as a return air plenum. This, of course, means that this area is kept at low humidity levels as well as the occupied spaces. If a ducted return system was used, then high humidity levels in the plenums where the ductwork is located should be considered in selecting insulation for the ductwork. We have experienced no condensation on system start-up after a long weekend. We attribute this to the gradual pull-down effect of both temperature and humidity, as the air units gradually reduce the supply air temperature down to its designed setpoint of 45 degrees.

2. Airflow. Reducing the temperature of the distributed air by 10 degrees results in a reduction of primary air of approximately 33 percent. Since this reduced airflow might cause comfort problems, we installed parallel fan-powered boxes to mix return air with supply air and keep delivered airflows at a higher level. We were also concerned that as the VAV boxes throttled back at part load conditions, there might be a tendency to "dump" 45 degree air on the building occupants which would cause discomfort. So far, however, we have not experienced any comfort problems due to poor airflow. We utilized induction slot diffusers to promote air mixing at the ceiling and have not experienced any cold air dumping at part loads. For this reason and to keep operating costs at a minimum, we have not activated the fans in the VAV boxes during any of the cooling cycle. We let the boxes throttle all the way to zero airflow. The fans are then used as the first stage of heating when the space falls below the heating temperature setpoint. The DDC/VAV control system, however, does allow us to activate the fans for mixing purposes if we should ever desire to do so in the future. This can be done through a simple change in software.

3. Indoor Air Quality. The reduced primary airflows can be observed in the trend log in Attachment F. The automation system has the capability of summing all of the airflow of the individual VAV boxes. We can therefore monitor the average CFM per square foot of air delivery in the building. You can see from Attachment F, that we average between .46 and .50 CFM per square foot during the occupied part of the day. July 24th was a fairly mild day for summer, but we rarely see the building get above .6 CFM per square foot. We were concerned that a reduction in outside air quantities might cause higher concentrations of carbon dioxide, so we temporarily monitored CO_2 levels with a gas analyzer and found them to be well below acceptable limits (5000 parts per million listed

as a continuous exposure threshold limit by the American Conference of Government Industrial Hygienics in Publication ISBN:0-936712-78-3). We are no longer using an infrared gas monitor due to its cost, but feel it could be an economic strategy in controlling the quantity of outside air introduced into a building. The automation system could monitor CO_2 levels and only introduce the amount of outside air that was necessary to keep CO_2 at a satisfactory level.

4. Duct Air Temperature Gains. We were concerned that the low temperature air might experience higher than normal temperature gains prior to reaching the farthest box in the run. We have found that at medium to high airflows, the duct temperature gains are very minimal (1 or 2 degrees), while at low airflows, the duct temperature air gains can increase from 5 to 6 degrees when the VAV boxes are throttling back. This tendency actually helps promote higher airflows in a low temperature VAV system at part load. This phenomenon is demonstrated in Attachment G by observing simultaneous discharge air temperature from Air Unit #1 (44 degrees) and the inlet air temperature to two VAV boxes, which were located at the farthest point in their runs. VAV Box #9 was located upstairs and was an experiencing 40 percent of design flow with the air valve in the 37 percent open position. The inlet air temperature at this box was measured as 45 degrees or a 1 degree gain. VAV Box #7 was located downstairs and was only experiencing 25 percent of its design flow with the air valve in the 18 percent open position. The inlet temperature at this box was 49 degrees, which represented a 5 degree temperature increase. Both of these boxes were served by the same air unit and the readings were taken directly from the automation system less than one minute apart.

The trend log for Air Unit #1 is listed in Attachment F and gives supply air temperatures, return air temperatures, and space relative humidity over a twenty-four hour period. The duct static pressure is also listed, which is an indication of whether the air unit was operating or off.

<u>Ice Storage System</u>. Attachment A is a printout of the chilled water system graphic on the Building Automation System. Several input and output points have been added at their appropriate locations so the graphic represents live performance data of the system. Immediately below the graphic is a tabular output of some of the same points. The air handling units utilize 2-way valves and the system has a bypass line with a modulating relief valve designed to maintain system pressure. The system utilizes a 25% mixture of ethylene glycol and, therefore, does not use a city water makeup. Any loss of chilled water is handled by a makeup from a premixed glycol solution tank that is controlled by a level sensor in the expansion tank. The ice tanks are located immediately downstream of the chillers and the system flow through the ice tanks is controlled by the chilled water mixing valve (Item 3). This valve performs the following functions:

1. Freeze cycle - the valve is wide open to the tanks and allows full system flow through the tanks.
2. Melt cycle - the valve modulates system flow through the tanks to maintain setpoint of chilled water delivered to the air handlers.
3. Standby mode - this is the valve position when the chillers are running in the morning and it bypasses all of the system flow

around the tanks so that the ice can be saved for the "on peak" usage in the afternoon. The system is fairly simple in that it uses standard commercial air conditioning products and modular storage tanks that have no moving parts. The glycol solution is chilled to approximately 24° at night and circulated through the heat exchanger tubes in the tanks to freeze the water stored there. During the morning, the chillers run in their normal configuration and the solution bypasses the tanks to cool the building. At 11:50 a.m. the chillers are turned off and the chilled water modulation valve begins to modulate solution flow through the heat exchangers in the tank to allow the ice to melt and cool the building. The water that freezes and thaws in the tanks never leaves the tanks. This building has no nighttime janitorial or maintenance personnel on hand so it is crucial that the system completely freezes the tanks before personnel arrive at 6:00 a.m.. Failure to have a full ice charge can result in incapability to meet the load during afternoon, as the chillers must be kept off during the entire on peak cycle (noon to 8:00 p.m.) to avoid any demand charges during the summer months. Keeping the system simple and basic is a major step in insuring its reliability.

