

# Use of Energy Management and Control Systems for Performance Monitoring of Retrofit Projects

Final Summary Report

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## 1.0 Executive Summary

Traditionally, Energy Management and Control Systems (EMCSs) have been used to control HVAC, lighting, fire and security systems in buildings. Few EMCSs are used for long term trending and analysis of energy use (i.e., the storage and display of contiguous hourly data over one year).

Developments in three closely related fields may influence the way EMCSs are used in buildings in the future. First, efforts by researchers are beginning to show that continuous monitoring and analysis of a building's energy use can improve the performance of HVAC retrofits, and help to assure the persistence of the retrofit by constantly checking to see if the retrofit is performing as expected. Second, recent advances in computer technology are now bringing laboratory computing capabilities to the desks of building operators who will eventually inherit today's research in the form of improved building control.

Third, common communications protocol standards by ASHRAE and others will eventually allow for easy access to a vast plethora of control and communications systems. However, in order to accomplish this, EMCSs must be tapped for their ability to serve dual functions. First, they must be easy to use, dependable control systems; and second they must also begin to serve as effective sources of long term monitored data. This report provides a summary of efforts by several researchers to investigate whether EMCSs can be used to perform long term remote monitoring of energy use and environmental conditions in buildings, including an assessment of the use of EMCSs to provide data for the Texas LoanSTAR program.

The Texas LoanSTAR Monitoring and Analysis Program (MAP) is responsible for monitoring energy conservation retrofits at various sites throughout Texas. An important part of this program is gathering pertinent energy consumption and weather data from a site to determine the effectiveness of the retrofit projects. For this purpose, LoanSTAR researchers have installed dedicated data loggers at over 60 retrofit sites which now generate over 2,500 channels of hourly data. Most of the field data recorders in use in the LoanSTAR program are devices that are specifically designed to collect energy and/or weather data from appropriate sensors, store the data, and transmit the data via a telephone modem when polled, a task they perform quite well.

Although data loggers have proven effective in the data gathering process, it has been observed that many of these same functions may be accomplished by Energy Management and Control Systems (EMCSs). While it would seem obvious that an EMCS should not be installed strictly for monitoring energy usage, an existing EMCS may provide an alternative monitoring solution to the installation of a dedicated data logger in sites so equipped. The purpose of this project is to determine the monitoring capabilities of various EMCSs, and to identify advantages and disadvantages of utilizing existing systems for energy monitoring at LoanSTAR sites.

This EMCS Performance Monitoring project consists of three major tasks:

- (1) review the monitoring capabilities of EMCSs identified in previous research,
- (2) perform new case studies of retrofit monitoring with existing EMCSs, and
- (3) develop recommendations for EMCS monitoring and ways of improving EMCS monitoring capabilities based upon the results of (1) and (2).

All three tasks focus on the LoanSTAR program, but generalize results where possible.

This report was originally published in September 1991 and has undergone two revisions. The July 1992 revision included the information about the potential for LoanSTAR-type monitoring at the USDOE Forrestal and Germantown facilities, and the March 1993 revision included new information about the Teletrol EMCS in use at the Texas State Capitol.

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## 2.0 Introduction

The Texas LoanSTAR Monitoring and Analysis Program (MAP) is responsible for monitoring energy conservation retrofits at various sites throughout Texas. Additional information about the program can be found in Verdict et al. (1990), Turner (1990), O'Neal et al. (1990), Nutter et al. (1990), Haberl and Lopez (1991), Katipamula and Claridge (1991), Haberl et al. (1990), Claridge et al. (1990), and Claridge et al. (1991), as well as the additional reports provided in the bibliography in Section 9.

An important part of the LoanSTAR program is gathering pertinent energy consumption and weather data from a site to determine the effectiveness of the retrofit projects. For this purpose, LoanSTAR researchers have installed dedicated data loggers at over 60 retrofit sites, which now receive over 2,500 channels of hourly data. These devices are designed specifically to collect energy and/or weather data from appropriate sensors, store the data, and transmit them via a telephone modem when polled, a task they perform quite well.

Although data loggers have proven effective in the data gathering process, it has been observed that many of their functions may be accomplished by Energy Management and Control Systems (EMCSs). While it is obvious that an EMCS should not be installed strictly for monitoring energy usage, an existing EMCS may provide an alternative monitoring solution to the installation of a dedicated data logger in sites so equipped. The purpose of this project is to determine the monitoring capabilities of various EMCSs, and to identify advantages and disadvantages of utilizing existing systems for energy monitoring at LoanSTAR sites.

This EMCS Performance Monitoring project consists of three major tasks: (1) review the monitoring capabilities of EMCSs identified in previous research, (2) perform new case studies of retrofit monitoring with existing EMCSs, and (3) develop recommendations for EMCS monitoring and recommend ways of improving EMCS monitoring capabilities based upon the results of (1) and (2). All three tasks will focus on the LoanSTAR program, but will generalize results where possible.

## 2.1 Approach

The approach used to investigate whether or not long-term monitoring data could be obtained from EMCSs was to closely investigate several case studies, summarize what was learned, and make recommendations concerning EMCS systems in general.

To accomplish this, four sites were chosen in Texas. Later, sites were added in the Washington D.C. area at the request of DOE, and one site was added in Austin at the request of the Texas Governor's Energy Office. The four original sites in Texas include: the Texas Tech University Health Sciences Center Lubbock; the Zachry Engineering Center at Texas A&M University in College Station; the Prairie View A&M Campus west of Houston; and the University of Texas Southwestern Medical Center (UTSMC) in Dallas. The two

sites that were added to this study include the USDOE Forrestal Building in Washington, D.C., and the USDOE Germantown Facilities in Germantown, Maryland. The Austin site is the Texas State Capitol.

About midway through the study the University of Texas Southwestern Medical Center site was dropped and the Zachry Engineering Center was added. There were two primary reasons for this. First, the UTSMC administration decided to decline the LoanSTAR energy conservation loan. Second, since the Zachry Engineering Center contained the same EMCS as the UTSMC and also contained a LoanSTAR monitoring system it was seen as being a unique site where (eventually) side-by-side tests could be performed that compared data from the EMCS with data from the LoanSTAR monitoring system.

The two federal sites were added to the study to assist DOE in determining what measures could be taken in buildings that did not have an operable EMCS, a common occurrence in many state and federal facilities.

## **2.2 LoanSTAR Data Reporting procedures.**

Traditionally, the only monitored whole-building energy data has been the monthly utility bill. In many instances, this bill was sent to the accounting department and ignored by everyone except the accountants. In recent years, as energy management has become a visible activity, this billing data is sometimes examined by the energy manager, and in special cases may be normalized for weather, building area, etc. However, many large organizations such as government agencies, universities, etc., often have an entire complex of buildings on a single meter, significantly complicating the use of billing data for energy management.

During the last ten years, with the growth of demand side management programs, and the declining cost of data acquisition equipment and computers, there has been an increasing number of programs where a non-utility third party monitors a number of channels of energy and related data and archives the information for later analyses. The data may be recorded in monthly increments, but it is generally recorded more frequently, typically in daily or hourly increments. The general pattern for collecting and reporting these data has been to poll the data acquisition equipment at the building site by phone modem and archive the data on permanent medium for later analysis.

These data can also be used to provide near-term feedback to building operators. The use of consumption data to provide near-term feedback to owners and operators to increase operating efficiency has emerged in the last few years. Methods which provided real-time feedback on energy costs to homeowners were investigated in the 1970s (Seligman et al. 1978) but failed to catch on as concerns about energy costs waned. During the later portion of the 1980's, as energy costs began to rise again, researchers began to renew their investigations into the benefits of regular feedback.

In several of these case studies (Haberl and Claridge 1987; Haberl and Vajda 1988; Haberl and Komor 1990a, 1990b) it was shown that 5 to 15% of a building's energy use could be saved by providing building operators with timely feedback on their energy use so that they could assess the impact of their day to day operation and maintenance procedures. One study by Komor et al. (1990) investigated the different forms of feedback including monthly, daily, and hourly time series plots of consumption, and 3-dimensional time series plots. What was discovered was that specific formats for reporting energy use are better than others and that the time interval (i.e., monthly, daily, or hourly) used in the reporting had a significant impact on the kind of information the building operator was able to extract from the graph.

To this extent, the LoanSTAR program has developed several methods that are used to report the energy use in a building, specifically: (1) weekly inspection plots, (2) monthly energy consumption reports, (3) specially prepared data for browsing, and (4) special purpose graphics. Additional information regarding the reporting procedures can be found in Claridge et al. (1992).

Figure 2.1.2 is an example of the data path used to process incoming information from one of the LoanSTAR sites. Data are polled once per week and archived in both raw and processed format. Various modules have been developed for removing extraneous characters, checking for missing data, calculating derived weather channels, and producing various graphs.

Currently, the LoanSTAR program is collecting data from over 60 buildings and NWS weather stations which amounts to roughly 2,500 channels of data or about 2.5 Mbytes of information that must be processed each week. All data are processed with the ARCHIVE program (Feuerman and Kempton 1987) which provides for static high and low limits checks as well as other columnar processing. Additional information about acquiring the data can be found in Haberl and Lopez (1992), and in the LoanSTAR Monitoring Workbook (Haberl et al. (1992).

Data quality control is essential if the measured savings are to be meaningful. At most sites the monitoring equipment is installed by a subcontractor who checks initial readings from the system against hand measurements. High-low limits for each channel are checked with the ARCHIVE program. In addition, hard copy time series plots of all data collected are generated each week with a total of over 700 plots produced each week. The number of plots is somewhat smaller than the total number of channels collected since most electricity consumption is measured using two or three channels for three-phase service. A summary page of typically 10 plots is produced for each building as shown in Figure 2.1.3.

The summary page (Figure 2.1.3) shows whole-building electricity use, ambient dry-bulb temperature, relative humidity, and global horizontal solar radiation. It includes time series plots of hourly chilled water Btu (or chiller electricity), condensate Btu (or other heating quantity) as well as air handler/pump electricity and lighting/receptacles (a derived channel) whenever these are available. Cross plots of heating, cooling and sometimes air handler

energy use as functions of ambient temperature are also included. Additional plots may be included in the remaining slots as needed.

These plots are used for data quality control and as a diagnostic tool for examining unusual consumption. The inspection plots are first used by the installation subcontractors immediately following installation for range checking. They are scanned on a weekly basis by project personnel using a checklist to detect data problems.

A six page energy consumption report is sent monthly to each facility monitored. This report contains two pages of tables and text and four pages with graphs of consumption data for the previous month. The first page of the report provides a concise tabular summary of current energy consumption, retrofit savings and a comments section. The second page provides daily chilled water and hot water (or steam condensate) consumption as a function of daily average dry-bulb temperature. The third page of the report gives time series plots of the hourly chilled water and hot water consumption for the month. The fourth page provides a time series trace of the electricity use and the hourly dry bulb and humidity conditions for each site.

Figure 2.1.4 is an example of page four of the monthly report for the Zachry Engineering Center. The fifth page of the report gives two views of a three-dimensional surface plot of the whole-building electricity consumption. The sixth page contains a summary of the characteristics for each site and the current status of the retrofit. After the first consumption report is sent to the agency and operators a session is scheduled where personnel from the monitoring program meet with representatives from the agencies to discuss the report format, answer questions, and gather feedback from the agencies about the report format, and suggestions for improvements.

After several of these meetings had been scheduled it became clear that the agencies participating in the program wanted more feedback than was being provided by either the monthly report (and in some cases the weekly inspection plots). In fact, several of the agencies requested to "browse" through all the data collected for their sites and create their own graphs.

To accomplish it was decided to distribute data in a pre-compiled format that would facilitate the use of a commercially available, PC-based data browsing software (Lantern 1990). This software was originally developed to help organize and examine meteorological data, but is capable of handling most kinds of time series and geographically distributed data. It provides multiple window viewing and zoom-in capabilities by utilizing a cross-indexed, compiled data base structure. Data collected from each building monitored are precompiled by the LoanSTAR personnel and distributed once-per-month on diskette along with the monthly report. Agency personnel load the current month's data into the browsing software (which has been previously installed in the computer at their site) and are then able to create virtually any kind of graph they need.

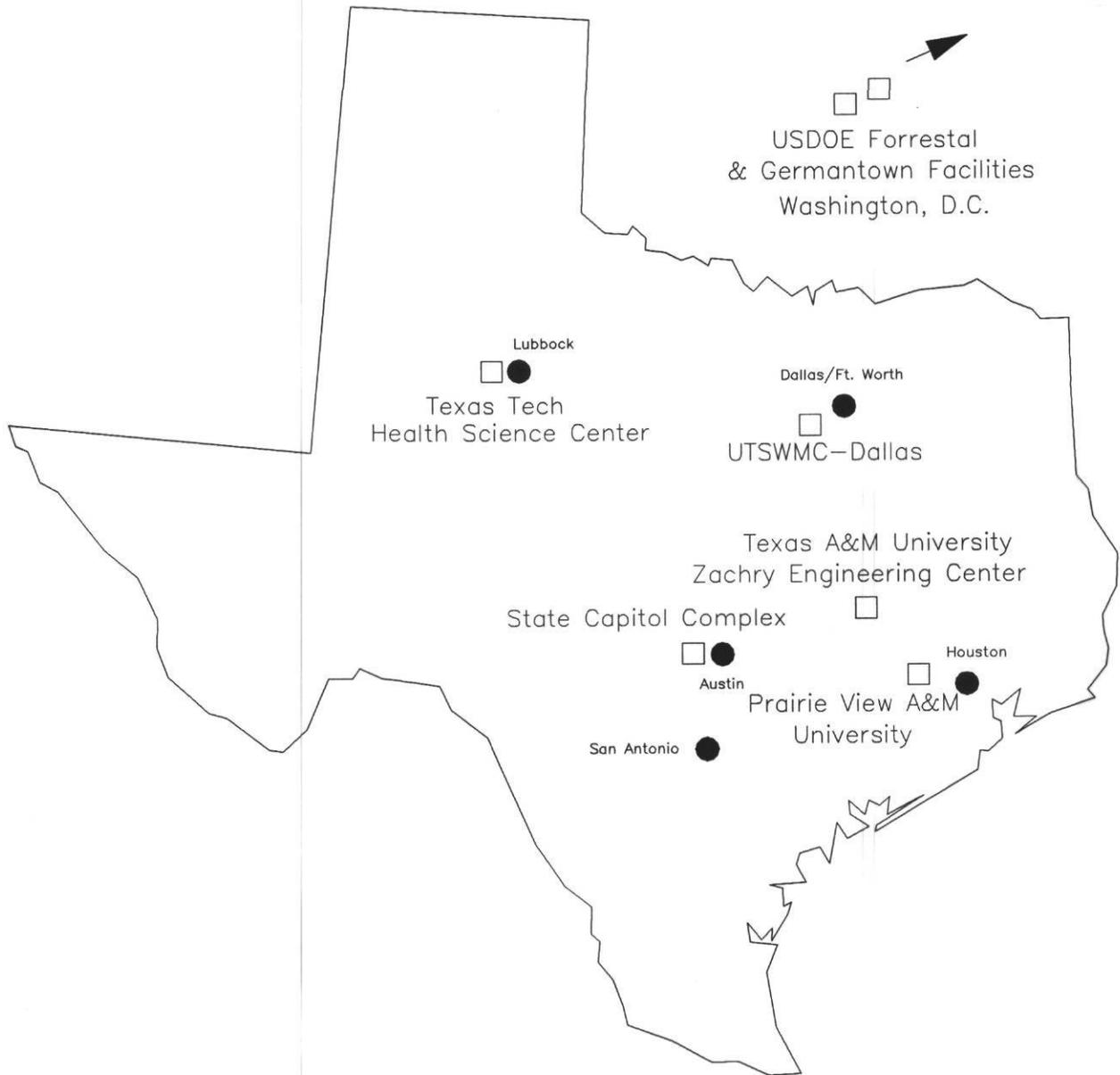
Other types of special purpose graphics are routinely in use in the LoanSTAR program including comparative 3-D plots (Figure 2.1.6) and temperature-specific humidity carpet plots (Figure 2.1.7). The comparative 3-D plots have proven useful for determining how well a model of non-weather dependent energy usage fits actual usage, for example a simple model of lighting and receptacle use for the ZEC is compared to the actual lighting and receptacle electricity use. Additional information on the use of these plots can be found in Haberl and Komor (1990a, 1990b), and in Bronson et al. (1991) where they have proven useful in calibrating the DOE-2 energy simulation program.

The temperature-specific humidity carpet plots (Tukey 1988, Tufte 1990) have proven useful for determining how thermal energy use varies with both temperature and humidity -- two variables that tend to be intercorrelated (i.e., one variable is related to the other). The plots shown in Figure 2.1.7 are being used to help assess the progress of calibrating the weather dependent energy use of the ZEC as simulated by the DOE-2 program (Haberl et al. 1991).

In general, the LoanSTAR program is attempting to provide a vast array of graphics to building operators and researchers -- all of which assume a common format for the building data. One can then imagine that it is important to be able to translate into/out of this format easily. The majority of the LoanSTAR buildings are using dedicated data loggers which have a known data format and therefore can readily be provided with the graphs that have been discussed.

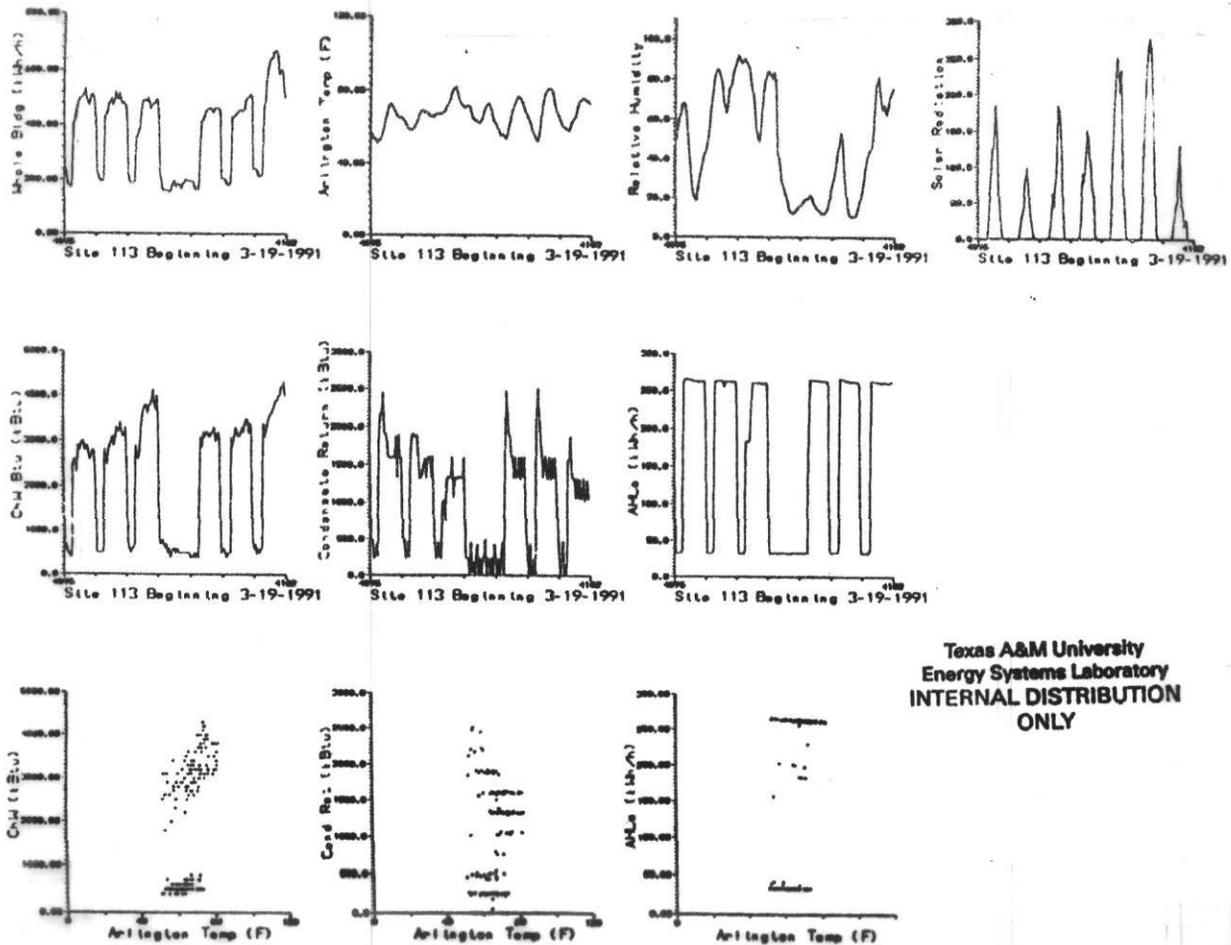
The remainder of this report describes the efforts that were undertaken to translate data in various EMCS formats into the LoanSTAR format. In each case special software routines had to be created for each EMCS vendor -- with the resultant final product being the standard LoanSTAR format data file from which any of the previously described routines can be developed. A summary is provided that pulls together information from the lessons that have been learned from this excursion into the EMCS world.

**Figure 2.1.1: EMCS Case Study Sites.** This figure shows the current EMCS case study sites including: the Texas Tech Health Sciences Center (Lubbock), the Zachry Engineering Center at Texas A&M University (College Station), the Prairie View A&M campus (near Houston), and the USDOE Forrestal Building (D.C.), and USDOE Germantown Complex (Germantown, M.D.).

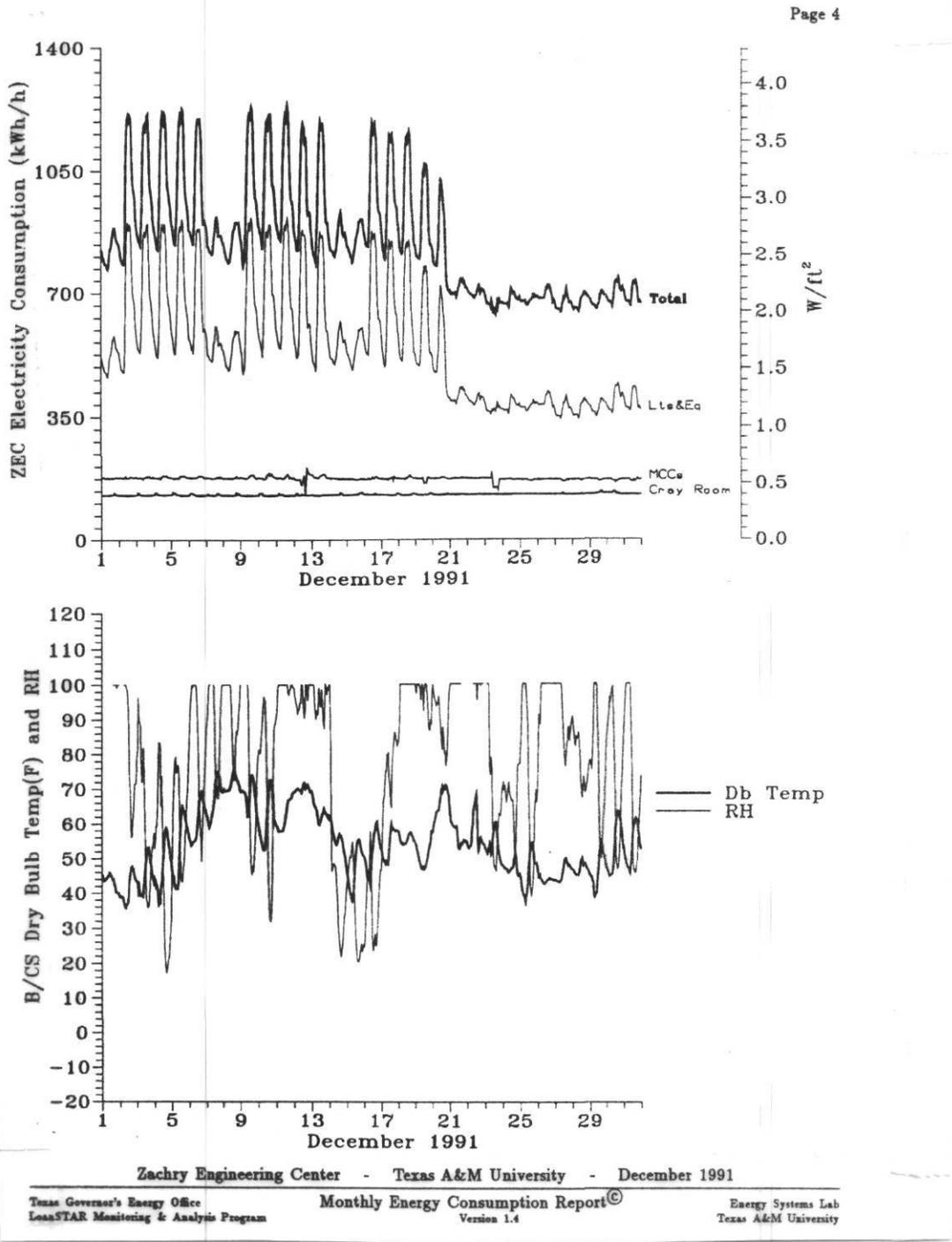




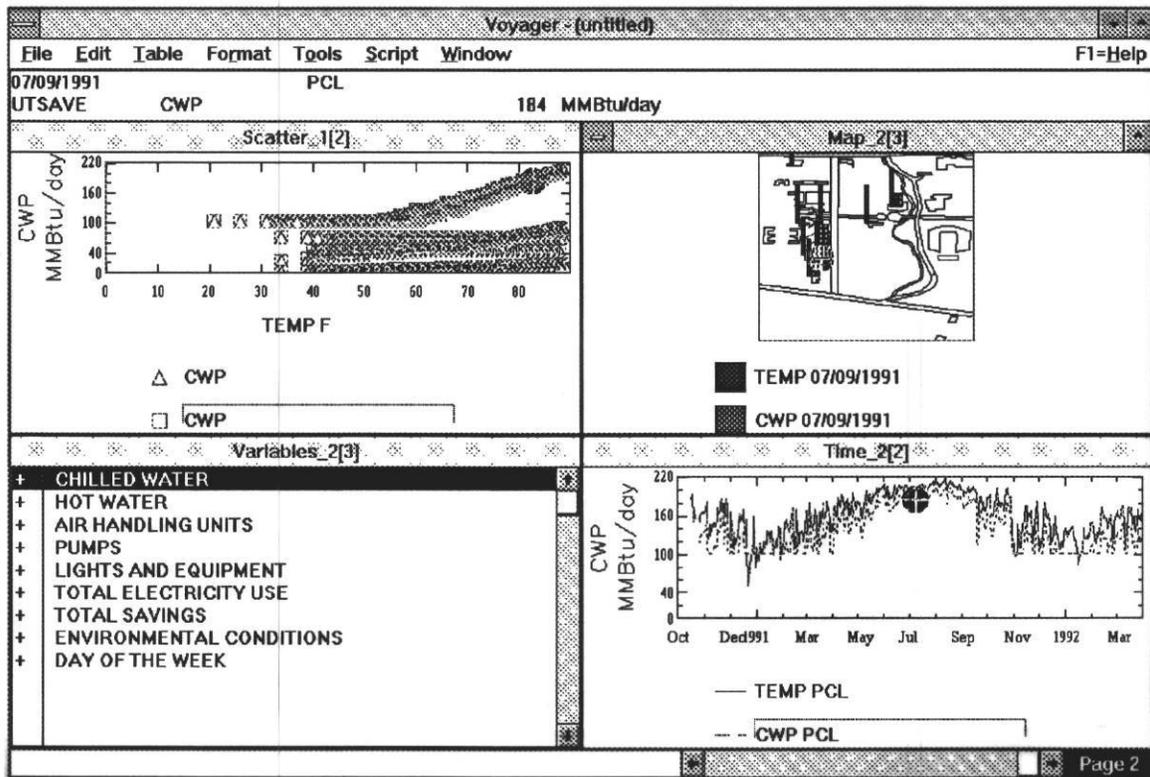
**Figure 2.1.3: Typical LoanSTAR inspection plots.** This figure shows typical inspection plots that are produced each week to view and inspect the incoming data. The format for these plots is produced in a similar fashion for each site to better facilitate the identification of erroneous data.



**Figure 2.1.4: Typical LoanSTAR Monthly Consumption Report.** This figure shows page 4 of the LoanSTAR Monthly Consumption Report for the Zachry Engineering Center. The upper graph shows whole-building electricity use, lighting and equipment electricity use, air handler energy use, and central computer energy use. The lower graph shows the hourly temperature and relative humidity data. The VAV retrofit for this site became operational in March 1991, resulting in a distinct drop in fan energy use.



**Figure 2.1.5: Special LoanSTAR Browsing Graphics.** Special-purpose browsing graphics are used by selected LoanSTAR agencies to allow the building operator the ability to create any type of 2-D and time series graph using the Voyager software (Lantern 1990). Each month specially prepared Voyager files are distributed to the agencies with the standard monthly report.



**Figure 2.1.6: Special LoanSTAR Graphics: Comparative 3-D plots.** Since all data collected are in a standard format, special-purpose graphics can easily, and routinely be produced for viewing certain characteristics. Comparative 3-D graphics represent one such graphic tool that can be used to evaluate how well a simulated non-weather dependent electricity profile matches the actual electricity profile (Bronson et al. 1991).

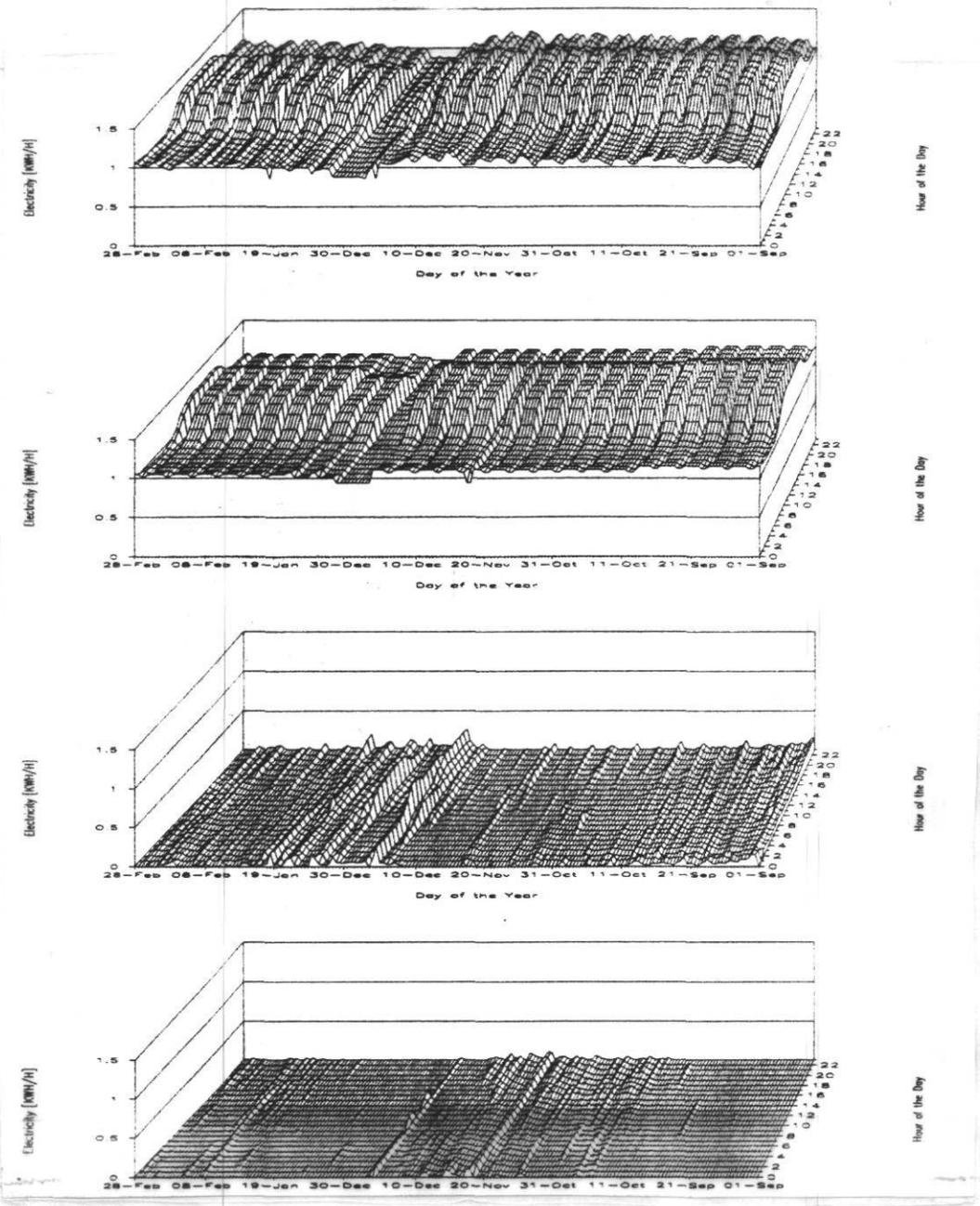
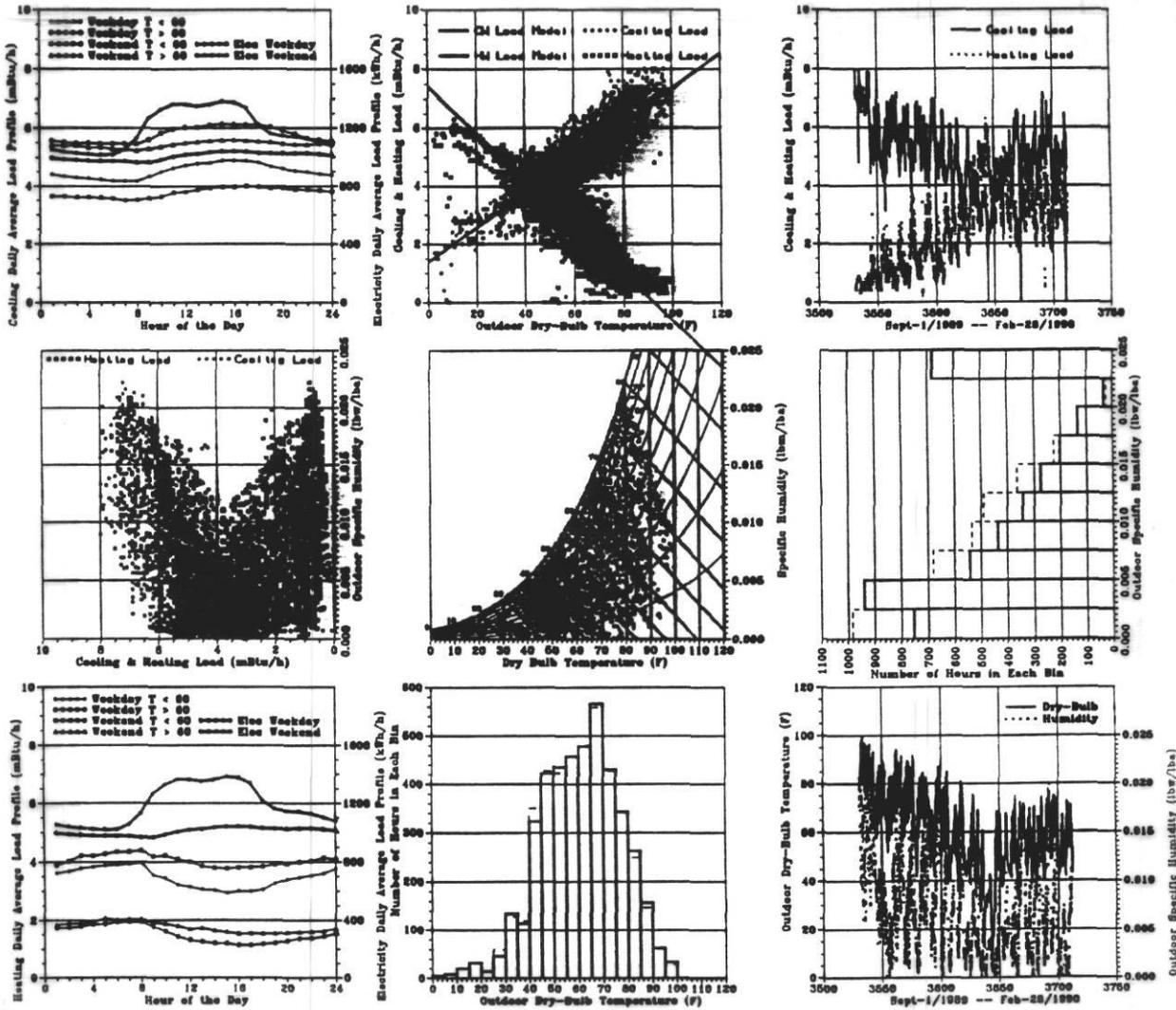


Figure 2.1.7: Special LoanSTAR Graphics: Carpet plots for temperature/humidity evaluation. This figure displays chilled water, hot water and electricity use data in a carpet plot format which helps facilitate the evaluation of the effect of temperature and humidity



### **3.0 Monitoring Capabilities of EMCS Versus Dedicated Monitoring Systems.**

The monitoring of energy usage can be defined by four primary steps: measurement, storage, access, and data processing (Heinemeier & Akbari 1991). The procedures used to accomplish these steps can vary significantly between dedicated monitoring systems and EMCSs (Table 3.1.1).

