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Evaluation of the Utility and Energy Monitoring and Control System Installed at the U.S. Army, Europe, 409th Base Support Battalion, Military Community at Grafenwöhr, Germany

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EXECUTIVE SUMMARY

Under the provisions of Interagency Agreement DOE 1938-B090-A1 between the U.S. Department of Energy (DOE) and the U.S. Army Europe (USAREUR), Martin Marietta Energy Systems, Inc., is providing technical assistance to USAREUR in the areas of computer science, information engineering, energy studies, and engineering and systems development. One of the initial projects authorized under this interagency agreement is the evaluation of utility and energy monitoring and control systems (UEMCSs) installed at selected U.S. Army installations in Europe. This report is an evaluation of the overall energy-conservation effectiveness and use of the UEMCS at the 409th Base Support Battalion located in Grafenwöhr, Germany.

The 409th Base Support Battalion is a large USAREUR military training facility that comprises a large training area, leased housing, the main post area, and the camp areas that include Camps Aachen, Algier, Normandy, Cheb, and Kasserine. All of these facilities are consumers of electrical and thermal energy. However, only buildings and facilities in the main post area and Camps Aachen, Algier, and Normandy are under the control of the UEMCS. The focus of this evaluation report is on these specific areas.

The UEMCS at the Grafenwöhr base is an AEG model CBA 130. The system hardware is divided into control room/utilities office area equipment and field-located equipment, called field-interface devices (FIDs). A cabinet in the control room houses the system central processing unit (CPU), hard- and floppy-disk drives for program and data storage, a video driver for the operator's video display, and terminations for cabling to the FIDs. The control room also contains an operator's video display, four printers for report and alarm documentation, a main programming and maintenance terminal, and a personal computer (PC) with interface software for programming and maintenance of the UEMCS. Programming and maintenance PCs are also located in the stove shop maintenance area and in the utilities office area. The FIDs interface field equipment to the UEMCS and provide local control of field equipment. Control programs are downloaded to the FIDs from the central CPU.

The main post area is heated predominantly by a hot water district heating system. A private utility company provides hot water district heating to the base. The district heating plant is located just outside the fence of the base. Hot water supply and return lines run underground from the plant to the base. Heat exchangers at the heat island buildings in the main post area transfer heat from the primary hot water supplied by the district heating system to a secondary water system that distributes heated water to various buildings on the base. Hot water from the nine heat islands is circulated to substations located at various buildings throughout the main post area for space heating and potable water heating. The substations are located close to the buildings in which the energy is used. For space heating, hot water from heat islands is circulated through radiators.

Fuel oil instead of hot water district heating is used in the field camp area. Typical facilities under UEMCS control in the field camps are shower and latrine buildings, mess halls, and barracks. A UEMCS FID typically is located in the shower and latrine building that serves the other types of buildings. An oil-fired boiler in the shower and latrine building generates potable hot water not only for that building but also for the mess hall. A water-to-air heat exchanger provides space heating in the shower and latrine. The UEMCS controls space temperature and relative humidity based on occupancy and season of the year. Separate oil-fired boilers and ventilation fans are used for space heating in the mess hall and barracks.

Monitoring and control of electrical energy is limited at Grafenwöhr. During the late 1980s, approximately 70–80 electrical meters were installed in a cross-section of locations under the auspices of the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (CERL) to evaluate electrical consumption at the base. These meters are monitored by the UEMCS, but the data are not saved. The field camp mess hall refrigerators will have load shedding capability soon. Presently, the UEMCS can enable and disable operation of the refrigerators. UEMCS personnel are awaiting installation of signal lines that will transmit electrical demand data from the electrical utility. With this information, the UEMCS can be programmed to load shed the refrigerators during peak demand times. Other areas that could benefit from load shedding include the cold storage facility—where huge refrigerators cool provisions for troops and other base personnel—and several sites that use air conditioner units. Street lighting control is accomplished by using local twilight switches, except at one street in the field camp where lights are controlled by the UEMCS. Problems have arisen, especially in the field camps, where the twilight switch photodetectors become covered with dust and therefore keep the lights lit too long.

A steady downward trend in normalized fuel consumption has occurred since the UEMCS was implemented. Fuel consumption has decreased from 16.38 Btu/HDD/ft^2 in 1982 to 10.04 Btu/HDD/ft^2 in 1992. However, building envelope retrofits and a hot water district heating system also have been implemented during that period. Good records were not available, but an analysis made on assumptions and comparisons with a similar evaluation at the Pirmasens, Germany, UEMCS shows that the base is experiencing a yearly energy savings of ~9,500 MBtu attributable to UEMCS operation. Based on FY 1992 fuel costs and official exchange rate, this energy savings corresponds to a yearly cost savings of $101,365. The simple payback period using this cost savings is 4.9 years. Although not as good as the 0.9-year simple payback period on which the UEMCS project was justified, 4.9 years is still within Energy Conservation Investment Program (ECIP) guidelines of 10 years. The energy-saved-to-cost ratio is found to be 19.2 rather than 105, just barely over ECIP guidelines of 18. It is difficult to say what the savings-to-investment ratio (SIR) is, since only FY 1992 costs were investigated, but it is safe to say that SIR > 1, which satisfies ECIP guidelines.

Recommendations to further increase energy and cost savings and improve operation of the UEMCS are as follows:

- The temperature of domestic hot water should be reduced and recirculation should be shut off at night.

- The under-capacity problem of the hot-water system in the field camp shower and latrine buildings should be evaluated so that the temperature of the domestic hot water can be reduced.

- Plans should be carried out to implement electrical demand limiting.
- Night setback/weekend shutdown applications should be increased.
- Motor pool buildings in the field camps and exterior lighting throughout the base should be added to the operation of the UEMCS.
- Existing electrical metering should be used to record facility energy performance and determine the potential energy and cost savings attributable to selected energy-conservation measures.
- The impact of not having a UEMCS maintenance contract in place at all times should be reconsidered.
- Documentation of energy consumption and cost savings should be improved.

ABSTRACT

The overall energy-conservation effectiveness and use of the utility and energy monitoring and control system (UEMCS) installed at the 409th Base Support Battalion located in Grafenwöhr, Germany, was evaluated.

The evaluation shows a steady downward trend in normalized fuel consumption since the UEMCS was implemented. Fuel consumption has decreased from 16.38 Btu/HDD/ft^2 in 1982 to 10.04 Btu/HDD/ft^2 in 1992. However, building envelope retrofits and a hot water district heating system also have been implemented during that period. Good records were not available, but an analysis made on assumptions and comparisons with a similar evaluation of the Pirmasens, Germany, UEMCS shows that the base is experiencing a yearly energy savings of ~9,500 MBtu attributable to UEMCS operation. Based on FY 1992 fuel costs and official exchange rate, this energy savings corresponds to a yearly cost savings of $101,365. The simple payback period using this cost savings is 4.9 years. Although not as good as the 0.9-year simple payback period on which the UEMCS project was justified, 4.9 years is still within Energy Conservation Investment Program (ECIP) guidelines of 10 years. The energy-saved-to-cost ratio is found to be 19.2 rather than 105, just barely over ECIP guideline of 18. It is difficult to say what the savings-to-investment ratio (SIR) is, since only FY 1992 costs were investigated, but it is safe to say that SIR > 1, which satisfies ECIP guidelines.

Recommendations are made to further increase energy and cost savings and improve operations of the UEMCS in the areas of domestic hot water temperature, electrical demand limiting, night setback/weekend shutdown applications, addition of the motor pool building to the UEMCS, electrical metering, UEMCS maintenance, and documentation of energy consumption and cost savings.

1. INTRODUCTION

1.1 BACKGROUND

Under the provisions of Interagency Agreement DOE 1938-B090-A1 between the U.S. Department of Energy (DOE) and the United States Army in Europe (USAREUR), Martin Marietta Energy Systems, Inc., is providing research and development support and technical assistance in the areas of computer science, information engineering, energy studies, engineering, and systems development. One of the initial projects authorized under this interagency agreement is the evaluation of the utility and energy monitoring and control systems (UEMCSs) operating at selected U.S. Army installations in Europe. Evaluation of the overall performance and energy efficiency of UEMCSs operated at U.S. Army installations in Baumholder, Göppingen, Grafenwöhr, Heidelberg, Hohenfels, and Pirmasens, Germany, either have been completed or are under way. This report presents the results of the evaluation of the UEMCS installed at USAREUR, 409th Base Support Battalion (409th BSB) Military Community at Grafenwöhr. The UEMCS is operated by the Directorate of Engineering and Housing (DEH) Utilities Division.

1.2 SCOPE (STATEMENT OF WORK)

The Oak Ridge National Laboratory (ORNL) was selected by Headquarters, USAREUR, Engineering and Housing Directorate, Utilities and Energy Branch in Heidelberg to evaluate the effectiveness and energy efficiency of UEMCSs at six U.S. Army installations in Germany. The fifth of these systems to be evaluated, which is the scope of this report, is the UEMCS installed at Grafenwöhr. This evaluation relies upon existing data and information and does not involve introducing metering and instrumentation to measure installation energy use.

The primary purpose of this evaluation is to see whether the UEMCS at Grafenwöhr is achieving its operational objectives of energy and cost savings. Available UEMCS project documentation is reviewed and evaluated for completeness, accuracy, and reasonableness. The Grafenwöhr UEMCS is described in terms of its current operations, as well as its capability for operational improvements. An assessment of site and physical conditions is performed based on visits to the various Grafenwöhr installations, facilities, and buildings served by the UEMCS. An in-depth analysis of energy consumption and energy and cost savings for the major facilities making up the Military Community at Grafenwöhr will demonstrate the positive results of past DEH Utilities Division efforts to conserve energy and improve energy efficiency, as well as identify opportunities for continued improvement. Finally, this evaluation focuses on a general assessment of UEMCS benefits not necessarily related to tangible energy and cost savings. This assessment is based, in part, on interviews with DEH Utilities Division management and operation personnel. The interviews addressed such issues as system operation and maintenance and the Energy Conservation Program.

2. PROJECT DESCRIPTION

2.1 GENERAL DESCRIPTION

The 409th BSB Military Community is a large military training facility that comprises a large training area, leased housing, the Main Post Area (MPA), and the Field Camps Aachen, Algier, Normandy, Cheb, and Kasserine. All these facilities are consumers of electrical and thermal energy. However, only buildings and facilities in the MPA and Field Camps Aachen, Algier, and Normandy are under the control of the UEMCS. Therefore, this project description will focus on the UEMCS itself and its application to monitor and control thermal and electrical energy consumption in the MPA and applicable field camps.

The UEMCS was first installed in the field camps during 1984. Until 1989, the field interface devices (FIDs) installed in the various buildings were programmed on location with a portable computer. Not until 1987 was this function performed remotely from the central UEMCS control room. This was the start of central UEMCS operations at Grafenwöhr. Starting in late 1987, the UEMCS was installed progressively in the MPA, and currently about 80% of the buildings and facilities in this area are under some form of UEMCS control. Although the UEMCS can control night setback (including designated day shutdown) in most buildings and facilities, setback is practiced in less that 50% of the MPA buildings. As a point of reference, the hot water district heating (DH) system in the MPA began operation in 1989. Building energy conservation retrofits (e.g., ceiling/roof insulation, external wall insulation, multi-pane windows) in the MPA and field camps started during 1985 and were essentially completed during 1991.

2.2 CONTROL SYSTEM DESCRIPTION

The UEMCS at the Grafenwöhr base is an AEG model CBA 130 (upgrade of AEG model Geazant 10). The system hardware is divided into control room/utilities office area equipment and field-located equipment called FIDs (Fig. 1). A cabinet in the control room houses the system central processing unit (CPU), hard- and floppy-disk drives for program and data storage, a video driver for the operator's video display, and terminations for cabling to the FIDs. The control room also contains an operator's video display, four printers for report and alarm documentation, a main programming and maintenance terminal, and a personal computer (PC) with interface software that allows programming and maintenance of the UEMCS. Programming and maintenance PCs are also located in the stove shop maintenance area and in the utilities office area (see Figs. 2, 3, and 4).

The data transmission medium between the control room and the FIDs is twisted/shielded-pair cabling. A total of 12 bus lines are available from the CPU to the FID network. Each bus line is capable of connecting to 99 FIDs. Communications occur at the rate of 1200 baud. The FIDs are of two types: an older version with fixed input/output (I/O) capabilities and a newer version in which the I/O can be mixed by inserting cards of different types. The newer version also has higher I/O capacity. The older version was limited to 40 digital inputs, 16 analog inputs, and 16 digital outputs. (Analog outputs were evidently not a

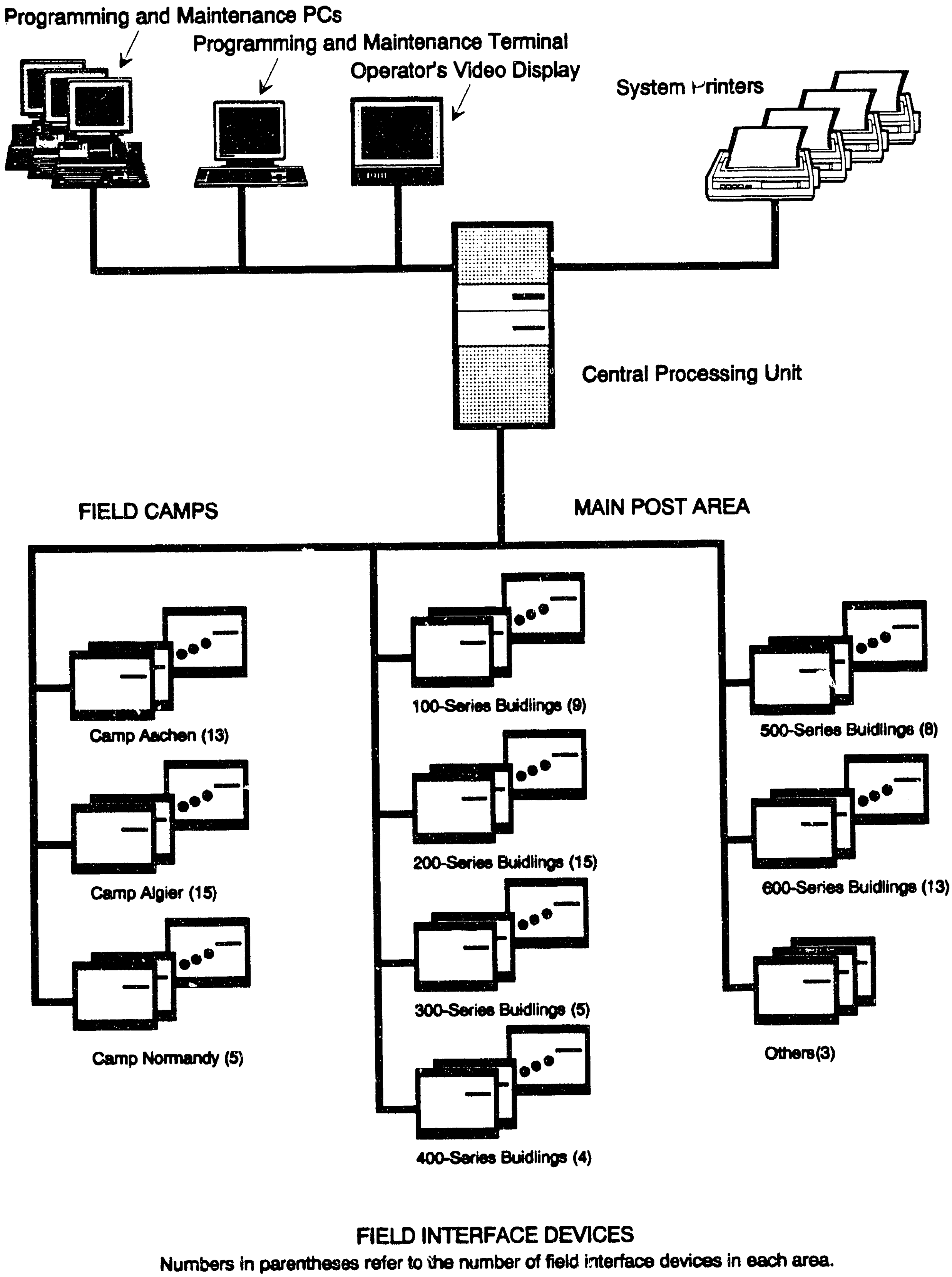

Fig. 1. AEG utilities energy monitoring and control system architecture.