Attachment C shows a trend log of the ice system performance and its various operating modes over a 24 hour period. Please note that the ice tanks only reached 91% capacity at 6:00 a.m. when the system was changed from the freeze mode to the standby mode. This is due to the fact that the building was temporarily experiencing a graveyard shift operation during the night and the air conditioning system was operated on a timed override basis (evidenced in Attachment D). Static pressure readout for air unit 1 shows that the unit was operating at 10:00 p.m. and also at midnight. The graveyard shift operation is not a normal function of this building and the system was not designed to support air conditioning usage after 9:00 p.m.

<u>Chillers</u>. Attachment D depicts a 24 hour trend log of the two air cooled chillers installed on the building. Chiller #2 utilizes four scroll compressors and chiller #1 utilizes two reciprocating compressors. They are both nominal 60 ton air cooled chillers. Chiller #2 is more efficient; therefore, it is the lead chiller and will be the last to unload. Attachment B shows a printout of the microprocessor panel for each individual chiller during the melt mode. You will note that all compressors are off and their respected amperage draw is 0. The chiller panel also enables us to monitor any diagnostics that might have occurred should the chillers experience problems overnight. The trend logs of all the analog points are very helpful in trouble shooting any problems that happen during an unoccupied mode of the building. The BAS also has a phone modem to monitor and control the building from a remote location, which is very helpful for this type of building usage.

<u>VAV Boxes</u>. Attachment G lists a printout of the microprocessor controller located on two of the VAV boxes. We are able to monitor valve position, air flow, setpoints, maximum and minimum air flow settings, night setback controls, and duct air temperature immediately ahead of the box. We also have the capability to deactivate the fan and heat during certain months as well as activate the fan at any given primary air flow rate to promote mixing, should it prove desirable. The direct digital control of the VAV boxes gives a tremendous amount of flexability to low temperature air distribution systems and is highly

recommended should low temperature air be the system of choice. DDC/VAV also gives the owner the capablility to monitor all the individual space temperatures at a glance. A few of these temperatures are shown in Attachment E.

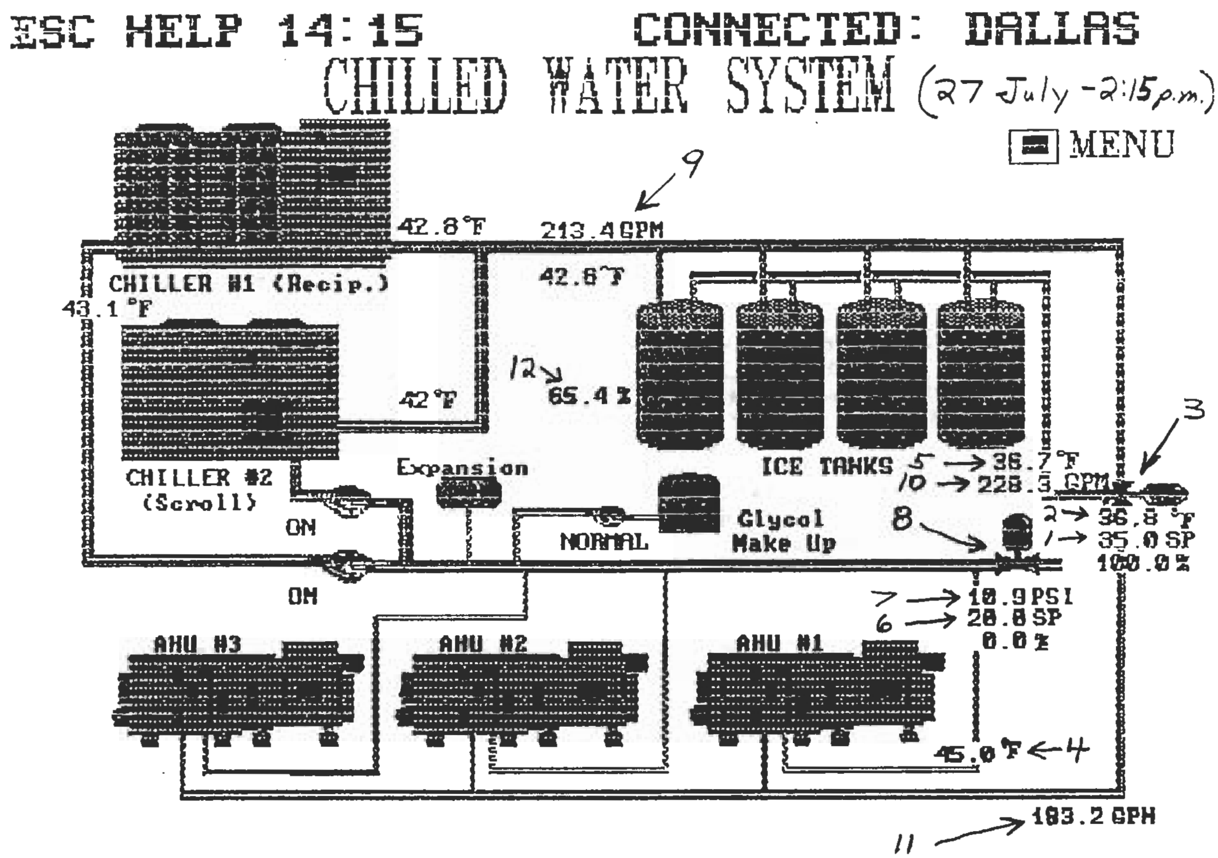
Air Handling Units. Attachment G lists a printout of the microprocessor located on air unit #1. DDC control systems have been an incredible asset in trouble shooting and setting up air balance on air distribution systems of all types. The capability to see at a glance supply air temperatures, return air temperatures, outside air temperatures, mixed air temperatures, cooling valve position, inlet guide vane position and implement changes from a central point enables the owner to setup and maintain a system at peak efficiencies.