#### **3.1 Monitoring with a Dedicated Monitoring System.**

In a dedicated monitoring system, or Data Acquisition System (DAS) the measurement, storage, access and processing of data are usually the sole purposes of the system. Prices of dedicated monitoring systems can vary from one manufacturer to another; however the hardware usually runs in the \$500 to \$5,000 range for a basic system that can monitor 4 to 40 channel systems (excluding sensors & installation). Including installation and sensors, such systems are in the \$1,000/point to \$2,500/point range. The sampling of data channels, conversion to engineering units, and data transfer are usually performed by the same microprocessor. Remote polling is usually accomplished via a directly connected modem.

DASs are usually meant to be very flexible, and can usually accept digital, analog, and sometimes direct power measurements. The specification and installation of sensors is usually performed by the researcher. This allows for greater control over sensor accuracy and placement, however, it can contribute substantially to the cost per point when special high accuracy sensors are specified. Connecting the sensors to the DAS usually requires direct wiring, which also contributes significantly to the price of the installed system.

The DAS to be used for monitoring must be specified, installed and programmed by the researcher. (Often, this can require considerable time learning a particular manufacturer's programming language and can change from one manufacturer to the next.)

The storage capacity of the DAS usually varies from one manufacturer to the next, and can vary according to other "internal" variables, for example: how many channels are being monitored, the accuracy of the stored variable, recording interval, etc. The amount of "onboard" storage is a critical variable since it determines the polling frequency. Since the memory structure in most DASs is usually configured like an electronic "Rolodex", when the memory becomes full it begins overwriting previously stored data. Therefore, one must transfer the data from the remote DAS memory to a central polling site before it is overwritten and lost -- hence the need for periodic polling to/from a central site. In the case where weekly polling is being used 168+ hourly records must be stored for each channel.

#### **3.2 Monitoring with an EMCS.**

In an EMCS, the measurement, storage, access and processing of data are not the sole purposes of the system. In fact, even the name "Energy Management and Control Systems" gives one a sense of their primary purpose -- the efficient management and control of HVAC

systems. To this extent, it is difficult, if not impossible to determine the cost of an energy management system installed solely for the purpose of monitoring since such systems rarely exist. However, it is fair to say that fully configured EMCSs (i.e., 1,000 to 2,000 points) are much more expensive than dedicated monitoring systems; usually in the \$500,000 to \$1,000,000 range, including installation. EMCSs usually require considerably more training and upkeep than DASs, although both systems should have some periodic recalibration of sensors.

The higher cost of EMCSs is due to several obvious reasons. First, they are usually performing very important control functions which means their internal software is far more complex (and more robust). Second, they usually are much more complex, and have many more points (which tends to make their cost per point less than a dedicated DAS). Their operating software can have several "modes" of operation including, emergency interrupts, network capabilities, training sessions, and even multi-user, multifunction tasks.

The sampling of data channels, conversion to engineering units, and data transfer can be performed by any one of several microprocessors contained within the EMCSs, or even by microprocessors located closer to the sensor (often at a remote location of the building) and transferred to the central EMCS for transfer to the polling computer via modem. Remote polling is usually accomplished via modem, although the connection of the modem can be at almost any point in the EMCS network.

EMCSs are also meant to be very flexible; virtually any signal that can be conditioned to a 4-20 mA or pulse signal can be evaluated and controlled by the EMCS. However, if the case study buildings are any indication, the specification and installation of sensors at a particular site is usually under the control of the EMCS contractor -- especially when service of the sensors is included. This can be a potential source of problems when the EMCS contractor installs sensors that do not meet the specifications of the researcher (although this was not experienced in the case study buildings). Connecting the sensors to the EMCS also requires direct wiring. However, if the EMCS is already installed, wiring can be substantially reduced because the EMCS's network can be utilized.

The installation and programming of the EMCS is usually not performed by the researcher. This can also require considerable time although for different reasons than those concerning the dedicated monitoring system. Installation, and fine-tuning of an EMCS is usually far more complicated than the installation of a dedicated monitoring system. This can be problem when time constraints are tight. In some cases the programming of EMCSs can be more complicated than the programming of DASs.

The "capture" of data in an EMCS is usually treated in an entirely different fashion than is used on a DAS. For the most part, EMCSs capture data using their "trending" files, which can contain extraneous data (e.g., ASCII headers and footers) that must be removed before the file can be processed by the researcher. Sometimes, these data are Change of Value (COV) data which are data that are recorded at intervals that are dictated by when a variable

changes. COV data may not be useful for monitoring purposes and almost always require further processing before they can be used by researchers as monitored hourly data. Additional information about the EMCS COV data is contained in the report by Heinemeier and Akbari (1991). Data which are trended by an EMCS must also be periodically transferred via polling to a centralized computer.

### **3.3 Why Investigate Monitoring with an EMCS?**

EMCSs have made tremendous strides in improving control capacity, user I/O, connectivity, and electronic storage capacity, and other important features. However, very little has been published about their ability to serve as long-term monitoring equipment. Capabilities for monitoring vary greatly from one manufacturer to the next, and even among different systems from the same manufacturer.

Clearly, in the case where a fully functioning EMCS already exists in a building, and the on-site personnel have the knowledge and ability to make the modifications to allow the system to serve as a monitoring system it would be to the researchers advantage to investigate the use of the EMCS for monitoring purposes.

**Table 3.1.1: Comparison of EMCS-Based Monitoring Capabilities.** This table lists the differences between the monitoring capabilities of dedicated and EMCS-based systems (Heinemeier and Akbari 1991).

	<b>Dedicated Monitoring:</b>	<b>EMCS:</b>
<b>Sensors:</b>	<ul style="list-style-type: none"> <li>+ Must be purchased</li> <li>+ Must be installed</li> <li>+ User can select type</li> <li>+ User can select accuracy</li> <li>+ User can calibrate</li> </ul>	<ul style="list-style-type: none"> <li>+ Often already exists</li> <li>+ Numerous points</li> <li>+ Used for control</li> <li>+ May have to add sensors</li> <li>+ Accuracy and calibration may be determined by EMCS manf.</li> </ul>
<b>Connections:</b>	<ul style="list-style-type: none"> <li>+ Must be purchased</li> <li>+ Must be installed</li> <li>+ No other traffic</li> <li>+ Can be sized for monitoring</li> </ul>	<ul style="list-style-type: none"> <li>+ Existing</li> <li>+ Sophisticated networks</li> <li>+ Other traffic can interfere with operation</li> <li>+ Must be added for expansion</li> </ul>
<b>Data Logging Processor:</b>	<ul style="list-style-type: none"> <li>+ Must be purchased</li> <li>+ Simple processor</li> </ul>	<ul style="list-style-type: none"> <li>+ Existing</li> <li>+ Sophisticated processor</li> </ul>
<b>Data Logging Software:</b>	<ul style="list-style-type: none"> <li>+ Must be purchased</li> <li>+ Simple sampling, conditioning, and averaging</li> <li>+ Software may be predefined</li> <li>+ Can be sized for monitoring</li> </ul>	<ul style="list-style-type: none"> <li>+ Existing</li> <li>+ Often simple sampling, conditioning, and averaging</li> <li>+ May be predefined</li> <li>+ Not defined for monitoring needs</li> <li>+ Can have sophisticated computation and calculation capabilities</li> </ul>
<b>Data Storage:</b>	<ul style="list-style-type: none"> <li>+ Must be purchased separately</li> <li>+ Often limited size</li> </ul>	<ul style="list-style-type: none"> <li>+ Existing</li> <li>+ Sometimes must be supplemented</li> <li>+ Both short and long term</li> <li>+ Sometimes limited in size</li> </ul>
<b>Modem:</b>	<ul style="list-style-type: none"> <li>+ Sometimes must be purchased</li> <li>+ Dedicated to data logger</li> </ul>	<ul style="list-style-type: none"> <li>+ Existing</li> <li>+ Also used by operator, vendors and unknown others</li> </ul>

#### 4.0 EMCS Case Study Sites

Originally, three case study sites were investigated for the EMCS project (Figure 1). They included the University of Texas Southwest Medical Center in Dallas, the Texas Tech Health Sciences Center in Lubbock, and the Prairie View A&M campus near Houston. A few months into the project, it was decided that the Zachry Engineering Center on the Texas A&M campus would replace the University of Texas Southwest Medical Center since the Zachry Engineering Center also contained a 50 channel data acquisition system and could eventually be used to compare data collected by the EMCS against similar data collected by the data logger.

Two additional sites were also added to the project in mid-course -- the USDOE Forrestal Building in Washington, D.C., and the USDOE Germantown complex in Germantown, Maryland. These last two sites were added to study buildings that do not have operable EMCSs and are being evaluated for the installation of dedicated monitoring systems typical of those being installed in the Texas LoanSTAR program.

During the Summer of 1992 the EMCSs at the Texas State Capitol were studied to see if they could provide consistent format into LoanSTAR type plotting routines.

#### 4.1 Texas Tech University Health Sciences Center.

The Texas Tech University Health Sciences Center (TTHSC) is a large medical research building located in Lubbock, Texas. The 811,131 square foot facility is scheduled to receive Energy Conservation Retrofit Measures (ECRMs) including lighting controls and retrofits, variable-speed air handler conversions, HVAC economizers, night setback controls, steam trap repairs, pipe insulation, and a new heating and chilled water pump controls. Additional ECRMs planned for the heating and cooling plant serving the facility include a chiller replacement, variable speed chilled water pumping, and steam-driven electrical generation at a pressure-reducing station. Expected savings from the measures total \$919,586 per year.

To date, only real-time information has been gathered from the EMCS there, though a software enhancement will soon allow trended energy information to be collected via modem. TTHSC staff have used the EMCS to collect energy consumption information for the medical center for the past several years.

Table 4.1.1 summarizes the EMCS capabilities at the Texas Tech Health Science Center (Heinemeier and Akbari 1991). The TTHSC has a Honeywell Delta 1000 EMCS that has about 1,800 to 2,000 points. The primary instrumentation for energy monitoring is at four mechanical "pods" serving the four different buildings. These points include chilled water supply and return temperatures and flow, condensate flow, and electrical consumption for each pod. Weather sensors and condensate meter points were added as part of the LoanSTAR program.

The TTHSC staff have used the EMCS to collect and store energy consumption information for the past several years. At the beginning of our analysis of this site a portion of these data were transferred and analyzed for use as historical data. However, it was found that a significant amount of the data that was collected could not be used for analysis because it contained data in the wrong format. For example, "snapshot" readings of hourly electric demand had been recorded for several years as shown in Figure 4.1.4. Such data is virtually worthless to the energy analyst because it does not represent the average energy consumption over the hour (or period of interest). Portions of the data were useful, including cumulative readings of steam and temperature data. However, the cumulative steam readings required additional processing to deliver consumption per hour because they were in a "odometer reset" format (i.e., one whereby the numbers accumulate up until it reaches a number like 9999 and then rolls over to 0).

In order to facilitate the transfer of hourly trend data over the phone lines the Energy Auditor program was purchased and installed. The Energy Auditor program allows trending of up to 999 points and has the capabilities to allow for transfer of the data to the hard disk on the PC on which the software is running. In general, the procedure that was used was to poll the PC that had the Energy Auditor running on it, command the Energy Auditor to poll the Honeywell Delta 1000, transfer the data to the PC containing the Energy Auditor package and then transfer the data to the LoanSTAR computers.

In order to accomplish this the Texas Tech personnel established hourly trend points for electrical power, cooling energy, steam energy use, and weather conditions on the Delta 1000 which were then transferred for analysis using the Energy Auditor software.

On the Delta 1000 systems, trending begins as soon as the points are initialized and continues at one hour increments from the point of initialization. Unfortunately, this means that if one is not careful to initialize trending exactly on the hour, the trending will be off by any difference established during initialization. This problem also occurred each time that the Delta 1000 lost power for any significant period.

Data were retrieved from the Delta 1000 using the Energy Auditor software and either the United States Mail (USPS) or the campus Internet as shown in Figure 4.1.2. The procedure that was established was to call the Energy Auditor software using phone lines from Texas A&M, and have the Energy Auditor software poll the Delta 1000 which transferred the data to the hard disk in .DIF (Data Interchange Format -- originally developed by Visicalc) on the PC that was running the Energy Auditor software as shown in Table 4.1.3. The keystrokes for accomplishing this are shown in Table 4.1.2.

Transferring the data back to Texas A&M then followed one of several paths. Initially, the quickest procedure was to have the operators copy the data onto a floppy and mail it to Texas A&M (the USPS route in Figure 4.1.2). An improved procedure was established to transfer the data via the internet that connected Texas Tech and Texas A&M. Eventually, working with Honeywell, a procedure was established to have the Energy Auditor poll the Delta 1000 and then deliver the data to Texas A&M over the phone lines.

Once the data were successfully transferred back to Texas A&M they were then translated into the LoanSTAR format. Although .DIF format can be read by many programs, it is bulky and cumbersome to manage. To accomplish this the Microsoft Excel program was used to translate into ASCII text format. Once in the ASCII text format the file was worked on by an AWK (we use Gnuware version of AWK or GAWK) script that removed unnecessary headers and non-numeric information as shown in Figure 4.1.3. (The programs for translating this file are contained in the appendix to this report.)

Once the data were in ASCII columnar format with headers, etc. removed they were then passed to the ARCHIVE program with the appropriate channel table to convert them to the LoanSTAR format for further processing. Table 4.1.4 contains the ARCHIVE channel table for the TTHSC. Table 4.1.5 shows the TTHSC data once it has passed through the ARCHIVE program. Table 4.1.6 contains the .LOG file that ARCHIVE produces each week that the data are processed. This log file contains instances where data have gone outside pre-established upper/lower limits and other useful information.

After the data are successfully processed with ARCHIVE they are then plotted with a commercial graphics package as shown in Figure 4.1.4. Each week these inspection plots

are produced and circulated to the TTHCS building operators to help troubleshoot the data that are being collected. The commercial graphics package that was used for these plots is the Graphed software by Golden Software (see the Bibliography for a complete description of all software used in this project).

**Table 4.1.1: Texas Tech EMCS Capabilities.** This table illustrates the capabilities of the Texas Tech EMCS (Heinemeier and Akbari 1991).

Device	Temp.	Stat.Point	%RH	Setpoint	Status
Cold Deck	*			*	
Hot Deck	*			*	
Reheat	*			*	
Preheat	*			*	
Supply Air	*		*	*	
Return Air	*			*	
Discharge	*			*	
Fan		*		*	*
Ind.Zone(s)	*			*	

Device	Temp.	Flow	Energy	RH	Setpoint	Status
Electric			*			
CW Supply	*	*	*			
CW Return	*	*			*	
CW Pump						*
HW Supply	*	*	*			
HW Return	*				*	
HW Pump						*
DWH Sup.	*					
Condensate						*
Outside Air	*	*	*	*		

**Table 4.1.2 : Operator keystrokes for retrieving data.**

THE PROCESS OF TRANSMISSION OF DATA IS ACCOMPLISHED IN TWO PHASES: PHASE I THE UPLOADING OF DATA FILES FROM THE PC AT TEXAS TECH. TO THE MAINFRAME COMPUTER. PHASE II THE TRANSMISSION OF THE DATA FROM THE MAINFRAME TO A&M VIA THE INTERNET. PHASE II BEGIN WITH THE PC BOOTED AND AT THE COMMAND PROMPT C:>\, THE DATA ON 3.5 OR 5.25 FLOPPY AND IN THE FLOPPY INSERTED IN THE RESPECTIVE DRIVE.

FOLLOW THE INSTRUCTIONS BELOW. TYPE EVERYTHING IN BOLDFACE AS THEY ARE.

**PHASE I**

**CONNECT 2400**

**PLEASE ENTER THE PASSWORD FOR THIS CONSOLE**

**XXXXXX**

**PLEASE ENTER YOUR INITIALS**

**XXX**

**PLEASE ENTER YOUR IDENTIFICATINO CODE FOR THIS TERMINAL**

**XXXXXX**

**PDC PLUS - MAIN MENU**

**1 - LOGICAL GROUPS**

**2 - DELTA 1000 DIRECT**

**3 - DPC SYSTEM PROGRAMMING**

**4 - HISTORICAL ACTIVITY REPORTS**

**5 - ENERGY AUDITOR OPTION**

**6 - DPC SYSTEM UTILIES**

**7 - DELTA 1000 ENGLISH LANGUAGE PROGRAMMING**

**8 - DELTA 1000 ALARM SUMMARY LOG**

**9 - INTECOM**

**ENTER YOUR CHOICE: 5**

**ENERGY AUDITOR OPTION**

**1 - TREND DEFINITION/MAINTENANCE**

**2 - TRENDED DATA REPORTS**

**3 - TREND FILE TO ".DIF" FILE CONVERSION**

**4 - DISPLAY/EDIT OPTIONS**

**(DEPRESS "ESC" THEN "ENTER" RETURN TO THE PREVIOUS MENU) 2**

**....the energy auditor then transferred the delta 1000 data...**

**Table 4.1.2 (cont) : Operator keystrokes for retrieving data.****PHASE II**

1. **TELIx**
2. **<ENTER>** (initializes the TELIX program)
3. **ALTD** (this displays the telephone number menu for the modem connection)
4. select the phone number (modem connects to the mainframe vax system for logon)
5. **v**
6. **ID <TAB>**
7. **password <TAB>**
8. **VM**
9. **KERMIT**
10. **RECEIVE** (file name example--012 DIF A)
11. **<PAGE UP Key>**
12. Select **KERMIT**
13. **A:** or **B:012.dif** (in dialog box)

data will now be uploaded to the mainframe computer when the transmission has been completed the screen will return to **KERMIT**.

14. **QUIT**
15. **ftp loanstar.tamu.edu**
16. **xxxxxx** (user ID)
17. **xxxxxx** (password)
18. **sendsite**
19. **put 012.dif**

file will be transferred to the A&M computer on completion of transfer subsequent files may be transferred with the **PUT** command

20. **BYE**

**Table 4.1.3: Texas Tech EMCS data file in the .DIF format.** This table contains Texas Tech data in the Data Interchange Format (DIF) that is used by the EMCS for transferring data from the EMCS.

DIF format:

```

BOT
1,0
"06/09/91"
1,0
"17:40"
0,917.00
V
0,499.00
V
0,843.00
V
0, 22.99
V
0, 68.40
V
0, 82.56
V
0, 4.72
V
0, 11.01
V
0, 4.87
V
0, 0.38
V
-1,0
BOT
1,0
"06/09/91"
1,0
"18:40"
0,730.00
V
0,397.00
V
0,898.00
V
0, 24.44
V
0, 70.40
V
0, 87.08
V
0, 5.06
V
0, 11.76
V
0, 5.24
V
0, 0.41
V
-1,0
BOT
    
```

**Table 4.1.4 : ARCHIVE channel table for the Texas Tech site.** The ARCHIVE channel table for the Texas Tech site is shown in this table. All data used in the LoanSTAR program are processed with the ARCHIVE program to assure a uniform data base structure. ARCHIVE performs useful data and time transformations and can perform high-low limit checks each time a site is polled.

DATE	Time	Raw	Raw	Arch	Name of Archive	Arch	Conv'n	Calib. or Error	Limatation	Channel		
MM/DD/YY	HH:mm	Line	coln	pos	Channel	Units	Format	Code	Constants	Code	Constants	Description
#4												
01/01/91	00:00	1	0	0	Begin							
01/01/91	00:00	1	1	1	site# -	I3	2	0	701	0		site#
01/01/91	00:00	1	1	2	Month MM	I3	1		0			Month
01/01/91	00:00	1	2	3	Day DD	I3	1		0			Day
01/01/91	00:00	1	3	4	Year YY	I3	1		0			Year
01/01/91	00:00	1	3	5	G-J -	I5	24	1	2	0		Gregorian - Julian
01/01/91	00:00	1	1	6	dec.t -	F10.4	28			0		decimal time
01/01/91	00:00	1	4	7	Time hhmm	I5	15			0		Time
01/01/91	00:00	1	5	8	PCPA Kwh	F9.3	1			0		1617.01 / Average power consumption pod A
01/01/91	00:00	1	6	9	PCPB Kwh	F9.3	1			0		1617.02 / Average power consumption pod B
01/01/91	00:00	1	7	10	PCPC Kwh	F9.3	1			0		1617.03 / Average power consumption pod C
01/01/91	00:00	1	8	11	SCPA MMBtu	F9.3	1			0		1607.04 / Average consumption rate, steam pod A
01/01/91	00:00	1	9	12	SCPB MMBtu	F9.3	1			0		1608.04 / Average consumption rate, steam pod B
01/01/91	00:00	1	10	13	SCPC MMBtu	F9.3	1			0		1609.04 / Average consumption rate, steam pod C
01/01/91	00:00	1	11	14	CWPA MBtu/hr	F9.3	1			0		1601.04 / Average cons. rate, chilled water pod A
01/01/91	00:00	1	12	15	CWPB MBtu/hr	F9.3	1			0		1603.04 / Average cons. rate, chilled water pod B
01/01/91	00:00	1	13	16	CWPC MBtu/hr	F9.3	1			0		1605.04 / Average cons. rate, chilled water pod C
01/01/91	00:00	1	14	17	CWPD MBtu/hr	F9.3	1			0		1610.04 / Average cons. rate, chilled water pod D
01/01/93	00:00	1	0	0	End							

**Table 4.1.5 : Texas Tech EMCS data file in the LoanSTAR format.** Texas Tech EMCS data that has been processed by the ARCHIVE program is shown in this table. The first column is the site number, and the six columns that immediately follow are calender and time values in different formats. Energy use data for this site begins in the eight column. The "-99.00" is inserted by ARCHIVE to identify data that fell outside the preset high-low limits.

701	6	25	91	91176	4193.0278	40	288	983	644	243.700	333.300	-99.000	102.500	166.600	112.900	13.380
701	6	25	91	91176	4193.0694	140	902	741	562	243.700	-99.000	-99.000	102.700	166.600	113.000	13.380
701	6	25	91	91176	4193.1111	240	509	471	453	243.700	333.300	-99.000	102.900	166.600	113.200	13.380
701	6	25	91	91176	4193.1528	340	114	196	355	243.700	333.300	-99.000	103.100	166.600	113.400	13.380
701	6	25	91	91176	4193.1944	440	732	923	262	243.700	-99.000	-99.000	103.200	166.600	113.600	13.390
701	6	25	91	91176	4193.2361	540	463	671	177	243.700	-99.000	-99.000	103.600	166.600	113.700	13.410
701	6	25	91	91176	4193.2778	640	231	554	281	243.700	-99.000	-99.000	103.900	166.600	114.100	13.520
701	6	25	91	91176	4193.3194	740	17	537	515	243.700	-99.000	-99.000	104.200	166.600	114.500	13.560
701	6	25	91	91176	4193.3611	840	998	764	122	243.900	333.300	-99.000	104.600	166.600	115.000	13.620
701	6	25	91	91176	4193.4028	940	94	110	871	244.200	333.300	-99.000	105.000	166.600	115.500	13.670
701	6	25	91	91176	4193.4444	1040	246	495	721	245.000	333.300	-99.000	105.400	166.600	116.000	13.730
701	6	25	91	91176	4193.4861	1140	418	901	560	245.500	-99.000	-99.000	105.800	166.600	116.500	13.790
701	6	25	91	91176	4193.5278	1240	546	276	379	245.700	333.300	-99.000	106.200	166.600	117.000	13.840
701	6	25	91	91176	4193.5694	1340	675	664	210	245.900	333.300	-99.000	106.600	166.600	117.500	13.900
701	6	25	91	91176	4193.6111	1440	811	46	95	246.200	-99.000	-99.000	107.000	166.600	118.000	13.950
701	6	25	91	91176	4193.6528	1540	928	429	939	246.600	333.300	-99.000	107.400	200.000	118.500	14.000
701	6	25	91	91176	4193.6944	1640	53	790	752	246.700	-99.000	-99.000	107.800	166.600	119.000	14.060
701	6	25	91	91176	4193.7361	1740	61	977	269	246.800	333.300	-99.000	108.200	200.000	119.500	14.110
701	6	25	91	91176	4193.8611	2040	704	12	713	247.600	333.300	-99.000	109.300	200.000	120.700	14.210
701	6	25	91	91176	4193.9028	2140	469	971	691	247.600	-99.000	-99.000	109.600	166.600	121.000	14.280
701	6	25	91	91176	4193.9444	2240	249	904	714	247.700	333.300	-99.000	109.900	200.000	121.300	14.350
701	6	25	91	91176	4193.9861	2340	957	751	660	247.700	333.300	-99.000	110.200	166.600	121.500	14.350
701	6	26	91	91177	4194.0278	40	583	570	574	250.600	-99.000	-99.000	110.300	166.600	121.600	14.350
701	6	26	91	91177	4194.0694	140	208	354	469	250.600	-99.000	-99.000	110.500	166.600	121.800	14.360
701	6	26	91	91177	44.1111	240	834	97	355	250.600	-99.000	-99.000	110.700	166.600	122.000	14.360
701	6	26	91	91177	44.1528	340	452	824	234	250.600	-99.000	-99.000	110.900	166.600	122.100	14.360
701	6	26	91	91177	4194.1944	440	85	538	102	250.600	-99.000	-99.000	111.100	166.600	122.300	14.360
701	6	26	91	91177	4194.2361	540	837	280	974	250.600	333.300	-99.000	111.400	200.000	122.500	14.400

**Table 4.1.6:** *.LOG file produced by the ARCHIVE program for the Texas Tech data.* This .LOG file is produced each time ARCHIVE processes data for a site. It includes some basic statistics about which file has been read, which channel table was used, and the names of the .LOG and output files. It also includes information about how many lines were processed (not shown), how many processing errors and missing data occurred and where those errors occurred in the input file.

Log of Archive, version: 1.41 of 15 June 1987, processed on 15 Jul 1991

Files:

RAW DATA goutput.txt  
CHANNEL TABLE 012.tbl  
ARCHIVE goutput.ach  
LOG goutput.log

Archive delimiter is " " .

Missing or bad data values are replaced by the value -99.000 .

Line errors: are identified by their line number in the raw data file.

Data errors: are identified by the channels name, line and position

within the case: "name "(line in case/position in line).

Line numbers in raw data file are shown as |number| or as \*number\*

|numbers| indicates a line of data, \*numbers\* is a comment line.

First case on raw data: 91 176 00:40

-----  
BeginDate: 91 001 00:00

First output case: 91 176 00:40  
-----

Data Error:

|1| 6 25 91 040 288 983 644 243.7 333.3 9999 102.5 166.6 112.9 13.38

Value out of bounds: "tsc "(1/10);

Data Error:

|2| 6 25 91 140 902 741 562 243.7 9999 9999 102.7 166.6 113 13.38

Value out of bounds: "tsb "(1/9); "tsc "(1/10);

Data Error:

|3| 6 25 91 240 509 471 453 243.7 333.3 9999 102.9 166.6 113.2 13.38

Value out of bounds: "tsc "(1/10);

Data Error:

|4| 6 25 91 340 114 196 355 243.7 333.3 9999 103.1 166.6 113.4 13.38

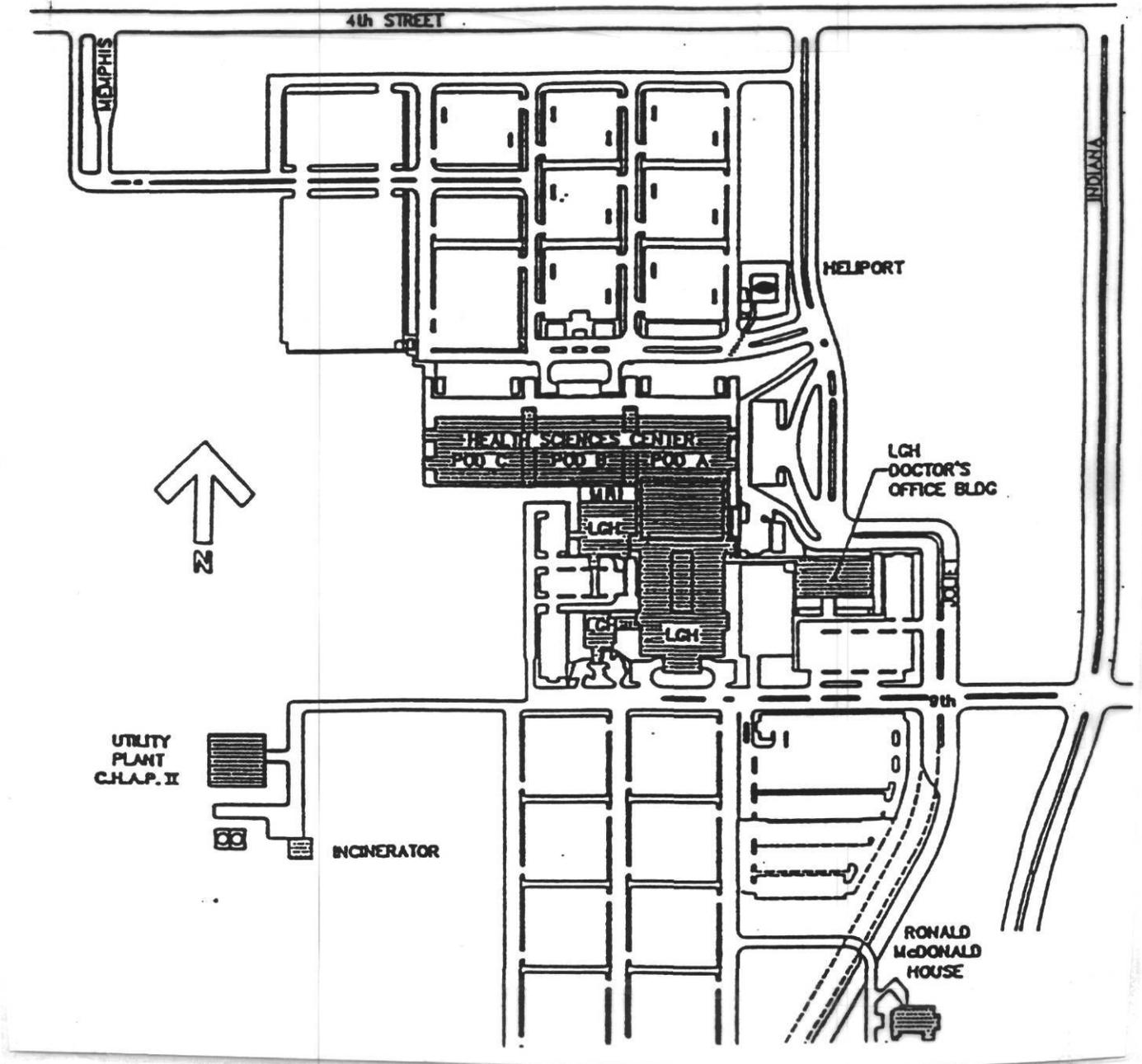
Value out of bounds: "tsc "(1/10);

Data Error:

|5| 6 25 91 440 732 923 262 243.7 9999 9999 103.2 166.6 113.6 13.39

Value out of bounds: "tsb "(1/9); "tsc "(1/10);

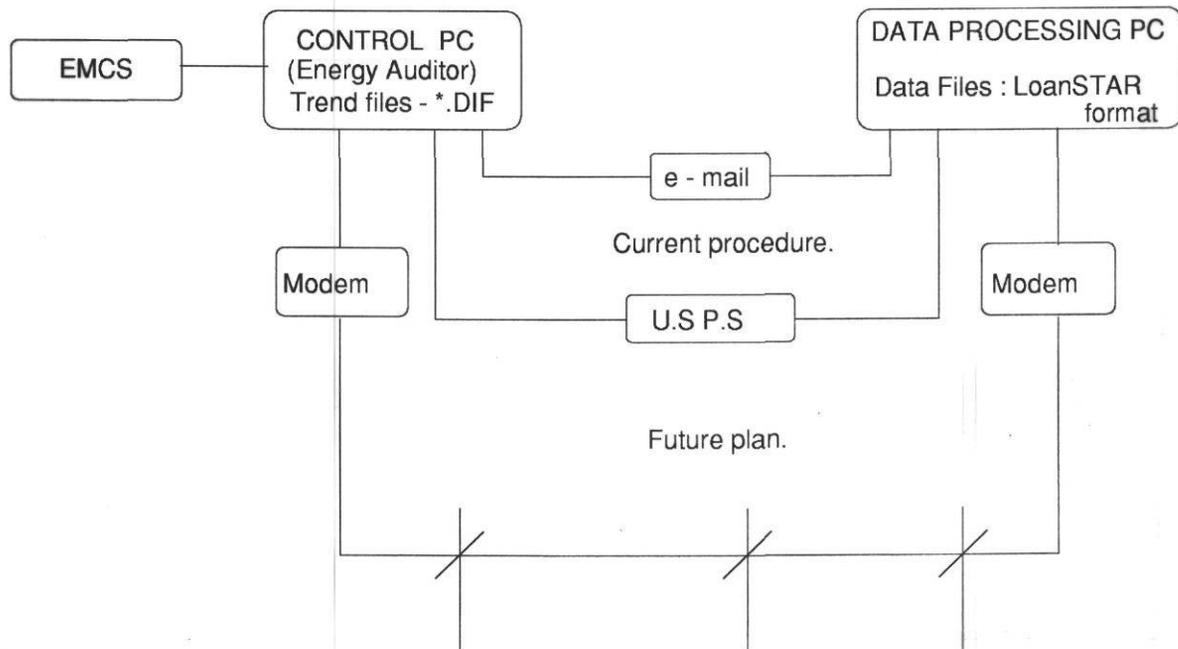
**Figure 4.1.1: The Texas Tech University Health Sciences Center.** The Texas Tech University Health Sciences Center (TTHSC) is a large 811,131 square foot medical research building located in Lubbock, Texas.