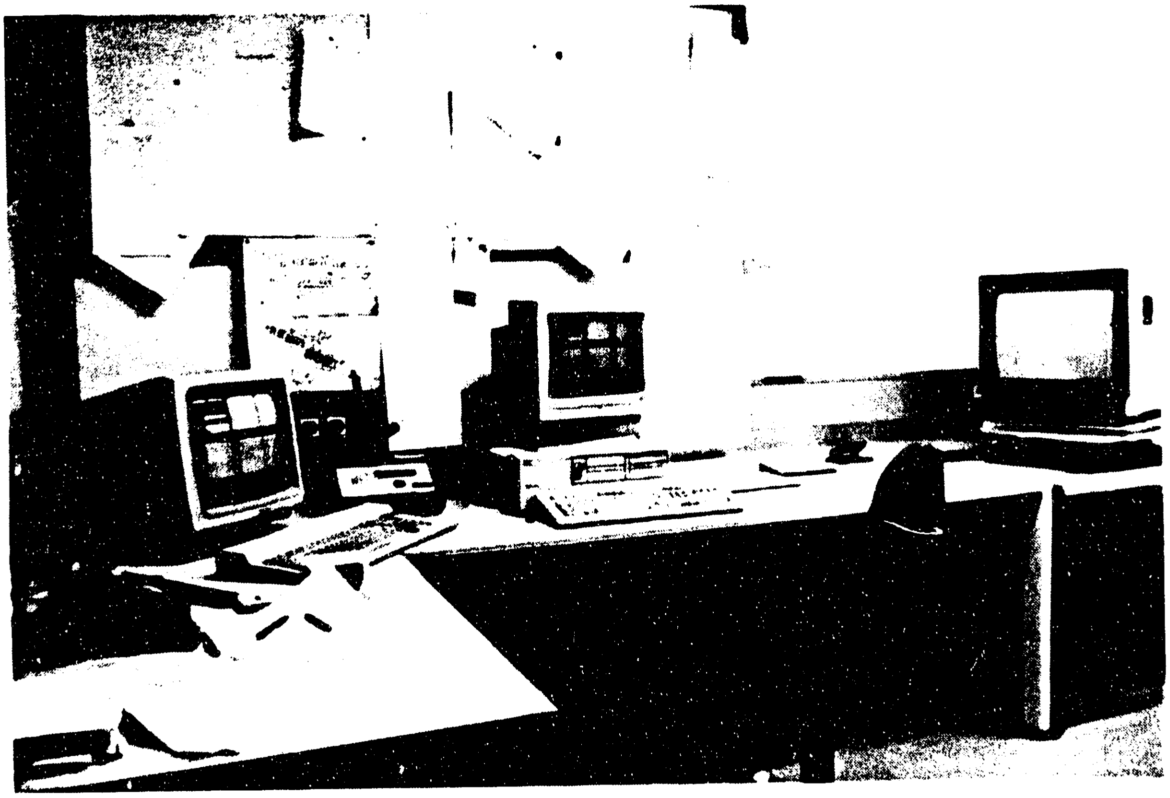

Fig. 2. UEMCS operator's central control station, including, from left to right, programming and maintenance terminal, personal computer, and the operator's video display.

standard feature of the old FIDs, but UEMCS personnel were able to wire in analog outputs when needed.) The newer version accepts any mix of up to 16 cards. The card types and capacity per card are digital input, 24; analog input, 16; analog output, 8; and digital output, 6. Grafenwöhr personnel have found the older types limiting and have requested upgrades to the newer models. The older version is also more susceptible to lightning damage.

In the field, local/auto control at each FID is provided by a switch. The status of the switch is monitored by the UEMCS. If a problem arises with the FID, the switch can be changed from auto to local control to enable continued operation of the heating or electrical system. Because the switch status is monitored by the UEMCS, unreported field problems will be logged by the UEMCS and noted by UEMCS operating personnel for subsequent action. Monitoring the switch status also allows UEMCS operating personnel to observe when tampering with the local UEMCS equipment has occurred.

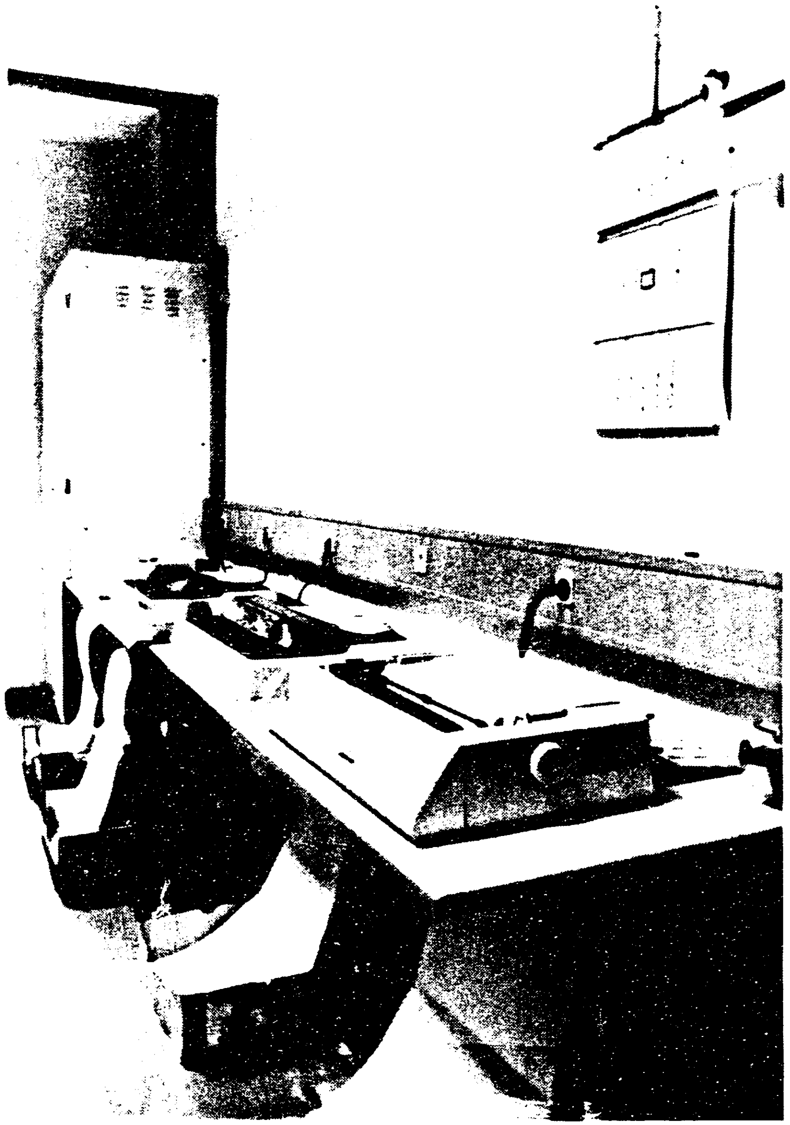

Fig. 3. UEMCS printers (foreground) and central processing unit cabinet (background).

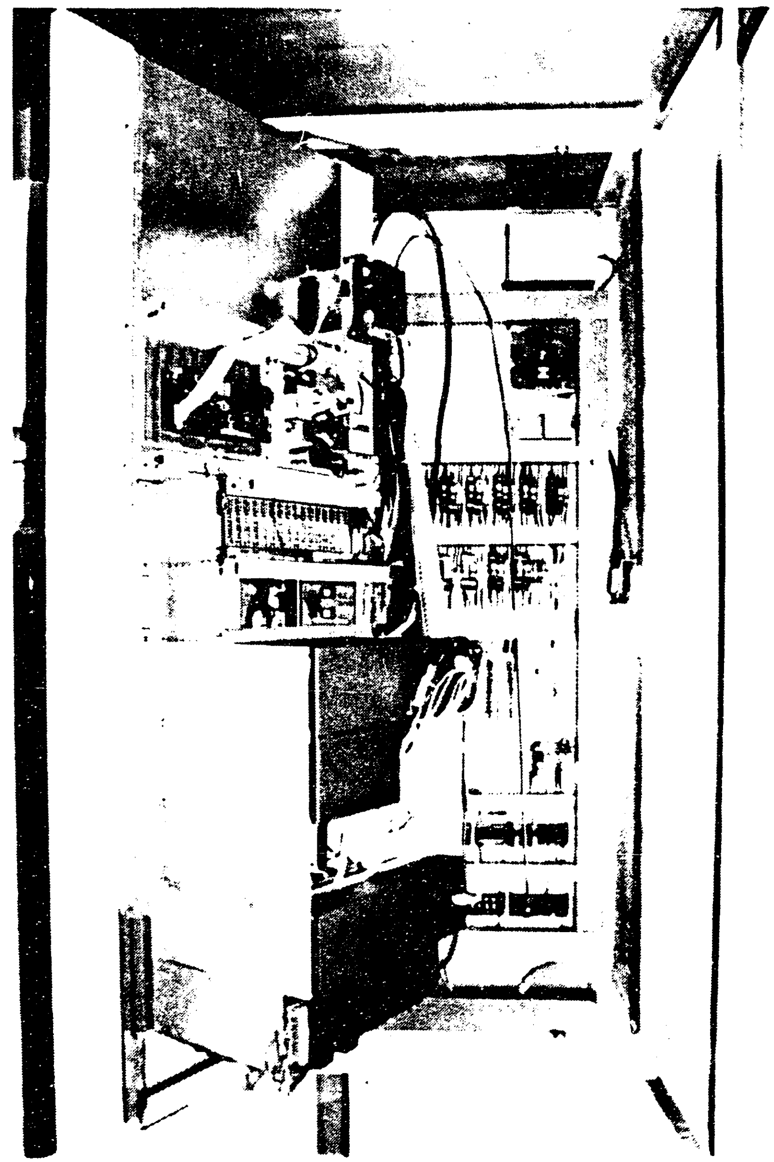

Fig. 4. UEMCS central processing unit cabinet with front subpanel opened to show internal contents and the electrical terminations in the rear.

2.3 MONITORING AND CONTROL OF THERMAL ENERGY SYSTEMS

Over 75% of the total energy consumed by the Military Community at Grafenwöhr is thermal energy. Over 50% of this thermal energy is consumed in the MPA and over 35% in the field camps. Thermal energy for space heating of buildings and for domestic hot water heating are, therefore, major targets for improved energy efficiency and reduced energy consumption using the UEMCS.

2.3.1 Field Camps

Camps Aachen, Algier, and Normandy are military field camps used by soldiers participating in short-term (several weeks) field training exercises. The field camps comprise a series of living quarter complexes, each normally consisting of eight barracks, two mess halls, and one shower and latrine building. Approximately 30 of these living quarter complexes are connected to the UEMCS. During a field trip the following buildings, making up a typical field camp living quarters complex in Camp Algier, were visited:

- Building 2225—shower and latrine
- Building 2344—mess hall
- Building 2343—barracks (billet)

The UEMCS substation shown in Fig. 5 is located in building 2225. Also located in this shower and latrine building is an oil-fired boiler that generates domestic hot water not only for the shower and latrine building but also for the mess halls. In addition, this boiler provides building 2225 with thermal energy for space heating via a water-to-air heat exchanger. Separate oil-fired furnaces with air-to-air heat exchangers and ventilation fans provide space heating for each of the mess halls and barracks. No hot water is provided to the barracks. The UEMCS provides the following monitoring and control functions:

- **Barracks (Billet)**

  An oil-fired furnace and associated ventilation fan, similar to the one shown in Fig. 6, are used for space heating and ventilation. When the building is occupied, the UEMCS controls this furnace to maintain a space heating temperature of 65–68°F (18–20°C). This equipment is shut off when the building is unoccupied for extended periods. The UEMCS is capable of temperature setback but is not used to perform this function because of the unpredictable 24-hour occupancy patterns of troops using the barracks. The UEMCS also is capable of monitoring room temperature.