Conclusion. We feel that the thermal storage/low temp VAV system we selected for our office/warehouse application has been a good decision for the following reasons:

1. The added first cost for the system will be paid back in approximately two and one-half years at the current utility rate structure. The payback was possible because of the cash incentive offered by T.U. Electric for the off peak storage system.

2. The low temperature air distribution system has enabled us to reduce both first and operating cost of the airside components. The major comfort benefit from the system has been the reduced relative humidity in the occupied spaces. It has been a truly noticable improvement on hot, muggy days. Low temperature systems could be economically applied to applications that demand lower than normal relative humidity, such as data processing, semi-conductor manufacturing, supermarket and healthcare.

3. The DDC control systems incorporated into this building have greatly assisted in keeping the comfort levels at their optimum. Improved comfort levels can have a definite effect on the productivity of the occupants and DDC controls can be well worth the investment as they keep the HVAC system at its peak performance.

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CMD=)               14:18  FRI  27-JUL-90          CONNECTED TO REMOTE: DALLAS
                                                               OPERATOR: AAA
14) 02-04 OUTSIDE AIR TEMP              99 DEG

Type number of selection, then press "S" to select it
Building Status: S-select Display, L-list, N-next, P-previous  3

ICE SYSTEM          Status: S-select Point, L-list all
 1) 11-03 CHW MIXING SETPT           35.0 DEG       (S-select for override)
 2) 02-02 MIXED CHW SUP TEMP         36.8 DEG
 3) 12-01 CHW MIXING VALVE          100.0 PCT       (S-select for override)
 4) 02-05 BLDG CHW RET TEMP          45.1 DEG
 5) 02-08 ICE TANK SUP TEMP          36.8 DEG
 6) 11-04 CHW BYPASS SETPT           20.0 PSI       (S-select for override)
 7) 02-03 CHW DIFF PRESSURE          12.0 PSI
 8) 12-02 CHW BYPASS VALVE            0.0 PCT       (S-select for override)
 9) 02-06 PRIMARY LOOP FLOW         213.4
10) 02-09 ICE TANK FLOW             228.0
11) 02-07 BUILDING FLOW             182.7
12) 02-01 ICE TANK METER             65.2 PCT

Type number of selection, then press "S" to select it
[redacted] REMOTE KEYS ë ELAPSED TIME (MINUTES): 018 [redacted]
 M=MENU, S=SELECT, L=LIST, N=NEXT, P=PREVIOUS, H=HELP, R=REPEAT, C=CLEAR, A=ACK
F1-HANG UP F5-PRINT DISPLAY F7-TURN ECHO ON F9-TURN CAPTURE ON F10-GRAPHIC MODE
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ATTACHMENT B

ICE SYSTEM - JULY 24, 1990 - 3:15 P.M. (MELT MODE)

ICE SYSTEM	Status: S-select Point, L-list all	
1) 11-03 CHW MIXING SETPT	35.0 DEG	(S-select for override)
* 2) 02-02 MIXED CHW SUP TEMP	37.0 DEG	
3) 12-01 CHW MIXING VALVE	100.0 PCT	(S-select for override)
4) 02-05 BLDG CHW RET TEMP	44.9 DEG	
5) 02-08 ICE TANK SUP TEMP	36.8 DEG	
6) 11-04 CHW BYPASS SETPT	20.0 PSI	(S-select for override)
7) 02-03 CHW DIFF PRESSURE	13.7 PSI	
8) 12-02 CHW BYPASS VALVE	0.0 PCT	(S-select for override)
9) 02-06 PRIMARY LOOP FLOW	212.8	
10) 02-09 ICE TANK FLOW	223.4	
11) 02-07 BUILDING FLOW	174.3	
12) 02-01 ICE TANK METER	45.8 PCT	

CHILLER #1	Status: S-select Point, L-list all
1) 18-84 CH1 SUPPLY TEMP	42.6 DEG
2) 18-85 CH1 RETURN TEMP	42.9 DEG
3) 18-86 COMMON CHWS TEMP	42.7 DEG
4) 19-11 CH1 COMP1 ON-OFF	OFF
5) 19-12 CH1 COMP2 ON-OFF	OFF
6) 19-13 CH1 COMP 1-2 FAIL	NORMAL
7) 23-01 CH1 MAKE ICE (S-select for override)	OFF/PCL
8) 23-02 CH1 ON-OFF (S-select for override)	OFF/PCH
9) 23-03 CHW PUMP #1 ON-OFF (S-select for override)	ON/PCL
10) 01-02 CHW PUMP #1 STATUS	ON
11) 23-04 CHW PUMP #2 ON-OFF (S-select for override)	ON/PCL
12) 01-03 CHW PUMP #2 STATUS	ON