**Figure 4.1.2: Hardware configuration for the Texas Tech site.** This figure illustrates the data paths for the Texas Tech site that are either currently in use or are being planned for use. Data are extracted from the EMCS by a control PC which places the information into .DIF files for transfer. For the prototype data were transferred to A&M for further processing via U.S.Mail (USPS), or via an email connection through the statewide campus ethernet campus connection. Direct communication (excluding data transfer) via modem connection is possible with the hardware at the Texas Tech site.

## HARDWARE CONFIGURATION

---

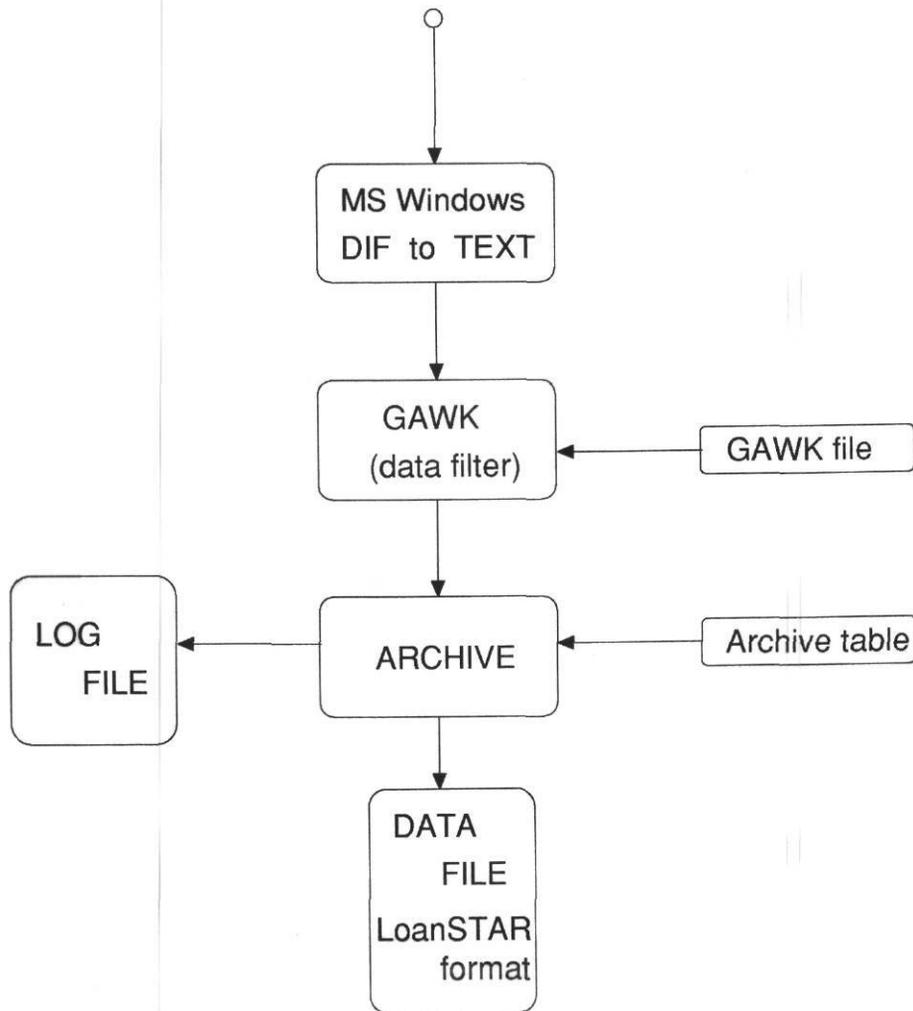


**Figure 4.1.3:** *Data processing stream for the Texas Tech site.* This figure shows the data processing streams that are required to translate the Honeywell data into LoanSTAR format once the data have been received.

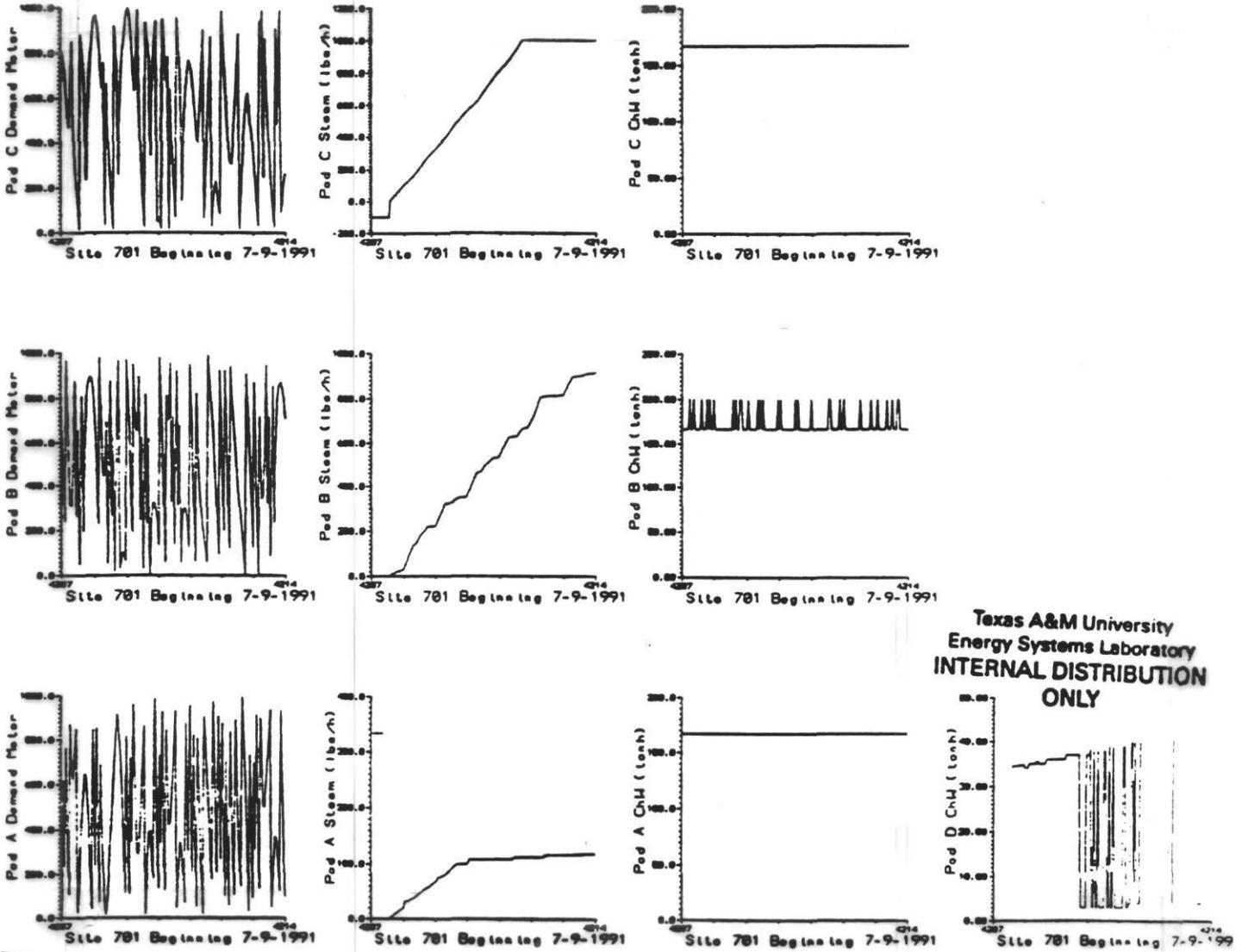
## DATA PROCESSING STREAM

---

Data from the HONEYWELL DELTA 1000 EMCS is converted into a DIF format by the Energy Auditor Software.



**Figure 4.1.4: LoanSTAR-type inspection plots for Texas Tech.** This figure contains an example of the inspection plots that are produced each week when the Texas Tech data are retrieved from the site. (NOTE: The data shown represent early attempts to poll the site. Several channels are obviously indicating problematic traces -- one of the values of using graphical inspection plots).



## 4.2 The Texas A&M Zachry Engineering Center.

The Zachry Engineering Center is a large, multipurpose building which contains classrooms, laboratories, faculty-staff offices, and a large central computer facility. It is located on the Texas A&M University campus in central Texas about two hours Northwest of Houston. The ZEC, (and 250+ other buildings) on the central campus receive steam, hot water, chilled water, electricity, and communication services from a centralized utility distribution system.

The four story, 324,400 square foot facility was built in the early 1970's. The building measures 339 feet (the long axis) by 221 feet and is 60 feet in height. The long axis is oriented in a Northeast to Southwest direction and the building is not shaded by any other structures. Parking is provided under the facility for 82 cars. Figure 4.2.1 shows the building (#223) as it is located on the Texas A&M campus. One of the distinguishing features of the building is a large centralized three story atrium in the Southwestern half of the building which provides access to the surrounding classrooms, and offices. About 2,500 square feet of Northeast facing clerestory lighting helps to illuminate the central staircase and computing facility.

The building can be characterized as an internal load dominated, high mass structure with 6-inch concrete walls. Only about 9% of the exterior envelope is glazed. This consists of about 2,500 square feet of single pane glazing between exterior concrete utility chaseways.

The building has a maximum occupancy of 2,300 occupants which occurs during peak periods each semester. The occupancy profiles are characterized by an 8:00 a.m. to 7:00 p.m. weekday schedule. Significant evening usage of the building occurs during the weekdays between 7:00 p.m. and midnight. Weekend usage is moderate.

The building's average air-change rate is strongly driven by the 10-20% fresh air that is supplied to the air-handling units (AHUs). Internal lighting loads (2 W/ft<sup>2</sup>) and equipment loads (2.4 W/ft<sup>2</sup>) peak during the weekdays in the early afternoon. Considerable electricity is consumed in the evening by the central computing facility.

The building was built with 12 constant volume, dual-duct AHUs which provide 330,500 CFM to the 90+ zones in the building. These were retrofit with variable speed drives and variable flow terminal boxes in early 1991. The AHUs are located in the parking garage with return air paths provided by the concrete chaseways that encircle the exterior of the building. Control of the ventilation systems is provided by 90+ zone thermostats. Prior to a recent VAV retrofit the AHUs operated continuously. Secondary chilled water pumps and hot water pumps are manually switched on to provide for varying levels of cooling or heating capacity. A detailed description of the HVAC system is provided in the papers by Katipamula and Claridge (1991; 1992).

The ZEC is equipped with a Landis Gyr EMCS. The system has the potential for

approximately 30,000 points, and is interconnected for energy monitoring via the campus phone system. Points include chilled water Btu, hot water Btu, and whole building electricity, as well as many other points that are associated with conditions in the air-handling units.

Since the ZEC is located on the same campus as the polling computer, communications with the Landis and Gyr system were easier to accomplish than polling remote sites. The close proximity of the ZEC EMCS and the presence of a separate Landis Gyr communications network on campus allowed for communications by several means. Polling could be accomplished via modem through the campus phone system or by RS232 connection to the EMCS in the building that contained the polling computer which allowed for communication to the ZEC EMCS via the Landis Gyr campus network. This report will discuss the polling that was accomplished via the campus phone system.

Table 4.2.1 contains a listing of the main points that are being monitored by the Landis Gyr system. Figure 4.2.2 is a diagram of the polling arrangement using the campus phone system and modems at both the polling computer and the EMCS. Table 4.2.2 contains keystrokes from a typical polling session with the ZEC EMCS via the campus phone lines. Polling was accomplished with a commercial communications package (Procomm) one of many different such packages that are available for such purposes. Table 4.2.3 shows a trend file from a polling session. Obviously, a rather rigorous AWK script was necessary to strip unnecessary header and non-numeric data prior to passing the data to the ARCHIVE program. (The programs for translating this file are contained in the appendix to this report.) Figure 4.2.3 illustrates the data processing scheme that was needed to convert the data from EMCS to LoanSTAR format and Figure 4.2.4 shows an inspection plot of the data that have successfully passed through the LoanSTAR conversion.

Table 4.2.4 contains the ARCHIVE channel table for processing data from the ZEC's EMCS. Table 4.2.5 shows the ZEC EMCS data in the LoanSTAR format and Table 4.2.6 shows the .LOG file produced by the ARCHIVE file for the ZEC EMCS data. Figure 4.2.4 is a LoanSTAR-type inspection plot for the ZEC EMCS data.

Although the polling and access to the Landis Gyr was simplified because the building was close at hand other problems began to plague the process. For example, since polling was accomplished through a node that was also used for troubleshooting and/or operation, often times a significant amount of dialing and redialing was needed to catch the phone line when it was not busy. Obviously, another modem or off-hour phone calls could have eliminated this problem. The final solution was to connect the appropriate EMCS node via the Landis Gyr campus network. This was accomplished by directly connecting to the RS232 port on a local Landis EMCS (located down the hall from the polling computer). A significant amount of programming in Landis Gyr's PPCL programming language was necessary to capture the necessary trend data. Furthermore, the PPCL uses Change of Variable values to record energy use and this may lead to inaccuracies if the user selects energy change values that result in time intervals that are greater than one hour.

*Table 4.2.1 : EMCS Capabilities*

Device	Temp.	Stat.Point	%RH	Setpoint	Status
Cold Deck	*	*		*	
Hot Deck	*	*		*	
Reheat					
Preheat					
Supply Air	*		*	*	
Return Air	*			*	
Discharge	*			*	
Fan	*	*		*	*
Ind.Zone(s)	*			*	

Device	Temp.	Flow	Energy	RH	Setpoint	Status
Electric			*			
CW Supply	*	*				
CW Return	*	*				
CW Pump						
HW Supply	*	*				
HW Return	*	*				
HW Pump						
DHW Sup.	*					
Condensate						
Outside Air						

**Table 4.2.2 : Operator keystrokes for retrieving data.** This table contains the typical operator keystrokes that are required for polling and retrieving the data from the Zachry Engineering Center EMCS (ZEC) using the Procomm communications package.

**Key Strokes for the Landis and Gyr EMCS at the Zachry Engineering. Center.**

NOTE - PROCOMM IS A STANDARD COMMUNICATION SOFTWARE. FOLLOW THE INSTRUCTIONS BELOW FROM THE PROCOMM DIRECTORY. TYPE EVERY THING IN BOLD FACE AS THEY ARE.

1. **PROCOMM**
2. **ALT D**
3. **Revise.**
4. **choose number.**
5. **name : ZACHRY ENGG. CENTER**
6. **number : XXX-XXX-XXXX,,,,,,,,,XXX**
7. **save entry[y].**
8. **= > enter number**
9. **Point.**
10. **Trend.**
11. **Multipoint.**
13. **Here.**
14. **enter hours (ex. 168 HOURS = = 1 WEEK)**
15. **enter sample rate ( ex. 60 MIN)**
16. **enter point names (ex. WATT = WHOLE BUILDING ELECTRIC)**
17. **press PAGEDOWN**
18. **press 7.**
19. **enter data file name.**
20. **hit return to start polling.**
21. **after completion press ESC**
22. **ALT H**
23. **ALT X**

**Table 4.2.3 : Zachry EMCS data file in raw format.** This table shows the raw data format for the data that are received from the ZEC EMCS prior to processing into the LoanSTAR format.

B6CDS  
 > Point name?B6SPD  
 > Point name?B7CDS  
 > Point name?B7SPD  
 > Point name?  
 Command successful

Trend Multi-point Report 14:12 03-Sep-91

	B6CDS	B6SPD	B7CDS	B7SPD
	PSI		PSI	
	30	30	30	30
27-Aug				
28-Aug				
29-Aug				
30-Aug				
31-Aug				
15:10	2.612	11.94	3.052	14.40
16:10	2.813	12.09	3.105	14.40
....				
etc.				
....				
13:10	2.476	12.45	2.795	13.47
14:10	2.448	12.78	2.65	14.50

End of Report

> Point, Time, Message, Cancel, Hello ?P  
 > Log, Display, Monitor, Trend, Subptlog ?T  
 > Display, Listpoints, Multipoint ?L  
 > Here, Printer ?H  
 > Point name?B6\*  
 Command successful

Trend List of Points 14:14 03-Sep-91

B6CDS (CLD DEC STAT)	Time: 30	minutes	144	samples
B6SPD (SPEED CONT )	Time: 30	minutes	144	samples
B6MAT (MIX AIR TEMP)	Time: 15	minutes	250	samples
B6CDT (COLD DEC TMP)	Time: 15	minutes	250	samples
B6HDS (HOT DEC STAT)	Time: 15	minutes	200	samples
B6HS (HIGH STATIC )	COV		50	samples
B6HDT (HOT DEC TMP)	Time: 15	minutes	200	samples

End of Report

**Table 4.2.4 : ARCHIVE channel table for the Zachry site.** The ARCHIVE channel table for the ZEC EMCS is shown in this table. All data used in the LoanSTAR program are processed with the ARCHIVE program to assure a uniform data base structure. ARCHIVE performs useful data and time transformations and can perform high-low limit checks each time a site is polled.

DATE	Time	Raw	Raw	Arch	Name of Archive	Arch	Conv'n	Calib.	or Error	Limatation	Channel		
MM/DD/YY	HH:mm	Line	coln	pos	Channel	Units	Format	Code	Constants	Code	Constants	Description	
#													
01/01/91	00:00	1	0	0	Begin								
01/01/91	00:00	1	1	1	site#	-	I3	2	0	715	0	site#	
01/01/91	00:00	1	1	2	Month	MM	I3	1		0		Month	
01/01/91	00:00	1	2	3	Day	DD	I3	1		0		Day	
01/01/91	00:00	1	3	4	Year	YY	I3	1		0		Year	
01/01/91	00:00	1	3	5	G-J	-	I5	24	1	2	0	Gregorian - Julian	
01/01/91	00:00	1	1	6	dec.t	-	F10.4	28		0		decimal time	
01/01/91	00:00	1	4	7	Time	hhmm	I5	15		0		Time	
01/01/91	00:00	1	5	8	CDS	PSI	F9.3	1		1	0	100000	pt. 1 PSI - B6CDS
01/01/91	00:00	1	6	9	SPD	PSI	F9.3	1		1	0	100000	pt. 2 PSI - B6SPD
01/01/91	00:00	1	7	10	MAT	DEG	F9.3	1		1	0	100000	pt. 3 Temp - B6MAT
01/01/91	00:00	1	8	11	CDT	DEG	F9.3	1		1	0	100000	pt. 4 Temp - B6CDT
01/01/99	00:00	1	0	0	End								

**Table 4.2.5: Zachry EMCS data file in the LoanSTAR format.** Zachry EMCS data that has been processed by the ARCHIVE program is shown in this table. The first column is the site number, and the six columns that immediately follow are calendar and time values in different formats. Energy use data for this site begins in the eighth column.

715	8	31	91	91243	4260.6319	1510	2.612	11.940	3.052	14.400
715	8	31	91	91243	4260.6736	1610	2.813	12.090	3.105	14.400
715	8	31	91	91243	4260.7153	1710	2.821	12.110	2.921	13.940
715	8	31	91	91243	4260.7569	1810	2.904	12.200	3.180	14.330
715	8	31	91	91243	4260.7986	1910	2.734	12.110	3.079	14.260
715	8	31	91	91243	4260.8403	2010	2.937	12.590	3.082	14.280
715	8	31	91	91243	4260.8819	2110	2.916	12.610	2.965	13.840
715	8	31	91	91243	4260.9236	2210	3.025	12.490	3.231	14.140
715	8	31	91	91243	4260.9653	2310	2.896	12.370	3.233	14.150
715	9	1	91	91244	4261.0069	10	3.054	12.850	3.181	13.810
715	9	1	91	91244	4261.0486	110	2.930	12.700	2.982	13.400
715	9	1	91	91244	4261.0903	210	3.183	12.360	3.252	13.830
715	9	1	91	91244	4261.1319	310	3.097	12.260	3.289	13.790
715	9	1	91	91244	4261.1736	410	3.069	12.550	3.241	13.710
715	9	1	91	91244	4261.2153	510	3.002	12.490	3.108	13.450
715	9	1	91	91244	4261.2569	610	3.169	12.300	3.313	14.030
715	9	1	91	91244	4261.2986	710	2.994	12.000	3.306	14.190
715	9	1	91	91244	4261.3403	810	3.163	12.390	3.244	14.170
715	9	1	91	91244	4261.3819	910	2.926	12.230	3.058	13.650
715	9	1	91	91244	4261.4236	1010	2.908	11.950	3.096	14.190
715	9	1	91	91244	4261.4653	1110	2.745	11.640	3.063	13.990
715	9	1	91	91244	4261.5069	1210	2.829	11.960	2.996	14.080
715	9	1	91	91244	4261.5486	1310	2.723	11.970	2.752	13.500
715	9	1	91	91244	4261.5903	1410	2.924	11.970	3.068	14.170
715	9	1	91	91244	4261.6319	1510	2.687	11.700	2.954	14.330
715	9	1	91	91244	4261.6736	1610	2.795	11.870	2.922	14.410
715	9	1	91	91244	4261.7153	1710	2.726	11.640	2.718	13.870
715	9	1	91	91244	4261.7569	1810	2.785	12.040	2.902	14.160
715	9	1	91	91244	4261.7986	1910	2.919	12.070	2.891	13.850
715	9	1	91	91244	4261.8403	2010	3.136	13.090	3.130	13.990
715	9	1	91	91244	4261.8819	2110	3.167	13.310	2.854	13.470
715	9	1	91	91244	4261.9236	2210	3.440	13.120	3.150	14.020
715	9	1	91	91244	4261.9653	2310	3.093	12.720	3.094	14.160
715	9	2	91	91245	4262.0069	10	3.049	12.440	3.177	14.230
715	9	2	91	91245	4262.0486	110	2.980	12.320	2.954	13.760
715	9	2	91	91245	4262.0903	210	3.241	12.620	3.202	14.500
715	9	2	91	91245	4262.1319	310	3.141	12.600	3.253	14.140
715	9	2	91	91245	4262.1736	410	3.220	12.760	3.196	14.070
715	9	2	91	91245	4262.2153	510	3.239	12.590	3.010	13.320
715	9	2	91	91245	4262.2569	610	3.288	12.490	3.124	13.860
715	9	2	91	91245	4262.2986	710	3.194	12.170	3.086	13.740
715	9	2	91	91245	4262.3403	810	3.153	12.370	3.001	13.730
715	9	2	91	91245	4262.3819	910	2.408	11.970	2.729	13.160
715	9	2	91	91245	4262.4236	1010	2.720	12.630	2.801	14.260
715	9	2	91	91245	4262.4653	1110	2.453	12.440	2.849	14.570
715	9	2	91	91245	4262.5069	1210	2.481	12.970	2.724	14.940
715	9	2	91	91245	4262.5486	1310	2.389	12.630	2.682	13.940
715	9	2	91	91245	4262.5903	1410	2.537	13.040	2.710	14.850
715	9	2	91	91245	4262.6319	1510	2.414	12.580	2.565	14.930
715	9	2	91	91245	4262.6736	1610	2.512	12.600	2.540	15.000
715	9	2	91	91245	4262.7153	1710	2.467	11.960	2.412	14.010
715	9	2	91	91245	4262.7569	1810	2.793	12.280	2.787	14.830
715	9	2	91	91245	4262.7986	1910	2.581	11.790	3.008	14.500
715	9	2	91	91245	4262.8403	2010	2.590	12.050	3.030	13.900
715	9	2	91	91245	4262.8819	2110	2.614	11.680	3.058	13.290
715	9	2	91	91245	4262.9236	2210	2.841	11.790	3.068	13.830
715	9	2	91	91245	4262.9653	2310	2.606	11.610	3.091	13.770
715	9	3	91	91246	4263.0069	10	2.656	11.830	3.224	13.660

**Table 4.2.6:** .LOG file produced by the ARCHIVE program for Zachry data. A .LOG file is produced each time ARCHIVE processes data for a site. It includes some basic statistics about which file has been read, the channel table used, and the names of the LOG and output files. It also includes information about how many lines were processed, how many processing errors and missing data occurred and where those errors occurred in the input file.

Log of Archive, version: 1.41 of 15 June 1987, processed on 20 Sep 1991

Files:

RAW DATA zach.out  
CHANNEL TABLE zach.tbl  
ARCHIVE zach.ach  
LOG zach.log

Archive delimiter is " ".

Missing or bad data values are replaced by the value -99.000 .

Line errors: are identified by their line number in the raw data file.

Data errors: are identified by the channels name, line and position within the case: "name "(line in case/position in line).

Line numbers in raw data file are shown as |number| or as \*number\*  
|numbers| indicates a line of data, \*numbers\* is a comment line.

First case on raw data: 91 243 15:10

-----  
BeginDate: 91 001 00:00

First output case: 91 243 15:10  
-----

Line Error: less channels than 8, as expected from channeltable:

|1| 8 31 91 1510

....

etc.

....

Line Error: less channels than 8, as expected from channeltable:

|20| 9 01 91 1010

\*\*\* \*\* No further line errors will be listed for errors of this type \*\*\* \*\*

-----  
EndDate: 99 001 00:00

Last output case: 91 246 14:10  
-----

STATISTICS:

73 lines read from beginning of raw data file.

73 lines processed between Begin and End dates.

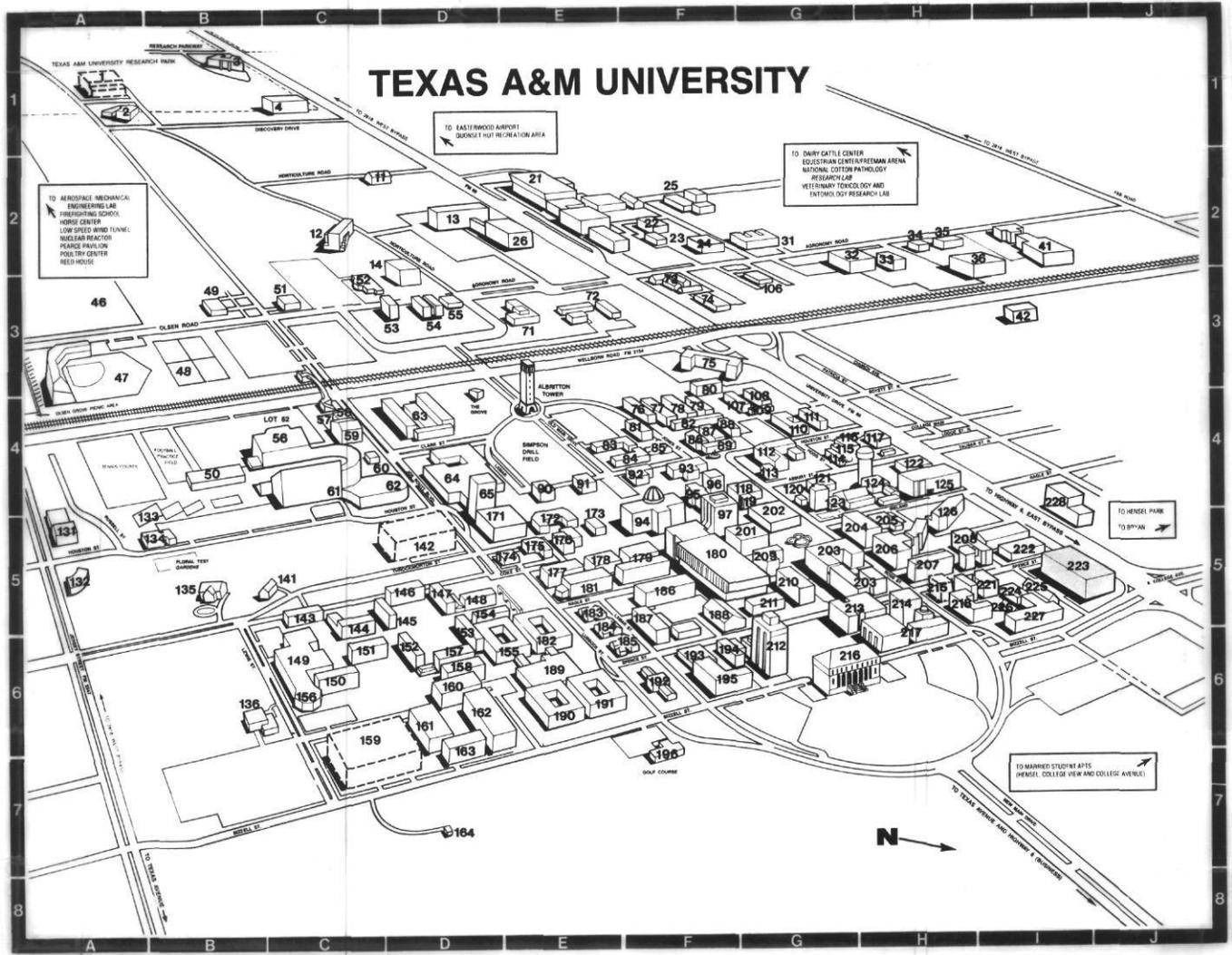
(including 0 comments and 1 all-blank lines)

72 line errors detected.

0 data errors, and 288 missing data detected, itemized below:

Arc	Channel	Error	Missing
pos	name	count	count
8	CDS	0	72
9	SPD	0	72
10	MAT	0	72
11	CDT	0	72

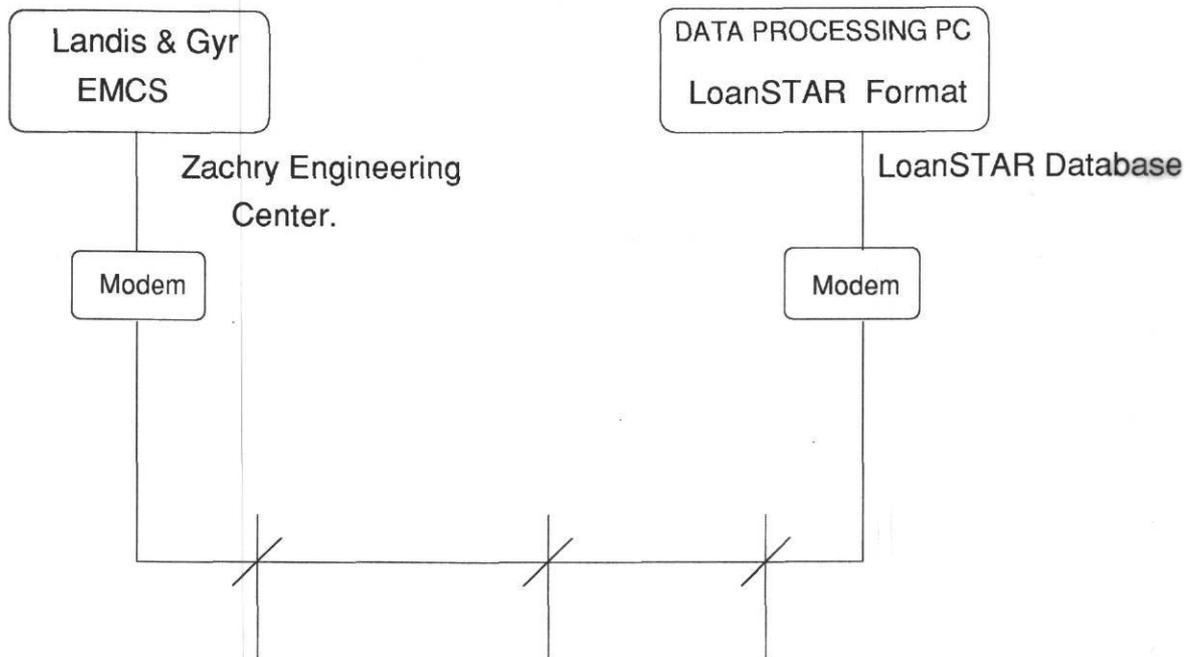
Figure 4.2.1: The Zachry Engineering Center on the Texas A&M University Campus. The ZEC is shown in lower right corner of the campus (building #223).