- **Mess Halls**

  The oil-fired furnace and associated ventilation fan shown in Fig. 6 are controlled by the UEMCS to maintain a space heating temperature of 65-68°F (18–20°C) during occupancy, but they are shut down when the mess hall facilities are not in use for an extended period. Again, the UEMCS is capable of temperature setback but is not being used for the reasons stated earlier. The UEMCS also is capable of monitoring room temperature and of turning the electric power on or off to the three large refrigerators in each mess hall. Domestic hot water from the mess halls is generated by the oil-fired

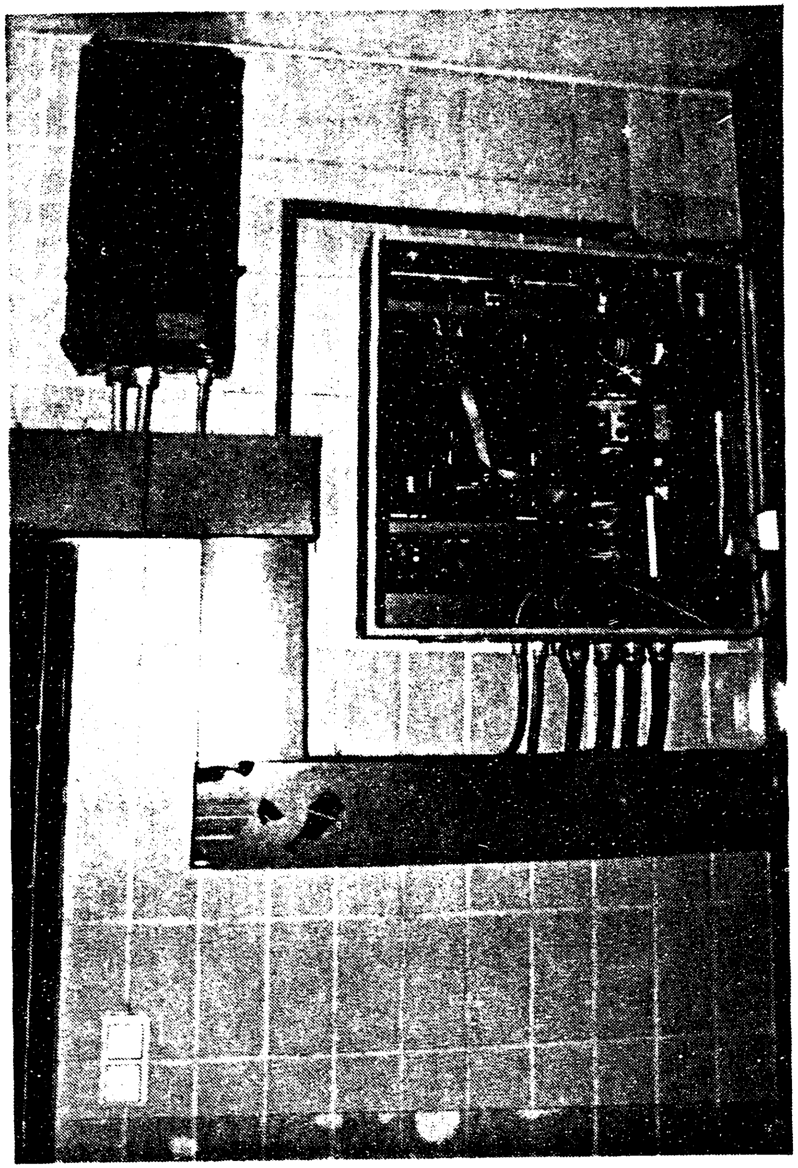

Fig. 5. Field Camp Algier, shower/latrine building 2225, typical utility and energy management control system substation field interface device.

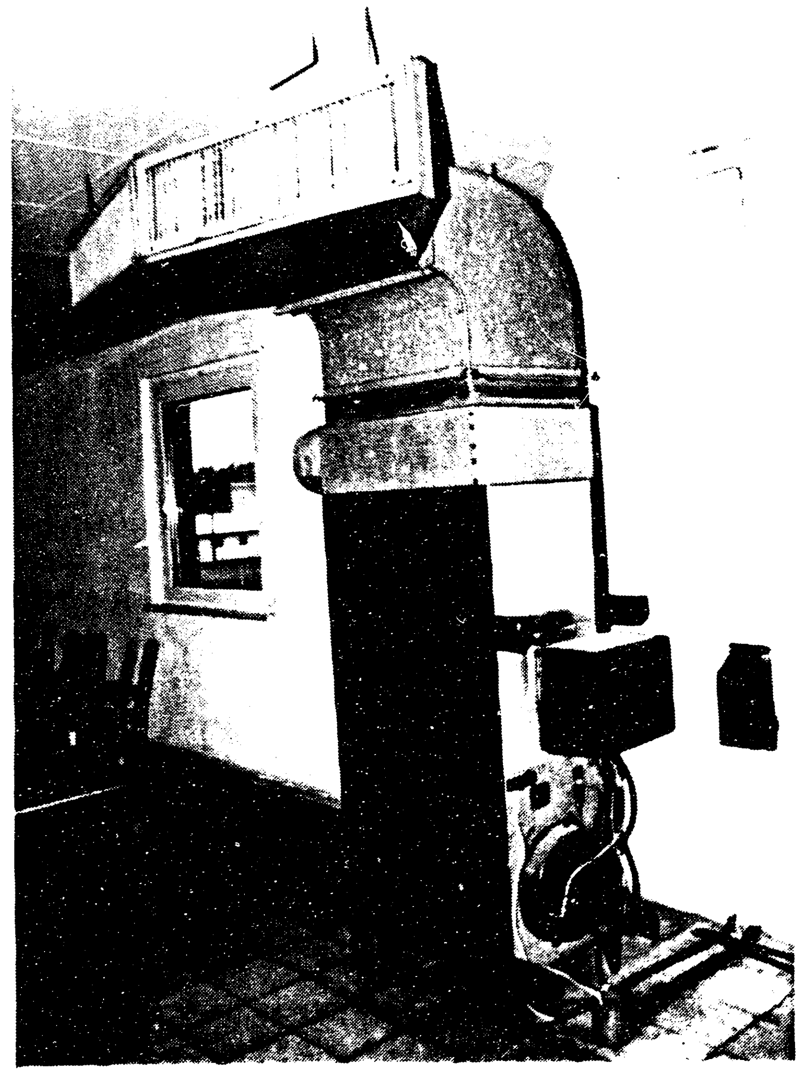

Fig. 6. Field Camp Algier, mess hall building 2344, typical oil-fired furnace for space heating.

boiler located in the shower and latrine building. The temperature of the hot water is controlled by the UEMCS.

- **Shower and Latrine**

  The typical shower and latrine operates under four different scenarios:

  - *Winter occupied.* The building temperature is maintained at 68–70°F (20–21°C); the domestic hot water is maintained at 158°F (70°C); and the ventilation system is automatically turned on if the relative humidity in the shower and latrine facility exceeds 65–70%. The hot water is maintained at such a high temperature because more than the planned number of troops occupy the typical barracks and use the shower and latrine.

  - *Winter unoccupied.* The space heating temperature is maintained at a minimum 59°F (15°C) to prevent freezing of water pipes (domestic hot water is not heated), and the ventilation system will operate if the relative humidity level exceeds 65–70%.

  - *Summer occupied.* The ventilation system will operate if the relative humidity exceeds 65–70%, and the domestic hot water is maintained at 158°F (70°C). The oil-fired boiler is used only for ventilation, not for heating, during the summer.

  - *Summer unoccupied.* The only UEMCS control function operating is the ventilation system, which will switch on if the relative humidity exceeds 65–70%.

The UEMCS also monitors room temperature, room relative humidity, supply air temperature, return air temperature, and secondary domestic hot water temperature in the field camp living quarter complex buildings.

2.3.2 Main Post Area

The central hot water DH system comprises a primary high-temperature 320°F (160°C) DH distribution system connected via primary heat exchangers to nine DH substations or heat islands. The secondary side of each of these heat exchangers is connected to a secondary low-temperature 194°F (90°C) DH system that distributes thermal energy to the various buildings and facilities located in these heat islands.

Fränkische Gas-Liefrungs, GmbH (FGL) is a private utility that constructed a gas-fired boiler DH plant just outside the fence of the MPA (Fig. 7). This facility was built at no cost to the U.S. government, which in return guarantees a thermal energy load for 10 years. The four gas-fired water tube boilers, shown in Fig. 8, have a nominal capacity of 2,900 MBtu/h (8,500 kW) each. They produce 230–320°F (110–160°C) hot water at 205 psi (1.4 MPa) that is supplied through 12-in. (25-cm) diameter pipes to the MPA primary high-temperature DH distribution system. The return hot water from the primary distribution system ranges from 176 to 194°F (80 to 90°C), depending on the season of the year.

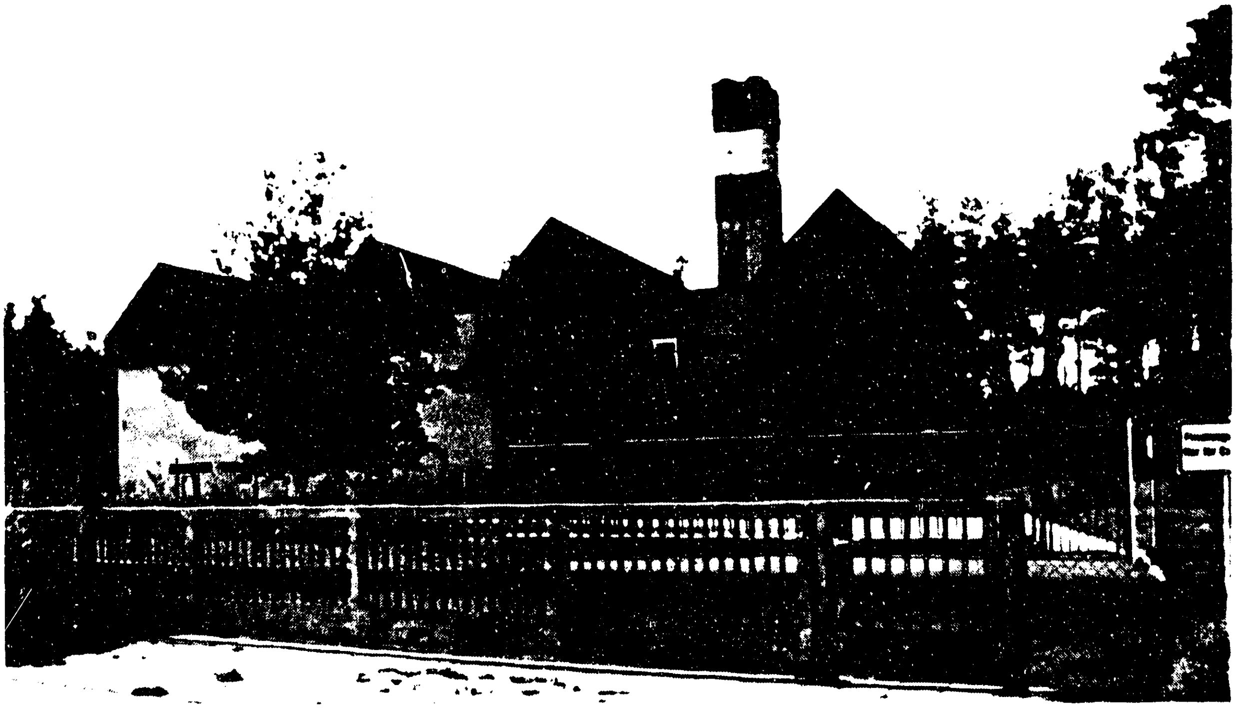

Fig. 7. Private utility (Frankische Gas-Lieferungs, GmbH) gas-fired boiler, hot water district heating plant serving the Grafenwöhr main post area.

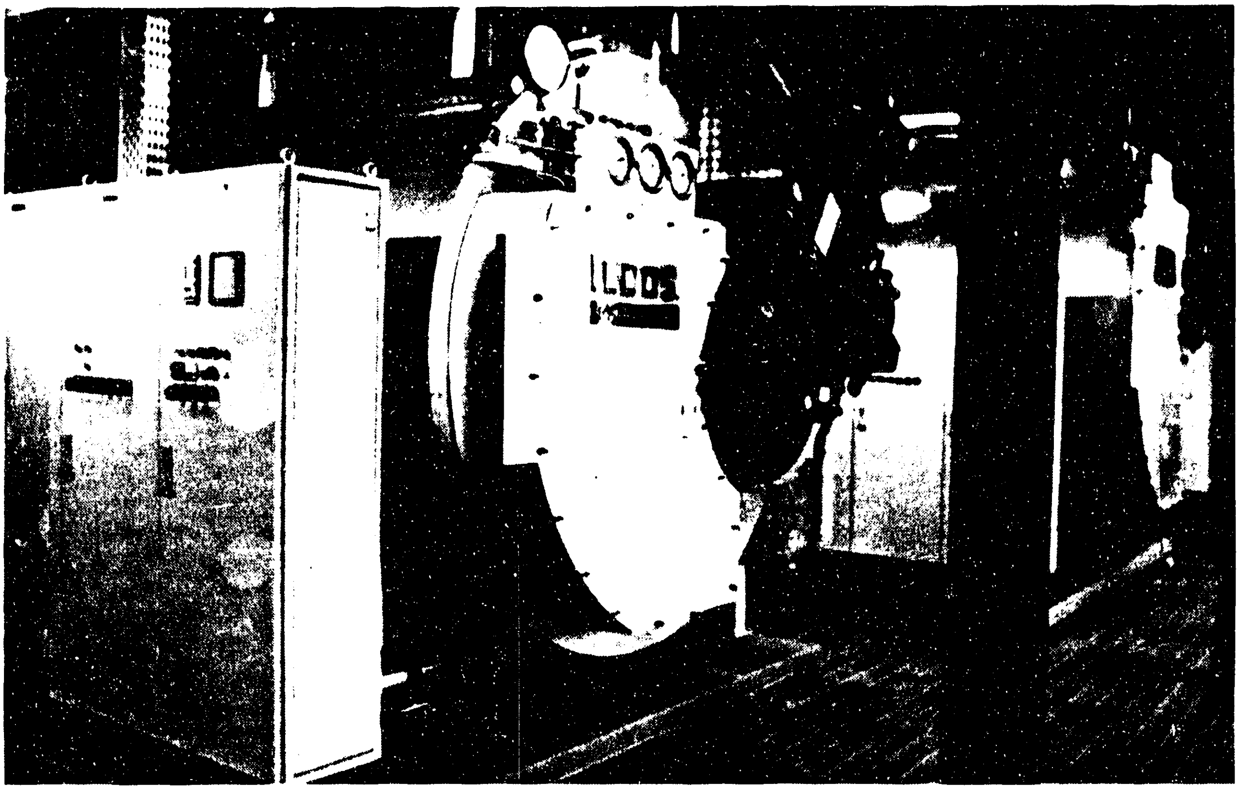

Fig. 8. Hot water district heating plant, gas-fired water tube boiler.

The DH substation in building 285, which is typical of other DH substations, was visited (Fig. 9). It provides thermal energy to more than 50 buildings located in the MPA, most of them military family housing. In the substation are water-to-water heat exchangers that receive the high-temperature hot water on the primary side and distribute it on the secondary side as low-temperature hot water to the buildings in this heat island. The temperature of the secondary hot water varies from 176°F (80°C) in the summer to 194°F (90°C) in the winter. Return secondary distribution system temperatures range from 158 to 167°F (70 to 75°C). The UEMCS FID performs the following control functions in the building 285 DH substation:

- control of the mixing valves that regulate the flow of high-temperature hot water to the heat exchangers in the primary high-temperature distribution system;
- control in the secondary low-temperature distribution system of the variable-speed pumps that control the flow of low-temperature hot water to the various buildings served by the substation;
- control (on/off) of water flow (primary and secondary) for selected heat exchangers, providing the ability to deactivate a particular heat exchanger.