CHILLER #2	Status: S-select Point, L-list all	
1) 11-11 CH2 NORMAL SETPT	65 DEG	(S-select for override)
2) 11-12 CH2 ICE SETPOINT	20 DEG	(S-select for override)
3) 08-16 CH2 ENABLE-DISABLE	DISABL/PCH	(S-select for override)
4) 08-17 CH2 ICE ENABLE	DISABL/PCH	(S-select for override)
5) 19-18 CH2 COMMUNICATIONS	YES	
6) 18-53 CH2 CHWR TEMP	43 DEG	
7) 18-54 CH2 CHWS TEMP	43 DEG	
8) 18-55 CH2 ACTIVE SETPT	65 DEG	
9) 18-56 CH2 COMP#1 PER RLA	0 PCT	
10) 18-57 CH2 COMP#2 PER RLA	0 PCT	
11) 18-58 CH2 COMP#3 PER RLA	0 PCT	
12) 18-59 CH2 COMP#4 PER RLA	0 PCT	
13) 19-19 CH2 LATCHING ALARM	NORMAL	
14) 19-20 CH2 CHILLER STATUS	DISABL	
15) 19-21 CH2 CHW FLOW	YES	
16) 19-22 CH2 COMP #1	OFF	
17) 19-23 CH2 COMP #2	OFF	
18) 19-24 CH2 COMP #3	OFF	
19) 19-25 CH2 COMP #4	OFF	

* Mixed CHW Sup Temp is temperature of water distributed to AHU's. Sensor is downstream of Ice Mixing Valve.

ATTACHMENT C

T R E N D   L O G   R E P O R T

DATE	TIME	ICE TANK METER	*ICE TANK SUP TEMP	** MIXED CHW SUP TEMP	ICE SYS. OPERATING MODE
23-JUL-90	04:01 PM	60.6 PCT	37.7 DEG	37.7 DEG	MELT
23-JUL-90	05:01 PM	43.5 PCT	38.5 DEG	38.6 DEG	MELT
23-JUL-90	06:01 PM	28.1 PCT	39.2 DEG	39.2 DEG	MELT
23-JUL-90	07:01 PM	12.2 PCT	40.2 DEG	40.0 DEG	MELT
23-JUL-90	08:01 PM	-2.0 PCT	42.3 DEG	42.3 DEG	MELT
23-JUL-90	09:01 PM	-2.4 PCT	30.2 DEG	29.8 DEG	FREEZE
23-JUL-90	10:01 PM	-2.2 PCT	31.6 DEG	31.3 DEG	FREEZE
23-JUL-90	11:01 PM	12.1 PCT	31.0 DEG	30.4 DEG	FREEZE
24-JUL-90	12:01 AM	35.1 PCT	31.2 DEG	31.0 DEG	FREEZE
24-JUL-90	01:01 AM	47.4 PCT	30.6 DEG	30.1 DEG	FREEZE
24-JUL-90	02:01 AM	58.1 PCT	30.3 DEG	30.0 DEG	FREEZE
24-JUL-90	03:01 AM	68.3 PCT	30.2 DEG	29.8 DEG	FREEZE
24-JUL-90	04:01 AM	78.3 PCT	29.9 DEG	29.5 DEG	FREEZE
24-JUL-90	05:01 AM	86.2 PCT	30.4 DEG	30.1 DEG	FREEZE
24-JUL-90	06:01 AM	91.2 PCT	31.2 DEG	31.0 DEG	STANDBY
24-JUL-90	07:01 AM	90.0 PCT	32.4 DEG	33.5 DEG	STANDBY
24-JUL-90	08:01 AM	89.9 PCT	32.5 DEG	38.9 DEG	STANDBY
24-JUL-90	09:01 AM	88.3 PCT	32.5 DEG	37.4 DEG	STANDBY
24-JUL-90	10:01 AM	87.4 PCT	32.8 DEG	37.0 DEG	STANDBY
24-JUL-90	11:01 AM	85.7 PCT	32.7 DEG	38.9 DEG	STANDBY
24-JUL-90	12:01 PM	82.8 PCT	33.9 DEG	35.0 DEG	MELT
24-JUL-90	01:01 PM	72.0 PCT	35.5 DEG	35.6 DEG	MELT
24-JUL-90	02:01 PM	60.9 PCT	36.4 DEG	36.5 DEG	MELT
24-JUL-90	03:01 PM	49.1 PCT	36.7 DEG	36.8 DEG	MELT

* Ice Tank Supply Temp - This sensor is located at leaving glycol side of tanks and upstream of mixing valve (Item 5 on Attachment A)

** Mixed CHW Supply Temp - This sensor is located downstream of mixing valve and is the temperature of the glycol solution distributed to Air Units. (Item 2 on Attachment A)

NOTE: The Chilled Water Mixing Valve (Item 3 on Attachment A) operates as follows:

SYSTEM MODE	VALVE POSITION
Freeze	Full Flow Through Tanks
Melt	Modulate Flow Through Tanks to Maintain Setpoint
Standby	Bypass Flow Around Tanks