**Figure 4.2.2: Hardware configuration for the Zachry site.** This figure shows the hardware configuration for the ZEC. Since the site was located close to the office where the polling computer was located the data were collected via modem over the campus phone system.

## HARDWARE CONFIGURATION

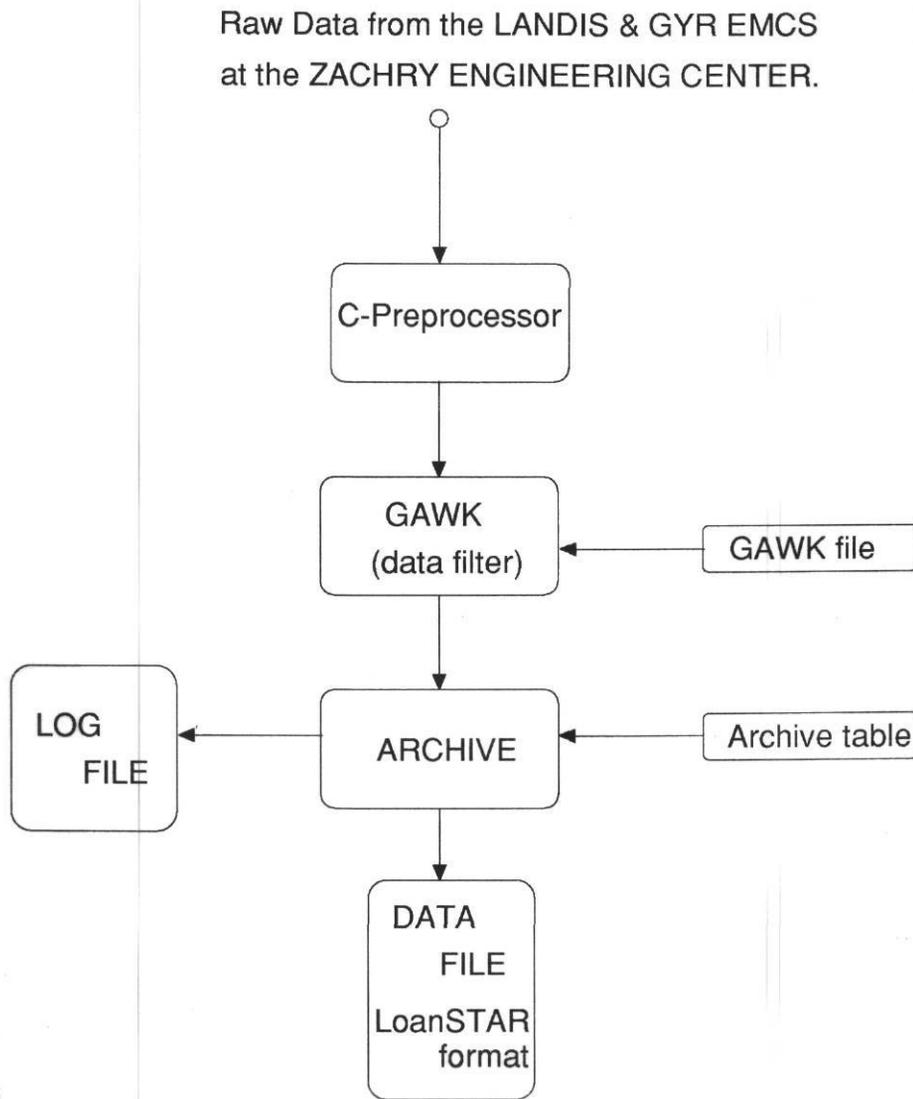
---



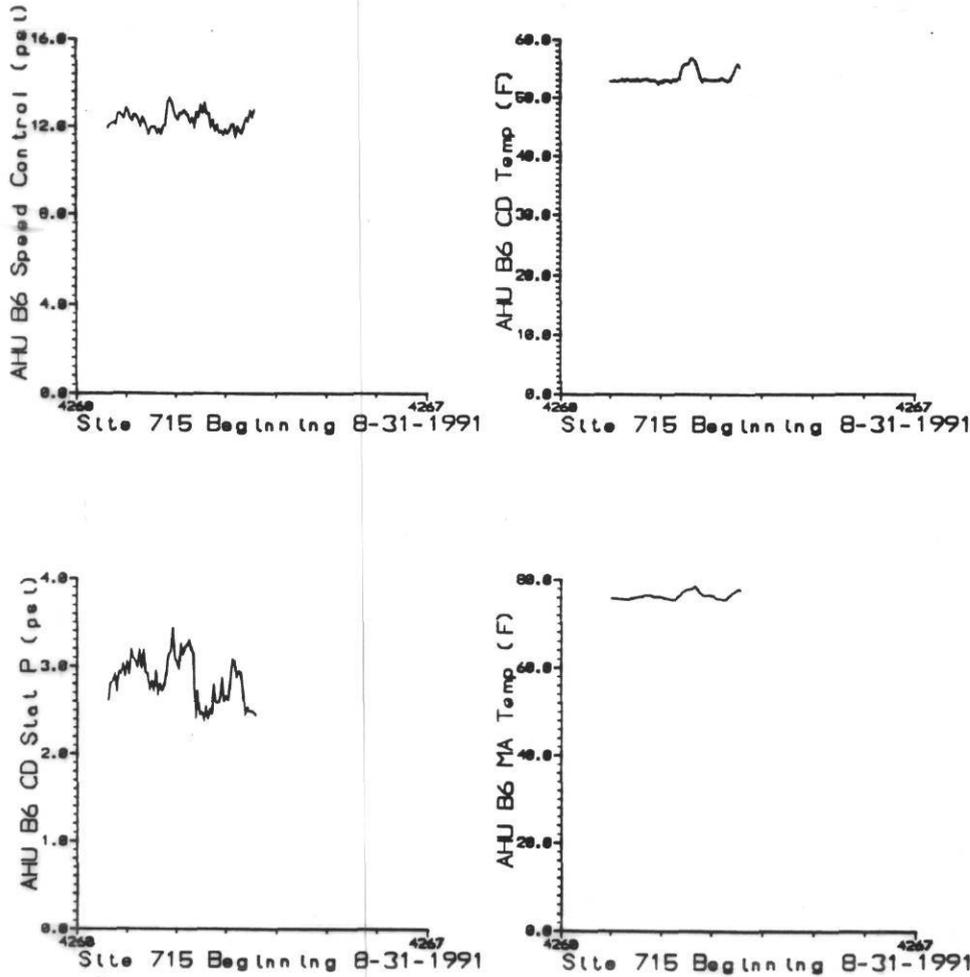
**Figure 4.2.3:** *Data processing stream for the Zachry site.* This figure shows the data processing streams that are required to convert the Landis Gyr data into LoanSTAR format once the data have been received.

## DATA PROCESSING STREAM

---



**Figure 4.2.4:** LoanSTAR-type inspection plots for the Zachry Engineering Center (ZEC). This figure shows the LoanSTAR inspection plots for four channels of data collected from the ZEC.



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### 4.3 Prairie View A&M Campus

The Prairie View A&M Campus is located about 50 miles west of Houston and contains 1,945,952 square feet of conditioned space in 46 buildings (Figure 4.3.1). Most of these buildings receive electricity (1,876,851 sqft.), heating (1,695,176 sqft.) and chilled water (1,423,408 sqft.) from a centralized distribution system. Energy conservation measures recommended for funding by the LoanSTAR program include: improved lighting controls and retrofit of inefficient fixtures, variable speed pumping for the main chilled water loop and hot water loop in the central plant, a chiller upgrade, an extensive steam leak repair effort, and automatic controls to operate several large pumping stations during off-peak hours. The expected payback for these measures is \$298,000 per year. The final selection of retrofits has yet to be determined.

In 1987 Prairie View A&M University started a large scale energy management program with Johnson Controls. By April of 1990 this energy management program was saving \$80,000 per month. A large portion of these savings are attributable to the installation and use of the Johnson Controls EMCS which was used in this study. Additional information about the Prairie View energy management program, including an analysis that uses normalized sliding indicators can be found in the report by Haberl et al. (1991).

The Prairie View A&M campus (PVAM) is equipped with a Johnson Controls JC 85/40 EMCS that is connected to over 2000 points throughout the campus. Table 4.3.1 includes a summary of the types of points that are being monitored. Of importance to this study, Johnson Controls connected whole-building electric and thermal monitoring to over 35 buildings as part of their shared savings service contract with PVAM University. Sites such as PVAM are an ideal case study because of their economies of scale. If it could be shown that the EMCS can effectively be made to serve a dual purpose, namely, as a building control system for the PVAM operators and as a remote data acquisition system for monitoring the savings from an energy retrofit then the extra effort expended to translate data are justified.

Since Johnson Controls has an energy management contract with PVAM University it was necessary to work extensively with Johnson Controls during this prototype effort. The JC 85/40 can trend up to 99 points and can store 3000 samples for each point within its memory (a limit set by the size of the PC on which the software is running). The JC 85/40 EMCS at PVAM consisted of a Johnson Controls TI 990-12 minicomputer, the actual processor that performs the control functions, and a PC that is used for administrative functions and trending. As such, the equipment at PVAM only allowed for the trending of 200 points for each channel being sampled.

The JC 85/40 also allows for trending at the remote control units or Digital System Controllers (DSCs). Up to 400 points can be trended at this level. However, only 64 samples of data points can be stored before the memory is overwritten which would necessitate the need for a periodic uploading to the JC 85/40.

As with almost all EMCSs the JC 85/40's performance degrades as points are added to the trend file, so the number of points and the trending rate is carefully watched by the EMCS operators least they end up with a very slow system response rate. This was not a problem at PVAM.

One major limitation to using the EMCS at PVAM University is that the Johnson Controls operators use the trending facility to troubleshoot the system and for their maintenance logs. During the time that the prototype was being investigated this averaged 30 to 40 channels, and could go as high as 80 of the 99 channels.

For the purposes of the prototype the data collected by the JC 85/40 included whole-building thermal and electric data for one building. At the time that the prototype was being assembled the JC 85/40 only had the capabilities of trending hourly samples of energy use. For example, the electrical energy use was measured using a pulse counter, where each pulse represents a given amount of energy use. The hourly sample, which was recorded in the trend, only represented the number of pulses that had been recorded in the previous minute, rather than the previous hour. Although the JC 85/40 had a facility for totalizing energy use from such pulses into daily counts for reporting purposes, the current version of the software would not allow for mixed hourly totalized and averaged information to be trended. The programming of the trending did allow for data to be captured on the hour regardless of when the trending was initialized.

In a similar fashion to the Honeywell Delta 1000, direct polling of trend data from the JC 85/40 was not immediately accomplished. However, thanks to some clever programming by the Johnson Controls operators, this was eventually accomplished by declaring the modem to be a printer and having the JC 85/40 print the trend data to the printer/modem. Capture of the data by the polling computer was then accomplished by echoing the data on the screen to the disk for storage.

Data are retrieved from Prairie View by modem from Texas A&M as shown in Figure 4.3.2. At Prairie View the modem is directly connected to the JC 85/40 although a PC could have been configured for this purpose using additional software from Johnson Controls. Table 4.3.2 contains the operator keystrokes for retrieving the data from the JC 85/40. A commercial communications package was used for this purpose (PROCOMM).

As with most of the EMCS sites, once communications have been established one must go through a series of EMCS-specific commands to reach the necessary data in the trend file. For the JC 85/40 this is illustrated in Table 4.3.2 with the resultant capture file being shown in Table 4.3.3. This capture file required additional preprocessing once it was received at A&M as shown in Figure 4.3.3. (The programs for translating this file are contained in the appendix to this report.)

Once the data were properly prepared they were then processed with the ARCHIVE program

using the appropriate channel table. Table 4.3.4 contains the ARCHIVE channel table for the Prairie View site. Table 4.3.5 contains the JC 85/40 data in LoanSTAR format, and Table 4.3.6 contains a typical log session produced each time the file is run through the ARCHIVE program. In a similar fashion to the other EMCS sites the end result of all this processing each week is to produce an inspection plot such as that shown in Figure 4.3.4.

**Table 4.3.1: EMCS Capabilities.** The EMCS capabilities for the Prairie View A&M are shown in this report as determined by Heinemeier and Akbari (1991).

Device	Temp.	Stat.Point	%RH	Setpoint	Status
Cold Deck	*			*	
Hot Deck	*			*	
Reheat	*			*	
Preheat	*			*	
Supply Air	*		*	*	
Return Air	*			*	
Discharge	*			*	
Fan		*		*	*
Ind.Zone(s)	*			*	

Device	Temp.	Flow	Energy	RH	Setpoint	Status
Electric			*			
CW Supply	*	*	*			
CW Return	*	*			*	
CW Pump						*
HW Supply	*	*	*		*	
HW Return	*					
HW Pump						*
DWH Sup.	*					
Condensate						*
Outside Air	*			*		

**Table 4.3.2: Operator keystrokes for retrieving data.** This table contains the typical operator keystrokes that are required for polling and retrieving the data from the Prairie View EMCS using the Procomm communications package.

**Key Strokes for the Johnson Controls EMCS at PRAIRIE VIEW A & M UNIV.**

NOTE - PROCMM IS A STANDARD COMMUNICATION SOFTWARE. FOLLOW THE INSTRUCTIONS BELOW FROM THE PROCMM DIRECTORY. TYPE EVERY THING IN BOLD FACE AS THEY ARE. THE USER MUST KNOW THE POINT NUMBERS.

1. **PROCMM**
2. **ALT D**
3. **Revise**
4. *choose number*
5. **name : PRAIRIE VIEW A & M UNIV.**
6. **number : XXX-XXX-XXXX**
7. *after you see "pvam university" hit return*
8. *after you see "log in" enter XXXX*
9. **press PAGEDOWN**
10. *press 7*
11. *enter data file name*
12. *for each point type "O,SUM,TREND,VAL,(point number)"*
13. **print "HC4"**
14. **print E for execute**
14. *after all the points have been polled type QUIT*
15. **press ESC**
16. **ALT H**
17. **ALT X**

**Table 4.3.3: Prairie View EMCS data file in raw format.** This table illustrates the raw data format for data retrieved from the Prairie View EMCS.

SYSTEM INFORMATION - TREND VALUE SUMMARY PGM DAY 5 THU 8 AUG 1991 15:54:58 PAGE: 1

POINT NUMBER : 41 SAMPLE STATUS : BEG  
 POINT ID : H LIB - JB COLEMAN BLG - BUILDING BTU - KBTU/HR CALC SAMPLE RATE : 1 HR  
 SAMPLE # BEGIN TIME : 11:00 ON 8/05/91 END TIME : \_\_\_\_ ON \_\_\_\_ LAST SAMPLE : 77

---

1- 10	0.00	0.00	0.00	OFFLINE	0.00	0.00	0.00	0.00	0.00	0.00
11- 20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21- 30	0.00	OFFLINE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31- 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41- 50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51- 60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61- 70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71- 80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

...END...  
 O,SUM,TRD,VAL,42  
 O,SUM,TRD,VAL,42,HC4  
 EXE/IGN (E/I) E

SYSTEM INFORMATION - TREND VALUE SUMMARY PGM DAY 5 THU 8 AUG 1991 15:55:34 PAGE: 1

POINT NUMBER : 42 SAMPLE STATUS : BEG  
 POINT ID : H LIB - JB COLEMAN BLG - BUILDING KW - KW READING SAMPLE RATE : 1 HR  
 SAMPLE # BEGIN TIME : 11:00 ON 8/05/91 END TIME : \_\_\_\_ ON \_\_\_\_ LAST SAMPLE : 77

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1- 10	388.80	388.80	388.80	OFFLINE	324.00	324.00	388.80	388.80	324.00	324.00
11- 20	324.00	259.20	259.20	129.60	64.80	64.80	129.60	64.80	129.60	64.80
21- 30	129.60	OFFLINE	324.00	388.80	324.00	324.00	324.00	388.80	388.80	259.20
31- 40	324.00	324.00	324.00	324.00	324.00	324.00	259.20	129.60	64.80	129.60
41- 50	129.60	129.60	129.60	64.80	129.60	324.00	324.00	324.00	388.80	324.00
51- 60	324.00	324.00	324.00	388.80	324.00	388.80	388.80	324.00	388.80	259.20
61- 70	259.20	64.80	129.60	129.60	64.80	64.80	64.80	129.60	129.60	324.00
71- 80	388.80	388.80	388.80	388.80	324.00	388.80	388.80			

...END...

SYSTEM INFORMATION - TREND VALUE SUMMARY PGM DAY 5 THU 8 AUG 1991 15:57:24 PAGE: 1

POINT NUMBER : 43 SAMPLE STATUS : BEG  
 POINT ID : H LIB - JB COLEMAN BLG - BUILDING TON - CHW TONNAGE SAMPLE RATE : 1 HR  
 SAMPLE # BEGIN TIME : 11:00 ON 8/05/91 END TIME : \_\_\_\_ ON \_\_\_\_ LAST SAMPLE : 77

---

1- 10	213.20	188.30	213.50	OFFLINE	186.90	191.20	200.50	182.90	213.80	180.60
11- 20	164.80	165.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21- 30	418.00	OFFLINE	172.00	184.00	190.10	188.70	193.40	150.80	179.40	164.40
31- 40	161.80	169.30	181.70	146.40	182.70	196.20	0.00	0.00	0.00	0.00
41- 50	0.00	0.00	0.00	0.00	254.10	177.50	174.00	172.30	171.50	168.80
51- 60	176.80	181.90	162.20	166.70	180.20	166.70	181.70	143.00	158.70	157.60
61- 70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	262.10	132.50
71- 80	159.00	145.20	154.60	172.20	162.30	167.40	171.50			

...END...

**Table 4.3.4: ARCHIVE channel table for the Prairie View site.** The ARCHIVE channel table for the Prairie View site is shown in this table. All data used in the LoanSTAR program are processed with the ARCHIVE program to assure a uniform data base structure. ARCHIVE performs useful data and time transformations and can perform high-low limit checks each time a site is polled.

DATE	Time	Raw	Raw	Arch	Name of Archive	Arch	Conv'n	Calib. or Error	Limatation	Channel	
MM/DD/YY	HH:mm	Line	coln	pos	Channel	Units	Format	Code	Constants	Code Constants	Description
#4											
01/01/91	00:00	1	0	0	Begin						
01/01/91	00:00	1	1	1	site# -	I3	2	0	710	0	site#
01/01/91	00:00	1	1	2	Month MM	I3	1		0		Month
01/01/91	00:00	1	2	3	Day DD	I3	1		0		Day
01/01/91	00:00	1	3	4	Year YY	I3	1		0		Year
01/01/91	00:00	1	3	5	G-J -	I5	24	1	2	0	Gregorian - Julian
01/01/91	00:00	1	1	6	dec.t -	F10.4	28		0		decimal time
01/01/91	00:00	1	4	7	Time hhmm	I5	15		0		Time
01/01/91	00:00	1	5	8	BTU kbtu/hr	F9.3	1	1	0	1000	pt. 41 btu - kbtu/hr calc
01/01/91	00:00	1	6	9	KW KW	F9.3	1	1	0	1000	pt. 42 KW - reading
01/01/91	00:00	1	7	10	CWT TON	F9.3	1	1	0	1000	pt. 43 CHW Tonnage
01/01/91	00:00	1	8	11	WBT DEG	F9.3	1	1	0	1000	pt. 45 Wet bulb temp.
01/01/99	00:00	1	0	0	End						

**Table 4.3.5: Prairie View EMCS data file in the LoanSTAR format.** Prairie View EMCS data that has been processed by the ARCHIVE program is shown in this table. The first column is the site number, and the six columns that immediately follow are calendar and time values in different formats. Energy use data for this site begins in the eighth column. The "-99.00" is inserted by ARCHIVE to identify data that fell outside the preset high-low limits.

710	8	5	91	91217	4234.4583	1100	0.000	388.800	213.200	73.140
710	8	5	91	91217	4234.5000	1200	0.000	388.800	188.300	72.580
710	8	5	91	91217	4234.5417	1300	0.000	388.800	213.500	72.580
710	8	5	91	91217	4234.5833	1400	-99.000	-99.000	-99.000	-99.000
710	8	5	91	91217	4234.6250	1500	0.000	324.000	186.900	69.460
710	8	5	91	91217	4234.6667	1600	0.000	324.000	191.200	69.360
710	8	5	91	91217	4234.7083	1700	0.000	388.800	200.500	69.830
710	8	5	91	91217	4234.7500	1800	0.000	388.800	182.900	70.380
710	8	5	91	91217	4234.7917	1900	0.000	324.000	213.800	72.540
710	8	5	91	91217	4234.8333	2000	0.000	324.000	180.600	70.700
710	8	5	91	91217	4234.8750	2100	0.000	324.000	164.800	71.680
710	8	5	91	91217	4234.9167	2200	0.000	259.200	165.400	71.720
710	8	5	91	91217	4234.9583	2300	0.000	259.200	0.000	72.560
710	8	6	91	91218	4235.0000	0	0.000	129.600	0.000	72.860
710	8	6	91	91218	4235.0417	100	0.000	64.800	0.000	73.490
710	8	6	91	91218	4235.0833	200	0.000	64.800	0.000	72.960
710	8	6	91	91218	4235.1250	300	0.000	129.600	0.000	73.450
710	8	6	91	91218	4235.1667	400	0.000	64.800	0.000	72.980
710	8	6	91	91218	4235.2083	500	0.000	129.600	0.000	72.490
710	8	6	91	91218	4235.2500	600	0.000	64.800	0.000	72.950
710	8	6	91	91218	4235.2917	700	0.000	129.600	418.000	73.400
710	8	6	91	91218	4235.3333	800	-99.000	-99.000	-99.000	-99.000
710	8	6	91	91218	4235.3750	900	0.000	324.000	172.000	76.590
710	8	6	91	91218	4235.4167	1000	0.000	388.800	184.000	74.510
710	8	6	91	91218	4235.4583	1100	0.000	324.000	190.100	72.300
710	8	6	91	91218	4235.5000	1200	0.000	324.000	188.700	71.480
710	8	6	91	91218	4235.5417	1300	0.000	324.000	193.400	70.460
710	8	6	91	91218	4235.5833	1400	0.000	388.800	150.800	70.360
710	8	6	91	91218	4235.6250	1500	0.000	388.800	179.400	70.080
710	8	6	91	91218	4235.6667	1600	0.000	259.200	164.400	68.790
710	8	6	91	91218	4235.7083	1700	0.000	324.000	161.800	68.910
710	8	6	91	91218	4235.7500	1800	0.000	324.000	169.300	68.910
710	8	6	91	91218	4235.7917	1900	0.000	324.000	181.700	69.920
710	8	6	91	91218	4235.8333	2000	0.000	324.000	146.400	69.410
710	8	6	91	91218	4235.8750	2100	0.000	324.000	182.700	69.780
710	8	6	91	91218	4235.9167	2200	0.000	324.000	196.200	69.500
710	8	6	91	91218	4235.9583	2300	0.000	259.200	0.000	71.010
710	8	7	91	91219	4236.0000	0	0.000	129.600	0.000	70.720
710	8	7	91	91219	4236.0417	100	0.000	64.800	0.000	70.600
710	8	7	91	91219	4236.0833	200	0.000	129.600	0.000	71.140
710	8	7	91	91219	4236.1250	300	0.000	129.600	0.000	71.270
710	8	7	91	91219	4236.1667	400	0.000	129.600	0.000	71.770
710	8	7	91	91219	4236.2083	500	0.000	129.600	0.000	72.280
710	8	7	91	91219	4236.2500	600	0.000	64.800	0.000	72.220
710	8	7	91	91219	4236.2917	700	0.000	129.600	254.100	72.690
710	8	7	91	91219	4236.3333	800	0.000	324.000	177.500	75.080

**Table 4.3.6:** *.LOG file produced by the ARCHIVE program for the Prairie View EMCS data.*  
 This .LOG file is produced each time ARCHIVE processes data for a site. It includes some basic statistics about which file has been read, which channel table was used, and the names of the .LOG and output files. It also includes information about how many lines were processed (not shown), how many processing errors and missing data occurred and where those errors occurred in the input file.

Log of Archive, version: 1.41 of 15 June 1987, processed on 10 Oct 1991

Files:

RAW DATA prv.out  
 CHANNEL TABLE prv.tbl  
 ARCHIVE prv.ach  
 LOG prv.log

Archive delimiter is " ".

Missing or bad data values are replaced by the value -99.000 .

Line errors: are identified by their line number in the raw data file.

Data errors: are identified by the channels name, line and position

within the case: "name "(line in case/position in line).

Line numbers in raw data file are shown as |number| or as \*number\*

|numbers| indicates a line of data, \*numbers\* is a comment line.

First case on raw data: 91 217 11:00

-----  
 BeginDate: 91 001 00:00                      First output case: 91 217 11:00  
 -----

Data Error:

|4| 8 05 91    1400   -99   -99   -99   -99  
 bad number: "BTU    "(1/5); bad number: "KW    "(1/6); bad number: "CWT    "(1/7); bad number: "WBT    "(1/8);

Data Error:

|22| 8 6 91    800   -99   -99   -99   -99  
 bad number: "BTU    "(1/5); bad number: "KW    "(1/6); bad number: "CWT    "(1/7); bad number: "WBT    "(1/8);

-----  
 EndDate: 99 001 00:00                      Last output case: 91 220 15:00  
 -----

STATISTICS:

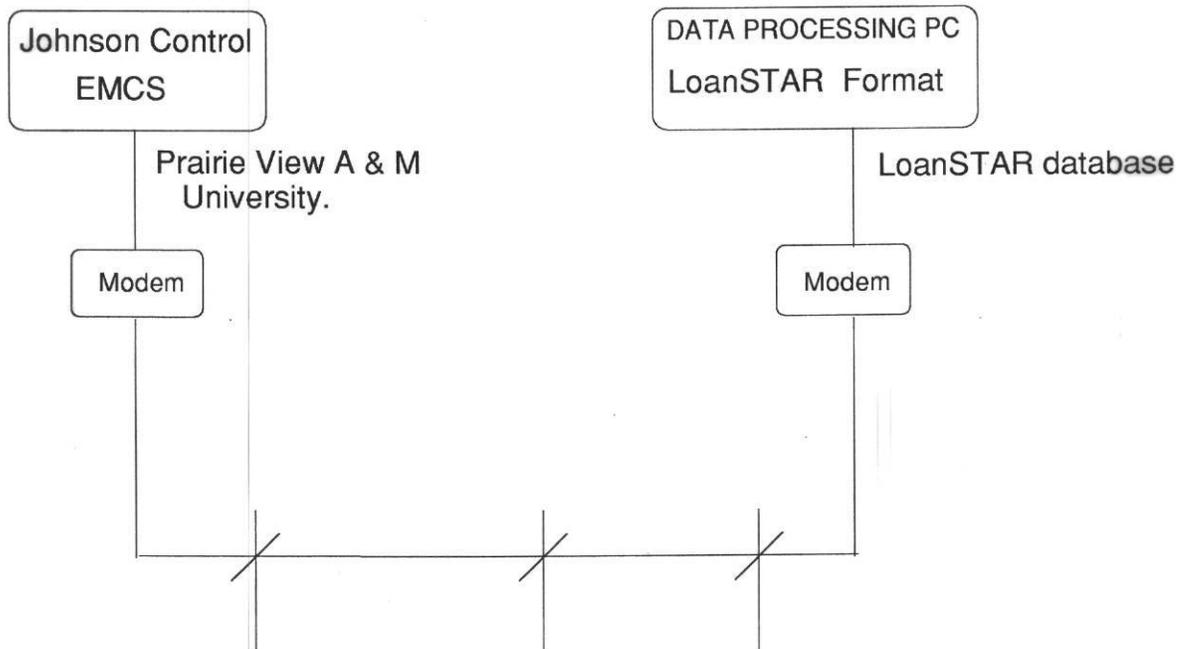
77 lines read from beginning of raw data file.  
 77 lines processed between Begin and End dates.  
 (including 0 comments and 0 all-blank lines)  
 0 line errors detected.

8 data errors, and 0 missing data detected, itemized below:

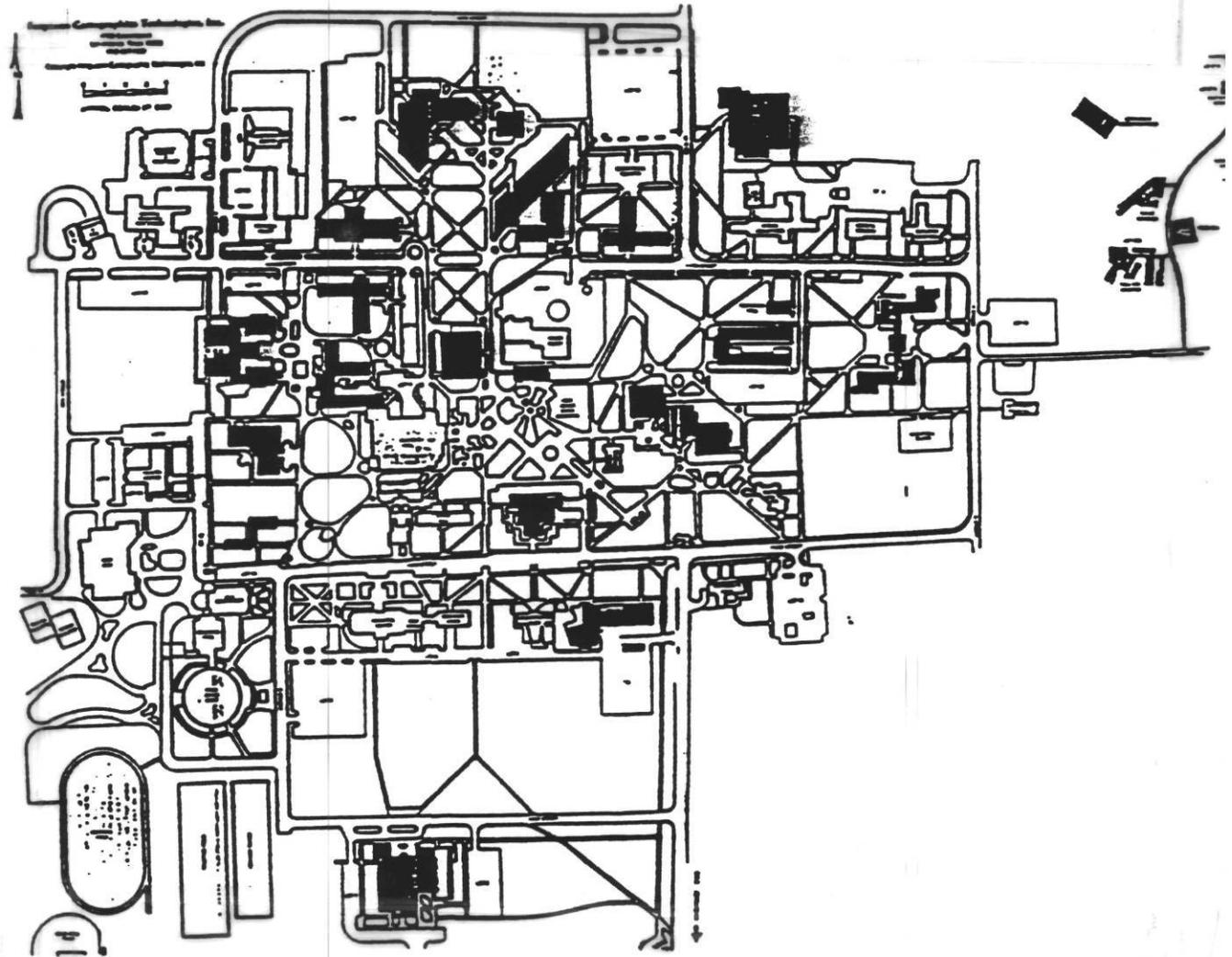
Arc pos	Channel name	Error count	Missing count
8	BTU	2	0
9	KW	2	0
10	CWT	2	0
11	WBT	2	0

**Figure 4.3.2:** *Hardware configuration for the Prairie View site.* This figure shows the hardware configuration required to obtain data from the Johnson Controls EMCS. A future configuration showing the addition of a PC running the Extended Application Workstation is also indicated.

## ----- HARDWARE CONFIGURATION



**Figure 4.3.1: The Prairie View A&M University Campus.** This figure shows an aerial-view of the Prairie View A&M University Campus near Houston which contains about 40 buildings that are controlled by a centralized EMCS.



**Figure 4.3.3:** *Data processing stream for the Prairie View site.* This figure shows the data processing stream that is required to convert the Johnson Controls data into LoanSTAR format once the data have been received.

## DATA PROCESSING STREAM

Raw Data from the JOHNSON CONTROL EMCS  
at PRAIRIE VIEW A & M UNIVERSITY.