In addition, the UEMCS monitors the following points:

- primary supply temperature;
- primary return temperature;
- primary return flow rate;
- secondary supply temperature;
- secondary return temperature and pressure; and
- status (on/off) of distribution system equipment such as pumps and valves, and of system alarms such as the secondary system high-temperature alarm.

Low-temperature 176-194°F (80-90°C) hot water from the substation circulates through the secondary distribution system to the MPA facilities and buildings that make up a heat island (Fig. 10). Two family housing units (buildings 202 and 275) that are supplied with thermal energy from the building 285 DH substation were visited. Figure 11 illustrates the thermal energy distribution system for space heating and domestic hot water heating of these family housing units. The thermal energy distribution system illustrated in Fig. 11 is typical of the DH/UEMCS installation in many other MPA buildings.

Note that night setback of the space heating system is the principal conservation measure controlled by the UEMCS to reduce thermal energy consumption in the MPA. Currently, night setback is practiced in less than 50% of the MPA buildings. Where it is practiced, the building space heating system nominal daytime operating temperature of 71.5°F (22°C) is set back at night to 64.5°F (18°C). Setback periods vary according to building use. For example, temperature setback starts in family housing at 23:00, and normal space heating temperatures are restored at about 03:30. During the winter, the temperature of the hot water to the radiators is varied from 86 to 140°F (30 to 60°C), depending upon outside temperature, to achieve night setback. During the summer, heat is provided as required for several hours during the morning (04:30 to 09:00) and in the evening (18:00 to

Fig. 9. Main post area building 285, district heating system substation.

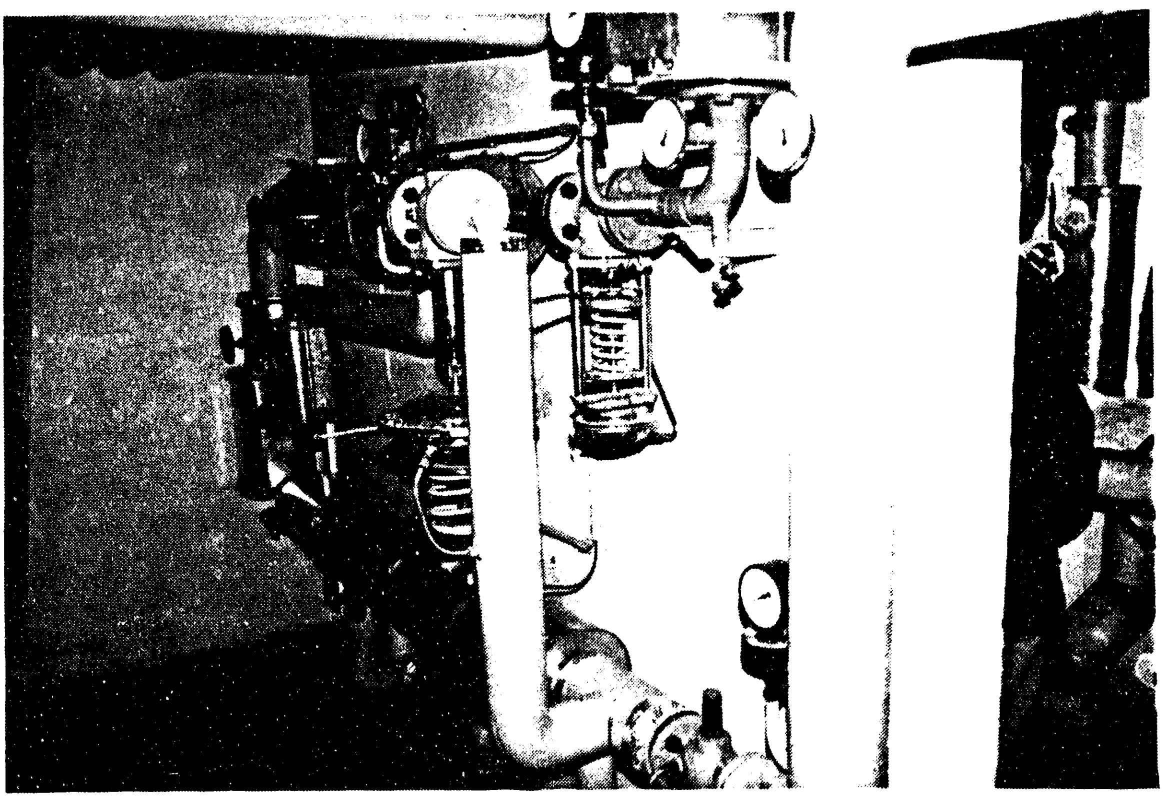

Fig. 10. Main post area building 275, typical family housing unit, low-temperature hot water district heating installation.

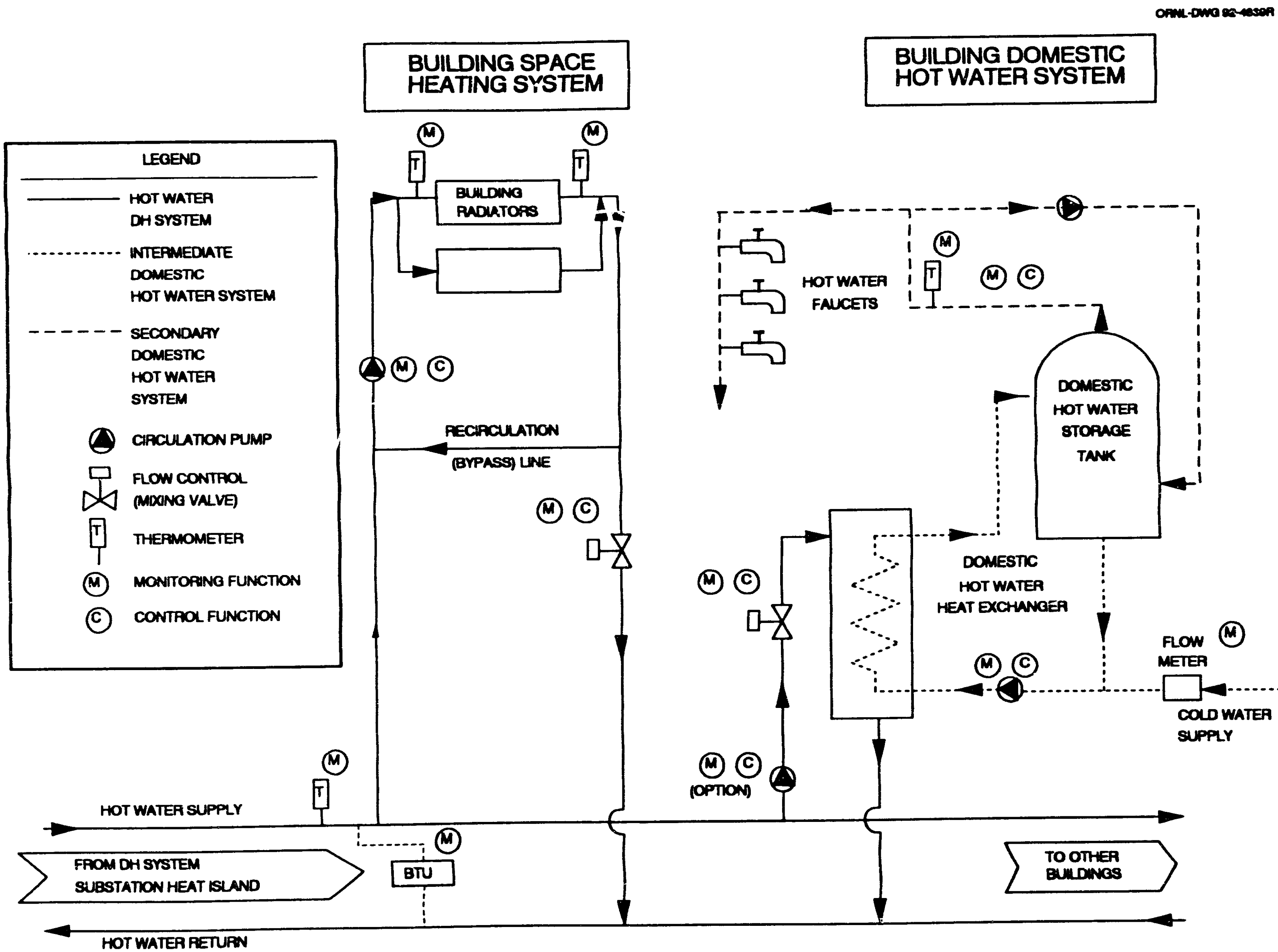

Fig. 11. Grafenwöhr main post area: typical district heating system/utility and energy management control system building installation.

22:30). In other cases, the circulation is shut off entirely; that is, no heat is provided to the radiators.

Typically, the low-temperature hot water from the substation is circulated through the radiators for space heating and through a domestic hot water heat exchanger for domestic hot water heating. The temperature of the water returned from the radiators is maintained in the range of 86–140°F (30–60°C) by controlling the mixing valve. This set point temperature depends upon the season and the outside temperature. During summer, the entire hot water space heating system can be shut down. This is done under UEMCS control by shutting down the circulation pump and closing the mixing valve simultaneously (no recirculation). The hot water from the substation is circulated through the primary side of the domestic hot water heat exchanger. The domestic hot water temperature is manually set in the range of 122–140°F (50–60°C) to suit conditions in individual MPA buildings. This set point temperature is maintained primarily by UEMCS control of the pump that circulates hot water in the intermediate domestic hot water system through the secondary side of the domestic hot water heat exchanger. A secondary domestic system circulates hot water between the domestic storage tank and the faucets located in individual rooms. The UEMCS also controls the pump that circulates domestic hot water through this secondary system. The pump currently operates 5 min in every 15 min, 24 h per day.

The UEMCS typically performs the following functions to control space and hot water heating of MPA buildings and facilities:

- Control of the mixing valve in the return line to the substation to maintain the temperature of the hot water circulating through the building radiators.
- On/off control of the circulation pump that supplies hot water from the substation to the radiators.
- On/off control of the pump that circulates hot water through the intermediate domestic hot water system between the domestic hot water storage tank and the secondary side of the domestic hot water heat exchanger.
- Control of the pump that circulates hot water through the building secondary domestic hot water system. NOTE: DOMESTIC HOT WATER TEMPERATURE IS NOT CONTROLLED DIRECTLY BY THIS PUMP.
- In more recent installations, control of the mixing valve in the hot water supply line from the substation controlling the flow of water to the domestic hot water heat exchanger.

In addition, the UEMCS monitors the following points:

- domestic hot water temperature,
- cold water flow into the domestic hot water system,
- status of circulating pumps,
- hot water supply temperature from the substation,
- hot water supply temperature to the radiators,
- hot water return temperature from the radiators, and

- heat value (Btu meter) of water returned to the substation.

2.4 MONITORING AND CONTROL OF ELECTRICAL ENERGY SYSTEMS

Monitoring and control of electrical energy is limited at Grafenwöhr. During the late 1980s, 70 to 80 electrical meters were installed under the auspices of the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory in a cross-section of locations to evaluate electrical consumption at the base. These meters are monitored by the UEMCS, but the data are not saved. At the UEMCS console, three categories of data are tabulated: the current day's consumption, monthly consumption, and yearly consumption. The consumption data are printed out only on request. UEMCS personnel have software to allow saving the data to hard disk or tape, but they have not implemented it yet. The energy conservation manager has none of the electrical consumption reports. Plans are to install a PC connected to the UEMCS in the energy conservation manager's office. When that terminal is connected, the manager will have better access to the consumption data.

Refrigerators at the field camp mess halls, main post clubs, and the Burger King restaurant will have load-shedding capability soon. Presently, the UEMCS can enable and disable operation of the refrigerators. UEMCS personnel are awaiting the installation of signal lines that will transmit electrical demand data from Obag GmbH, the electrical utility. With this information, the UEMCS can be programmed to load shed the refrigerators during peak demand times.

Other areas that could benefit from demand limiting include the cold storage facility in building 295—where huge refrigerators cool provisions for troops and other base personnel—and several sites that use air conditioner units. The base has a total of 26 unitary unit air conditioners for a total rating of 480 kW, and 21 window units for a total of 110 kW.

Street lighting control is through local twilight switches, except at one street in the field camp where lights are controlled by the UEMCS. Problems have arisen with the twilight switches, especially in the field camps where the switch photodetectors become covered with dust and keep the lights on for too long.

Electrical energy consumption at Grafenwöhr is lowest in the summer months, higher in the winter and spring months, and highest in the late autumn months. Figure 12 shows monthly electrical energy consumption and peak demand from 1989 to 1991. Generally speaking, peak demand and total consumption track each other, although in 1990 peak demand during the summer and early fall months appeared to be higher than normal. High excursions in peak demand, as shown, indicate that peak shaving probably could have been used to save money. On a daily basis, typical electrical consumption curves for the base can be divided into weekdays and weekend days. Figure 13 shows the average weekday and weekend day for August 1992. The average consumption is arrived at by summing consumption in 15-min intervals for all days in each category and dividing by the number of days in each category. The average weekday shows a sharp rise in demand between 07:00 and 08:00, a dip in demand at lunch time, and a drop in demand between 16:00 and 17:00, as would be expected for a typical work day. Between 20:00 and 23:00, there is another peak, which is attributed to housing occupants' use of electricity for dinner preparation, entertainment, and lightning. For the typical weekend day, the demand is fairly flat all day except for a peak between 20:00 and 23:00, similar to the weekday peak during this time period.

Figure 14 shows electrical demand for the day of August 20, 1992. This day contains the peak demand for the month. Unlike most other days that show fairly flat demands in the morning and afternoon, August 20 shows very jagged peaks in the afternoon. This represents a potential peak-shaving opportunity. Obag, the electrical utility, bills Grafenwöhr for peak demand at the rate of 232.8 DM/kW, which is applied to the average of the two highest peaks for the year. The two peaks usually occur in the fall. Daily demand data for other months of the year were not gathered, but to demonstrate a point, assume that the month of August represents the peak demand for the year. As shown in Fig. 14, it appears that ~160 kW of demand would have to be load shed for 45-90 min to shave the peak off the demand curve. For thermal loads, 45-90 min is not an extraordinarily long time constant, especially if load shedding can be shared among similar units (some units operate while others are switched off). At the rate of 232.8 DM/kW and the 1992 exchange rate of 1.9 DM to $1 (and assuming that this example represents the average of the two highest peaks for the year), a savings of $20,693 would be attributed to peak shaving the electrical load shown for August 20, 1992 by 160 kW for 45-90 min. This example cannot show the actual benefits that could be obtained from implementing peak shaving because electrical demand data were not available for the months that contained the highest demand peaks. However, the example does show that the electrical demand curve does contain spikes on certain days, and this is where peak shaving can have the most cost-savings benefit.