ATTACHMENT D

CHILLERS

TREND LOG REPORT

DATE	TIME	CH1 RETURN TEMP	CH1 SUPPLY TEMP	COMMON CHWS TEMP	ICE TANK METER
23-JUL-90	04:01 PM	44.8 DEG	44.5 DEG	44.3 DEG	60.6 PCT
23-JUL-90	05:01 PM	45.2 DEG	45.1 DEG	45.1 DEG	43.5 PCT
23-JUL-90	06:01 PM	45.7 DEG	45.3 DEG	45.2 DEG	28.1 PCT
23-JUL-90	07:01 PM	46.3 DEG	46.3 DEG	45.9 DEG	12.2 PCT
23-JUL-90	08:01 PM	47.8 DEG	47.4 DEG	47.3 DEG	-2.0 PCT
23-JUL-90	09:01 PM	31.3 DEG	23.9 DEG	23.5 DEG	-2.4 PCT
23-JUL-90	10:01 PM	34.4 DEG	28.1 DEG	28.1 DEG	-2.2 PCT
23-JUL-90	11:01 PM	31.6 DEG	24.5 DEG	24.4 DEG	12.1 PCT
24-JUL-90	12:01 AM	34.8 DEG	26.3 DEG	26.2 DEG	35.1 PCT
24-JUL-90	01:01 AM	31.3 DEG	24.1 DEG	23.8 DEG	47.4 PCT
24-JUL-90	02:01 AM	31.0 DEG	23.8 DEG	23.6 DEG	58.1 PCT
24-JUL-90	03:01 AM	30.8 DEG	23.5 DEG	23.2 DEG	68.3 PCT
24-JUL-90	04:01 AM	30.8 DEG	23.4 DEG	23.1 DEG	78.3 PCT
24-JUL-90	05:01 AM	33.7 DEG	26.2 DEG	25.9 DEG	86.1 PCT
24-JUL-90	06:01 AM	37.5 DEG	29.0 DEG	28.7 DEG	91.2 PCT
24-JUL-90	07:01 AM	36.3 DEG	36.1 DEG	33.3 DEG	90.0 PCT
24-JUL-90	08:01 AM	44.3 DEG	40.8 DEG	38.2 DEG	89.9 PCT
24-JUL-90	09:01 AM	42.6 DEG	39.4 DEG	36.7 DEG	88.3 PCT
24-JUL-90	10:01 AM	42.4 DEG	38.9 DEG	36.2 DEG	87.4 PCT
24-JUL-90	11:01 AM	44.1 DEG	41.6 DEG	38.6 DEG	85.7 PCT
24-JUL-90	12:01 PM	41.5 DEG	41.3 DEG	41.1 DEG	82.8 PCT
24-JUL-90	01:01 PM	42.0 DEG	41.9 DEG	41.7 DEG	72.0 PCT
24-JUL-90	02:01 PM	42.6 DEG	42.4 DEG	42.3 DEG	60.9 PCT
24-JUL-90	03:01 PM	43.1 DEG	43.0 DEG	42.8 DEG	49.1 PCT

DATE	TIME	CH2 CHWR TEMP	CH2 CHWS TEMP	CH2 COMP #1	AHU #1 STATIC PRES
23-JUL-90	04:01 PM	44 DEG	44 DEG	OFF	2.5 IN
23-JUL-90	05:01 PM	45 DEG	44 DEG	OFF	2.5 IN
23-JUL-90	06:01 PM	45 DEG	45 DEG	OFF	2.7 IN
23-JUL-90	07:01 PM	46 DEG	45 DEG	OFF	2.6 IN
23-JUL-90	08:01 PM	47 DEG	47 DEG	OFF	2.5 IN
23-JUL-90	09:01 PM	30 DEG	24 DEG	ON	0.2 IN
23-JUL-90	10:01 PM	32 DEG	26 DEG	ON	3.8 IN
23-JUL-90	11:01 PM	31 DEG	25 DEG	ON	0.1 IN
24-JUL-90	12:01 AM	35 DEG	28 DEG	ON	3.5 IN
24-JUL-90	01:01 AM	30 DEG	24 DEG	ON	0.0 IN
24-JUL-90	02:01 AM	30 DEG	24 DEG	ON	0.0 IN
24-JUL-90	03:01 AM	30 DEG	24 DEG	ON	0.2 IN
24-JUL-90	04:01 AM	30 DEG	24 DEG	ON	0.2 IN
24-JUL-90	05:01 AM	32 DEG	26 DEG	ON	0.2 IN
24-JUL-90	06:01 AM	36 DEG	30 DEG	ON	3.1 IN
24-JUL-90	07:01 AM	35 DEG	30 DEG	ON	3.4 IN
24-JUL-90	08:01 AM	42 DEG	36 DEG	ON	2.7 IN
24-JUL-90	09:01 AM	41 DEG	34 DEG	ON	2.7 IN
24-JUL-90	10:01 AM	41 DEG	34 DEG	ON	2.7 IN
24-JUL-90	11:01 AM	42 DEG	36 DEG	ON	2.6 IN
24-JUL-90	12:01 PM	41 DEG	41 DEG	OFF	2.4 IN
24-JUL-90	01:01 PM	42 DEG	42 DEG	OFF	2.3 IN
24-JUL-90	02:01 PM	42 DEG	42 DEG	OFF	2.6 IN
24-JUL-90	03:01 PM	43 DEG	42 DEG	OFF	2.7 IN

ATTACHMENT E

OCCUPIED SPACE TEMPERATURES

ADMIN-GEN TEMPS Status: S-select Point, L-list all

1)	18-07	GRAY'S OFFICE	73 DEG
2)	18-08	SIEBERT'S OFFICE	74 DEG
3)	18-03	MAIN CONFERENCE RM	71 DEG
4)	18-01	LITERATURE ROOM	72 DEG
5)	18-02	KITCHEN	70 DEG
6)	18-15	LOUNGE AREA	71 DEG
7)	18-17	TRAINING ROOM	73 DEG
8)	18-19	MAIN ENTRANCE AREA	68 DEG
9)	18-06	THE ICS DEMO ROOM	73 DEG