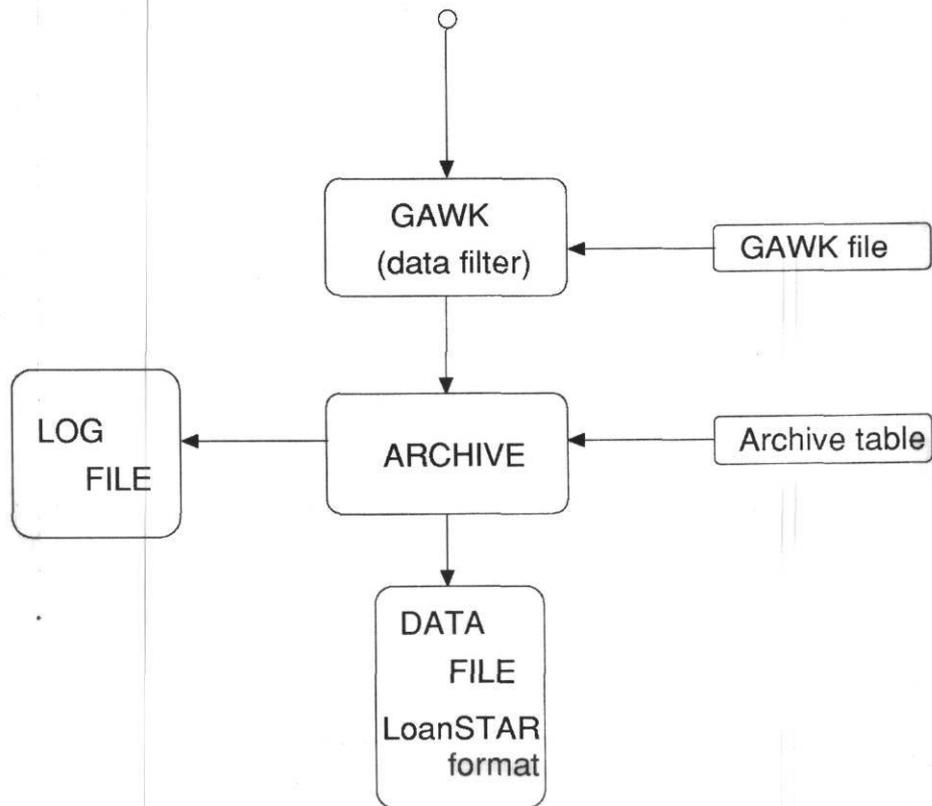
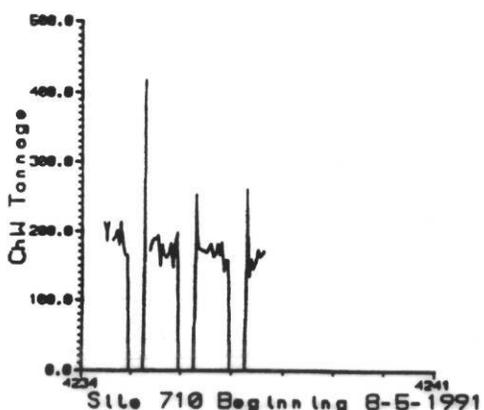
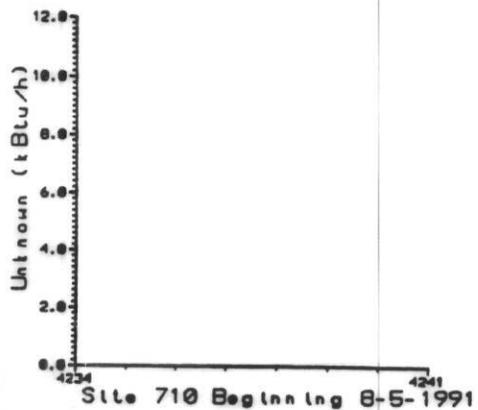
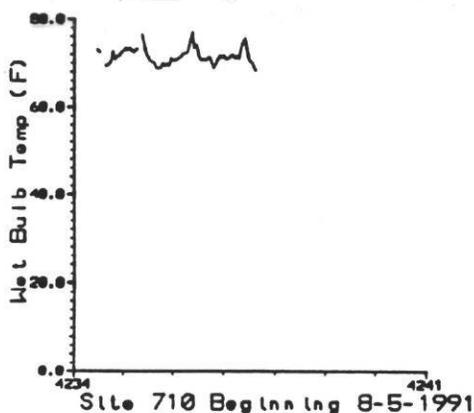
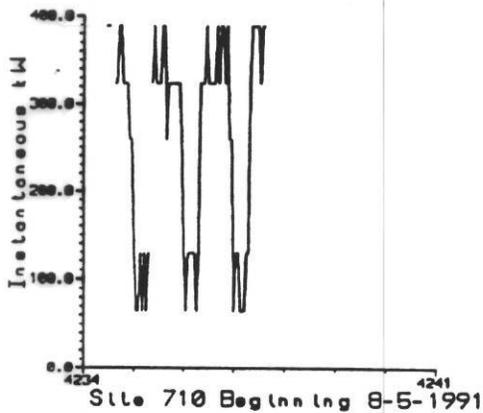


Figure 4.3.4: LoanSTAR-type inspection plots for the Prairie View site. This figure shows the LoanSTAR inspection plots for four channels of data collected from the Prairie View site.



Texas A&M University  
Energy Systems Laboratory  
INTERNAL DISTRIBUTION

#### 4.4 USDOE Forrestal Building

The USDOE Forrestal building, located at 1000 Independence Avenue, was originally built in 1970 for the Department of Defense. The building was named by President Lyndon Johnson after the first Secretary of Defense, James Forrestal. Since April, 1978 the Forrestal building has served as the headquarters for the Department of Energy.

The Forrestal building is actually comprised of a north, south and west wing connected by underground corridors and aerial walkways. Figure 4.4.1 illustrates the layout of the building and shows the location of the proposed loggers. The north wing is elevated 4 stories above street level and is comprised mostly of executive offices. The south building is connected to the north building with four aerial walkways and to the west building with underground corridors. The south building surrounds an interior courtyard and contains office space, several small cafeterias and an employee gym. The west building is comprised mostly of a cafeteria and related services.

The building is primarily constructed of precast and cast-in-place concrete. Precast recessed windows units, encasing 1/4 inch plate glass, are the most prominent feature of the envelope. A poured-in-place shear wall on the south side and north side of the south building are the only exterior walls that do not contain the recessed window units.

The 1,632,000 square foot facility contains 315,430 square feet of parking and 1,316,570 square feet of office space and corridors. In general, the exterior of the building is composed of cast-in-place concrete with minimum insulation. A large portion of the building (668,150 square feet) is actually below grade.

The Forrestal building receives steam and chilled water from the Central heating and refrigeration plant (located at 12th. and C streets, SW). Steam is metered at the Forrestal building with an insert-type turbine meter, chilled water is metered at the Central plant (although a new ultrasonic chilled water meter was installed recently in the Forrestal building). Electricity, natural gas and potable water are provided by local utilities and are separately metered within the facility.

Energy consumption for the period 1985 to 1986 was approximately 185,000 MBtu per year or about 140,000 Btu/sqft (excluding the parking area). During this period utility costs totaled \$4,065,785, consisting of \$2,206,657 for electricity (demand + usage), \$838,564 for purchased steam, \$1,018,719 for purchased chilled water, and \$1,844 for natural gas.

The Forrestal building is heated and cooled by two primary types of systems: four-pipe fan coil units (south and west exposures) and two-pipe fan coil units. Other specialty systems include reheat coils, baseboard units (cafeterias and corridors), north building (fourth floor) hydronic slab heating, heating and ventilating unit heaters (garage), and specialty computer room cooling systems. Ventilation for the building is provided by a low pressure air distribution system serviced by air handling units located in 22 mechanical rooms. Hot water

is supplied by four domestic water converters. Three supply 105F water for lavatories and one supplies 140F water for kitchen use. Normal business hours are 8:30 a.m. to 5:30 p.m., Monday through Friday. The building is usually not used on the weekend. Additional information including an energy analysis on the building can be found in the report by Haberl (1988).

At the present time the USDOE Forrestal building does not have a functional EMCS. Water, natural gas, electricity, steam and chilled water are monitored daily at the building boundaries for internal tracking purposes. In order for the Forrestal staff to effectively analyze savings from energy retrofits, a multi-logger data acquisition system was recommended based on systems that are installed in the Texas LoanSTAR program.

Four separate proposals were presented that investigated the installation of a data acquisition system for monitoring the energy use in the Forrestal building: (1) a fully-configured monitoring system, (2) a system to monitor lighting loads only, (3) a system to monitor whole-building loads and weather conditions only, and (4) a system to monitor the daycare facility and weather conditions only. In the table that follows the full proposal is spelled out.

The preliminary engineering of a fully configured monitoring system that would be capable of monitoring both whole building thermal and electric and sub-metering on the lighting loads and the daycare center was completed by Texas A&M with the help of the National Center for Appropriate Technology (Ncat) and submitted to the DOE in the March 1991 Preliminary Engineering Survey (Claridge et al. 1991). The purpose of such a system would be to allow the DOE to have a showcase monitoring system that would make near-real-time data accessible to the national labs and interested others for studying the HVAC and lighting systems in the Forrestal building.

Such a system would be capable of monitoring the following points:

1. Whole-building electricity.
2. Whole-building natural gas.
3. Whole-building potable water.
4. Whole-building chilled water.
5. Whole-building steam and condensate.
6. Weather conditions (temperature, humidity, solar, wind).
7. Sub-metering of lighting.
8. Sub-metering of motor control centers.
9. Sub-metering of elevators.
10. Sub-metering of kitchen electric loads.
11. Selected sub-metering of computer centers.
12. Sub-metering of the daycare whole-building electricity.
13. Sub-metering of the daycare photoelectric electricity.
14. Sub-metering of the daycare heat pump electricity.
15. Sub-metering of the daycare lighting loads.

16. Sub-metering of the daycare interior conditions.
17. Sub-metering of the daycare solar water heating.

Such a system could be installed in 6 months for about \$243,174, and would include all necessary software/hardware for polling and archiving the data. The fully configured system would utilize at least five loggers as shown in Figure 4.4.1. Each of the loggers would primarily be placed in the electrical vaults to better utilize access to the electrical risers. A minimum of five loggers would be needed to avoid long communication line runs through troublesome ceiling tiles. Table 4.4.1 through 4.4.4 list the proposed channels for each of the loggers. Details concerning the alternative systems that were specified for the Forrestal building can be found in the Preliminary Engineering Survey.

In addition to an engineering survey, a proof-of-concept monitoring system was installed in the Forrestal building in September of 1991. The prototype system utilized mostly whole-building monitoring of thermal and electric loads as shown in Figure 4.2.2 and 4.2.3. Energy consumption recorded by the prototype system is merged with hourly weather data from the National Weather Service's National Airport station at Texas A&M through a connection to the NWS via the campus internet. Measurements from the NWS include dry bulb temperature, wet bulb temperature and wind speed.

Whole-building electricity was provided by PEPCo through an extension of their KYZ pulse for monitoring purposes. Whole-building steam and chilled water took advantage of existing meters, GSA's steam meter and a newly installed ultrasonic chilled water meter. The monitoring also included an arbitrary sampling of several motor control centers, a lighting panel, and an elevator panel to illustrate several different load profiles. Whole-building electricity for the daycare center is also being recorded with the prototype system. One prototype system was located in the C Vault and one system in the A Vault as shown in Figure 4.4.2. Whole-building thermal monitoring is being recorded through the C Vault.

Each week both loggers are called in the Forrestal building in a similar fashion as loggers are called in the LoanSTAR program using modems that are connected to the loggers as shown in Figure 4.4.4. Even the LoanSTAR data needs a slight amount of preprocessing before passing to the ARCHIVE program as shown in Figure 4.4.5. This is mainly to remove "/" ":" and non-numeric characters. The operator keystrokes for retrieving the data are shown in Table 4.4.6. Data in raw format from the Synergistics logger is shown in Table 4.4.7 with the ARCHIVE channel table shown in Table 4.4.8 and the resultant LoanSTAR output file in Table 4.4.9. The accompanying log file is then shown in Table 4.4.10. The resultant weekly inspection plot for the Forrestal building is shown in Figure 4.4.6.

**Table 4.4.1: Forrestal Data Logger #1 & #2 Configuration.** This table shows the proposed configurations of data logger #1 (Switchboard D), and data logger #2 (Switchboard E) in the southeast building of the USDOE Forrestal Complex.

**Logger #1** Synergistics C180 with 16 kWh & 16 digital channels.

<b>Switchboard D</b>			
Elevator P5 & P6	2CTs	Elevators	2 kWh & comb. board
Elevator P13 & P14	2CTs		
Elevator P7, P8, P9	2CTs		
Elevator P10, P11, P12	2CTs		
Riser L38	12CTs	Risers	3 kWh & comb. board
Riser L44	9CTs		
Riser L54	12CTs		
MCC-9 L54	4CTs	MCC	2 kWh

A0 Transformers	18CTs	A - Transformers	1 kWh & 5 comb. boards
B0 Transformers	18CTs	B - Transformers	1 kWh & 5 comb. boards
C0 Transformers	18CTs	C - Transformers	1 kWh & 5 comb. boards

**Logger #2** Synergistics C180 with 16 kWh & 16 digital channels.

<b>Switchboard E</b>			
Elevator P15 & P16	2CTs	Elevators	2 kWh & comb. board
Elevator P29 & P30	2CTs		
Elevator P17 & P18	2CTs		
Risers X38	9CTs	Risers	3 kWh & comb. board
Risers X46	9CTs		
Risers X54	9CTs		
Computer Chiller	3CTs	Computer	2 kWh
Computer	3CTs	Computer	3 kWh & comb. board
Computer	3CTs		
MCC-9-W38	3CTs	MCC	2 syn kWh
A0 Transformers	21CTs	A - Transformers	1 kWh & 5 comb. boards
B0 Transformers	21CTs	B - Transformers	1 kWh & 5 comb. boards
C0 Transformers	21CTs	C - Transformers	1 kWh & 5 comb. boards

**Table 4.4.2: Forrestral Data Logger #3 Configuration.** This table shows the proposed configuration of data logger #3 (Switchboard A) in the north building of the USDOE Forrestral Complex.

**Logger #3 Synergistics C180 with 16 kWh & 16 digital channels.**

<b>Switchboard A</b>			
Elevator P1 & P2	2CTs	Elevator	2 kWh & comb. board
Elevator P3 & P4	2CTs		
Riser F42	6CTs	Risers	3 kWh & 2 comb. boards
Riser D42	3CTs		
Riser D30	6CTs		
Riser D40	6CTs		
Riser F40	6CTs		
Ground Floor (West)	3CTs		
Ground Floor (East)	6CTs		
MCC-7-F36	2CTs	MCC	2 kWh & comb. board
MCC-G-1154	2CTs		
MCC-7-D46	2CTs		
Soff. Lighting	3CTs	Lighting	3 kWh
GA 301 RF Shield	3CTs	Security	1 Watt transducer, 1 dig
Emer. Operating Cntr.	3CTs	Emergency	1 Watt transducer, 1 dig
A0 Transformers	16CTs	A - Transformers	1 kWh & 4 comb. boards
B0 Transformers	16CTs	B - Transformers	1 kWh & 4 comb. boards
C0 Transformers	16CTs	C - Transformers	1 kWh & 4 comb. boards
Building kWh meter		Whole building kWh	1 dig
Bldg. Natural Gas Meter		Whole building N. G	1 dig
Building Water Meter		Whole building potable water	1 dig

**Table 4.4.3: Forrestal Data Logger #4 Configuration.** This table shows the proposed configuration of data logger # 4 (Switchboard B) in the north building of the USDOE Forrestal Complex.

**Logger #4** Synergistics C180 with 16 kWh & 16 digital channels.

<b>Switchboard B</b>			
Elevator P19, P20 & P21	2CTs	Elevator	2 kWh & comb. board
Elevator P22, P23, P24, & P28	2CTs		
Riser D15	6CTs	Risers	3 kWh & 2 comb. boards
Riser F15	3CTs		
Riser F30	6CTs		
Riser D19	3CTs		
Riser F19	6CTs		
Ground Floor (West)	6CTs		
Ground Floor (East)	3CTs		
MCC-7-D12	2CTs	MCC	2 kWh & comb. board
MCC-G-F7	2CTs		
MCC-7-F23 & MCC D23	2CTs		3 kWh
Soff. Lighting	3CTs	Lighting	
Telephone Room	3CTs	Telephone	2 kWh
A0 Transformers	16CTs	A - Transformers	1 kWh & 4 comb. boards
B0 Transformers	16CTs	B - Transformers	1 kWh & 4 comb. boards
C0 Transformers	16CTs	C - Transformers	1 kWh & 4 comb. boards

**Table 4.4.4: Forrestal Data Logger #5 Configuration.** This table shows the proposed configuration of data logger #5 (Switchboard C) in the USDOE Forrestal Complex.

**Logger #5** Synergistics C180 with 16 kWh, 16 digitals, & 16 analog inputs.

<b>Switchboard C</b>			
L11-6-R28,H28,L28	3CTs	Risers	3 kWh, 12 comb. board
L11-1-S18, S19, L11-S19	3CTs		
L11-6-616	3CTs		
L11-W14, L11-6-X18	3CTs		
L11-1-S11, S12	3CTs		
L11-6-W11, L11-1-68	3CTs		
MCC-G-W15	2CTs	MCC	2 kWh & comb. board
MCC-G-T8	2CTs		
750 KVA Transformer	9CTs	Kitchen	3 kWh
Daycare Feed	3CTs	Daycare Total	3 kWh
Daycare Lights	3CTs	Daycare Lights	1 dig
Daycare Heat Pump	12CTs	Daycare Heat Pump	1 dig

A0 Transformers	10CTs	A - Transformers	1 kWh & 3 comb. boards
B0 Transformers	10CTs	B - Transformers	1 kWh & 3 comb. boards
C0 Transformers	10CTs	C - Transformers	1 kWh & 3 comb. boards

CHW Btu		Whole-building CW	1 dig
CHW flow		Whole-building CW	1 dig
Steam Btu		Steam Btu	1 dig
Condensate flow		Condensate Flow	1 dig
Condensate Btu		Condensate Btu	1 dig

*Table 4.4.4: Forrestal Data Logger #5 Configuration(cont).*

Weather Station Channels		
Wind	Wind	1 analog
Horizontal Solar Radiation	Horiz.Solar	1 analog
Tilted solar radiation	Tilted Solar	1 analog
Ambient relative humidity	Amb.R.H.	1 analog
Ambient temperature	Amb.Temp.	1 analog

Solar Evaluation Channels		
Solar input to H/X Btu	Solar Btu	1 dig
Solar H/X out Btu	Solar Btu	1 dig
DHW H/X total Btu	DHW Btu	1 dig
PV output kWh	3 CT PV kWh	1 Watt transducer, 1 dig
4 Heat Pump R/A temp.	Heat Pump Temp.	4 analog
4 Heat Pump R/A humidity	Heat Pump R.H.	4 analog
Potable Water temp.	Potable Water	1 analog

**Table 4.4.5: Forrestral operator keystrokes for retrieving data.** This table contains the typical operator keystrokes that are required for polling and retrieving the data from the Forrestral data loggers using the Synernet communications package.

THE PROCESS OF TRANSMISSION OF DATA IS ACCOMPLISHED IN ONE PHASE. THE FOLLOWING INSTRUCTIONS ARE TYPICAL OF THE KEYSTOKES THAT ARE NECESSARY FOR POLLING ANY OF THE LOANSTAR SITES WITH THE MANUFACTURER'S SOFTWARE. THIS PROCEDURE ASSUMES THE AT USER IS IN THE MANUAL MODE OF POLLING. THIS MODE OF POLLING IS USED SO THAT EXACTLY ONE WEEK OF CAN BE RETRIEVED, 168 RECORDS FROM MIDNIGHT ON MONDAY TO MIDNIGHT ON THE NEXT MONDAY.

1. CD\SYNER (this is in the case that the software is kept in the \SYNER directory)
2. PARSET (this initiates the polling software which is part of several programs. This software is menu driven, hence the following commands are in response to the menu selection. Prior to this the user would have had to setup the site with the QUEUE command).
3. LOGGER(S) (this is the first menu selection that is chosen which leads to another menu).
4. PICK FROM EXISTING LOGGERS.
5. 905/A/.../A                   ...this is the site number, etc.
6. CONNECT                       ...this is echoed back by PARSET
7. PHONE DIALER                 ...this is the next selection on the menu
  - DIAL PREFIX
  - PHONE NUMBER nnn,nnn,nnnn     ...enter the phone number
  - DIAL SUFFIX .
8. TERMINAL                     ...once the connection has been established the user goes to the Terminal menu selection
9. READ STATUS DATA         ...this is the first thing that must be done each week is to check the logger clock against the PC clock
10. <ESC>                       ...this breaks back into the terminal mode
  - ...This next step assumes that the user has written down the last TSR from the previous week's polling session. Otherwise, one needs to check the TSRs in the logger and make sure that the TSR being asked for is for midnight.
11. READ TSR                    ...this is the menu choice that activates the reading of the Time Series Records (TSR).
  - ENTER STARTING TSR INDEX:     NNN ...this is where the user needs to know the previous weeks ending TSR.
  - ENTER ENDING TSR INDEX:     NNN ... this number would be the previous weeks ending TSR + 168 records.
- (S)creen or (F)ile    F         ...this choice tells the polling PC to place the records in a file
- Output File Name:    9050201.RAW   ....this is typical of the kind of name for the raw data from site 905 taken on 2/1/92
- File Type:           (R)eal         ...this is a choice of variable type
- Header Titles:      (N)one         ....this avoids having the headers in the output file
- ESC                    ...this ends the Terminal Session
12. CONNECT           ....the user then needs to select connect to disconnect the logger.
- DISCONNECT AND HANG UP
- QUIT

The user now has 168 records on the PC disk in the file named 9050201.RAW that can be processed for graphing.

**Table 4.4.6: Forrestal data file in raw format.** This table illustrates the raw data format for data retrieved from one of the Forrestal data loggers that were installed for proof of concept monitoring.

1/7/92 0:0:0	192	"V"	"	0.027	0.001	-0.010	0.985	0.966	0.451	0.057	0.107	0.000	3.445	4.071
3.655 3144.000														
1/7/92 1:0:0	193	"V"	"	0.029	0.001	-0.010	0.987	0.977	0.449	0.062	0.109	0.000	3.466	4.105
3.689 3135.000														
1/7/92 2:0:0	194	"V"	"	0.028	0.000	-0.010	0.990	0.980	0.451	0.061	0.109	0.000	3.493	4.133
3.718 3129.000														
1/7/92 3:0:0	195	"V"	"	0.027	0.001	-0.010	1.015	0.995	0.477	0.045	0.105	0.000	3.527	4.149
3.733 3114.000														
1/7/92 4:0:0	196	"V"	"	0.027	0.001	-0.010	1.008	0.993	0.473	0.039	0.106	0.000	3.521	4.149
3.736 3120.000														
1/7/92 5:0:0	197	"V"	"	5.339	5.703	5.578	0.997	0.970	0.462	8.031	8.230	8.366	3.396	4.011
3.597 3567.000														
1/7/92 6:0:0	198	"V"	"	9.570	10.255	10.046	1.075	1.054	0.513	14.033	14.556	14.891	3.806	4.447
4.031 4068.0														
1/7/92 7:0:0	199	"V"	"	9.565	10.213	10.072	1.449	1.346	0.835	14.054	14.493	14.891	5.410	6.028
5.578 4374.00														
1/7/92 8:0:0	200	"V"	"	9.533	10.208	10.056	2.319	2.402	1.551	13.918	14.378	14.797	8.633	9.544
9.031 4932.00														
1/7/92 9:0:0	201	"V"	"	9.544	10.234	10.077	3.029	3.014	2.106	14.012	14.504	14.922	11.490	12.474
11.877 5496.														
1/7/92 10:0:0	202	"V"	"	9.533	10.213	10.067	2.828	2.854	1.944	13.949	14.410	14.839	10.925	11.909
11.323 5703.														
1/7/92 11:0:0	203	"V"	"	9.512	10.182	10.051	2.977	2.967	2.067	13.876	14.336	14.776	11.888	12.840
12.243 5745.														
1/7/92 12:0:0	204	"V"	"	9.491	10.177	10.030	2.358	2.457	1.527	13.865	14.326	14.755	9.292	10.266
9.758 5715.														
1/7/92 13:0:0	205	"V"	"	9.486	10.161	10.004	2.009	2.434	1.207	13.865	14.336	14.744	7.895	9.073
8.675 5730.														
1/7/92 14:0:0	206	"V"	"	9.481	10.166	9.999	2.089	2.549	1.286	13.865	14.347	14.755	8.000	9.204
8.822 5706.														
1/7/92 15:0:0	207	"V"	"	9.502	10.161	10.004	1.874	2.263	1.107	13.939	14.399	14.797	7.289	8.398
8.000 5664.														
1/7/92 16:0:0	208	"V"	"	9.512	10.177	10.015	1.923	2.319	1.134	13.960	14.420	14.818	7.660	8.780
8.393 5604.														
1/7/92 17:0:0	209	"V"	"	9.538	10.192	10.009	1.957	2.411	1.157	13.970	14.451	14.807	7.901	9.083
8.691 5370.														
1/7/92 18:0:0	210	"V"	"	9.570	10.213	10.015	1.961	2.413	1.161	14.043	14.525	14.849	7.916	9.094
8.691 4551.														
1/7/92 19:0:0	211	"V"	"	9.596	10.266	10.077	1.737	1.767	1.042	14.242	14.713	15.090	6.969	7.749
7.299 3639.														
1/7/92 20:0:0	212	"V"	"	9.633	10.271	10.088	1.555	1.595	0.884	14.284	14.734	15.079	6.012	6.786
6.357 2934.														
1/7/92 21:0:0	213	"V"	"	2.154	2.279	2.224	1.184	1.184	0.593	3.205	3.333	3.322	4.356	5.036
4.610 2598.000														
1/7/92 22:0:0	214	"V"	"	0.027	0.002	-0.009	1.080	1.058	0.513	0.085	0.112	0.000	3.812	4.474
4.045 2439.000														
1/7/92 23:0:0	215	"V"	"	0.027	0.002	-0.009	1.007	0.974	0.454	0.085	0.113	0.000	3.555	4.194
3.770 2409.000														
1/8/92 0:0:0	216	"V"	"	0.027	0.002	-0.010	1.034	1.002	0.479	0.085	0.113	0.000	3.597	4.235
3.806 2415.000														
1/8/92 1:0:0	217	"V"	"	0.027	0.002	-0.010	1.060	1.031	0.495	0.086	0.115	0.000	3.762	4.413
3.979 2406.000														
1/8/92 2:0:0	218	"V"	"	0.026	0.002	-0.010	1.001	0.961	0.441	0.082	0.111	0.000	3.524	4.162
3.731 2394.000														

NOTE: Selected data values have been trimmed to facilitate an improved presentation in this table.

**Table 4.4.7 : ARCHIVE channel table for the Forrestal site.** The ARCHIVE channel table for the Forrestal site is shown in this table. All data used in the LoanSTAR program are processed with the ARCHIVE program to assure a uniform data base structure. ARCHIVE performs useful data and time transformations and can perform high-low limit checks each time a site is polled.

Date	Time	Raw-Data	Arch	Name of Archive	Arch	Conv'n	Conv'n	Error	Error	Channel	
MM/DD/YY	HH:mm	lin	coln	coln	Format	Code	Constants	Code	Constants	Description	
(YY DDD)	pos	pos	pos	Units							
#											
03/12/90	00:00	1	0	0	Begin	DOE/Vault A				Beginning date	
03/12/90	00:00	1	1	1	Site	-	I3	2	0 905	0	Site #
03/12/90	00:00	1	1	2	Mon-Raw	MM	I3	1		0	Month
03/12/90	00:00	1	2	3	Mon-Raw	DD	I3	1		0	Day
03/12/90	00:00	1	3	4	Mon-Raw	YY	I3	1		0	Year
03/12/90	00:00	1	3	5	Greg-Jul	MMDDYY	I5	24	1 2	0	Gregorian Date to Julian
03/12/90	00:00	1	4	7	Time	HH mm	I5	16	5	0	Time
03/12/90	00:00	1	3	6	Greg-Dec	DDD.frac	F10.4	28		0	Gregorian Date to Jul.Decimal
03/12/90	00:00	1	6	8	MCC7 A	F9.3	F9.3	1		1 -1 3000	MCC-7-F36 Phase A (kWh/h)
03/12/90	00:00	1	7	9	MCC7 B	F9.3	F9.3	1		1 -1 3000	MCC-7-F36 Phase B (kWh/h)
03/12/90	00:00	1	8	10	MCC7 C	F9.3	F9.3	1		1 -1 3000	MCC-7-F36 Phase C (kWh/h)
03/12/90	00:00	1	9	11	Elev A	F9.3	F9.3	1		1 -1 3000	Elevators Phase A (kWh/h)
03/12/90	00:00	1	10	12	Elev B	F9.3	F9.3	1		1 -1 3000	Elevators Phase B (kWh/h)
03/12/90	00:00	1	11	13	Elev C	F9.3	F9.3	1		1 -1 3000	Elevators Phase C (kWh/h)
03/12/90	00:00	1	12	14	MCC7 Av	F9.3	F9.3	1		1 -1 3000	MCC-7-F36 Phase A (kVA/h)
03/12/90	00:00	1	13	15	MCC7 Bv	F9.3	F9.3	1		1 -1 3000	MCC-7-F36 Phase B (kVA/h)
03/12/90	00:00	1	14	16	MCC7 Cv	F9.3	F9.3	1		1 -1 3000	MCC-7-F36 Phase C (kVA/h)
03/12/90	00:00	1	15	17	Elev Av	F9.3	F9.3	1		1 -1 3000	Elevators Phase A (kVA/h)
03/12/90	00:00	1	16	18	Elev Bv	F9.3	F9.3	1		1 -1 3000	Elevators Phase B (kVA/h)
03/12/90	00:00	1	17	19	Elev Cv	F9.3	F9.3	1		1 -1 3000	Elevators Phase C (kVA/h)
03/12/90	00:00	1	18	20	WBldg	F9.3	F9.3	1		1 -1 3000	Total Bldg (kWh/h)
03/11/99	23:00	1	0	0	End	DOE/Vault A					

**Table 4.4.8: Forrestral data file in the LoanSTAR format.** Forrestral data that has been processed by the ARCHIVE program is shown in this table. The first column is the site number, and the six columns that immediately follow are calender and time values in different formats. Energy use data for this site begins in the eighth column. The "-99.00" is inserted by ARCHIVE to identify data that fell outside the preset high-low limits.

905	1	7	92	92007	4389.0	0	0.027	0.0	-0.0	0.9	0.966	0.451	0.057	0.107	0.000	3.445	4.071
3.655	-99.																
905	1	7	92	92007	4389.0	100	0.029	0.0	-0.0	0.9	0.977	0.449	0.062	0.109	0.000	3.466	4.105
3.689	-99.																
905	1	7	92	92007	4389.0	200	0.028	0.0	-0.0	0.9	0.980	0.451	0.061	0.109	0.000	3.493	4.133
3.718	-99.																
905	1	7	92	92007	4389.1	300	0.027	0.0	-0.0	1.0	0.995	0.477	0.045	0.105	0.000	3.527	4.149
3.733	-99.																
905	1	7	92	92007	4389.1	400	0.027	0.0	-0.0	1.0	0.993	0.473	0.039	0.106	0.000	3.521	4.149
3.736	-99.																
905	1	7	92	92007	4389.2	500	5.339	5.7	5.5	0.9	0.970	0.462	8.031	8.230	8.366	3.396	4.011
3.597	-99.																
905	1	7	92	92007	4389.2	600	9.570	10.2	10.0	1.0	1.054	0.513	14.033	14.556	14.891	3.806	4.447
4.031	-99.																
905	1	7	92	92007	4389.2	700	9.565	10.2	10.0	1.4	1.346	0.835	14.054	14.493	14.891	5.410	6.028
5.578	-99.																
905	1	7	92	92007	4389.3	800	9.533	10.2	10.0	2.3	2.402	1.551	13.918	14.378	14.797	8.633	9.544
9.031	-99.																
905	1	7	92	92007	4389.3	900	9.544	10.2	10.0	3.0	3.014	2.106	14.012	14.504	14.922	11.490	12.474
11.877	-99.																
905	1	7	92	92007	4389.4	1000	9.533	10.2	10.0	2.2	2.854	1.944	13.949	14.410	14.839	10.925	11.909
11.323	-99.																
905	1	7	92	92007	4389.4	1100	9.512	10.1	10.0	2.9	2.967	2.067	13.876	14.336	14.776	11.888	12.840
12.243	-99.																
905	1	7	92	92007	4389.5	1200	9.491	10.1	10.0	2.3	2.457	1.527	13.865	14.326	14.755	9.292	10.266
9.758	-99.																
905	1	7	92	92007	4389.5	1300	9.486	10.1	10.0	2.0	2.434	1.207	13.865	14.336	14.744	7.895	9.073
8.675	-99.																
905	1	7	92	92007	4389.5	1400	9.481	10.1	9.9	2.0	2.549	1.286	13.865	14.347	14.755	8.000	9.204
8.822	-99.																
905	1	7	92	92007	4389.6	1500	9.502	10.1	10.0	1.8	2.263	1.107	13.939	14.399	14.797	7.289	8.398
8.000	-99.																
905	1	7	92	92007	4389.6	1600	9.512	10.1	10.0	1.9	2.319	1.134	13.960	14.420	14.818	7.660	8.780
8.393	-99.																
905	1	7	92	92007	4389.7	1700	9.538	10.1	10.0	1.9	2.411	1.157	13.970	14.451	14.807	7.901	9.083
8.691	-99.																
905	1	7	92	92007	4389.7	1800	9.570	10.2	10.0	1.9	2.413	1.161	14.043	14.525	14.849	7.916	9.094
8.691	-99.																
905	1	7	92	92007	4389.7	1900	9.596	10.2	10.0	1.7	1.767	1.042	14.242	14.713	15.090	6.969	7.749
7.299	-99.																
905	1	7	92	92007	4389.8	2000	9.633	10.2	10.0	1.5	1.595	0.884	14.284	14.734	15.079	6.012	6.786
6.357	2934.																
905	1	7	92	92007	4389.8	2100	2.154	2.2	2.2	1.1	1.184	0.593	3.205	3.333	3.322	4.356	5.036
4.610	2598.																
905	1	7	92	92007	4389.9	2200	0.027	0.0	-0.0	1.0	1.058	0.513	0.085	0.112	0.000	3.812	4.474
4.045	2439.																
905	1	7	92	92007	4389.9	2300	0.027	0.0	-0.0	1.0	0.974	0.454	0.085	0.113	0.000	3.555	4.194
3.770	2409.																
905	1	8	92	92008	4390.0	0	0.027	0.0	-0.0	1.0	1.002	0.479	0.085	0.113	0.000	3.597	4.235
3.806	2415.																
905	1	8	92	92008	4390.0	100	0.027	0.0	-0.0	1.0	1.031	0.495	0.086	0.115	0.000	3.762	4.413
3.979	2406.																
905	1	8	92	92008	4390.0	200	0.026	0.0	-0.0	1.0	0.961	0.441	0.082	0.111	0.000	3.524	4.162
3.731	2394.																