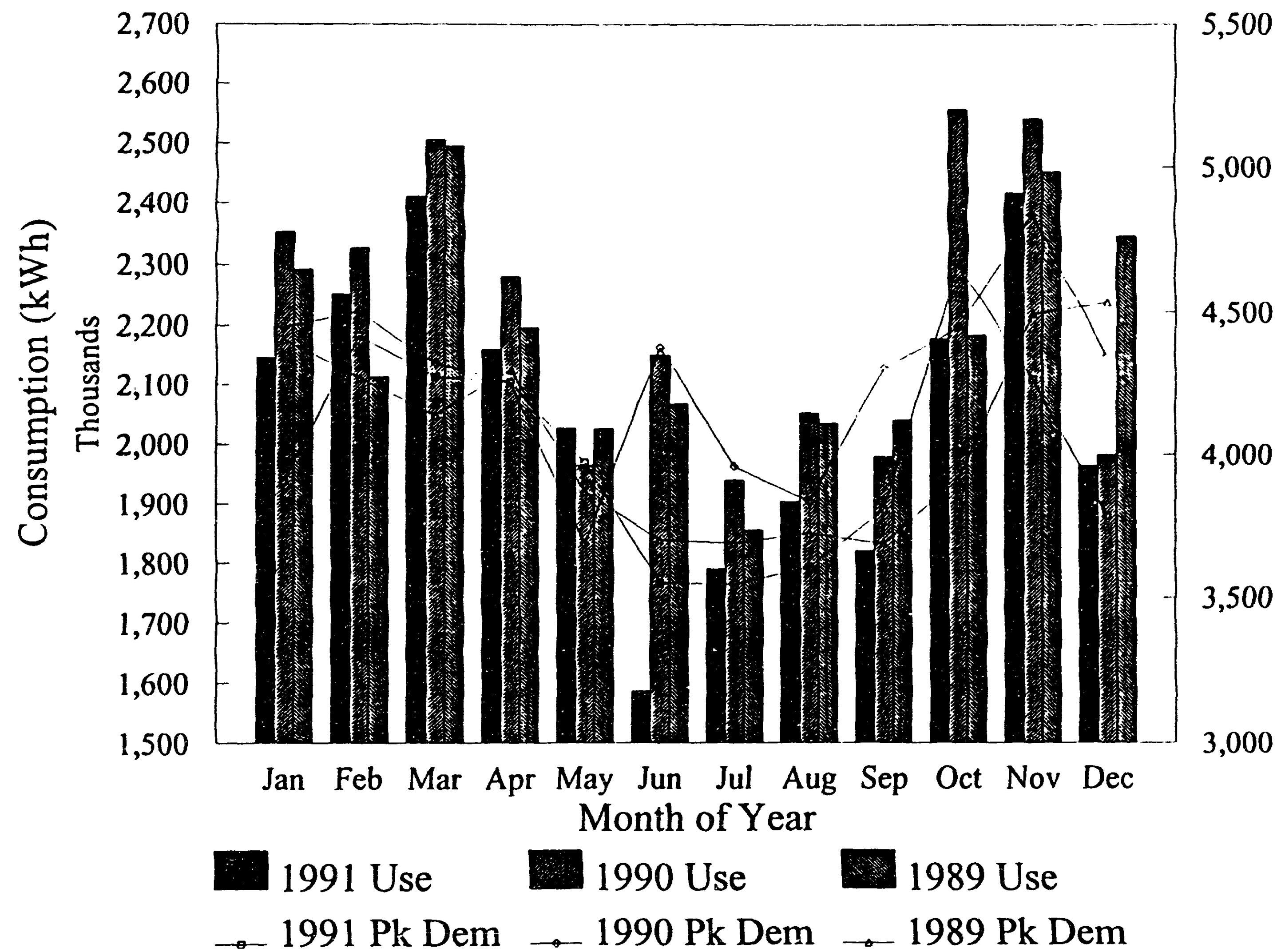

Fig. 12. Grafenwöhr electrical energy consumption and peak demand, 1989–1991.

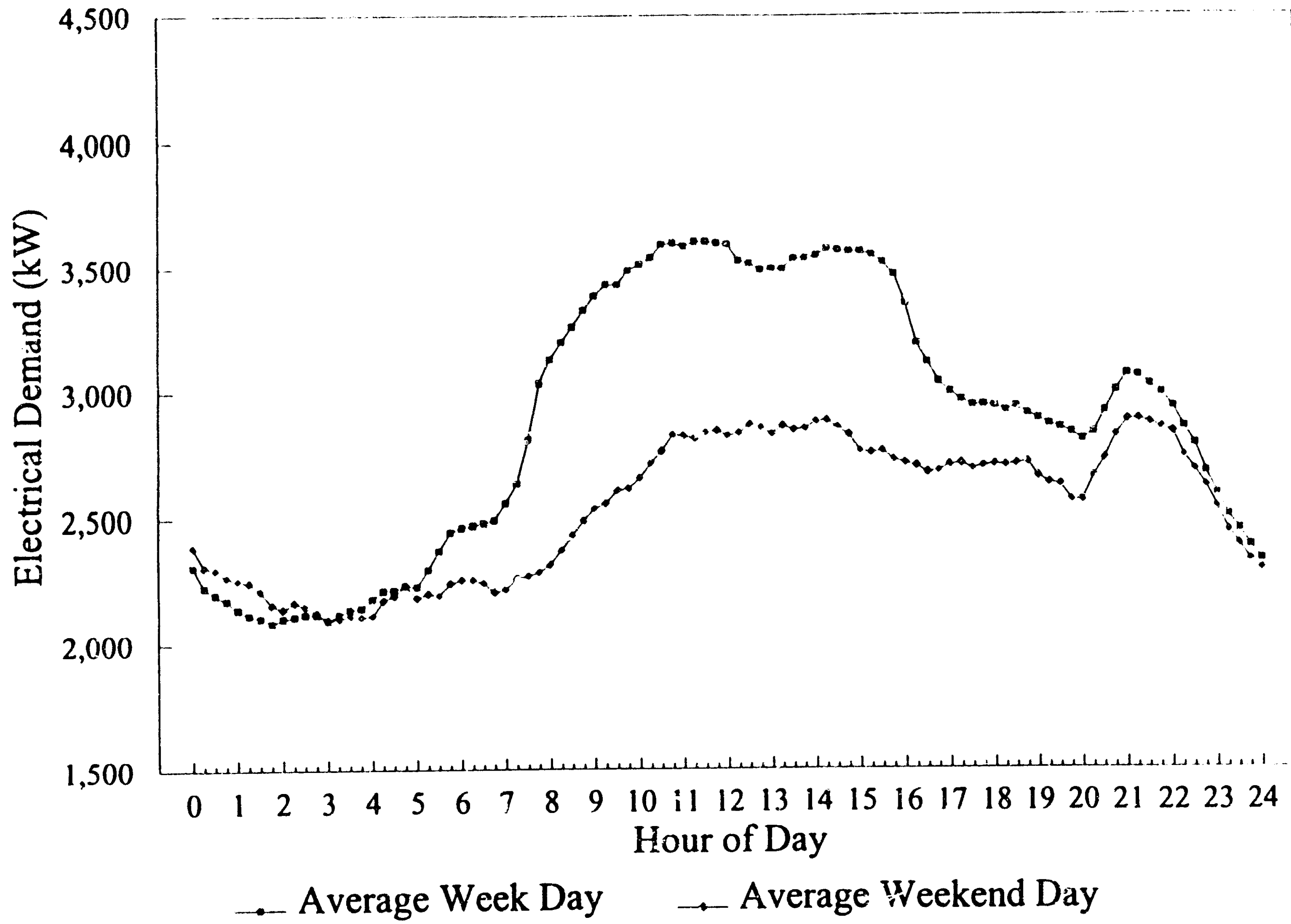

Fig. 13. Average electrical demand for weekday and weekend day, August 1992.

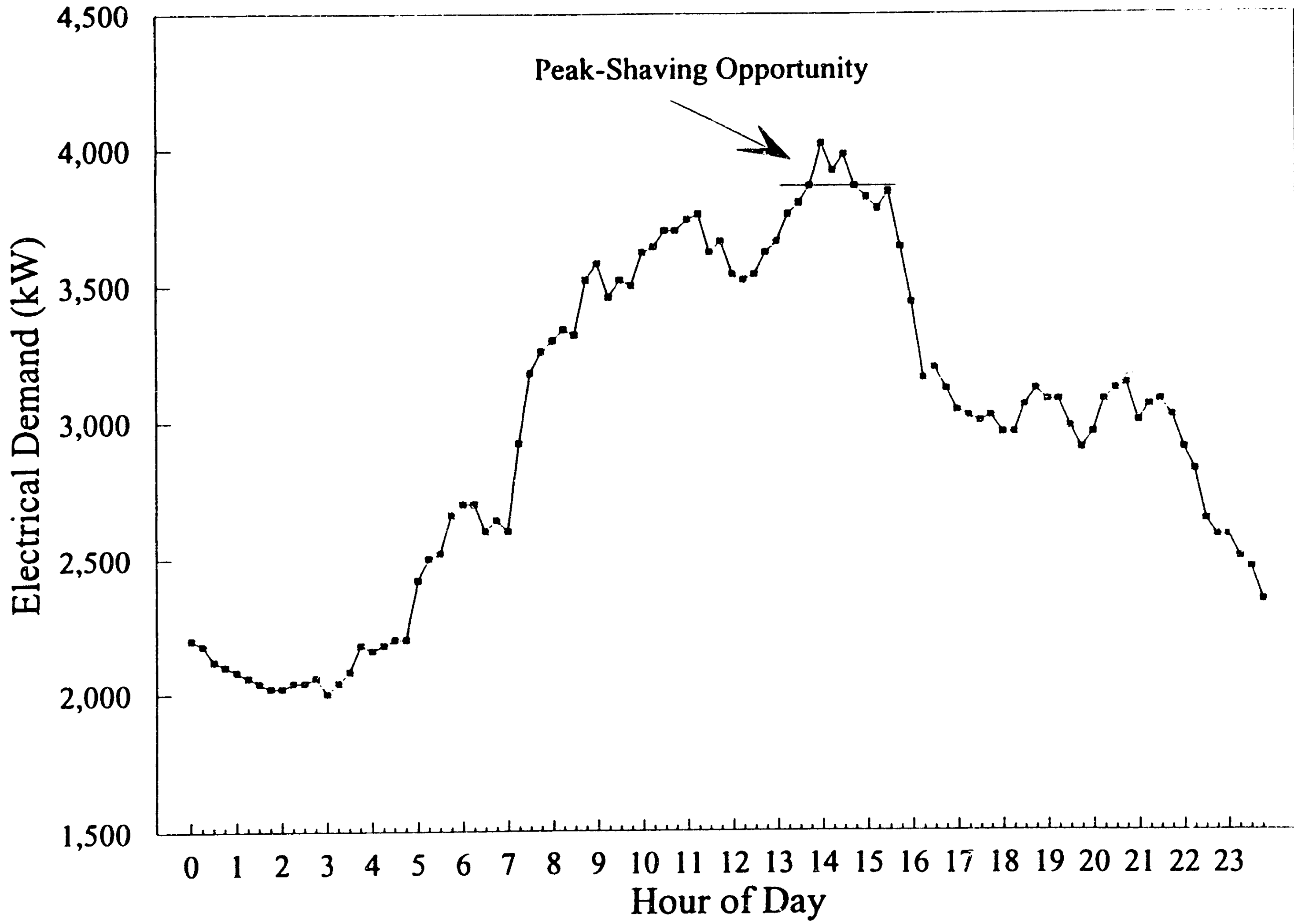

Fig. 14. Electrical demand for August 20, 1992, showing peak-shaving opportunity.

3. EVALUATION OF PROJECT DOCUMENTATION

On July 13, 1992, a letter was sent to Headquarters USAREUR requesting that copies of selected UEMCS project documentation and other pertinent records be made available for review by ORNL personnel during their scheduled visit to Grafenwöhr. The requested information was assembled by Grafenwöhr DEH Utilities Division personnel for use by ORNL personnel during the 2-week site visit. During the course of the visit, the ORNL principal investigators posed many questions and requested pertinent supplemental information. All questions were answered in a forthright and open manner. Whenever supplemental information was available, it was provided to the investigators in a timely manner. Overall, the quality of project documentation was satisfactory, and the cooperation afforded ORNL investigators by DEH management and UEMCS operations personnel was excellent.

Because the site visit occurred September 7-18, 1992, complete FY 1992 fuel/energy consumption data were not available, Accordingly, DEH personnel were requested to furnish this information to the investigators as soon as it became available. Upon returning to ORNL, the investigators began their analysis and evaluation of the UEMCS and identified additional information and data necessary to complete the evaluation. DEH personnel were requested to furnish this information, which was received at ORNL on November 19, 1992.

The AEG model CBA 130 UEMCS installed at Grafenwöhr is well documented in terms of manuals, engineering drawings, etc. Likewise, the engineering drawings and associated data describing the installation of this UEMCS to the various Grafenwöhr electrical and thermal energy systems are well documented. This documentation enabled the investigators to gain a thorough understanding of UEMCS operations in a timely manner.

Attention was next directed toward gaining a better understanding of fuel/energy consumption trends at Grafenwöhr over a 10-year period during which the major energy conservation projects were implemented. These projects included progressive installation and operation of the UEMCS, progressive implementation of building envelope energy conservation retrofits, and the installation and operation of the hot water DH system in the MPA. Good general records of the total annual energy consumption by fuel/energy type are maintained by 100th Area Service Group DEH, Utilities Branch personnel. Unfortunately, these general records do not subdivide energy consumption data for the major areas such as the MPA and the field camps. Therefore, overall energy consumption trends can be determined on an annual basis but cannot be determined accurately on an area-by-area basis, for example, for Camp Aachen or the 200 series buildings in the MPA. Fortunately, fuel oil consumption records are maintained for the various main areas of Grafenwöhr. The investigators therefore were able to perform a comparative analysis of thermal energy consumption (MBtu/year) and thermal energy efficiency (Btu/HDD/ft^2) for the various major areas. The results of these analyses are illustrated in Sect. 5.