ACCT-DSO TEMPS Status: S-select point, L-list all

1)	18-11	ACCOUNTING AREA	73 DEG
2)	18-12	DEALER SALES AREA	74 DEG
3)	18-16	US - D MANAGER	75 DEG
4)	18-20	ACCT COMPUTER ROOM	72 DEG
5)	18-98	ACCT MANAGER	72 DEG

TREND LOG REPORT

DATE	TIME	GROUP 1 AVG TEMP	GROUP 8 AVG TEMP	DEMO RM HUMIDITY	OUTSIDE AIR TEMP
23-JUL-90	04:01 PM	73 DEG	74 DEG	34 PCT	86 DEG
23-JUL-90	05:01 PM	73 DEG	74 DEG	35 PCT	88 DEG
23-JUL-90	06:01 PM	73 DEG	74 DEG	35 PCT	88 DEG
23-JUL-90	07:01 PM	73 DEG	73 DEG	37 PCT	88 DEG
23-JUL-90	08:01 PM	73 DEG	73 DEG	38 PCT	89 DEG
23-JUL-90	09:01 PM	77 DEG	77 DEG	37 PCT	85 DEG
23-JUL-90	10:01 PM	74 DEG	78 DEG	39 PCT	84 DEG
23-JUL-90	11:01 PM	77 DEG	79 DEG	38 PCT	83 DEG
24-JUL-90	12:01 AM	78 DEG	74 DEG	41 PCT	82 DEG
24-JUL-90	01:01 AM	78 DEG	77 DEG	41 PCT	81 DEG
24-JUL-90	02:01 AM	79 DEG	79 DEG	44 PCT	80 DEG
24-JUL-90	03:01 AM	80 DEG	80 DEG	47 PCT	79 DEG
24-JUL-90	04:01 AM	80 DEG	80 DEG	49 PCT	78 DEG
24-JUL-90	05:01 AM	80 DEG	80 DEG	49 PCT	78 DEG
24-JUL-90	06:01 AM	79 DEG	76 DEG	34 PCT	78 DEG
24-JUL-90	07:01 AM	74 DEG	74 DEG	38 PCT	79 DEG
24-JUL-90	08:01 AM	73 DEG	74 DEG	40 PCT	79 DEG
24-JUL-90	09:01 AM	72 DEG	73 DEG	39 PCT	81 DEG
24-JUL-90	10:01 AM	72 DEG	73 DEG	35 PCT	83 DEG
24-JUL-90	11:01 AM	72 DEG	73 DEG	35 PCT	87 DEG
24-JUL-90	12:01 PM	72 DEG	73 DEG	34 PCT	89 DEG
24-JUL-90	01:01 PM	74 DEG	73 DEG	34 PCT	93 DEG
24-JUL-90	02:01 PM	73 DEG	73 DEG	35 PCT	81 DEG
24-JUL-90	03:01 PM	73 DEG	73 DEG	35 PCT	83 DEG

ATTACHMENT F

AIRFLOWS

TREND LOG REPORT

DATE	TIME	BLDG. TOTAL CCFM	CFM PER SQ. FT.	PPM CO-2	OUTSIDE AIR TEMP
23-JUL-90	04:01 PM	138	.48	1481	86 DEG
23-JUL-90	05:01 PM	140	.48	1471	88 DEG
23-JUL-90	06:01 PM	138	.48	1474	88 DEG
23-JUL-90	07:01 PM	133	.46	1486	88 DEG
23-JUL-90	08:01 PM	131	.45	1505	89 DEG
23-JUL-90	09:01 PM	0	0	1489	85 DEG
23-JUL-90	10:01 PM	42	.15	1504	84 DEG
23-JUL-90	11:01 PM	0	0	1496	83 DEG
24-JUL-90	12:01 AM	40	.14	1464	82 DEG
24-JUL-90	01:01 AM	0	0	1478	81 DEG
24-JUL-90	02:01 AM	0	0	1465	89 DEG
24-JUL-90	03:01 AM	0	0	1437	79 DEG
24-JUL-90	04:01 AM	0	0	1441	78 DEG
24-JUL-90	05:01 AM	47	.16	1438	78 DEG
24-JUL-90	06:01 AM	135	.47	1434	78 DEG
24-JUL-90	07:01 AM	140	.48	1409	79 DEG
24-JUL-90	08:01 AM	155	.53	1414	79 DEG
24-JUL-90	09:01 AM	133	.46	1449	81 DEG
24-JUL-90	10:01 AM	135	.47	1525	83 DEG
24-JUL-90	11:01 AM	135	.47	1544	87 DEG
24-JUL-90	12:01 PM	142	.49	1406	89 DEG
24-JUL-90	01:01 PM	146	.50	1410	93 DEG
24-JUL-90	02:01 PM	137	.47	1433	81 DEG
24-JUL-90	03:01 PM	132	.46	1425	83 DEG