NOTE: Selected data values have been trimmed to facilitate an improved presentation in this table.

**Table 4.4.9:** .LOG file produced by the ARCHIVE program for the Forrestral data. This .LOG file is produced each time ARCHIVE processes data for a site. It includes some basic statistics about which file has been read, which channel table was used, and the names of the .LOG and output files. It also includes information about how many lines were processed (not shown), how many processing errors and missing data occurred and where those errors occurred in the input file.

Log of Archive, version: 1.41 of 15 June 1987, processed on 15 Jan 1992

Files:

RAW DATA 90592014.dat  
CHANNEL TABLE 4\_4\_8.tbl  
ARCHIVE 90592014.ach  
LOG 90592014.log

Archive delimiter is " " .

Missing or bad data values are replaced by the value -99.000 .

Line errors: are identified by their line number in the raw data file.

Data errors: are identified by the channels name, line and position

within the case: "name "(line in case/position in line).

Line numbers in raw data file are shown as |number| or as \*number\*

|numbers| indicates a line of data, \*numbers\* is a comment line.

First case on raw data: 91 198 07:40

-----  
BeginDate: 90 071 00:00

First output case: 91 198 07:40

-----  
Line Error: less channels than 18, as expected from channeltable:

|1| 7 17 91 7 40 0 1 0.572 0.000 0.002 0.001

-----  
EndDate: 99 070 23:00

Last output case: 91 201 09:15

#### STATISTICS:

884 lines read from beginning of raw data file.

884 lines processed between Begin and End dates.

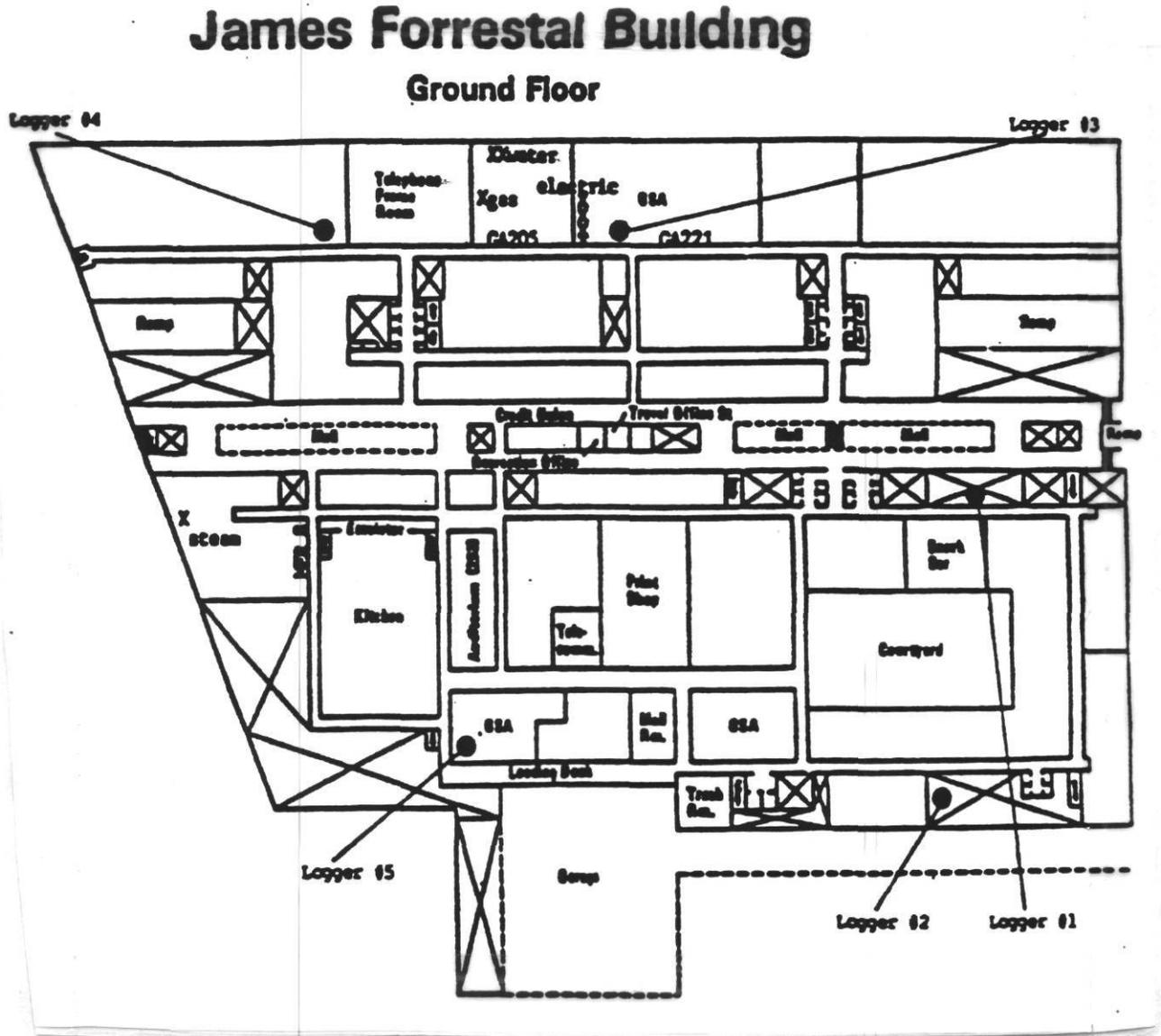
(including 0 comments and 0 all-blank lines)

884 line errors detected.

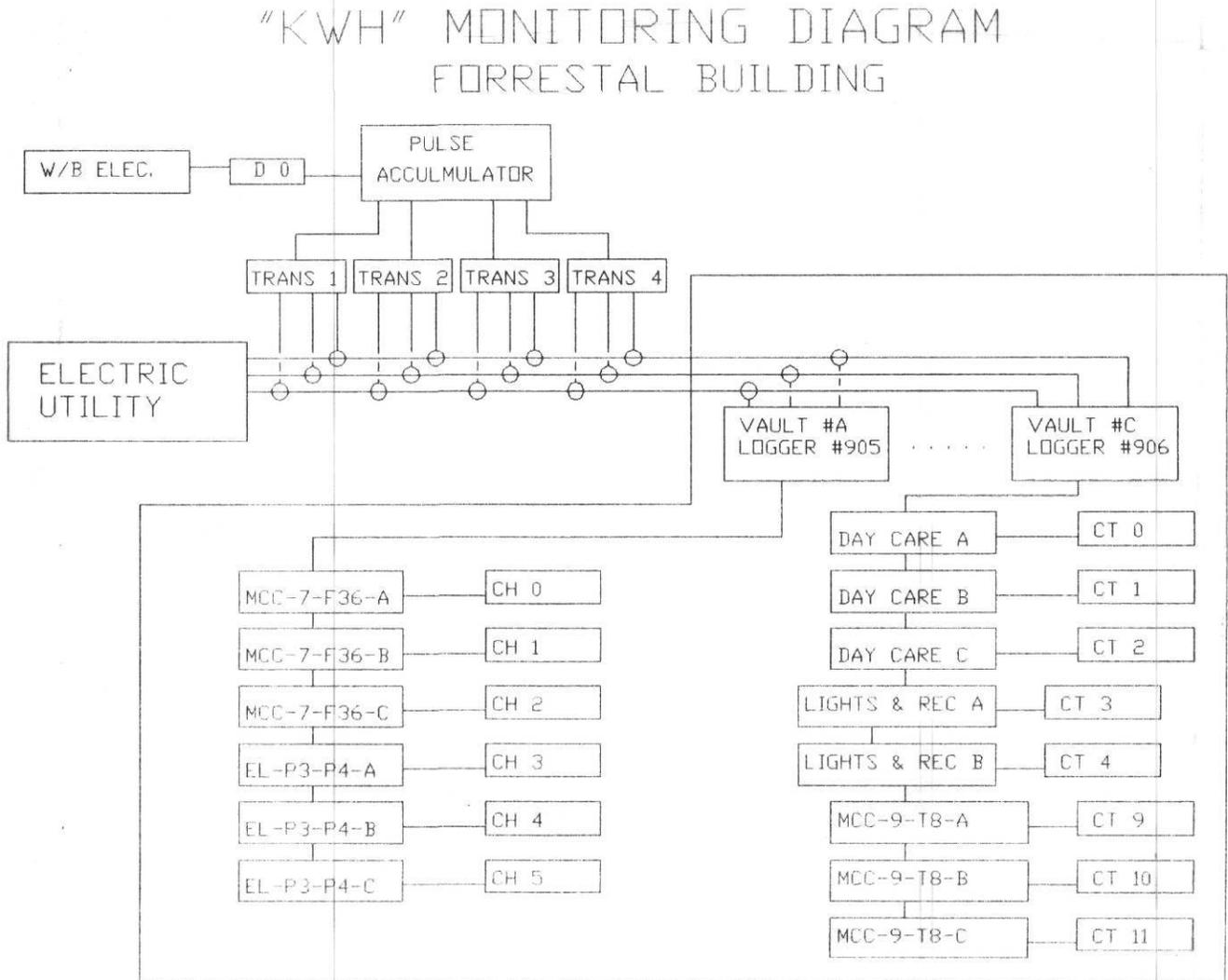
0 data errors, and 6188 missing data detected, itemized below:

Arc pos	Channel name	Error count	Missing count
14	MCC7 Av	0	884
15	MCC7 Bv	0	884
16	MCC7 Cv	0	884
17	Elev Av	0	884
18	Elev Bv	0	884
19	Elev Cv	0	884
20	WBldg	0	884

Figure 4.4.1: Floor plan of the USDOE Forrestal Building. This figure shows the floor plan for the USDOE Forrestal building and includes the location of the data loggers.

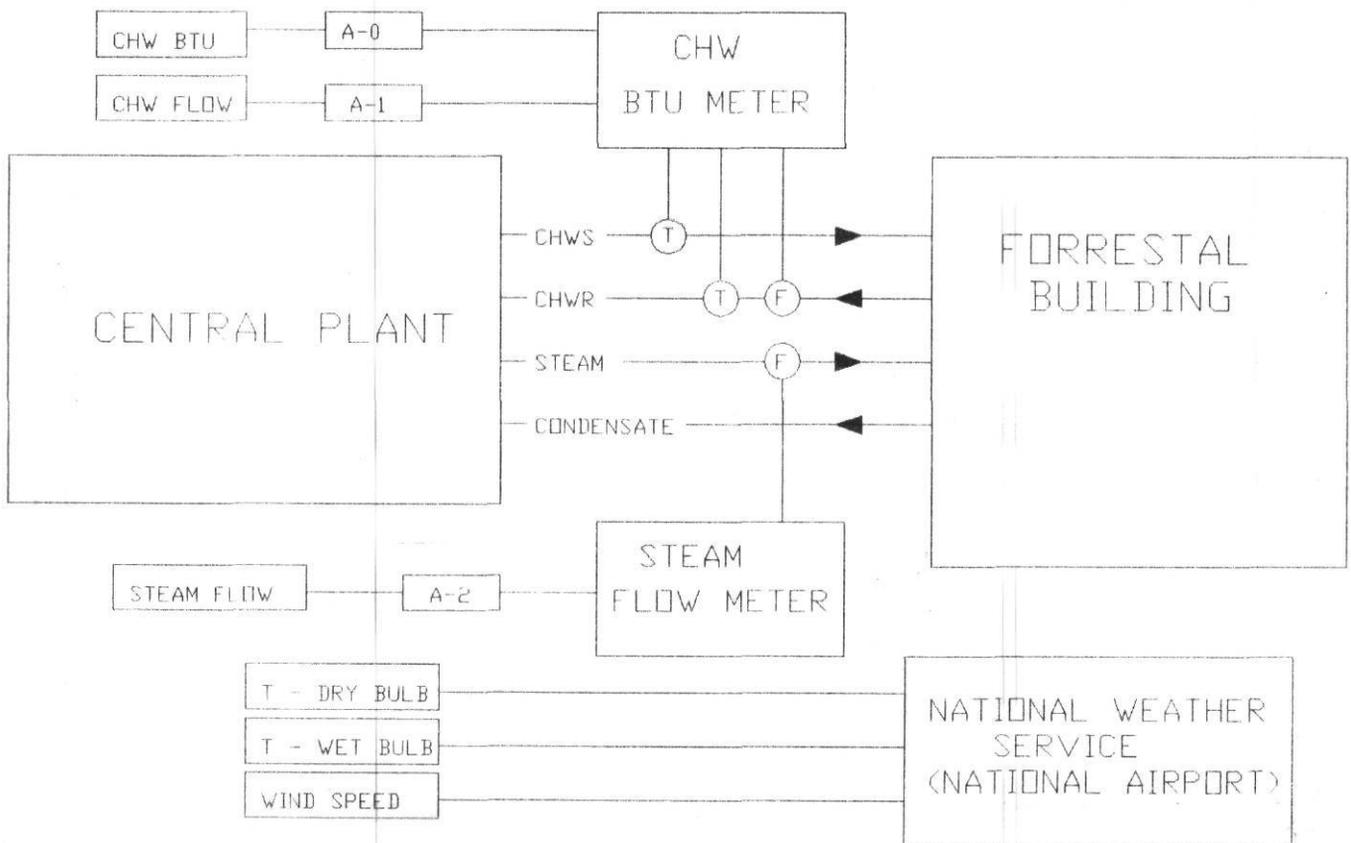


**Figure 4.4.2: kWh Monitoring Diagram for the Forrestal Building.** This figure is a diagram of the electricity monitoring system that has been installed in the Forrestal building that monitors whole-building electricity, and selected submetered channels, including motor control centers, elevators, lights and receptacles, and the whole-building feed from the daycare center.



**Figure 4.4.3: Thermal Monitoring Diagram for the Forrestal Building.** This figure is a diagram of the thermal monitoring at the Forrestal building which includes whole-building chilled water, and whole-building steam use. Weather data (i.e., dry-bulb temperature, wet-bulb temperature, and wind speed) are being imported from the National Weather Service.

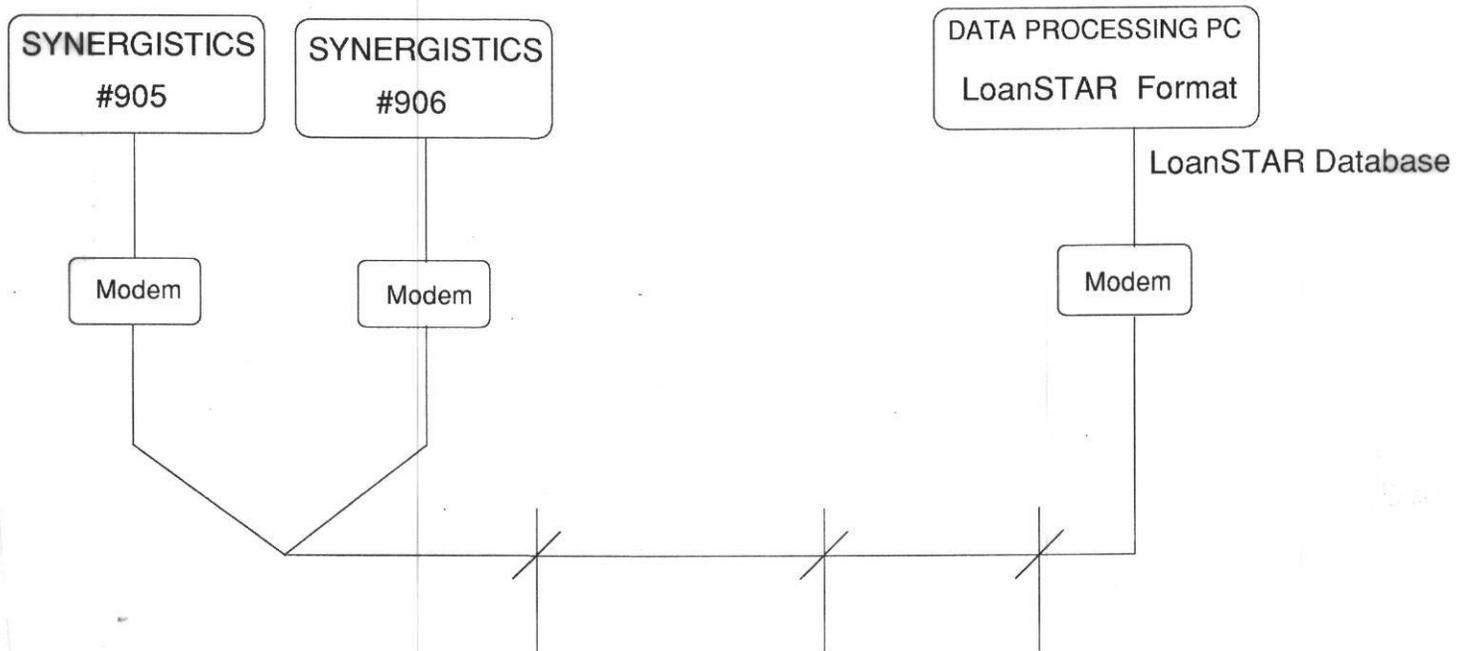
## "THERMAL" MONITORING DIAGRAM FORRESTAL BUILDING



**Figure 4.4.4:** Hardware configuration for the Forrestal site. This figure shows the hardware configuration for the Forrestal site. Data are collected via modem over long distance campus phone lines.

## HARDWARE CONFIGURATION

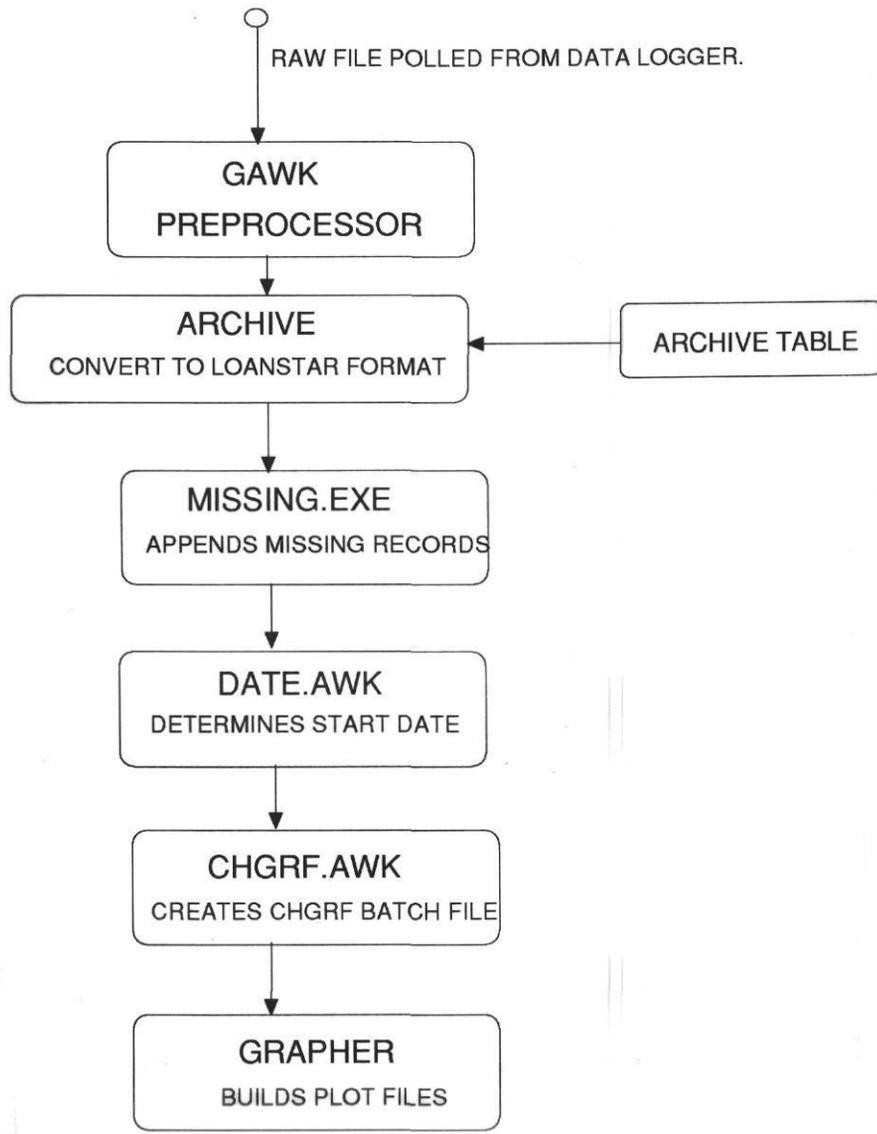
---



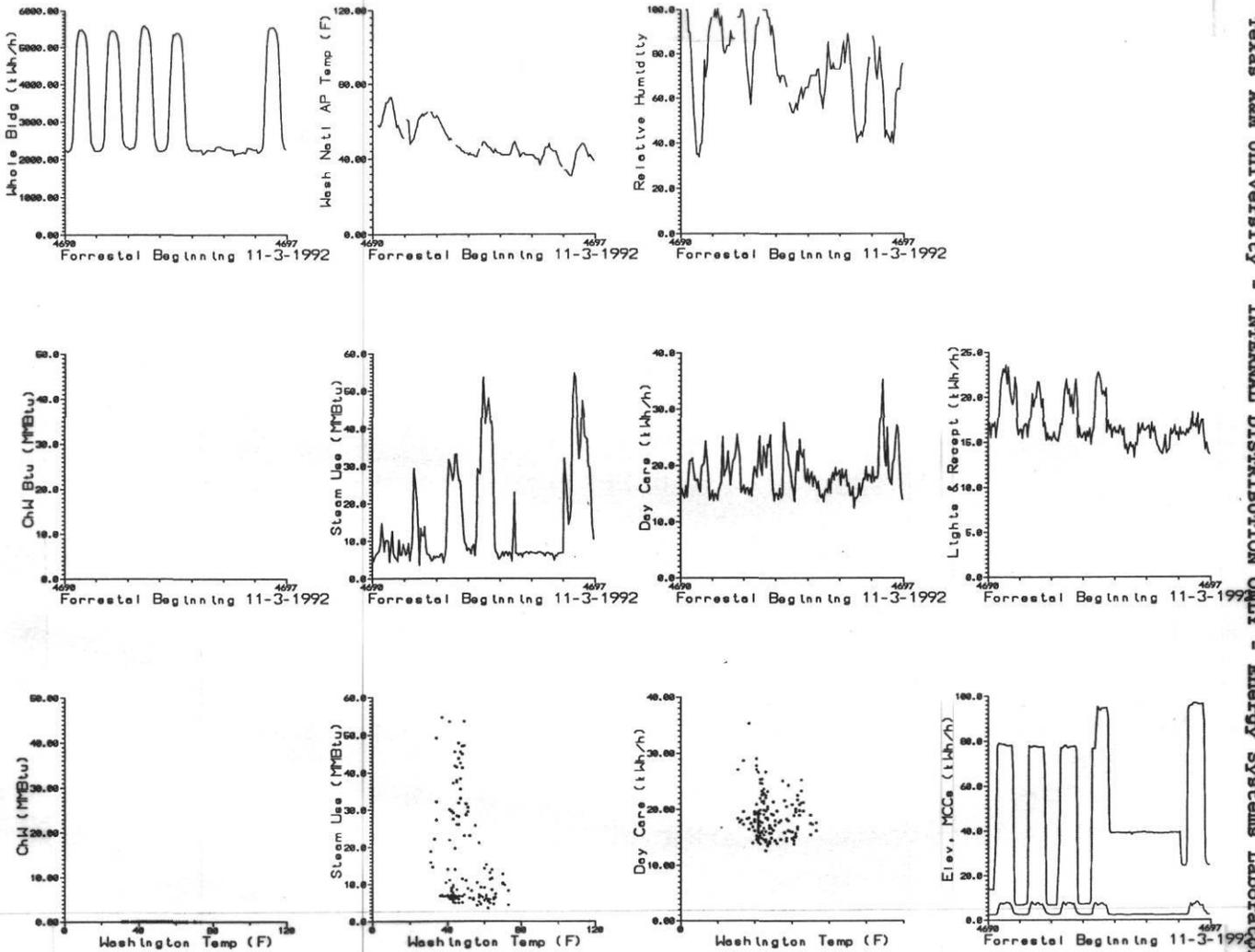
**Figure 4.4.5: Data processing stream for the Forrestal site.** This figure shows the data processing streams that are required to convert the Synergistics data into LoanSTAR format once the data have been received.

### DATA PROCESSING STREAM

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**Figure 4.4.6: LoanSTAR-type inspection plots for the Forrestal site.** This figure shows the LoanSTAR inspection plots for the channels from the Forrestal building.



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#### 4.5 The USDOE Germantown Facilities

The USDOE Germantown complex is located on a large 100 acre complex in Germantown, Maryland. The main building and support buildings were completed in 1958 for the United States Atomic Energy Commission. The entire complex is composed of a main building, an auditorium, a boiler house, an equipment storage building, a maintenance building sewer ejector and water pumping stations, a radio building and a large water tower. Figure 4.5.1 shows the layout of the main building and the locations of the proposed data loggers.

The entire ground floor of the main building was originally designed to serve as a blast shelter for the complex during a time of a national emergency. Hence, special ventilation systems for heating, and cooling systems, independent electrical systems, material supply, blast doors and solid concrete construction were added features for this portion of the building. The computer center, wings "F, G, H, and J" of the main building and the maintenance building were added to the complex in 1973.

The main building is composed of numerous inter-connecting narrow wings of five stories each. The primary construction is masonry and concrete with a brick veneer, single pane glazing and minimal insulation, typical of 1950s construction. The main and adjunct buildings comprise 596,000 square feet of which 390,000 square feet are office space for administrative personnel and support staff.

The Germantown complex uses about 104,300 MBtu per year or about 267,300 Btu/sqft (using net square footage). Utility costs for 1986 to 1987 totaled \$1,168,000 or about \$2.99/sqft. Electricity represented \$871,013 and heating oil for the boilers amounted to \$297,016.

The main building at the Germantown complex uses 125 psig steam for heating and chiller water for cooling. The boiler house has two 14,000 lb/hr and one 8,000 lb/hr Babcock and Wilcox water tube, forced draft boilers that can burn #6 or #2 oil supplied by two 30,000 gallon underground storage tanks. Chilled water is provided by two 750-ton chillers and one 350-ton chiller. Three 75-ton chillers (originally installed for the shelter and configured to operate using pond water) could also be used with certain modifications. Condensing water is provided by one 4.2 MBtu and one 18 MBtu condensing tower.

The primary heating/cooling systems are perimeter induction units. Ventilation is supplied by air-handling units located throughout the complex. Domestic water heating is provided by steam converters for restroom and kitchen end-use requirements. Normal business hours for the Germantown complex are from 8:30 a.m. to 5:00 p.m., Monday through Friday. Additional information including an analysis of the energy consumption can be found in the report by Haberl (1988).

At the present time the USDOE Germantown complex does not have a functional EMCS. Water, electricity, steam and oil are monitored daily at the complex boundaries for internal

tracking purposes. In order for the Germantown staff to effectively analyze savings from energy retrofits, a multi-logger data acquisition system was recommended based on systems that are installed in the Texas LoanSTAR program.

Three separate proposals were presented that investigated the installation of a data acquisition system for monitoring the energy use at the Germantown complex, including: (1) a fully-configured monitoring system, (2) a system to monitor whole-complex loads and weather conditions only, and (3) a system to monitor only the daycare facility and weather conditions. In tables that follow the full proposal is spelled out.

The preliminary engineering of a fully configured monitoring system that would be capable of monitoring both whole building thermal and electric and sub-metering on the lighting loads and the daycare center was completed by Texas A&M with the help of the National Center for Appropriate Technology (Ncat) and submitted to the DOE in the March 1991 Preliminary Engineering Survey (Claridge et al. 1991). The purpose of such a system would be to allow the DOE to have a showcase monitoring system that would make near-real-time data accessible to the national labs and interested others for studying the HVAC and lighting systems in the Germantown complex.

Such a system would be capable of monitoring the following points:

1. Whole-complex electricity.
2. Whole-complex oil use.
3. Whole-complex potable water.
4. Whole-complex chilled water.
5. Whole-complex steam, condensate and boiler water.
6. Weather conditions (temperature, humidity, solar, wind).
7. Sub-metering of motor control centers.
8. Sub-metering of Emergency Power Generators and fuel use.
9. Selected sub-metering of computer centers.
10. Sub-metering of the daycare whole-complex electricity.
11. Sub-metering of the daycare photoelectric electricity.
12. Sub-metering of the daycare heat pump electricity.
13. Sub-metering of the daycare lighting loads.
14. Sub-metering of the daycare interior conditions.
15. Sub-metering of the daycare solar water heating.

Such a system could be installed in 6 months for \$221,680 and would include all necessary software/hardware for polling and archiving the data. The fully configured system would utilize at least seven loggers as shown in Figure 4.5.1. A minimum of seven loggers would be needed to avoid long communication line runs. Table 4.5.1 through 4.5.4 list the proposed channels for each of the loggers. Details concerning the alternative systems that were specified for the Germantown Complex can be found in the Preliminary Engineering Survey.

**Table 4.5.1: Germantown Data Logger #1 Configuration.** This table shows the proposed configuration of data logger #1 (Boiler Room) at the USDOE Germantown Complex.

**Logger # 1** 1 Synergistics C140 with 8 kWh, 8 digital, 8 analog channels.

<b>Boiler Room</b>			
Boiler Feedwater		Boiler Feedwater	1 dig
Boiler Makeup Water		Boiler Makeup Water	1 dig
Steam Temp.		Steam Temperature	1 analog
Steam Pressure		Steam Pressure	1 analog
Potable Water		Potable Water	3 dig
Boiler Fuel Oil		Boiler Fuel Oil	1 dig
Boiler Room Electricity	3 CTs	Boiler Room Electricity	3 kWh
Generator Fuel Oil*		Generator Fuel Oil	1 dig
Generator Electricity*	3 CTs	Generator Electricity	3 kWh

\*Also tied into this logger through 200' buried trench -- 35 kW Emergency Generator

**Table 4.5.2: Germantown Data Logger #2 & #3 Configuration.** This table shows the proposed configurations of data loggers #2 and #3 (Equipment & Daycare buildings) at the USDOE Germantown Complex.

**Logger #2** Synergistics Datamate 20 with 8 digital channels.

Equipment Building			
Pepco Electric Meter		Whole-building Electric	1 dig
Potable Water		Potable Water	2 dig

**Logger #3** Synergistics C180 with 16 digital, 15 kWh 16 analog channels.

Daycare Center:			
Total Electric	3 CTs	Whole-building Electric	3 kWh
Lighting	3 CTs	Lighting	3 kWh
Heat Pump Electric	12 CTs	Heat Pump Electric	3 kWh

Weather Station Channels			
Wind		Wind	1 analog
Horizontal Solar Radiation		Horizontal Solar	1 analog
Tilt Solar Radiation		Tilted Solar Radiation	1 analog
Ambient Relative Humidity		Ambient Relative Humidity	1 analog
Ambient Temperature		Ambient Temperature	1 analog

Solar Evaluation Channels			
Solar Input to Heater Btu		Solar panel Btu	1 dig
Heat Exchanger Output Btu		Solar H/X Btu	1 dig
Total DHW Output Btu		DHW Btu	1 dig
PV Output kWh	3 CTs	PV kWh	1 transducer, 1 dig
Heat Pump Air Temperature		Heat Pump Air Temperature	4 analog
Heat Pump Relative Humidity		Heat Pump Rel. Humidity	4 analog
Potable Water Temp. (CW & HW)		Potable Water Temp.	1 analog

**Table 4.5.3: Germantown Data Logger #4 Configuration.** This table shows the proposed configuration of data logger #4 (Load Centers 2 and 3) at the USDOE Germantown Complex.

**Logger # 4** 1 Synergistics C180 Logger with 16 kWh & 16 digital channels.

<b>Main Load Center</b>			
E27-5 Computer	3 CTs	Computer	3 kWh
E27-3 Cooling Towers	2 CTs	Cooling Towers	2 kWh
E27-9 Chiller #1	2 CTs	Chiller #1 Electric	2 kWh
E27-10 Chiller #2	2 CTs	Chiller # 2 Electric	2 kWh
E27-11 MCC	2 CTs	MCC	2 kWh
Main Pepco Elec.		Whole-building electric	2 dig
Chiller #1 CW gal.		Chiller #1 gal.	1 dig
Chiller # 2 CW gal.		Chiller #2 gal.	1 dig
Chiller # 1 Load Btu		Chiller #1 Btu	1 dig
Chiller # 2 Load Btu		Chiller # 2 Btu	1 dig
Generator electric	3 CTs	Generator Electric	1 transducer, 1 dig
Generator Fuel Oil		Generator Electric	1 dig

**Table 4.5.4: Germantown Data Logger #5, #6, & #7 Configuration.** This table shows the proposed configuration of data logger #5 (Load Center #4), data logger #6 (Load Center #1), and data logger #7 (Emergency Generator Room).