Unfortunately, good cost records associated with the procurement and installation of the UEMCS have not been maintained over the years. The series of Military Construction Project Data sheets (DD Form 1391) do not accurately reflect the actual UEMCS installed at Grafenwöhr. For example, they specify a "ripple" control system similar to the Computerized Utilities Monitor and Control System (CUMACS) installed at Heidelberg, when the Grafenwöhr UEMCS actually uses a cable-based twisted/shielded pair data transmission medium. Initial project cost estimates documented on the Form DD-1391 for this project do not accurately reflect current actual costs. One reason is that the UEMCS has been progressively upgraded over the years, but the project documentation has not followed suit. For example, an updated life cycle cost analysis based on actual project cost has not been performed since before the initial UEMCS became operational during 1984. As a result, an accurate baseline of estimated energy and cost savings has not been established for the Grafenwöhr UEMCS.

Another problem with determining energy and cost savings attributed to the UEMCS is that DEH personnel apparently have not tried to calculate and document cost savings based on actual reduced energy consumption over the past 10 years (FY 1982–FY 1992). Furthermore, the net annual energy savings, based on reduced annual energy consumption, are reported only in general overall terms. Consequently, energy and cost savings attributed specifically to the UEMCS cannot be segregated from other major energy conservation program activities including large-scale building energy conservation retrofits and operation of the hot water DH system in the MPA. These complications will become more apparent in Sect. 5, which is an in-depth analysis of energy and cost savings.

4. ASSESSMENT OF SITE AND PHYSICAL CONDITIONS

4.1 MAIN POST AREA

The first impression on entering the Military Community at Grafenwöhr is of an attractive, well maintained facility with many of the attributes of a college campus. The buildings and facilities are spread out as in a suburban residential community. All major facilities are contained within a single geographic area, and the buildings and facilities under UEMCS control are further concentrated in East Camp Grafenwöhr. By contrast, many other USAREUR military installations in Germany are more congested, and buildings under UEMCS control are more closely concentrated within a given facility. Also, many other USAREUR installations are composed of a main facility and several satellite facilities located a considerable distance from the main facility. In many instances, this layout requires independent thermal energy systems as well as multiple UEMCSs. Grafenwöhr has the distinct advantage of being a single contained installation served by one versatile UEMCS.

Within the MPA, the Grafenwöhr UEMCS controls operations in approximately 80% of the buildings and facilities. Actual operations vary by building area, however. For example, the UEMCS operates in most of the MPA series 100 buildings, which are 80% family housing units, but in only about 50% of the almost exclusively administrative series 300 buildings. The series 400 buildings—consisting of 60% administrative buildings and other facilities including workshops, the officers club, and the dispensary—are estimated to be about 70% under UEMCS control. Even though 80% of the buildings and facilities in the MPA are under UEMCS control, less than 50% of them practice night temperature setback.

Currently no electrical energy systems in the MPA are under UEMCS control. DEH Utilities Division personnel report that they are on the verge of implementing demand side management for selected electrical systems. Although thermal energy systems historically represent the greatest potential for energy savings, UEMCS control of electrical energy systems also offers significant potential for energy and cost savings. Several primary candidates for UEMCS control of MPA electrical energy systems are as follows:

- refrigeration systems in cold storage building 295, including five 22 kW compressor units;
- air conditioning units, including 26 unitary air conditioners ($\sim$480 kW, total) and 21 window air conditioners ($\sim$110 kW, total);
- electric dryers in family housing units; and
- exterior street and building lighting.

Finally, several years ago CERL had elaborate electrical metering and instrumentation installed in selected Grafenwöhr MPA facilities. One of those is building 272, a typical family housing unit. Elaborate meters were installed to measure 110- or 220-V electrical energy supplied to each apartment, as well as to the washers and dryers in the basement. A separate meter also records total electrical energy consumption in building 272. Utilities Division personnel have an opportunity to use these meters to document building energy performance and determine the potential energy and cost savings resulting from the implementation of selected conservation measures.

4.2 FIELD CAMP AREA

The field camps were the first area of the base to have UEMCS control. Installation of the system started in 1984 at Camps Aachen and Algier. At first a portable computer had to be used for local configuration of the FIDs. At that time, only local programming could be done. In 1987 the system was upgraded so that overriding of control parameters could be done from the central control room. Installation of the UEMCS in Camps Aachen and Algier is complete, although the FIDs installed there are outdated. A newer type of FID would allow more I/O capacity and be less susceptible to lightning damage (see Sect. 2.2). Installation of the new type of FID for the UEMCS in Camp Normandy, which began in 1990, is about half finished. The two remaining camps at the base, Kasserine and Cheb, do not have UEMCS interfaces.

Tampering with the UEMCS was a problem at first in the field camps. Ice packs were placed over the temperature sensors in an attempt to heat the barracks to a higher temperature than the UEMCS had been programmed for. Switching the FIDs from automatic to manual mode was another unauthorized way to override the UEMCS to provide additional heat. These occurrences have decreased as UEMCS personnel have made field camp personnel more aware of the proper operation and benefits of the system.

Night setback is still not implemented in the field camps because troops often return to the camp in the middle of the night and desire warm facilities while preparing to go to sleep.

The field camp building inspector checks building occupancy and alerts UEMCS personnel when the building will be empty. UEMCS personnel then program the FIDs to shut the heat off for the period when the buildings are unoccupied. Plans are in place to install occupancy sensors, but they have not been implemented yet.

There are about 20 motor pool buildings in the field camp areas. These buildings are used periodically on an unpredictable schedule (normally 3-6 week periods to repair military vehicles). While these buildings are in use, they use large quantities of fuel oil for space and hot water heating. Large doors are often left open during cold weather, and the oil-fired boilers are left on after the users of the motor pool buildings depart. These buildings are not currently under UEMCS control. If they were, features would be added such as interlocks on the doors to shut down the boilers automatically if the doors are open, switches that must be activated every 12 or 24 hours to ensure continued boiler operation for heating, and sensors to monitor occupancy.

Currently only one street in the field camps has exterior lights that are under UEMCS control. The investment costs for connecting all street lights presently controlled by twilight switches to UEMCS control would not be recovered by the savings from using UEMCS control. Only if a new street light system is installed or old lights are replaced will the connection to the UEMCS be made. The proposed system would use lamps with two bulbs, one of which would be shut off during late off-duty hours.

Storage tanks for fuel oil are located near the barracks. A leakage monitor alarm feeds into the UEMCS, but the level of fuel in the tanks must be checked manually. There would be no return on investment to install level sensors on these tanks now because of the high cost of the retrofitting labor necessary. However, the relatively low capital and labor cost of installing level sensors in replacement or additional fuel oil tanks, if they are necessary for other reasons, would be paid back in a short interval. Less manpower would be needed to check fuel levels because they could be monitored remotely at the central control room.

The temperature of the water in the shower buildings is kept at a higher-than-normal level because of lack of capacity in the hot water heating system. There are times when more soldiers use the showers than the system was designed for. To compensate for the higher-than-normal flow of water during these times, the temperature is increased.

The field camp area is periodically used for reforgers, events in which as many as 25,000 troops converge at the base for training exercises. The barracks, latrines, and mess halls are filled past capacity. Tents are erected for supplemental barracks, mess halls, provision storage, ammunition storage, recreational uses, and administrative uses. An elaborate piping system is constructed to provide hot water for cleaning vehicles and equipment. Portable, oil-fed heaters are used for space heating in the tents and for cooking. Needless to say, a reforger represents a spike in thermal and electrical consumption for the base. It also represents a problem in tracking energy efficiency because facilities are used past normal capacity. When energy is normalized according to heated floor-space area, the reforger area is not included, as only temporary shelters are involved.

Because of the training mission of the base, troops are billeted there for only a few weeks at a time. Energy efficiency in the camps suffers because of the sporadic occupancy. When we visited the field camp area, it appeared to be under-utilized. At such times, it is likely that much energy is being used to keep the camp in standby status, as shown in the operating scheme in Sect. 2.3.1. Yet at other times, such as during a reforger, the camp facilities are over-utilized and excess energy is used.

4.3 MILITARY TRAINING AREA

A special concern at Grafenwöhr has been the electricity consumption of target heaters in the training ranges. The director and deputy director of Engineering and Housing stated during a briefing that this is the main energy consumption problem. The heaters are used to warm pop-up targets used during training exercises so that the targets will be visible in thermal viewfinders. In the past, the target heaters were energized all day, representing a large electrical load. We were asked to investigate possibilities for reducing consumption there. A visit to the training range revealed that three conservation efforts are already under way.

First, instead of heating all targets all day, range operators energize only the targets that will be used for a particular exercise and only for the duration of the exercise. In one case, this practice meant that only ~20 of a total ~100 heaters had to be energized for an exercise in a particular range. The range operator, Tim Noall, should be contacted regarding this effort.

Second, the new remote target system (RETS) is being installed to control operation of the targets and heaters. RETS will enable the operators to energize the heaters for a given period before the target is used and to deenergize them afterward. Simulation Training Instrumentation Command, also known as STRICOM, of Orlando, Florida, is the organization responsible for implementing this system. Niels Johannison, the local representative at Grafenwöhr, can be contacted for information.

Third, different thermal paints with different emissivity properties are being evaluated. They may eliminate the need to heat the targets on sunny days, and they would significantly reduce the amount of heat required at other times (from six heaters to perhaps only two). An initial evaluation showed promising results, and a second evaluation is under way. James Cruthers or Bob Watts should be contacted for further information on this effort.

The brief investigation at the training ranges revealed that conservation efforts are under way, but also indicated a lack of communication between training range design and operations members and DEH Utility Division members. It is recommended that a closer association be initiated between the two groups.

5. ANALYSIS OF ENERGY AND COST SAVINGS

5.1 ENERGY SAVINGS ATTRIBUTED TO UEMCS OPERATIONS

The UEMCS at Grafenwöhr was conceived in 1982 and is documented in FY 1982 and FY 1983 Military Construction Project Data sheets (DD Form 1391) (refs. 1-3). The most comprehensive of these data sheets, which is based upon a capital construction cost of $328,000 (ref. 2) projects the following energy and cost savings:

• annual energy savings	52,131 MBtu/year
• first year annual ($) savings	$541,571/year
• total net discounted savings (15-year life)	$6,947,665
• SIR[a]	21.18
• simple pay-back period (SPP)[b]	0.6 year
• energy-saved-to-cost ratio (E/C)[c]	159

Using the annual energy and cost savings numbers outlined, and based upon an actual UEMCS project installation (construction) low bid of $494,300 (ref. 3), the listed cost parameters are modified as follows:

• SIR[a]	14.06
• simple pay-back period (SPP)[b]	0.9 year
• energy saved to cost ratio (E/C)[c]	105

These early estimates of projected UEMCS energy and cost savings will serve as a point of reference for this analysis.

Table 1 summarizes the annual energy consumption by fuel and energy type for the Military Community at Grafenwöhr. This table and Fig. 15 cover the 11-year period (FY 1982-FY 1992) during which the following major energy conservation retrofit programs took place:

• UEMCS	(1984-1992)
• building envelope energy conservation retrofits	(1985-1991)
• hot water district heating systems	(1989-1992).

During this 11-year period, total energy consumption was reduced from 531,390 to 443,346 MBtu/year, a 16.6% overall reduction. These figures do not reflect energy savings accurately because building floor area increased overall during this same period from 4,018,650 to 5,125,280. This represents a 27.5% increase in building space that must be served by Grafenwöhr thermal and electrical energy systems. The fact that the number of annual heating degree days (HDDs) varies from a high of 7,578 during FY 1987 to a low of 6,241 during FY 1983 also affects the energy savings assumptions that can be made if only

aTotal net discounted savings/ECIP project investment cost.

bECIP project investment cost/first-year dollar savings.

cAnnual MBtu of energy saved/($K) ECIP project investment cost.

Table 1. Grafenwöhr annual energy consumption by fuel and energy type (MBtu/year)

Fuel and energy type	FY 1982	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992
Fuel oil No. 2	346,980	331,484	356,529	314,249	377,344	331,927	328,666	205,075	185,782	180,032	176,102
Fuel oil No. 6	76,125	67,616	48,559	36,376	39,865	46,422	49,582	5,486	0	0	0
Natural gas	0	0	0	1,306	3,010	3,287	3,979	3,227	3,808	3,553	3,735
Propane gas	0	0	134	76	156	136	350	662	506	798	708
Coal—anthracite	38,390	33,649	36,884	29,966	22,440	21,097	16,004	0	0	0	0
Coal—other	0	0	0	54	54	54	54	54	54	54	0
District heating (purchased)	0	0	0	0	0	0	0	115,344	149,213	165,137	158,030
Thermal energy (subtotal)	461,495	432,749	442,106	382,027	442,869	402,923	398,635	329,848	339,363	349,574	338,575
Electrical energy	69,895	73,568	83,699	92,455	104,100	105,631	109,104	114,246	114,032	105,840	104,771
Total energy consumption	531,390	506,317	525,805	474,482	546,969	508,554	507,739	444,094	453,395	455,414	443,346
Building $ft^2 \times 1000$	4,018.65	4,134.00	4,100.11	4,128.17	4,147.42	4,534.28	4,616.32	4,714.43	4,944.63	5,061.68	5,125.28
Heating degree days (HDD)	7012	6241	7428	7329	7239	7578	6381	6333	6496	6941	6577
Total MBtu/1000 ft^2	132.23	122.48	128.24	114.94	131.88	112.61	109.99	94.20	91.69	89.97	86.50
Thermal Btu/HDD/ft^2	16.38	16.77	14.52	12.63	14.75	11.73	13.53	11.05	10.57	9.95	10.04