DATE	TIME	AHU #1 STATIC PRES	AHU #1 RA TEMP	AHU #1 SA TEMP	DEMO RM HUMIDITY
23-JUL-90	04:01 PM	2.5 IN	76 DEG	45 DEG	34 PCT
23-JUL-90	05:01 PM	2.5 IN	76 DEG	45 DEG	35 PCT
23-JUL-90	06:01 PM	2.7 IN	76 DEG	45 DEG	35 PCT
23-JUL-90	07:01 PM	2.6 IN	76 DEG	46 DEG	37 PCT
23-JUL-90	08:01 PM	2.5 IN	76 DEG	48 DEG	38 PCT
23-JUL-90	09:01 PM	0.2 IN	80 DEG	75 DEG	37 PCT
23-JUL-90	10:01 PM	3.8 IN	82 DEG	44 DEG	39 PCT
23-JUL-90	11:01 PM	0.1 IN	79 DEG	72 DEG	38 PCT
24-JUL-90	12:01 AM	3.5 IN	80 DEG	44 DEG	41 PCT
24-JUL-90	01:01 AM	0.0 IN	77 DEG	70 DEG	41 PCT
24-JUL-90	02:01 AM	0.0 IN	76 DEG	78 DEG	44 PCT
24-JUL-90	03:01 AM	0.2 IN	76 DEG	79 DEG	47 PCT
24-JUL-90	04:01 AM	0.2 IN	77 DEG	80 DEG	49 PCT
24-JUL-90	05:01 AM	0.2 IN	77 DEG	80 DEG	49 PCT
24-JUL-90	06:01 AM	3.1 IN	77 DEG	44 DEG	34 PCT
24-JUL-90	07:01 AM	3.4 IN	75 DEG	43 DEG	38 PCT
24-JUL-90	08:01 AM	2.7 IN	75 DEG	45 DEG	40 PCT
24-JUL-90	09:01 AM	2.7 IN	75 DEG	43 DEG	39 PCT
24-JUL-90	10:01 AM	2.7 IN	75 DEG	43 DEG	35 PCT
24-JUL-90	11:01 AM	2.6 IN	75 DEG	45 DEG	35 PCT
24-JUL-90	12:01 PM	2.4 IN	75 DEG	43 DEG	34 PCT
24-JUL-90	01:01 PM	2.3 IN	76 DEG	44 DEG	34 PCT
24-JUL-90	02:01 PM	2.6 IN	75 DEG	44 DEG	35 PCT
24-JUL-90	03:01 PM	2.7 IN	76 DEG	43 DEG	35 PCT

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                         DUCT TEMP GAINS              ATTACHMENT G
 AHU #1 SALES-ACCT  Status: S-select Point, L-list all
 1) 07-09 AHU #1                 OCCUPY/PCL    COOLING
     Zone temp  (18-24):     73 DEG        (S-select for override)
 2) 11-01 AHU #1 SA SETPT        44 DEG OPR    (S-select for override)
 3) 18-70 AHU #1 SA TEMP         44 DEG  - Duct Air Temp @ AHU Discharge
 4) 18-74 AHU #1 COOLVLV POS     52 PCT
 5) 08-01 AHU #1 COOLING         ENABLE/       (S-select for override)
 6) 18-71 AHU #1 RA TEMP         76 DEG
 7) 18-72 AHU #1 MA TEMP         77 DEG
 8) 18-75 AHU #1 OA DAMP POS     100 PCT
 9) 08-02 AHU #1 OA OPEN         ENABLE/       (S-select for override)
 10) 08-03 AHU #1 OA CLOSED      ENABLE/       (S-select for override)
 11) 11-02 AHU #1 STATIC SETP    2.0 IN        (S-select for override)
 12) 18-73 AHU #1 STATIC PRES    2.8 IN
 13) 18-76 AHU #1 IGV POS        0 PCT
 14) 02-04 OUTSIDE AIR TEMP      82 DEG

 Upload Completed
VAV CU 1: VAV UCM  9 NEW CNST SALES MGR Status
Communications      UP,  Unit type        VFED
Control mode    OCCUPY,  Control action   COOL
Fan control     ENABLE,  Fan               OFF
Heat control    ENABLE,  Heat              OFF
Flow control      AUTO
Position           37%,  Flow          462 CFM - Medium Flow @ 40%
Control offset  DISABL,  Group number    8
Zone temp       72 DEG,  Aux temp       45 DEG - Duct Air Temp @ Box
Active cooling setpoint                 73 DEG   Inlet - 1° Temp Rise
Active heating setpoint                 70 DEG   From Air Unit
Occupied cooling setpoint               74 DEG
Occupied heating setpoint               71 DEG
Unoccupied cooling setpoint             85 DEG
Unoccupied heating setpoint             65 DEG
Maximum flow setpoint                 1100 CFM
Minimum flow setpoint                    0 CFM
Minimum heating flow setpoint            0 CFM
Fan control offset                       3 DEG

VAV CU 1: VAV UCM  7 DISTRICT MANAGER   Status
Communications      UP,  Unit type        VFED
Control mode    OCCUPY,  Control action   COOL
Fan control     ENABLE,  Fan               OFF
Heat control    ENABLE,  Heat              OFF
Flow control      AUTO
Position           18%,  Flow          286 CFM - Low Flow @ 25%
Control offset  DISABL,  Group number    3
Zone temp       73 DEG,  Aux temp       49 DEG - Duct Air Temp @ Box
Active cooling setpoint                 73 DEG   Inlet - 5° Temp Rise
Active heating setpoint                 70 DEG   From Air Unit
Occupied cooling setpoint               74 DEG
Occupied heating setpoint               71 DEG
Unoccupied cooling setpoint             85 DEG
Unoccupied heating setpoint             65 DEG
Maximum flow setpoint                 1100 CFM
Minimum flow setpoint                    0 CFM
Minimum heating flow setpoint            0 CFM
Fan control offset                       3 DEG
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ATTACHMENT H

3 3 DAY ENERGY REPORT

	Demand PROGRAM A		Demand PROGRAM B	
24-JUL-90	ON-PEAK	103 KW AT 11:59 AM	ON-PEAK	0 KW AT 00:00
	OFF-PEAK	176 KW AT 11:27 AM	OFF-PEAK	0 KW AT 00:00
23-JUL-90	ON-PEAK	105 KW AT 11:59 AM	ON-PEAK	0 KW AT 00:00
	OFF-PEAK	185 KW AT 09:27 PM	OFF-PEAK	0 KW AT 00:00
This B.P.	ON-PEAK	127 KW AT 11:59 AM	ON-PEAK	0 KW AT 00:00
	OFF-PEAK	225 KW AT 11:42 AM	OFF-PEAK	0 KW AT 00:00