**Logger # 5:** Synergistics C140 with 8 digital, 8 kWh, 8 analog channels.

Load Center #4			
MCC 1	2 CTs	MCC 1	2 kWh
MCC2	2 CTs	MCC 2	2 kWh
Chiller	2 CTs	Chiller Electric	2 kWh
Chiller CW gal.		Chiller CW Gal.	1 dig
Chiller Load Btu		Chiller Btu	1 dig
100 kW Generator Electric		Generator Electric	1 Watt transducer, 1 dig
100 kW Generator Fuel Oil		Generator Fuel Oil	1 dig

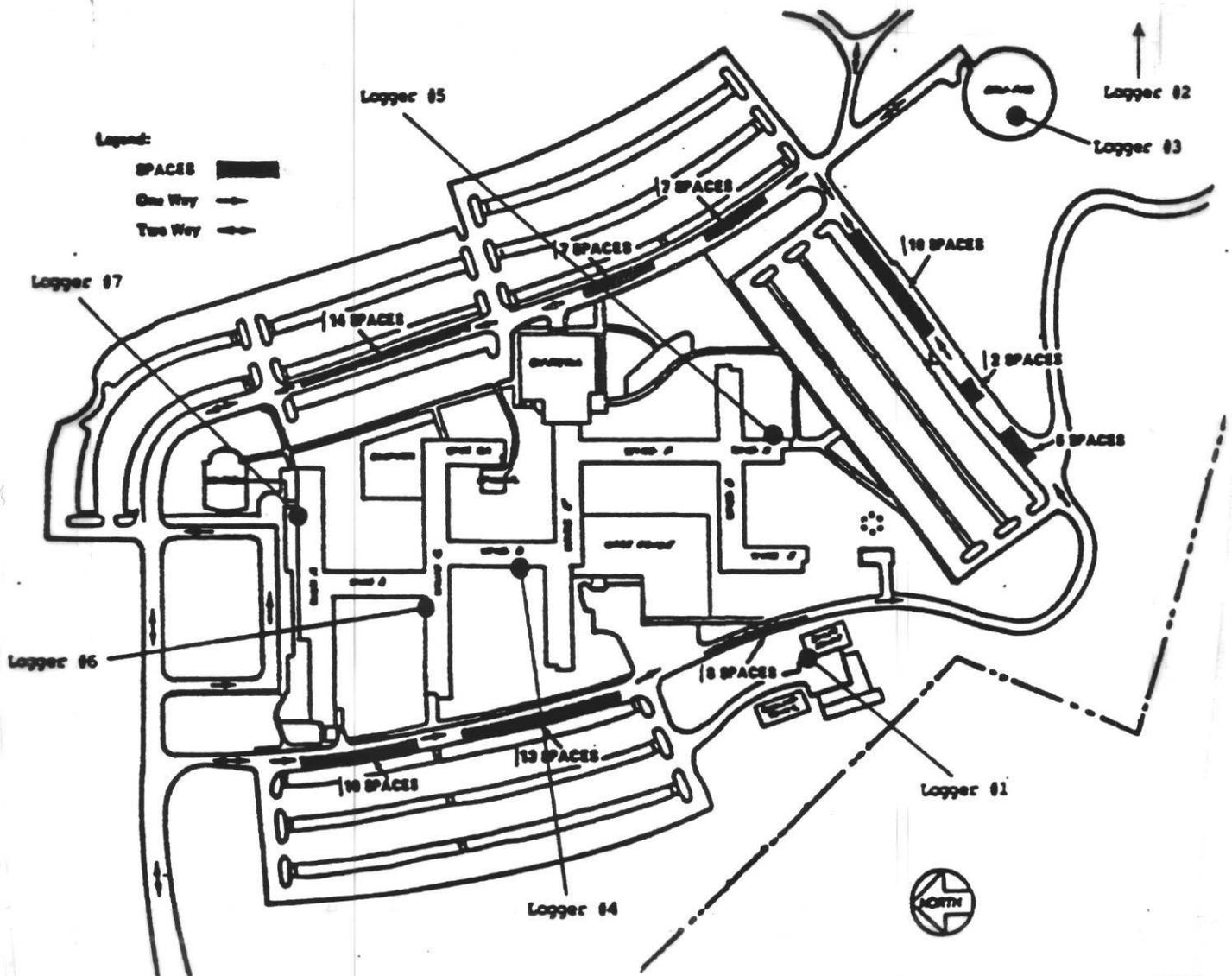
**Logger #6** Synergistics Datamate 10 - 4 digital.

Load Center #1			
MCC		MCC	1 dig

**Logger #7** Synergistics Datamate 10 - 4 digital.

200 kW Emer. Generator room			
Em. Generator Electric	3CTs	Generator Electric	1 Watt transducer, 1 dig.
Em. Generator. Fuel Oil		Generator Fuel Oil	1 dig

Figure 4.5.1: Plan view of the USDOE Germantown Facility. This figure show a plan view of the USDOE Germantown Facility; DOE's classified facility located in Germantown, Maryland.



## 4.6 The Texas State Capitol Complex.

At the request the Texas Governor's Energy Office, the Texas State Capitol Complex was studied to see if the installed EMCSs could be made to be compatible with the LoanSTAR trend logging and graphics that currently have been developed with dedicated DASs. During the Summer of 1992 the EMCSs in the Texas State Capitol Complex were studied in detail and the results reported by Heinemeier and Akbari (1992).

Most of the state buildings in Austin are a part of a five million square foot complex of 42 buildings. The complex is currently organized into five geographic zones as shown in Table 4.6.1 and in Figure 4.6.1. At the present time there are six major EMCSs in use at the complex: A Honeywell security and fire system, a Landis & Gyr Powers System 600, a Honeywell Excel Classic, an Andover system, a Johnson Controls 85/40, and Teletrol Integrator 286 systems in two buildings: the Sam Houston building and the (new) Capitol Extension building.

The Teletrol Integrator 286 is essentially a PC that is very capable of talking to virtually any other device. The Teletrol system can be programmed in C, and is supplied with a library of C functions such as schedules, and PID loops, etc. The Teletrol box contains a PC mother board, A/D boards and a modem. The controller communicates via a 250 kBaud LAN, phone lines, or RS232 connection to a local workstation. In order for the workstation to communicate to the Integrator it is best for it to run Teletrol's Management/Communications Package (MCP). Other packages can also be used to communicate to the Integrator including PCANYWHERE.

In the Teletrol system any point can be trended using the History facility. Data are stored in the controller's memory, and can be retrieved to the Workstation at any time. Data that are trended can be snap-shot, average, minimum or maximum data. COV data can also be trended. Up to 999 samples can be trended per point or 20,000 samples in total memory. The time interval and begin point must be specified in order to collect average data. One must be careful when restarting the system to resynchronize all trend logs (which might require come additional C code).

It was determined that the existing Teletrol system at the Capitol was not suitable for testing protocols so a loaner system was borrowed from Teletrol and tested at Texas A&M using a set up that is diagrammed in Figure 4.6.2. Basically, an Integrator was set up with several test channels and the data protocol tested and verified using the campus phone lines as shown to simulate a conversation with a remote field unit.

Table 4.6.2 contains the operator keystrokes for retrieving data from the Teletrol EMCS via the campus phone lines using the Teletrol Management and Communications Package (MCP) resident on the polling computer (other software packages such as PCANYWHERE can be used). Table 4.6.3 gives a look at the raw data from the Teletrol Integrator prior to processing into LoanSTAR format.

Raw data from the Teletrol Integrator was not immediately ready for processing by the ARCHIVE program which meant that a small awk script was necessary (NOTE: a copy of the awk script for the Teletrol is included in the appendix). Such a script removed any non-columnar ascii data to prepare the data for input into ARCHIVE. Figure 4.6.3 is a flow chart of the processing routines.

Once the data had been cleaned by the awk script they were ready for input into the ARCHIVE program. Table 4.6.4 is the ARCHIVE channel table that was used to process the raw data from Table 4.6.3 into the ARCHIVE formatted data in Table 4.6.5. The .LOG file from the sample processing session is listed in Table 4.6.6. Once processed the Teletrol data can then be plotted in inspection plot format as shown in Figure 4.6.4. Additional information about how to develop and use inspection plots can be found in the LoanSTAR Workbook (Haberl et al. 1992).

**Table 4.6.1: State of Texas Capitol Complex EMCSs.** This table contains information about the EMCSs at the Texas Capitol Complex that was collected during the Summer months of 1992 (Heinemeier and Akbari 1992).

CODE:	Name:	EMCS:	Zone:	LoanSTAR:
CPX	Capitol Extension	TELE	CAP	Yes
SHB	Sam Houston Building	TELE	CAP	Yes
BHB	Brown-Heatley Building	JC85	REM	
OCS	One Capitol Square/Wm. Clements	L&GP	SFA	
WBT	William B. Travis	EXCL	SFA	Yes
JER	James Earl Rudder Building	EXCL	REM	
SCB	Supreme Courts Building	ANDO	CAP	
PDB	Price Daniels Building	ANDO	CAP	
SFA	Stephen F. Austin	DELT	SFA	Yes
INX	Insurance Annex Building	DELT	REM	Yes
LBJ	Lyndon B. Johnson	DELT	SFA	Yes
JHR	John H. Reagan	DELT	CAP	Yes
CAP	State Capitol	DELT	CAP	Yes
INS	Insurance Building	DELT	CAP	Yes
ARC	Archives and Library	DELT	CAP	Yes
MAN	Governor's Mansion		REM	
CSB	Central Services Building	PNEU	SFA	
MUS	Museum	META	CAP	
SAN	San Antonio		SAN	
THO	Ernest O. Thompson	PNEU	REM	
WIN	Winters Comlex (3 buildings)	DELT	WIN	

**ZONE KEY:**

CAP = Capitol Zone  
 REM = Remote Zone  
 SFA = S.F. Austin Zone  
 SAN = San Antonio Zone  
 WIN = Winters Zone

**EMCS KEY:**

TELE = Teletrol Integrator 286  
 JC85 = Johnson Controls 85/40  
 L&GP = Landis & Gytr Powers System 600  
 EXCL = Honeywell Excel  
 ANDO = Andover  
 DELT = Honeywell Delta 1000  
 PNEU = Pneumatic controls (no EMCS)

**Table 4.6.2 : Operator keystrokes for retrieving data.** This table contains the typical operator keystrokes that are required for polling and retrieving the data from a Teletrol EMCS.

Note : Management and Communications Package (MCP) is a menu driven software that is used to communicate with the TELEtrol EMCS. It is assumed the trending for the desired channels have been programmed. Everything in italics is the menu option provided by the program.

1. At the DOS prompt from the TELEtrol directory type **MCP**.
2. Enter User name.
3. Enter Password.
4. Choose the appropriate zone. ex. WERC076.
5. Choose *Report*.
6. From *Report* choose *History Samples*.
7. Hit ESC twice.
8. Choose *Transfer*.
9. Choose *Everything*.
10. Choose *Upload* from the bottom right corner of the screen.
11. Specify the data file name to upload the trend information.
12. After successful transfer of data, Choose. *File*.
13. Choose *Exit to DOS*.

**Table 4.6.3: Teletrol EMCS data file in raw format.** This table shows the raw data format for the data that are received from the Teletrol EMCS prior to processing into the LoanSTAR format.

```

2 Point Data TestVoltag value 100 100 0060:00 10/09 18:00
5.2 10/09/92 18:00:00
5.2 10/09/92 19:00:00
5.2 10/09/92 20:00:00
5.2 10/09/92 21:00:00
5.2 10/09/92 22:00:00
5.2 10/09/92 23:00:00
5.1 10/10/92 0:00:00
5.1 10/10/92 1:00:00
5.2 10/10/92 2:00:00
5.2 10/10/92 3:00:00
5.1 10/10/92 4:00:00
5.2 10/10/92 5:00:00
5.2 10/10/92 6:00:00
5.2 10/10/92 7:00:00
5.2 10/10/92 8:00:00
5.2 10/10/92 9:00:00
5.1 10/10/92 10:00:00
5.2 10/10/92 11:00:00
5.1 10/10/92 12:00:00
5.2 10/10/92 13:00:00
5.2 10/10/92 14:00:00
5.2 10/10/92 15:00:00
5.2 10/10/92 16:00:00
5.2 10/10/92 17:00:00
5.2 10/10/92 18:00:00
5.1 10/10/92 19:00:00
5.2 10/10/92 20:00:00
5.2 10/10/92 21:00:00
5.2 10/10/92 22:00:00
5.2 10/10/92 23:00:00
5.2 10/11/92 0:00:00
5.2 10/11/92 1:00:00
5.2 10/11/92 2:00:00
5.2 10/11/92 3:00:00
5.1 10/11/92 4:00:00
5.2 10/11/92 5:00:00
5.2 10/11/92 6:00:00
5.2 10/11/92 7:00:00
5.2 10/11/92 8:00:00
5.1 10/11/92 9:00:00
5.2 10/11/92 10:00:00
5.1 10/11/92 11:00:00
5.2 10/11/92 12:00:00
5.1 10/11/92 13:00:00
5.2 10/11/92 14:00:00

```

(NOTE: the data stream was cut at this point to show the next line which occurs periodically)

```

5 Point Data RTD value 100 100 0060:00 10/09 18:00

```

**Table 4.6.4: ARCHIVE channel table for the Teletrol EMCS.** The ARCHIVE channel table for the Teletrol EMCS is shown in this table. All data used in the LoanSTAR program are processed with the ARCHIVE program to assure a uniform data base structure. ARCHIVE performs useful data and time transformations and can perform high-low limit checks each time a site is polled.

DATE	Time	Raw	Raw	Arch	Name of Archive	Arch	Conv'n	Calib. or Error	Limatation	Channel
MM/DD/YY	HH:mm	Line	coln	pos	Channel Units	Format	Code	Constants	Code	Constants Description
-----										
#4										
01/01/91	00:00	1	0	0	Begin					
01/01/91	00:00	1	1	1	site# -	I3	2	0	007	0 site#
01/01/91	00:00	1	1	2	Month MM	I3	1			0 Month
01/01/91	00:00	1	2	3	Day DD	I3	1			0 Day
01/01/91	00:00	1	3	4	Year YY	I3	1			0 Year
01/01/91	00:00	1	3	5	G-J -	I5	24	1	2	0 Gregorian - Julian
01/01/91	00:00	1	1	6	dec.t -	F10.4	28			0 decimal time
01/01/91	00:00	1	4	7	Time hhmm	I5	15			0 Time
01/01/91	00:00	1	5	8	TCH1 tch1	F9.3	1			0 Test Channel number 1
01/01/91	00:00	1	6	9	TCH2 tch2	F9.3	1			0 Test Channel number 2
01/01/91	00:00	1	7	10	TCH3 tch3	F9.3	1			0 Test Channel number 3
01/01/93	00:00	1	0	0	End					

**Table 4.6.5:** *Teletrol EMCS data file in the LoanSTAR format.* Teletrol EMCS data that has been processed by the ARCHIVE program is shown in this table. The first column is the site number, and the six columns that immediately follow are calendar and time values in different formats. Energy use data for this site begins in the eighth column.

7	10	9	92	92283	4665.7500	1800	5.200	54.100	53.400
7	10	9	92	92283	4665.7917	1900	5.200	54.100	53.500
7	10	9	92	92283	4665.8333	2000	5.200	54.100	53.500
7	10	9	92	92283	4665.8750	2100	5.200	54.200	53.100
7	10	9	92	92283	4665.9167	2200	5.200	54.200	53.300
7	10	9	92	92283	4665.9583	2300	5.200	54.100	53.400
7	10	10	92	92284	4666.0000	0	5.100	54.200	53.400
7	10	10	92	92284	4666.0417	100	5.100	54.200	53.400
7	10	10	92	92284	4666.0833	200	5.200	54.200	53.400
7	10	10	92	92284	4666.1250	300	5.200	54.200	53.200
7	10	10	92	92284	4666.1667	400	5.100	54.100	53.000
7	10	10	92	92284	4666.2083	500	5.200	54.200	53.200
7	10	10	92	92284	4666.2500	600	5.200	54.100	53.000
7	10	10	92	92284	4666.2917	700	5.200	54.100	53.200
7	10	10	92	92284	4666.3333	800	5.200	54.200	53.200
7	10	10	92	92284	4666.3750	900	5.200	54.100	52.700
7	10	10	92	92284	4666.4167	1000	5.100	54.100	52.900
7	10	10	92	92284	4666.4583	1100	5.200	54.200	53.300
7	10	10	92	92284	4666.5000	1200	5.100	54.200	53.200
7	10	10	92	92284	4666.5417	1300	5.200	54.100	53.000
7	10	10	92	92284	4666.5833	1400	5.200	54.100	53.100
7	10	10	92	92284	4666.6250	1500	5.200	54.100	53.300
7	10	10	92	92284	4666.6667	1600	5.200	54.100	53.200
7	10	10	92	92284	4666.7083	1700	5.200	54.100	53.300
7	10	10	92	92284	4666.7500	1800	5.200	54.100	53.400
7	10	10	92	92284	4666.7917	1900	5.100	54.100	53.300
7	10	10	92	92284	4666.8333	2000	5.200	54.100	52.700

**Table 4.6.6:** .LOG file produced by the ARCHIVE program for the Teletrol data. A .LOG file is produced each time ARCHIVE processes data for a site. It includes some basic statistics about which file has been read, the channel table used, and the names of the LOG and output files. It also includes information about how many lines were processed, how many processing errors and missing data occurred and where those errors occurred in the input file.

Log of Archive, version: 1.41 of 15 June 1987, processed on 2 Mar 1993

Files:

RAW DATA telt  
CHANNEL TABLE teletrol.tbl  
ARCHIVE telt.ach  
LOG telt.log

Archive delimiter is " ".

Missing or bad data values are replaced by the value -99.000 .

Line errors: are identified by their line number in the raw data file.

Data errors: are identified by the channels name, line and position within the case: "name "(line in case/position in line).

Line numbers in raw data file are shown as |number| or as \*number\*  
|numbers| indicates a line of data, \*numbers\* is a comment line.

First case on raw data: 92 283 18:00

-----  
BeginDate: 91 001 00:00

First output case: 92 283 18:00  
-----

-----  
EndDate: 93 001 00:00

Last output case: 92 287 21:00  
-----

#### STATISTICS:

100 lines read from beginning of raw data file.

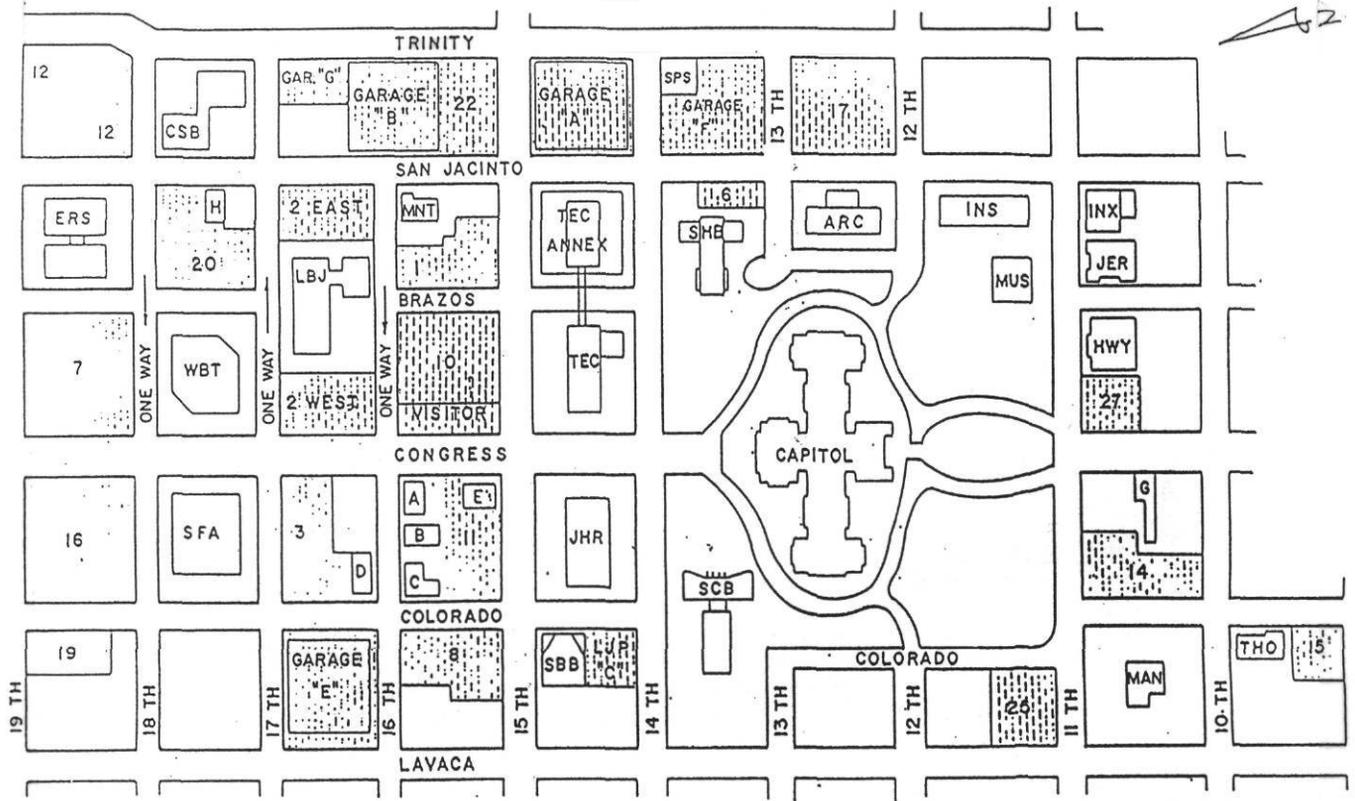
100 lines processed between Begin and End dates.

(including 0 comments and 0 all-blank lines)

0 line errors detected.

0 data errors, and 0 missing data detected

**Figure 4.6.1: The State of Texas Capitol Complex.** The Texas State Capitol complex is shown in this figure. Several of the buildings in the complex will be using the Teletrol system.



- ARC - ARCHIVES AND LIBRARY (LORENZO DE ZAVALA)
- CAP - STATE CAPITOL
- CSB - CENTRAL SERVICES BUILDING
- ERS - EMPLOYEES RETIREMENT SYSTEM
- HWY - HIGHWAY BUILDING
- INS - INSURANCE BUILDING
- INX - INSURANCE ANNEX BUILDING
- JHR - JOHN H. REAGAN
- LBJ - LYNDON B. JOHNSON
- LJP - LEON JAWORSKI PLAZA
- MAN - GOVERNOR'S MANSION
- MNT - MAINTENANCE SHOP BUILDING
- - PARKING LOTS

- MUS - MUSEUM
- SBB - STATE BAR BUILDING
- SCB - SUPREME COURTS BUILDING
- SFA - STEPHEN F. AUSTIN
- SHB - SAM HOUSTON BUILDING
- SPS - SENATE PRINT SHOP
- JER - JAMES E. RUDDER
- TEC - TEXAS EMPLOYMENT COMMISSION
- THO - ERNEST O. THOMPSON
- WBT - WILLIAM B. TRAVIS
- A - GETHSEMANE CHURCH
- B - ARCHEOLOGY LAB
- C - CARRINGTON-COVERT HOUSE
- D - EL ROSE

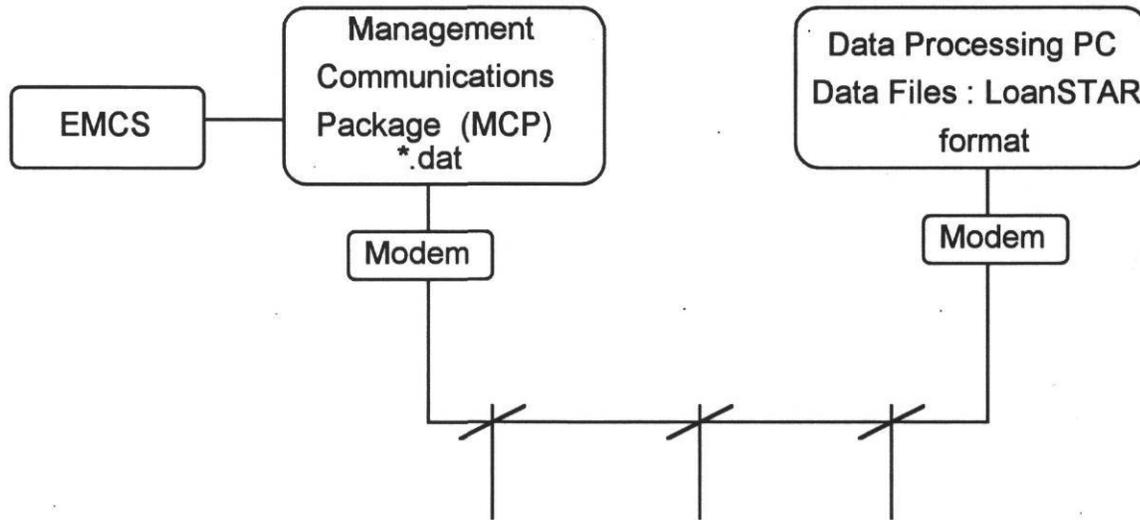
- E - AMERICAN LEGION BUILDING
- F - EPPRIGHT BUILDING
- G - OLD BAKERY
- H - SAN JACINTO WAREHOUSE

- BUILDINGS OUT OF CAPITOL COMPLEX
- ANSON JONES BLDG. 410 EAST 5TH. ST.
  - COSMETOLOGY BLDG. 1111 RIO GRANDE ST.
  - JAMES HARPER STARR 107 WEST 6TH. ST.
  - STATE WAREHOUSE 401 EAST 1ST. ST.
  - JOHN H. WINTERS COMPLEX 701 WEST 51ST. ST.
  - AIRCRAFT POOLING BOARD 4900 OLD MANOR
  - COMM. FOR THE BLIND ADMIN. BLDG. 4800 N. LAMAR
  - HUMAN SERVICES WHS. 1111 NORTH LOOP
  - STATE PURCHASING & GENERAL SERVICES COMMISSION

*Figure 4.6.2: Hardware configuration for the Teletrol test setup.* This figure shows the hardware configuration for the Teletrol test setup. Since the test was located in the same office where the polling computer was located the data were collected via modem over the campus phone system.

## HARDWARE CONFIGURATION

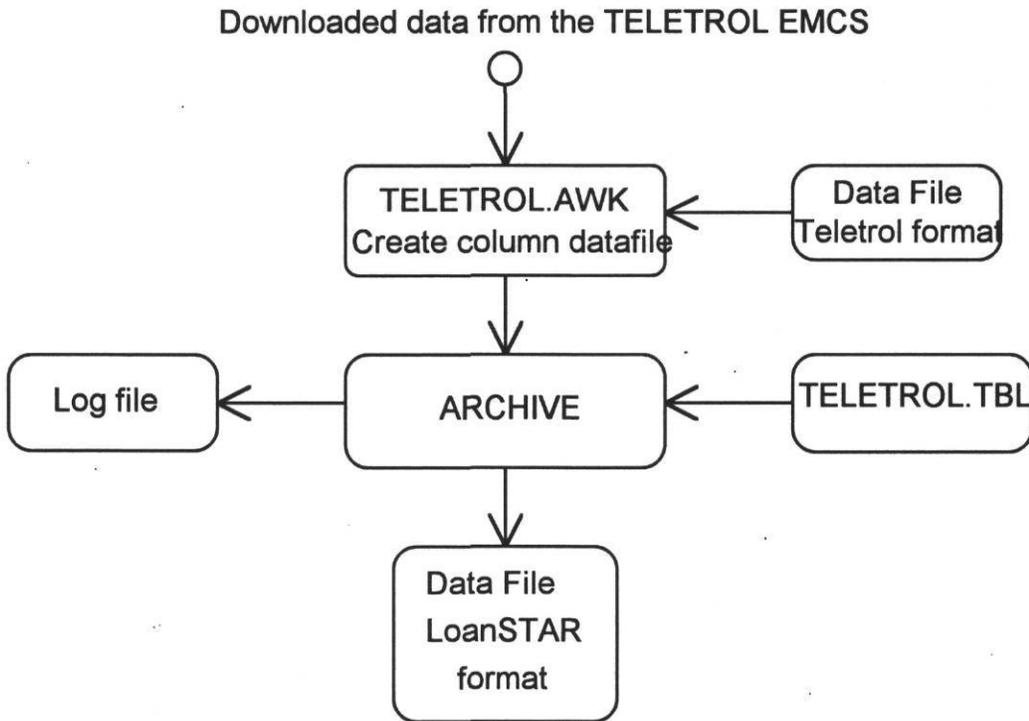
---



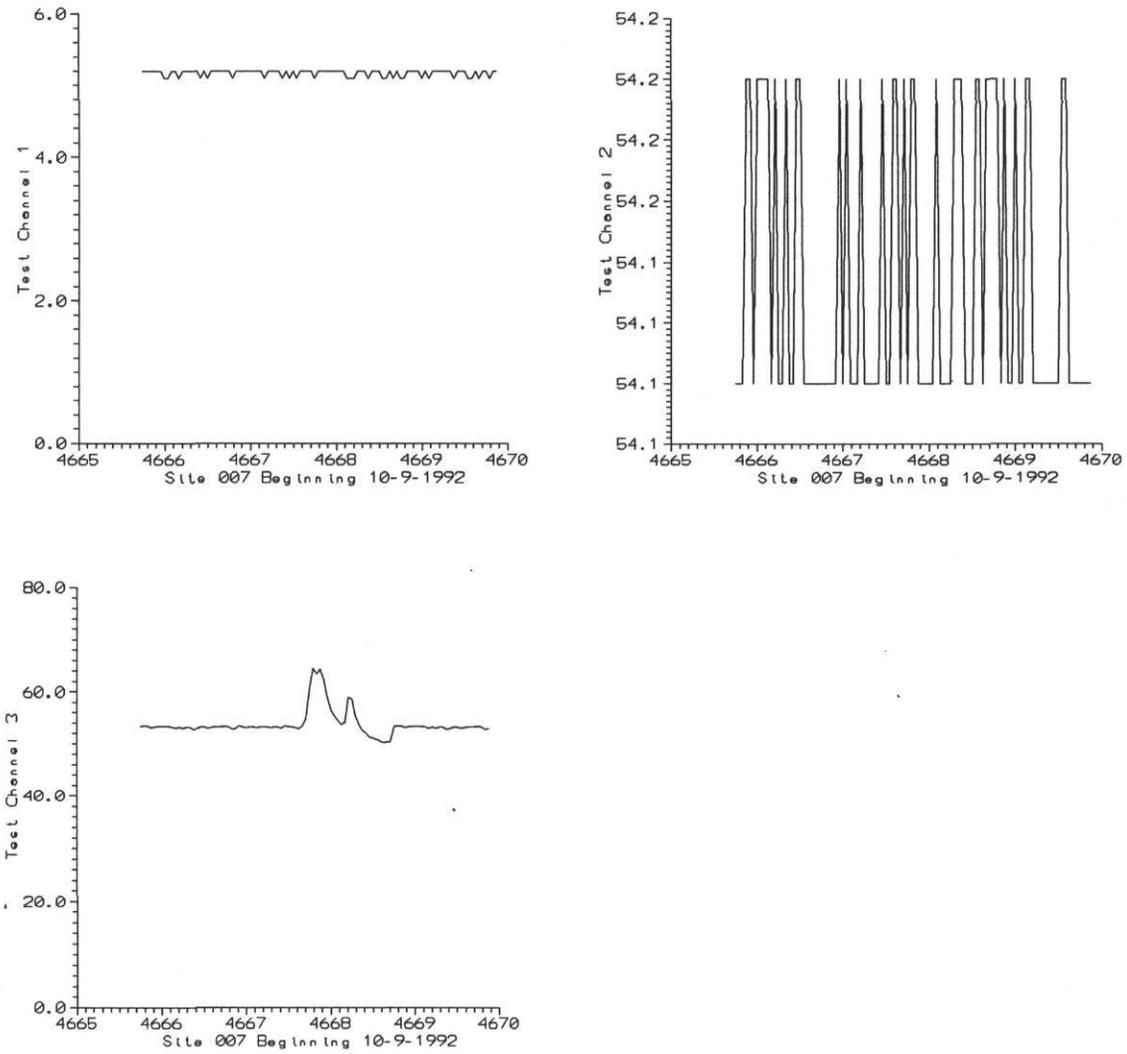
**Figure 4.6.3:** *Data processing stream for the Teletrol test setup.* This figure shows the data processing streams that are required to convert the Teletrol data into LoanSTAR format once the data have been received.

## DATA PROCESSING STREAM

---



**Figure 4.6.4:** LoanSTAR-type inspection plots for the Teletrol EMCS. This figure shows the LoanSTAR inspection plots for the channels of data collected from the Teletrol EMCS.



## 5.0 Evaluation of EMCS Capabilities

Table 5.1.1 contains general information regarding the capabilities of the three EMCSs that were used in this project (Heinemeier and Akbari 1991). In general, all three EMCSs could be used to gather acceptable quality monitoring data but required significant custom programming to accomplish this.

Good cooperation with the EMCS operators was essential.

In each of the following sections are specific details about each of the different systems that adds to Table 5.1.1.

### HONEYWELL DELTA 1000

1. The system has sufficient trend capacity but customizing the trending and data collection has drawbacks. This is due to the limitations in the menu selection of the version of the CIL programming language that was resident at the time of the tests.
2. Remote retrieval of data from the PC required a two-step procedure at the time that these tests were performed. The operator was required to capture the trend data to a disk file and then separately transfer that file to the polling computer.
3. Data from the EMCS can be retrieved in text format but problems were encountered with the file transfer of text format. .DIF files were found to be the best means of retrieving and transferring the data.
4. Data required additional processing to translate into LoanSTAR format.
5. The EMCS has a scan rate of one minute which is adequate for most trend purposes.