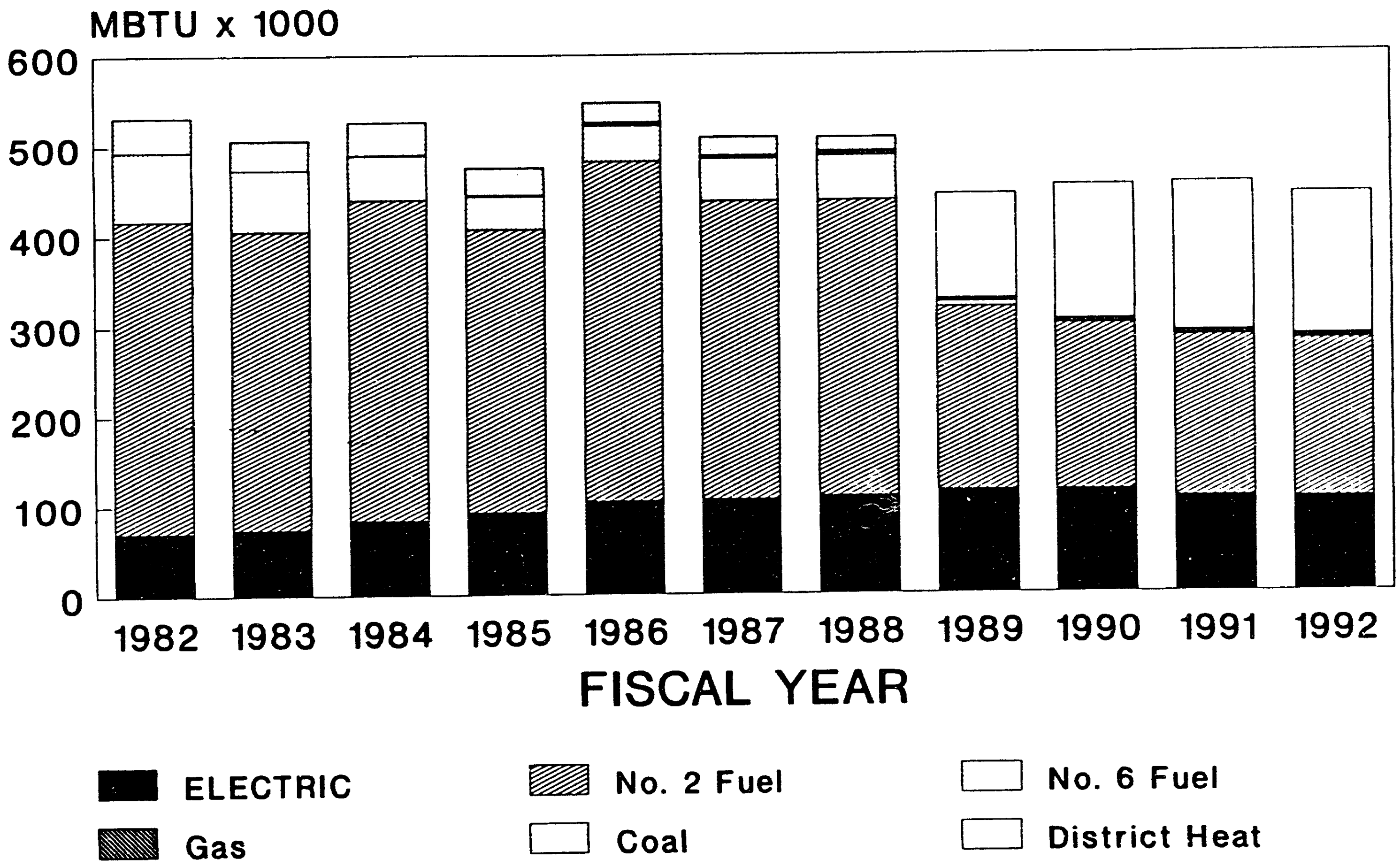

Fig. 15. Grafenwöhr total energy consumption by fuel type (thermal and electric).

total annual energy consumption figures are considered. Figure 16 more accurately reflects actual energy consumption trends during the period when major energy conservation retrofit program activities were under way. Since the UEMCS first became operational during FY 1984, we will focus on energy consumption trends for the 9-year period starting during FY 1984.

Total energy consumption between FY 1984 and FY 1992 was reduced from 128.2 to 86.5 MBtu/1000 ft^2, a 32.5% overall reduction in energy consumption for each 1000 ft^2 of floor area (Fig. 16). This is almost double the 16.6% reduction in energy consumption calculated on the basis of overall energy consumption alone, that is, not considering the 27.5% increase in building floor area that occurred between FY 1982 and FY 1992.

Assume that the building floor area during FY 1984 was the same as during FY 1992, namely 5,125,280 ft^2. Then using the FY 1984 calculated energy consumption rate of 128.2 MBtu/1000 ft^2, based on current building floor area, total energy consumption during FY 1984 would have been 657,061 MBtu/year. Based on this assumption, theoretically, energy consumption in Grafenwöhr facilities over the past 9 years has decreased from 657,061 to 443,346 MBtu/year, a net decrease of 213,715 MBtu. This 32.5% overall reduction in energy consumption represents an average energy savings (energy consumption reduction) of 23,746 MBtu/year between FY 1984 and FY 1992. These energy savings are attributed to the overall Grafenwöhr energy conservation program, which includes UEMCS operations, hot water DH system operations, and major building envelope energy conservation retrofits. Available Grafenwöhr energy consumption documentation is not adequate to determine how much of this estimated 23,746 MBtu/year energy saving can be attributed directly to UEMCS operations. Based on a previous UEMCS evaluation of the Military Community at Pirmasens, Germany (ref. 4), it can be conservatively stated that when building envelope energy conservation retrofits are implemented in buildings that are upgraded with a UEMCS-controlled hot water DH system, over 60% of the energy savings resulting from these conservation measures can be attributed to the building envelope retrofits alone. Using this estimating rule of thumb, then 40% of the estimated 23,746 MBtu/year, or approximately 9,500 MBtu/year can be attributed to UEMCS operations. This is a crude calculation, but is the best estimate that can be made based on available energy consumption data.

Total electrical energy consumption increased from 69,895 Mbtu during FY 1982 to 104,771 Mbtu during FY 1992, approximately a 50% increase overall (Table 1, Fig. 15). During the same time, building floor area increased by 27.5%. These figures show that on an MBtu/1000 ft^2 basis, overall electrical energy efficiency has decreased modestly from 17.4 MBtu/1000 ft^2 during FY 1982 to 20.4 MBtu/1000 ft^2 during FY 1992. This decrease may be attributed to an increase in the density of electrical equipment in common use these days such as computer and training equipment. That is not considered a major degradation in energy efficiency, but it emphasizes that considerable potential exists to implement energy conservation measures to reduce electrical energy consumption. All the apparent energy savings at Grafenwöhr to date can be attributed to improved performance of thermal energy systems.

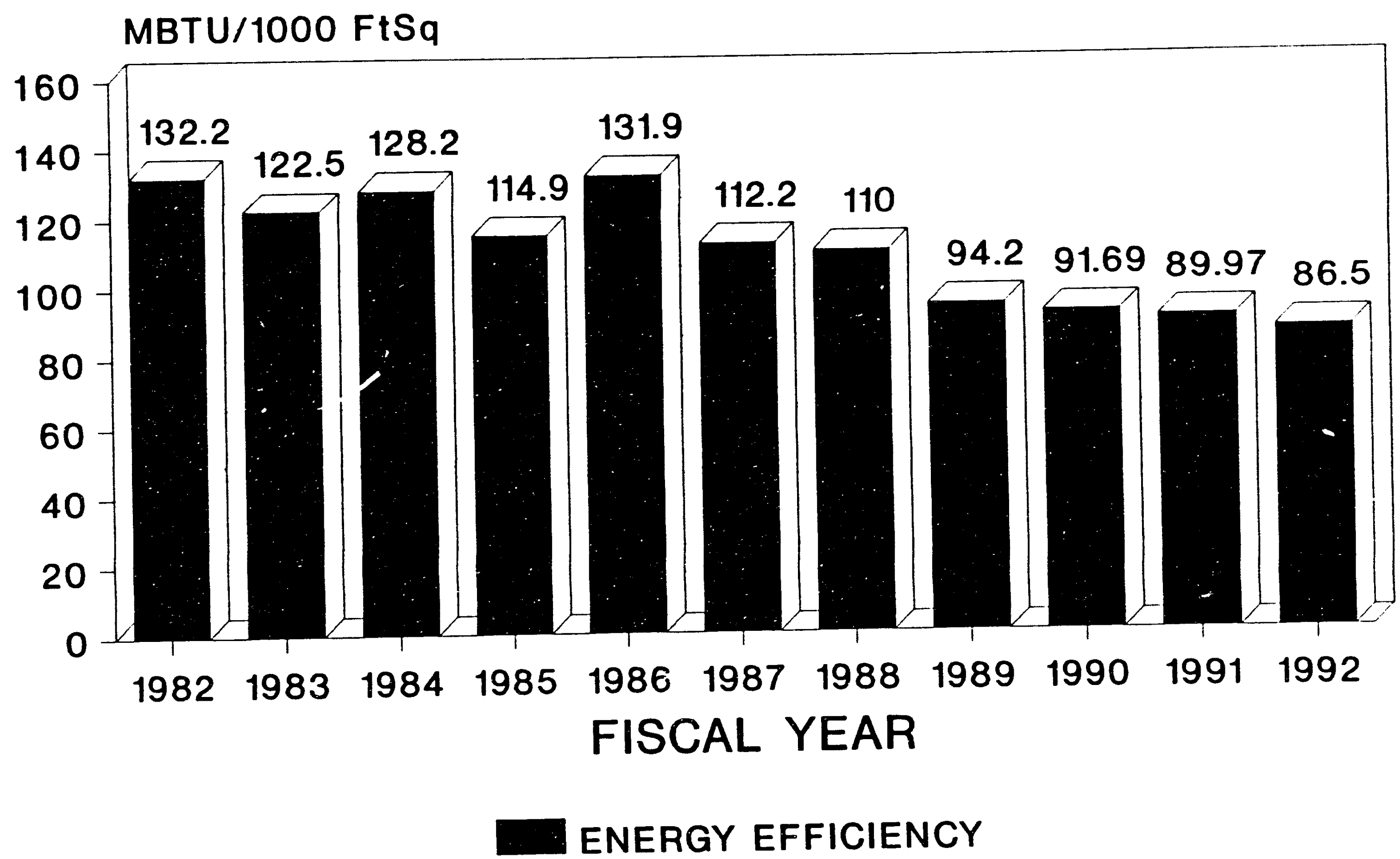

Fig. 16. Grafenwöhr total energy consumption, energy efficiency (MBtu/1000 ft^2).

An analysis of energy savings attributable to reduced thermal energy consumption is more meaningful, as it considers the important variable, HDD/year. Table 1 shows that thermal energy consumption between FY 1984 and FY 1992 was reduced from 442,106 to 338,575 MBtu/year. Taking into consideration both building floor area and HDD/year, Fig. 17 illustrates that energy consumption during this same period was reduced from 14.52 to 10.04 Btu/HDD/ft^2, a 30.9% overall improvement in thermal energy efficiency. Assuming the FY 1984 energy efficiency of 14.52 Btu/HDD/ft^2 and simulating an FY 1992 building floor area of 5,125,280 ft^2, thermal energy consumption during FY 1984 would have been 552,785 MBtu/year. Based on this assumption, theoretically, thermal energy consumption in Grafenwöhr facilities between FY 1984 and FY 1992 would have decreased from 552,785 to 338,575 MBtu/year, a net decrease of 214,210 MBtu. This is a 38.8% overall reduction in thermal energy consumption representing an average energy saving (energy consumption reduction) of 23,801 MBtu/year. These figures compare favorably with the 32.5% reduction in total (thermal plus electrical) energy consumption and the average energy savings of 23,746 MBtu/year. The slight improvement in thermal energy savings compared with total (thermal plus electrical) energy savings confirms the previous observation that there was a slight degradation in electrical energy efficiency (17.4 to 20.4 MBtu/1000 ft^2) between FY 1982 and FY 1992. More important, it confirms that reduced energy consumption and resultant energy savings realized at Grafenwöhr are attributable almost entirely to improved performance of thermal energy systems.

The high MBtu/1000 ft^2 energy consumption figures for FY 1986 on Figs. 16 and 17 need some explanation. Apparently the actual building floor area figures are belatedly entered into the Grafenwöhr real property records. Assuming a realistic 1-year delay, the 4,534,280 ft^2 recorded for FY 1987 should have applied during FY 1986. This would change the energy efficiency figures for FY 1986 from 131.88 to 120.6 MBtu/1000 ft^2, and change the thermal energy efficiency figures from 14.75 to 13.49 Btu/HDD/ft^2. Although this partially explains the comparatively high thermal energy consumption during FY 1986, it does not explain fully why the consumption of No. 2 fuel oil during FY 1986 is so high compared with FY 1985 (see Table 1).

Thermal energy consumption trends of the major facilities also merit examination. Table 2 records thermal energy consumption and related energy efficiency for each major facility for FY 1990 through FY 1992. Thermal energy efficiency in the MPA improved from 9.97 Btu/HDD/ft^2 during FY 1990 to 9.19 Btu/HDD/ft^2 during FY 1992. This is the same period during which the hot water DH system and associated UEMCS controls were installed and became operational in the MPA. Since the MPA is currently the largest consumer of thermal energy (see Fig. 18), this positive trend should be an incentive to Grafenwöhr DEH personnel to further implement UEMCS operation in the MPA. Conversely, Fig. 18 indicates that thermal energy consumption in the field camps is much smaller when compared with the MPA. However, during the 2-week site visit to evaluate the UEMCS, the ORNL investigators observed little activity and relatively low building occupancy in the field camps. If this situation changed and field camps achieved full occupancy, then energy consumption patterns in the field camps could change significantly.

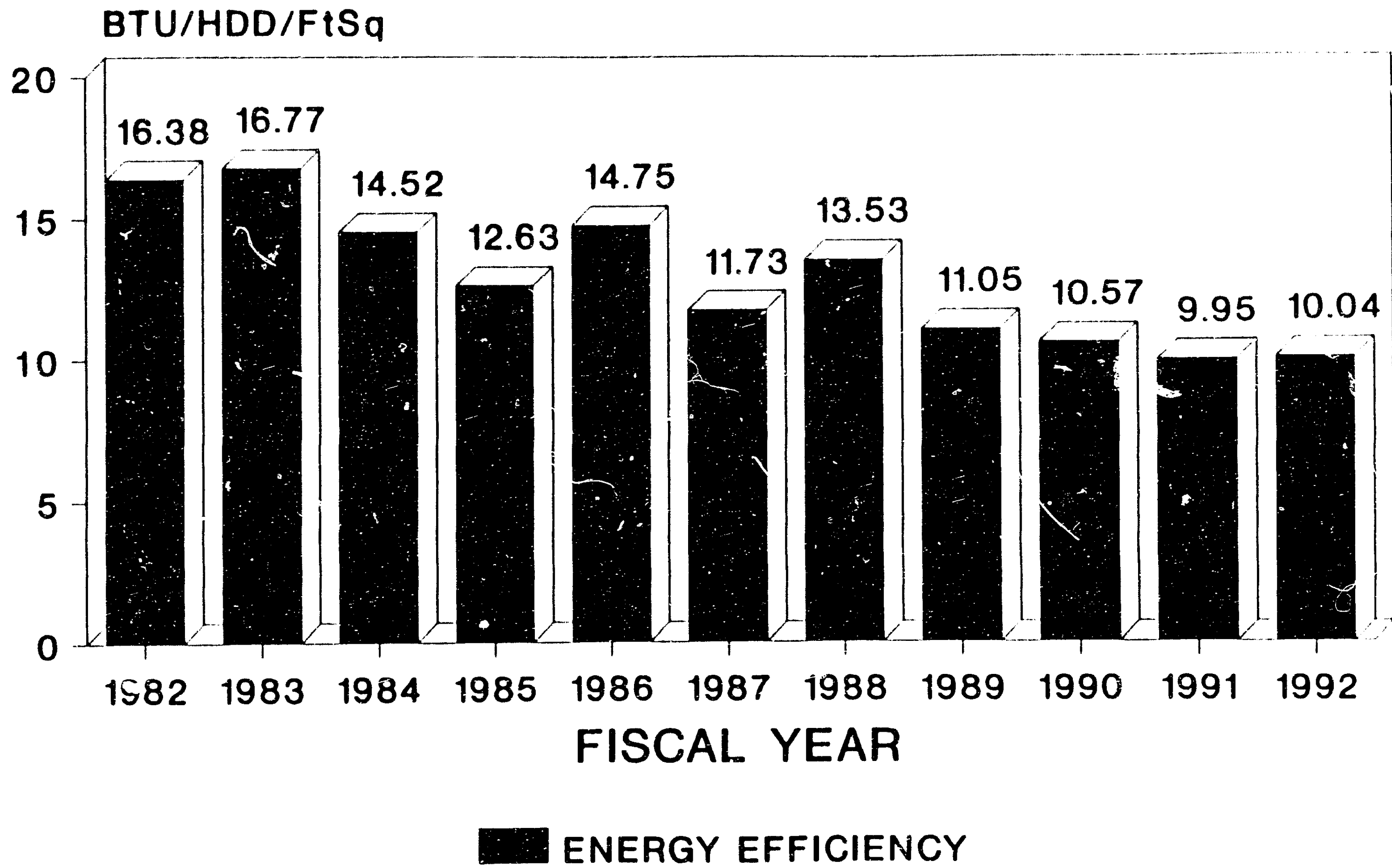

Fig. 17. Grafenwöhr thermal energy consumption, energy efficiency (Btu/HDD/ft^2)