DATE	USAGE	ON PEAK	OFF PEAK	USAGE	ON PEAK	OFF PEAK
24-JUL	2022.9 KWH	103 KW	176 KW	00000 KWH	0 KW	0 KW
23-JUL	2647.6 KWH	105 KW	185 KW	00000 KWH	0 KW	0 KW
22-JUL	1372.7 KWH	0 KW	132 KW	00000 KWH	0 KW	0 KW
21-JUL	2120.6 KWH	0 KW	148 KW	00000 KWH	0 KW	0 KW
20-JUL	3139.9 KWH	106 KW	182 KW	00000 KWH	0 KW	0 KW
19-JUL	3072.2 KWH	117 KW	212 KW	00000 KWH	0 KW	0 KW
18-JUL	2904.3 KWH	107 KW	182 KW	00000 KWH	0 KW	0 KW
17-JUL	2948.0 KWH	111 KW	178 KW	00000 KWH	0 KW	0 KW
16-JUL	2461.8 KWH	115 KW	185 KW	00000 KWH	0 KW	0 KW
15-JUL	1082.6 KWH	0 KW	148 KW	00000 KWH	0 KW	0 KW
14-JUL	1441.0 KWH	0 KW	135 KW	00000 KWH	0 KW	0 KW
13-JUL	3089.8 KWH	109 KW	175 KW	00000 KWH	0 KW	0 KW
12-JUL	3170.2 KWH	110 KW	178 KW	00000 KWH	0 KW	0 KW
11-JUL	3163.4 KWH	127 KW	219 KW	00000 KWH	0 KW	0 KW
10-JUL	3379.2 KWH	114 KW	209 KW	00000 KWH	0 KW	0 KW
09-JUL	3015.6 KWH	118 KW	225 KW	00000 KWH	0 KW	0 KW
08-JUL	1643.9 KWH	0 KW	169 KW	00000 KWH	0 KW	0 KW
07-JUL	2426.7 KWH	0 KW	168 KW	00000 KWH	0 KW	0 KW
06-JUL	3422.8 KWH	113 KW	219 KW	00000 KWH	0 KW	0 KW
05-JUL	3083.4 KWH	118 KW	217 KW	00000 KWH	0 KW	0 KW
04-JUL	2150.3 KWH	0 KW	144 KW	00000 KWH	0 KW	0 KW
03-JUL	3439.2 KWH	119 KW	219 KW	00000 KWH	0 KW	0 KW
02-JUL	3055.4 KWH	116 KW	223 KW	00000 KWH	0 KW	0 KW
01-JUL	1526.7 KWH	0 KW	145 KW	00000 KWH	0 KW	0 KW
30-JUN	2361.4 KWH	0 KW	143 KW	00000 KWH	0 KW	0 KW
29-JUN	3318.5 KWH	115 KW	196 KW	00000 KWH	0 KW	0 KW
28-JUN	3295.1 KWH	117 KW	207 KW	00000 KWH	0 KW	0 KW
27-JUN	3398.9 KWH	111 KW	204 KW	00000 KWH	0 KW	0 KW
26-JUN	3378.0 KWH	114 KW	218 KW	00000 KWH	0 KW	0 KW
25-JUN	3073.4 KWH	116 KW	193 KW	00000 KWH	0 KW	0 KW
24-JUN	1570.6 KWH	0 KW	151 KW	00000 KWH	0 KW	0 KW
23-JUN	2485.7 KWH	0 KW	172 KW	00000 KWH	0 KW	0 KW
22-JUN	3465.3 KWH	115 KW	220 KW	00000 KWH	0 KW	0 KW

ATTACHMENT I

1 2 MONTH ENERGY REPORT

		Demand PROGRAM A		Demand PROGRAM B
This B.P.	ON-PEAK	127 KW AT 11:59 AM	ON-PEAK	0 KW AT 00:00
	OFF-PEAK	225 KW AT 11:42 AM	OFF-PEAK	0 KW AT 00:00
Prev B.P.	ON-PEAK	121 KW AT 11:59 AM	ON-PEAK	0 KW AT 00:00
	OFF-PEAK	232 KW AT 09:37 AM	OFF-PEAK	0 KW AT 00:00
Y-T-D	ON-PEAK	179 KW AT 01:29 PM	ON-PEAK	0 KW AT 00:00
	OFF-PEAK	232 KW AT 09:37 AM	OFF-PEAK	0 KW AT 00:00

END OF B.P.	USAGE	ON PEAK	OFF PEAK	USAGE	ON PEAK	OFF PEAK
23-JUL	59757.3 KWH	127 KW	225 KW	00000 KWH	0 KW	0 KW
30-JUN	86790.1 KWH	121 KW	232 KW	00000 KWH	0 KW	0 KW
31-MAY	72361.1 KWH	179 KW	197 KW	00000 KWH	0 KW	0 KW
30-APR	48181.7 KWH	127 KW	175 KW	00000 KWH	0 KW	0 KW
31-MAR	61607.8 KWH	171 KW	220 KW	00000 KWH	0 KW	0 KW
28-FEB	47519.8 KWH	167 KW	210 KW	00000 KWH	0 KW	0 KW