### LANDIS & GYR POWERS SYSTEM 600 SCU

1. Customized trending and data collection required programming in L&GP's PPCL language. This task was reasonably straight forward once one master's PPCL.
2. Data must be retrieved at weekly intervals or less since memory limitations will cause the data to wrap over data that may not have been retrieved.
3. Data retrieval can be performed via an RS232 or RS232/modem port directly into the SCU (the local controller).
4. Data required additional processing to translate into LoanSTAR format.
5. The system is reported to have a scan rate of one second. It can be programmed to

record data at larger intervals if needed.

### **JOHNSON CONTROLS JC/85/40**

1. Remote trending can be accomplished but required additional modifications to the JC/85/40 configuration.
2. Conversion of the raw data into standard LoanSTAR format requires a fair amount of programming using a GAWK routine.
3. The JC 85/40 is reported to use a continuous scanning system which is capable of processing 1600 lines per second, this was felt to be adequate for trending purposes.
4. Data required additional processing to translate into LoanSTAR format.

### **SYNERGISTICS CONTROL SYSTEM C180**

1. This is a monitoring-only data acquisition system that is in use in the LoanSTAR program.
2. The smallest scan rate is once every six seconds. Data can be recorded in intervals as small as one minute.
3. Data can be retrieved via RS232 or via phone line through an attached modem.
4. Data required additional processing to translate into LoanSTAR format.

### **TELETROL INTEGRATOR 286**

1. Remote trending can be accomplished without additional modifications to the Teletrol Integrator 286.
2. Conversion of the raw data into standard LoanSTAR format requires a fair amount of programming using a GAWK routine.

**Table 5.1.1: Characteristics of EMCSs Investigated.** This table reports on the characteristics of the EMCSs investigated as evaluated by Heinemeier & Akbari (1991) .

MANUFACTURER AND MODEL	JOHNSON CONTROLS JC/85/40	HONEYWELL DELTA 1000	LANDIS & GYR POWERS SYSTEM 600 SCU
SYSTEM DESCRIPTION	Microprocessor host-based central station.	Microcomputer host-based central station.	Stand alone, microprocessor based programmable wall panel controller w/LAN capability.
INPUTS AND OUTPUTS	Numerous.	Proprietary.	10 digital-in, 16 analog, 8 digital-out.
DATA STORAGE SCHEME	Historical data stored as ASCII characters, proprietary data file format.	Historical data stored as ASCII characters, convertible to LOTUS compatible .DIF file, proprietary data file format.	Historical data stored as ASCII format.
AMOUNT OF END-USE DATA COLLECTED (4 VALUES @ 5 MIN)	Months.	Proprietary.	83 hours.
TYPE OF DATA COLLECTED	Any input/output.	Proprietary.	Any input/output temps, on/off times.
AVERAGING INTERVAL USED	Proprietary.	Proprietary.	1 min. to 1 hour.
OFFLINE DATA STORAGE	Floppy disk, hard disk.	Proprietary.	Hard disk, tape.
ON-BOARD DATA STORAGE	64K RAM	Proprietary.	128K RAM, 256K ROM
COMMUNICATION WITH SENSORS OR CONTROLLERS	CAL-1 proprietary protocol w/ direct wire optional PLC.	Proprietary.	Master/slave proprietary protocol w/ direct wire.
OPERATING SYSTEM	DX-10	Proprietary.	Proprietary
REPORT FLEXIBILITY	Selectable points/interval	Selectable point/interval.	Selectable points/interval
APPLICATION SOFTWARE	Written in Pascal.	Proprietary	N/A
REMOTE ACCESS	RS232C Port optional Hayes 1200 baud modem.	Proprietary.	RS232C Port Needs L&G software
ERROR DETECTION CORRECTION DURING REMOTE ACCESS	Proprietary.	Proprietary.	Proprietary

## 6.0 Conclusions/Recommendations

This work has successfully shown that useful trend information can be obtained from Energy Management and Control Systems. However, much work remains in making this a transparent and reliable process. Here are some of the conclusions that we have determined:

1. The three EMCSs considered in this study can be used to trend monitoring data. Each EMCS had its own peculiarities however. In each case significant programming was necessary to translate the format from each EMCS into a common format. EMCS manufacturers need to make their systems provide columnar data without headers or footers for easy processing.

At a minimum EMCS manufacturers should provide hourly trend information on the hour for a choice of the following variables: snap shot, average hourly, runtime, cumulative readings. In most cases this must use a separate trend log. Unfortunately, we noticed that EMCS operators tend to configure and reconfigure trend logs at will which defeats the purpose of downstream processing.

2. Significant barriers still remain for many existing EMCSs. In the case of one of the sites trend points were sometimes established at off-hour points. This was due to an initialization problem, namely, every time that the EMCS lost power it reset the trends to the current time, a major problem for downstream processing.

In another EMCSs a special algorithm had to be written in the EMCS language to integrate every 60 seconds and store at the hour. This gave a rough integral and experiences some problems with overflow since there was no modulus operator or conditional reset of values. This was worked around by resetting the values to 0 at the end of each hour which relies on proper timing of the EMCS and the PC running the communications software.

EMCS trend data is not particularly friendly. Sometimes it is in .DIF format, sometimes it include carriage returns in the middle of data lines (or no carriage return).

In several cases we found that remote access to an EMCS is not designed for efficient transfer of large amounts of columnar ASCII data. In several cases the EMCS would actually be locked-up during data transfer -- a serious problem when it is also being used for fire and security.

Trending at one of the EMCSs could only be accomplished using hourly samples of power, where the sample represented the previous minutes number of pulses. Although the EMCS had a facility for trending the pulses into daily totals no such capability existed for trending the information into hourly totals. Obviously, this problem that can be fixed with a new software release.

In a similar fashion one of the EMCSs had a problem with direct polling of trend data.

However, thanks to some clever programming by the EMCS operators, this was eventually accomplished by declaring the modem to be a printer and having the EMCS operator print the trend data to the printer/modem. Capture of the data by the polling computer was then accomplished by echoing the data on the screen to the disk for storage. Unfortunately this meant that all call-ins were treated as printers which caused a problem with control characters that are used for coloring the screen, etc.

One of the EMCSs uses Change of Value (COV) variables to record energy use. A COV is a record structure that records energy use only when a certain preset value of energy has been consumed. COVs work fine when the period that they report energy use for is significantly less than one hour. However, when this period exceeds one per hour a significant error can occur. For more about COVs and EMCS see the report by Heinemeier and Akbari (1991).

In another site the EMCSs used a different package on a PC to download data from the main computer. This package was unable to download and transfer data over the phone lines. A work-around solution had to be implemented to download the data and then manually transfer to the remote computer.

At yet another site the EMCS was periodically rebooted by new operator(s) who were unfamiliar with the project which meant that routines and data were dumped from the disk. At this particular no useful data were collected after 12+ months of effort. This is due mostly to communication problems between the experimenters, the facility operators and the EMCS field office. Unfortunately, since this site had a retrofit installed during this period, all PRE retrofit data were permanently lost.

3. In the future EMCS manufacturers will need to provide enhanced graphical viewing for 2-D, 3-D, and special purpose plots like psychrometric templates. Data should also be viewable in sub-hourly, hourly, daily and/or monthly summaries. Data should also be sortable, and statistical functions would be nice. It is not unreasonable to think that in ten years the need for lifetime building data may arise.

4. Other issues including economies of scale, and maintenance of systems. In general we find that when one has several buildings connected to an existing EMCS, and plans on performing some monitoring -- it might be in the facilities best interest to consider using the EMCS for monitoring. In several of the sites that we looked at this would have been an economically viable solution. However, on a single site basis, use of the EMCS is probably more expensive than a dedicated logger.

One final issue involves maintenance of the data acquisition systems. In the case that the EMCS is being used, the maintenance cost would be included in the EMCS contract. For a dedicated logger, especially in a remote facility, one needs to think seriously about who is going to maintain the logger, and how that logger will be maintained when it breaks. Although many of the sensors are reasonably robust (CTs, PTs, etc.), some are not (humidity, Btu), and will need periodic visits to recalibrate and check on the sensors.

## 7.0 Acknowledgments

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## 10.0 Appendix

### 10.1 LoanSTAR Processing routines

#### 10.1.1 Texas Tech University Health Sciences Center

This section of the appendix contains the data processing routines for preparing the raw data from the Honeywell Energy Auditor to be translated into LoanSTAR format. In general, here are the steps that are used in this process:

1. The trended data from the EMCS is in a format called Data Interchange Format (.DIF) which requires conversion to text format. This is currently done with the Microsoft Excel spreadsheet.
2. This trended data in the text format contains headers and date delimiters like colons, backslashes, etc., which are further filtered with GAWK. ARCHIVE is then used to convert the text file into standard LoanSTAR format which includes appending a site number, Julian and decimal dates, etc.
3. Inspection plots are generated with Grapher software (from Golden Software, Golden, Colorado).
4. The batch file executes each of the above listed processes sequentially.

In the pages that follow are the source code that is used to convert the Honeywell data into LoanSTAR format.

```

@echo off
rem ttl.bat 1.1 2/12/92
rem *****
rem Copyright (c) 1990, Texas Engineering Experiment Station
rem
rem Program: TTL.BAT
rem Version: 1.1
rem Last Update: 2/12/92
rem
rem DESCRIPTION: This batch file runs the convert routine and archives the
rem   resulting data file.
rem
rem HISTORY:
rem   Design: Raghu Belur
rem   Code: Raghu Belur
rem
rem MODIFICATIONS:
rem
rem HISTORY AND DISTRIBUTION RIGHTS
rem   DEVELOPED BY: Energy Systems Laboratory, Mechanical Engr. Dept.,
rem     Texas A & M Univ., College Station, Texas 77843-3123,
rem     (409) 845-1560
rem   SUPPORTED BY: State of Texas Governor's Energy Management Center
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rem WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT
rem LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY
rem AND FITNESS FOR A PARTICULAR PURPOSE. No support service will
rem be provided unless special arrangements have been made to do so. Certain
rem manufacturers and trade names are mentioned in this code for the purpose of
rem describing their communications protocol. Such reference does not constitute
rem an endorsement or recommendation of such equipment, but is provided for
rem informational purposes only.

rem *****

cd\
cd work\raghu\ttlbk\process
cls
copy c:\work\raghu\ttlbk\tt92%2\%1%2.dif winput.dif > nul

```

```
pront
pause
cd\
win c:\w\conv.rec
gawk -f c:\work\raghu\ttlbk\process\filter.awk c:\work\raghu\ttlbk\process\woutput.txt >
c:\work\raghu\ttlbk\process\goutput.txt
cd\
cd work\raghu\ttlbk\process
archive goutput.txt %1.tbl
type goutput.ach
rename goutput.ach %1%2.ach
rename goutput.log %1%2.log
del goutput.txt >nul
del woutput.txt >nul
del winput.dif
type %1%2.log
cls
echo copying processed file to disk.
echo please wait...
copy %1%2.log b: >nul
copy %1%2.ach b: >nul
copy %1%2.log c:\work\raghu\ttlbk\tt92%2 >nul
copy %1%2.ach c:\work\raghu\ttlbk\tt92%2 >nul
del %1%2.log
del %1%2.ach
```

```

# ttl.awk 1.1 2/12/92
*****
# Copyright (c) 1990, Texas Engineering Experiment Station
#
# Program: TTL.AWK
# Version: 1.1
# Last Update: 2/12/92
#
# DESCRIPTION: This program converts Texas Tech trending data to
# data format.
#
# HISTORY:
# Design: Raghu Belur
# Code: Raghu Belur
#
# MODIFICATIONS:
# NAME:          DATE:   VERSION: DESCRIPTION:
#
# HISTORY AND DISTRIBUTION RIGHTS
# DEVELOPED BY: Energy Systems Laboratory, Mechanical Engr. Dept.,
# Texas A & M Univ., College Station, Texas 77843-3123,
# (409) 845-1560
# SUPPORTED BY: State of Texas Governor's Energy Management Center
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#WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT
#LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY
#AND FITNESS FOR A PARTICULAR PURPOSE. No support service will
#be provided unless special arrangements have been made to do so. Certain
#manufacturers and trade names are mentioned in this code for the purpose of
#describing their communications protocol. Such reference does not constitute
#an endorsement or recommendation of such equipment, but is provided for
#informational purposes only.
*****
{
  gsub(/\/, " ");
  gsub(/:/, "");
  gsub(/ /, " ");
  print$0;
}

```

### 10.1.2 Zachry Engineering Center

This section of the appendix contains the data processing routines for preparing the raw data from the Landis Gyr system to be translated into LoanSTAR format. In general, here are the steps that are used in this process:

1. Data are preprocessed using the C code that is attached to append missing columns of data with -99.00.
2. The file is then filtered with GAWK to append the Gregorian data to the columnar format.
3. ARCHIVE is then used to convert the file into standard LoanSTAR format.
4. Inspection plots are then produced with Grapher.
5. The batch file then executes each of the above sequentially.

In the following pages are the source code routines that accomplish these tasks.

```

rem zach.bat      1.1 9/10/91
rem *****
rem Copyright (c) 1990, Texas Engineering Experiment Station
rem
rem Program: ZACH.BAT
rem Version: 1.1
rem Last Update: 9/10/91
rem
rem DESCRIPTION: This script controls the processing of the raw data from
rem  Zachry building.
rem
rem HISTORY:
rem  Design: Raghu Belur
rem  Code: Raghu Belur
rem
rem MODIFICATIONS:
rem  NAME:      DATE:  VERSION:  DESCRIPTION:
rem  Raghu Belur  09/10/91  1.1    Process Zachry data.
rem
rem HISTORY AND DISTRIBUTION RIGHTS
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rem informational purposes only.

rem *****

cls
echo Welcome to the wonderful world of GAWK programming

```

```
echo processing.....  
zachr %1 %2 > zach_pre.out  
gawk -f ooh.awk zach_pre.out %2 > zach.out  
archive zach.out zach.tbl  
del zach_pre.out  
del zach.out  
type zach.ach | more  
cls  
echo done
```

```

# zach.awk 1.1 9/10/91
#*****
# Copyright (c) 1990, Texas Engineering Experiment Station
#
# Program: ZACH.AWK
# Version: 1.1
# Last Update: 9/10/91
#
# DESCRIPTION: This program converts the Landis & Gyr data to loanstar
# data format.
#
# HISTORY:
# Design: Raghu Belur
# Code: Raghu Belur
#
# MODIFICATIONS:
# NAME:          DATE:  VERSION:  DESCRIPTION:
# Raghu Belur   09/10/91  1.1    Convert data to loanstar
#                format.
#
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#informational purposes only.

#*****

```

```

BEGIN{
no_of_chanls=ARGV[2];
ARGC=2;
flag=0;
i=1;
j=0;
count=0;
build_array();
}

/./ && flag==0{gsub(/./, " ");
year=$NF;
flag=1;
}

/-----/ && flag==1{
getline;
flag=2;
for(c=5; c < (no_of_chanls+5); c++)
array[0,c]=$c-4;
}

(/Jan/ || /Feb/ || /Mar/ || /Apr/ || /May/ || /Jun/) && flag==2{
gsub(/./, " ");
day=$1;
month=month_array[$2];
}

(/Jul/ || /Aug/ || /Sep/ || /Oct/ || /Nov/ || /Dec/) && flag==2{
gsub(/./, " ");
day=$1;
month=month_array[$2];
}

/./ && flag!=1{
gsub(/./, "");

for(j=0; j < NF; j++)
array[i,(j+3)]=$(j+1);
array[i,0]=month;
array[i,1]=day;
array[i,2]=year;
i++;
}

flag==2{
if($0=="End of Report")

```

```
    exit;  
}
```

```
END{  
  no_of_samples=i;  
  for(i=1; i <= no_of_samples; i++)  
  {  
    for(j=0; j <=(no_of_chanls+3); j++)  
    {  
      if((j==0) || (j==1) || (j==2))  
        printf("%4s",array[i,j]);  
      else printf("%10s",array[i,j]);  
    }  
    printf("\n");  
  }  
}
```

```
function build_array()  
{  
  month_array["Jan"]=1;  
  month_array["Feb"]=2;  
  month_array["Mar"]=3;  
  month_array["Apr"]=4;  
  month_array["May"]=5;  
  month_array["Jun"]=6;  
  month_array["Jul"]=7;  
  month_array["Aug"]=8;  
  month_array["Sep"]=9;  
  month_array["Oct"]=10;  
  month_array["Nov"]=11;  
  month_array["Dec"]=12;  
  return;  
}
```

```

/*zach.c 1.1 9/10/91 */
/*****
* Copyright (c) 1990, Texas Engineering Experiment Station
*
* Program: ZACH.C
* Version: 1.1
* Last Update: 9/10/91
*
* DESCRIPTION: This program inserts missing column data from Landis & Gyr
* raw data files.
*
* HISTORY:
* Design: Raghu Belur
* Code: Raghu Belur
*
* MODIFICATIONS:
* NAME:          DATE:   VERSION: DESCRIPTION:
* Raghu Belur   09/10/91 1.1   Insert missing column data.
*
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*****/

# include <stdio.h>
# include <string.h>

```

```

FILE *infile;
FILE *outfile;

void main(int argc, char *argv[])
{
char line_data[100];
char c;
int index=0, i;
int no_of_chanls;
int chanl_pos;

for(i=0; i<100; i++)
line_data[i]=' ';

infile=fopen(argv[1], "r");
no_of_chanls=atoi(argv[2]);

while(!feof(infile))
{
fgets(line_data,99,infile);
index = strlen(line_data);
if (line_data[index-1]=='\n')
{
index--;
line_data[index] = '\0';
}

if(index < 9*no_of_chanls)
line_data[(9*no_of_chanls+4)]='\0';

if((line_data[2])==':')
{
for(i=1; i<=no_of_chanls; i++)
{
chanl_pos=((i*9) - 1);
if((line_data[chanl_pos])==' ')
{
line_data[chanl_pos]='-';
line_data[(chanl_pos+1)]='9';
line_data[(chanl_pos+2)]='9';
} //end of if loop
} //end of for loop
} //end of if loop

printf("%s\n",line_data);
for(i=0; i<100; i++)
line_data[i]=' ';
} //end of while loop
fclose(infile);
}

```

### 10.1.3 Prairie View A&M Campus

This section of the appendix contains the data processing routines for preparing the raw data from the Prairie View Johnson Controls JC 85/40 to be translated into LoanSTAR format. In general, here are the steps that accomplish these tasks:

1. The raw data from this site is in a row format and requires a preprocessing routine to convert it into columnar format. This is done with GAWK.
2. ARCHIVE is then used to convert into the standard LoanSTAR format.
3. Inspection plots are then produced with Grapher.
4. The batch file executes each of the above mentioned processes sequentially.

In the pages that follow are the source code routines that perform these functions.

@echo off

```
rem prv.bat 1.1 9/10/91
rem *****
rem Copyright (c) 1990, Texas Engineering Experiment Station
rem
rem Program: PRV.BAT
rem Version: 1.1
rem Last Update: 9/10/91
rem
rem DESCRIPTION: This batch file runs the convert routine and archives the
rem resulting data file.
rem
rem HISTORY:
rem Design: Raghu Belur
rem Code: Raghu Belur
rem
rem MODIFICATIONS:
rem NAME: DATE: VERSION: DESCRIPTION:
rem Raghu Belur 09/10/91 1.1 Process and archive data.
rem
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rem \*\*\*\*\*

```
echo processing.....please wait...
gawk -f fun.awk prv.dat > prv.out
archive prv.out prv.tbl
cls
type prv.ach | more
echo done!!!!!!
```

```

# prv.awk 1.1 9/10/91
*****
# Copyright (c) 1990, Texas Engineering Experiment Station
#
# Program: PRV.AWK
# Version: 1.1
# Last Update: 9/10/91
#
# DESCRIPTION: This program converts Johnson trending data to loanstar
# data format.
#
# HISTORY:
# Design: Raghu Belur
# Code: Raghu Belur
#
# MODIFICATIONS:
# NAME:          DATE:  VERSION:  DESCRIPTION:
# Raghu Belur   09/10/91  1.1    Convert data to loanstar
#                  format.
#
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*****

```

```

BEGIN {
    j=0;
    k=0;
    offset=0;
    flag=0;
    chek=0;
    xit=0;
}

flag==0 && /POINT NUMBER/{
    array[0,(k+4)]=$4;
    k++;
}

flag==0 && /LAST SAMPLE/{
    gsub(/:/, "");
    no_of_samples=$NF;
    if(chek==0){
        prev_begin_time=$5;
        prev_begin_date=$7;
        chek++;
    } else {
        curr_begin_time=$5;
        curr_begin_date=$7;
    }
    if(curr_begin_time!=prev_begin_time || curr_begin_date!=prev_begin_date)
    {
        printf("Data missing. Exiting.....!!\n");
        xit=1;
        exit;
    }
}
}

```

```

flag==0 && /-----/{
    flag=1;
    getline;
}

flag==1{
    if($1!="...END...")
    {
        for(i=1; i<=(NF-2); i++)
        {
            p=i+offset;
            if($(i+2)=="OFFLINE")
                $(i+2)=-99;
        }
    }
}

```

```

        array[p,(j+4)]=$(i+2);
    }
    offset=offset+(NF-2);
}
else { flag=0;
        j++;
        offset=0;
    }
}

END{ if(xit==1)
    exit;
    array[0,0]=curr_begin_date;
    array[1,0]=curr_begin_date;
    array[0,3]=curr_begin_time;
    array[1,3]=curr_begin_time;
    time=curr_begin_time;
    for(i=2; i<=no_of_samples; i++)
    {
        time=(time+100);
        if(time<2400)
            array[i,3]=time;
        else { time=0;
              array[i,3]=0000;
            }
    }
    increment_date(curr_begin_date, no_of_samples);
    for(i=1; i<=no_of_samples; i++) {
        for(j=0; j<=(k+4); j++){
            if((j==0) || (j==1) || (j==2))
                printf("%4s",array[i,j]);
            else printf("%10s",array[i,j]);
        }
        printf("\n");
    }
}

```

```

function increment_date(date, total_samples)
{
    split(date, date_array, "/");
    prev_month=date_array[1];
    prev_day=date_array[2];
    prev_year=date_array[3];

    for(i=1; i<=total_samples; i++)
    {
        if(array[i,3]==0)
        {
            if(prev_day==31)
            {
                if(prev_month==12)

```

```

    {
      prev_month=1;
      prev_year++;
    }
  else
    {
      prev_month++;
    }
  prev_day=1;
}

else if(prev_day==30)
  {
    if(prev_month==4 || prev_month==6 ||
       prev_month==9 || prev_month==11)
      {
        prev_day=1;
        prev_month++;
      }
    else prev_day++;
  }
else if(prev_month==2)
  {
    if(prev_year >= 80)
      y=1900 + prev_year;
    else y=2000 + prev_year;

    feb_days=28;
    if(((y % 4)==0) && (((y % 100) !=0) || ((y % 400)==0)))
      feb_days++;
    if(prev_day==feb_days)
      {
        prev_day=1;
        prev_month++;
      }
  }
  else prev_day++;
}
array[i,0]=prev_month;
array[i,1]=prev_day;
array[i,2]=prev_year;
}
}

```

## 10.1.4 USDOE Forrestral Building and Germantown Facilities

This section of the appendix contains the data processing routines for preparing the raw data from the Synergistics into the plots that are contained in this report.

```

@echo off
rem r2a.bat 1.1 7/25/90
rem *****
rem Copyright (c) 1990, Texas Engineering Experiment Station
rem
rem Program: R2A.BAT
rem Version: 1.1
rem Last Update: 07/25/90
rem
rem DESCRIPTION: The purpose of this batch file is:
rem (a) filter raw data from C180 in Zachry
rem (b) archive filtered data
rem (c) generate records for missing data
rem
rem HISTORY:
rem   Design: Kristel A. Weber
rem   Code: Kristel A. Weber
rem
rem MODIFICATIONS:
rem   NAME:      DATE:  VERSION DESCRIPTION:
rem   Kristel A. Weber  07/25/90  1.1   New batch file to run convert
rem                                     program for Zachry data.
rem
rem Input : *.raw and date string
rem Usage : 001R2A site# YYDDD YYDDD date(mm-dd-yyyy) dec. date (xxxx)
rem         first YYDDD is date of data file, second is date of channel table
rem Output : *.acs
rem
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```

```

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rem informational purposes only.

```

```

rem *****

```

```

if "%1"==" " goto error
if "%2"==" " goto error
if "%3"==" " goto error

```

```

cd \work

```

```

if not exist raw\%1%2.raw goto error2

```

```

gawk -f \syu\raw2dat.awk < raw\%1%2.raw > %1%2.dat

```

```

archive %1%2.dat \work\cht\%1%3.cht

```

```

gawk -v site=%1 -f \syu\missing.awk < %1%2.ach > acs\%1%2.acs
copy %1%2.log \work\log > nul
copy miss%1.log \work\log > nul
del %1%2.log
del miss%1.log

```

```

call util\%1graph %1 %2

```

```

goto done

```

```

:error
echo      #1      #2      #3
echo Usage: R2A site_num YYDDD YYDDD(channel)
goto done

```

```

:error2
echo ERROR - %1%2.raw does not exist

```

```

:done

```

```

rem @(#)905graph.bat 1.1
rem *****
rem Copyright (c) 1990, Texas Engineering Experiment Station
rem
rem Program: 905graph.bat
rem Version: 1.1

```

```

rem DESCRIPTION: The purpose of this batch file is:
rem      Create inspection plots.

```

```

rem HISTORY:
rem   Design: Kristel A. Weber
rem   Code: Robert Lopez

```

```

rem Input : *.grf
rem Usage : 905graph site# YYDDD
rem
rem Output : *.ps
rem

```

```

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```

```

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```

```

rem *****
echo Processing data for Forrester/Vault A (Site 905)

```

```

if "%1"==" " goto error
if "%2"==" " goto error

cols < \work\acs\%1%2.acs 6 8:19 > \temp\t%1a.dat
cols < \work\acs\%1%2.acs 6 20 > \temp\t%1b.dat

gawk -f \work\util\%1date.awk \work\acs\%1%2.acs > \work\util\%1chgrf.bat

cd graph
for %%i in (t%1*.grf) do call \work\util\%1chgrf %%i

cd \temp
echo -----
echo Generating plot files
for %%i in (t%1*.grf) do grapher %%i

copy \work\util\a.plt + t%11.plt + \work\util\b.plt + t%12.plt %1temp1.plt > nul
copy \work\util\b.plt + t%13.plt + \work\util\c.plt + t%14.plt %1temp2.plt > nul
copy \work\util\b.plt + t%15.plt + \work\util\b.plt + t%16.plt %1temp3.plt > nul
copy %1temp1.plt + %1temp2.plt + %1temp3.plt %1plot1.plt > nul

copy \work\util\c.plt + t%17.plt + \work\util\b.plt + t%18.plt %1temp4.plt > nul
copy \work\util\b.plt + t%19.plt + \work\util\c.plt + t%110.plt %1temp5.plt > nul
copy \work\util\b.plt + t%111.plt + \work\util\b.plt + t%112.plt %1temp6.plt > nul
copy %1temp4.plt + %1temp5.plt + %1temp6.plt %1plot2.plt > nul

copy %1plot1.plt + %1plot2.plt %1one.plt > nul

copy \work\util\a.plt + \work\util\b.plt %1temp1.plt > nul
copy \work\util\b.plt + \work\util\c.plt %1temp2.plt > nul
copy \work\util\b.plt + t%113.plt + \work\util\b.plt %1temp3.plt > nul
copy %1temp1.plt + %1temp2.plt + %1temp3.plt %1two.plt > nul
echo Complete
echo -----

echo Creating Postscript file #1
plot %1one.plt /b > nul
echo Creating Postscript file #2
plot %1two.plt /b > nul

echo Cleaning...

del %1plot?.* > nul
del t%1*.dat > nul
del %1temp?.plt > nul
del t%1*.plt > nul
del t%1*.grf > nul

cd \work
del %1%2.dat > nul
del %1%2.ach > nul

goto done

```

```
:error  
echo Usage: 905graph site# YYDDD  
  
:done  
echo Processing completed for Forrestal/Vault A (Site 905)  
@echo off
```

```

rem doesumm.bat 1.1 7/25/90
rem *****
rem Copyright (c) 1990, Texas Engineering Experiment Station
rem
rem Program: doesumm.bat
rem Version: 1.1
rem
rem DESCRIPTION: The purpose of this batch file is:
rem     Create summary plot.
rem
rem HISTORY:
rem   Design: Kristel A. Weber
rem   Code: Kristel A. Weber
rem
rem
rem Input : *.grf
rem Usage : doesumm site# YYDDD
rem
rem Output : *.ps
rem
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rem manufacturers and trade names are mentioned in this code for the purpose of
rem describing their communications protocol. Such reference does not constitute
rem an endorsement or recommendation of such equipment, but is provided for
rem informational purposes only.
rem *****
rem @echo off

```

```
echo Creating summary for DOE Forrestal Bldg (Sites 905, 906)
```

```
if "%1"==" " goto error
```

```
if "%2"==" " goto error
```

```
echo Merging Washington weather data
```

```
cols ^\work\acs\905%2.acs ^\work\acs\906%2.acs a1:20 b8:15 b24 b26 vta%1.dat
```

```
gawk -f \work\util\doesumm.awk ta%1.dat > tb%1.dat
```

```
cols < \work\wea\dca%2.nws 8 9 > tc%1.dat
```

```
\month\air tc%1.dat td%1.dat 2
```

```
cols ^\work\wea\dca%2.nws ^td%1.dat a6 b4 b1 vte%1.dat
```

```
timemerg "tb%1.dat 2-8" "te%1.dat 2-3" > \temp\tsdoe.dat
```

```
del ta%1.dat
```

```
del tb%1.dat
```

```
del tc%1.dat
```

```
del td%1.dat
```

```
del te%1.dat
```

```
del *.alg
```

```
gawk -f \work\util\doedate.awk \work\acs\%1%2.acs > \work\util\doechgrf.bat
```

```
gawk -f \work\util\doedate2.awk \work\acs\%1%2.acs > \work\util\doechgr2.bat
```

```
cd \work\graph
```

```
call \work\util\doechgrf tsdoe10.grf
```

```
call \work\util\doechgr2 tsdoe8.grf
```

```
call \work\util\doechgrf tsdoe3.grf
```

```
call \work\util\doechgrf tsdoe2.grf
```

```
call \work\util\doechgrf tsdoe5.grf
```

```
call \work\util\doechgrf tsdoe6.grf
```

```
call \work\util\doechgrf tsdoe9.grf
```

```
call \work\util\doechgrf tsdoe11.grf
```

```
copy tsdoe1.grf \temp > nul
```

```
copy tsdoe4.grf \temp > nul
```

```
copy tsdoe7.grf \temp > nul
```

```
cd \temp
```

```
echo -----
```

```
echo Generating plot files
```

```
for %%i in (tsdoe*.grf) do grapher %%i
```

```
copy \work\util\a.plt + tsdoe1.plt + \work\util\b.plt + tsdoe2.plt %1temp1.plt > nul
```

```
copy \work\util\b.plt + tsdoe3.plt + \work\util\c.plt + tsdoe4.plt %1temp2.plt > nul
```

```
copy \work\util\b.plt + tsdoe5.plt + \work\util\b.plt + tsdoe6.plt %1temp3.plt > nul
```

```
copy %1temp1.plt + %1temp2.plt + %1temp3.plt %1plot1.plt > nul
```

```
copy \work\util\c.plt + tsdoe7.plt + \work\util\b.plt + tsdoe10.plt %1temp4.plt > nul
```

```
copy \work\util\b.plt + tsdoe9.plt + \work\util\c.plt + tsdoe8.plt %1temp5.plt > nul
```

```
copy \work\util\b.plt + tsdoe11.plt + \work\util\b.plt %1temp6.plt > nul
```

```
copy %1temp4.plt + %1temp5.plt + %1temp6.plt %1plot2.plt > nul
```

```
copy %1plot1.plt + %1plot2.plt doesumm.plt > nul
```

```
echo Complete
```

```
echo -----
```

```
echo Creating Postscript file
```

```
plot doesumm.plt /b > nul
```

```
echo Cleaning...
```

```
del tsdoe*.plt
```

```
del tsdoe*.grf
```

```
cd \work
```

```
goto done
```

```
:error
```

```
echo Usage: doesumm site# YYDDD
```

```
:done
```

```
echo Summary page completed for DOE/Forrestal Bldg (Sites 905, 906)
```

### 10.1.5 Texas State Capitol Complex Routines (Teletrol)

This section of the appendix contains the data processing routines for preparing the raw data from the Teletrol EMCS into the plots that are contained in this report.

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#describing their communications protocol. Such reference does not constitute  
#an endorsement or recommendation of such equipment, but is provided for  
#informational purposes only.

```
BEGIN{
    i = 1;
    Channel = 1;
    UnequalChannelIndex = 0;
}
/Point Data/ && NR==1{
    NumberOfRecords = $6;
    BeginDate = $9;
    BeginTime = $10;
}
/Point Data/{
    if(NumberOfRecords!=$6 || BeginDate!=$9 || BeginTime!=$10){
        UnequalChannelIndex = 1;
        exit;
    }
    if(NR!=1) Channel++;
    next;
}
Channel==1{
    DataStorageArray[i] = $1;
    if(index($2,"/")){
        DateStorageArray[i] = $2;
    }
}
```

```

        HourStorageArray[i] = $3;
    }
    else
    {
        DateStorageArray[i] = $3;
        HourStorageArray[i] = $4;
    }
    i++;
}
Channel!=1{
    DataStorageArray[i] = $1;
    i++;
}
END{
    if(UnequalChannelIndex)
        exit;
    for(k=1;k<=NumberOfRecords;k++){
        count = k;
        split(HourStorageArray[k],a,":");
        Hour = a[1]*100+a[2];
        split(DateStorageArray[k],a,"/");
        Month = a[1];
        Day = a[2];
        Year = a[3];
        printf("%d %d %d %04d",Month,Day,Year,Hour);
        for(i=1;i<=Channel;i++){
            if(i!=1) count = count + NumberOfRecords;
            printf(" %s ", DataStorageArray[count]);
        }
        printf("\n");
    }
}

```