Table 2. Grafenwöhr thermal energy consumption (not electrical) by major facility

	FY 1990			FY 1991			FY 1992		
	HDD = 6496			HDD = 6941			HDD = 6577		
Major Grafenwöhr facilities	Building ft^2	Thermal energy, MBtu/year	Btu/HDD/ft^2	Building ft^2	Thermal energy, MBtu/year	Btu/HDD/ft^2	Building ft^2	Thermal energy, MBtu/year	Btu/HDD/ft^2
Main Post Area	2,704,732	175,185	9.97	2,770,312	180,492	9.39	2,817,099	170,188	9.19
• Camp Aachen	426,167	34,813	12.58	426,167	37,376	12.64	426,167	33,169	11.83
• Camp Algier	494,951	51,226	15.93	494,951	55,502	16.16	494,951	55,021	16.90
• Camp Normandy	482,826	31,227	9.96	482,826	23,686	7.07	482,826	31,426	9.90
• Camp Cheb	27,501	3,019	16.90	27,501	3,022	15.83	27,501	2,256	12.47
• Camp Kasserine	84,679	13,193	23.98	84,679	12,268	20.87	84,679	6,130	11.01
• Other (reforger)	—	8,099	—	—	—	—	—	—	—
Field camps subtotal	1,516,124	141,577	14.38	1,516,124	131,854	12.53	1,516,124	128,002	12.84
Training area	346,311	13,170	5.85	342,636	19,716	8.29	342,636	27,097	12.02
Leased housing	377,467	9,431	3.85	432,603	17,512	5.83	449,425	13,288	4.50
Total Grafenwöhr facility	4,944,634	339,363	10.57	5,061,675	349,574	9.95	5,125,284	338,575	10.04

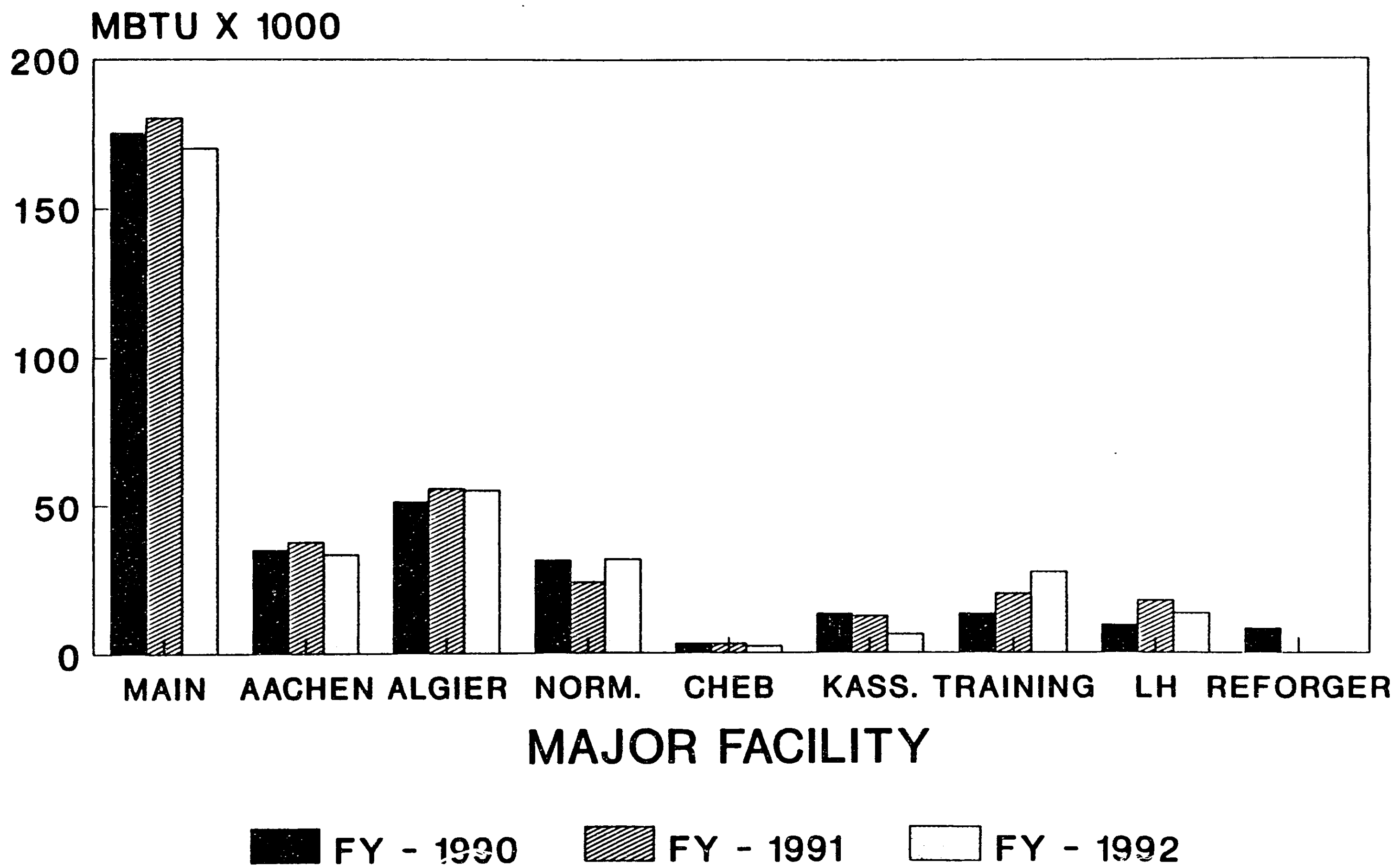

Fig. 18. Grafenwöhr total energy consumption by major facility.

Figure 19 compares thermal energy efficiency (MBtu/HDD/ft^2) among the major facilities. Since the MPA and field camps Aachen, Algier, and Normandy are the only major facilities under UEMCS control, discussion will focus on them. The thermal energy efficiency in the MPA is better than in the field camps and has progressively improved. The 9.19 Btu/HDD/ft^2 thermal energy efficiency in the MPA during FY 1992 compares favorably with the 9.29 Btu/HDD/ft^2 in a family housing community at Pirmasens during FY 1990 (ref. 4). The Military Community at Heidelberg achieved a 7.72 Btu/HDD/ft^2 energy efficiency during FY 1990 (ref. 5). These three military communities have in common a UEMCS-controlled hot water DH system. There are several reasons why the thermal energy efficiency at Heidelberg is better than in the Grafenwöhr MPA. First, UEMCS-controlled night temperature setback is practiced in most Heidelberg buildings; at Grafenwöhr, it is practiced in less than 50% of the MPA buildings. At Heidelberg, domestic hot water temperatures are maintained at a lower set point temperature of 105°F (40.5°C) and the circulation system is shut down 5 or 6 hours at night. At Grafenwöhr, domestic hot water temperatures are maintained in the range of 122–140°F (50–60°C) and circulation is not shut down during the late night hours. The thermal energy performance of the Grafenwöhr UEMCS could be further improved by expanded UEMCS operation in most MPA buildings and by more optimal control of energy conservation measures such as domestic hot water thermal energy consumption.

There are probably many reasons why the thermal energy efficiency in the field camps is not as good as in the MPA. Night setback is not practiced. Domestic hot water temperatures are maintained at 158°F (70°C) to compensate for undercapacity. Motor pool buildings are not under UEMCS control. And these buildings have a past history of abusive energy use. Of major concern, however, is the fact that the energy consumption figures for the field camps in Table 2 are based on partial building and facility occupancy. If these facilities were fully utilized, it is suspected that the thermal energy efficiency of these field camps would be worse and the Btu/HDD/ft^2 figures in Fig. 19 would increase. The field camps, therefore, represent a significant opportunity to further reduce thermal energy consumption and improve thermal energy efficiency.

5.2 COST SAVINGS ATTRIBUTED TO UEMCS OPERATIONS

To document cost savings for UEMCS operations to the U.S. government, the cost of energy in U.S. dollars must be known. Essentially no electrical energy savings result from UEMCS operations. Therefore, the cost of thermal energy will be the main concern of this section. Costs for the most current full year, FY 1992, will be used. An average cost of thermal energy will be defined so that a cost savings can be calculated from the energy savings calculated earlier in this section.

If the energy value of all thermal fuel types at Grafenwöhr is totalled for FY 1992, the percentage for each fuel type can be determined as shown in Table 3. The cost per MBtu is calculated by totalling the year's cost for each fuel and dividing by the total energy value for each fuel. From these figures, the contribution to the average MBtu cost is calculated for each fuel type by multiplying the percent usage per MBtu by the cost per MBtu. Then all of these contributions are summed to arrive at a weighted average cost per MBtu for each fuel.

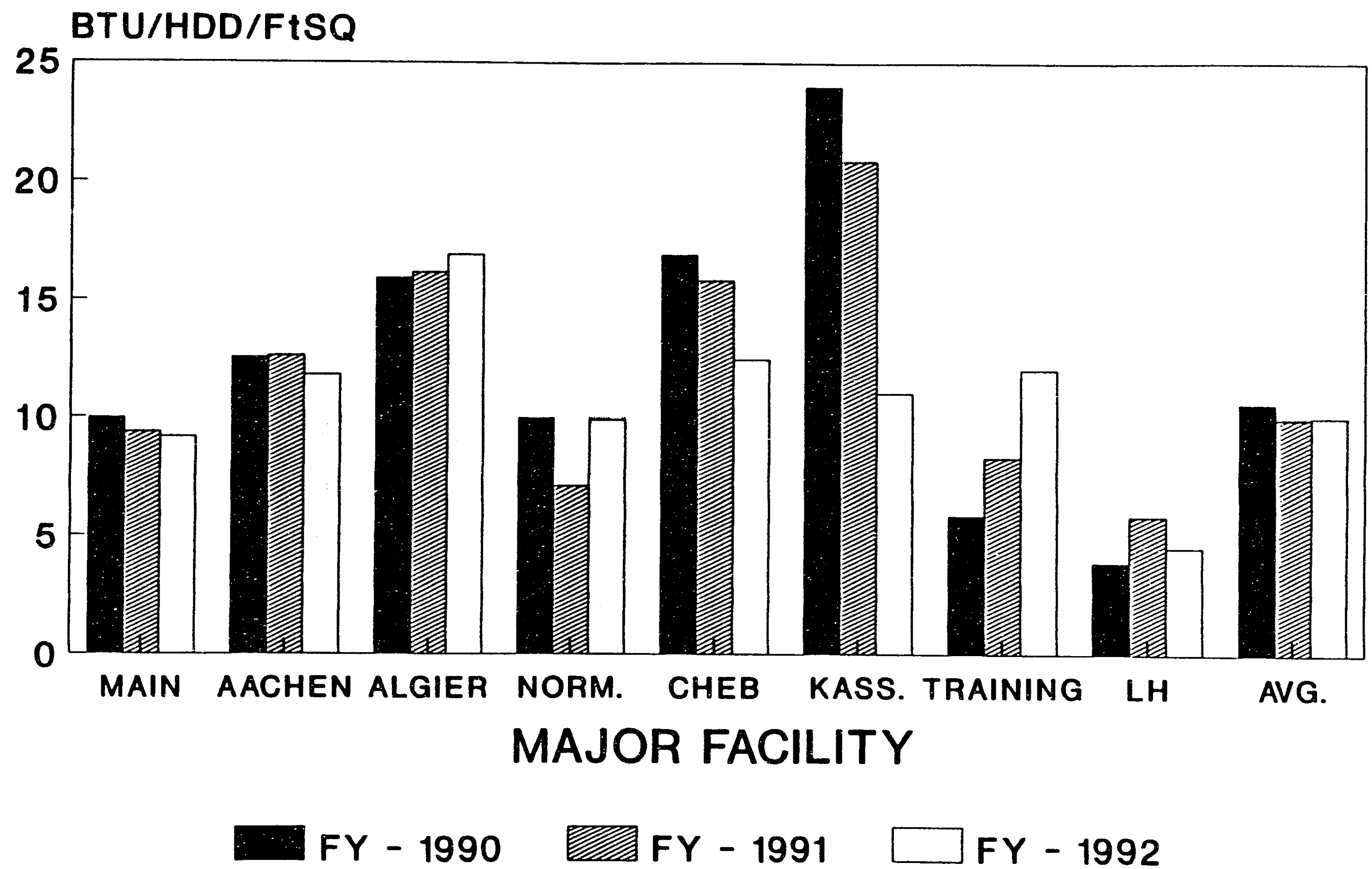

Fig. 19. Grafenwöhr thermal energy consumption by major facility, energy efficiency (Btu/HDD/ft^2).

Table 3. Calculation of the cost of an average MBtu of fuel in FY 1992

Fuel type	Percent usage by MBtu	Cost per MBtu	Contribution to average MBtu cost
Natural gas	1.1	$7.98	$0.09
Fuel oil No. 2	52.0	$4.54	$2.36
Propane	0.2	$7.24	$0.01
Purchased heat (district heat)	46.7	$17.58	$8.21
	Cost of average MBtu of fuel		**$10.67**

For an average cost of $10.67/MBtu and an average energy savings of 9,500 MBtu per year attributable to the UEMCS (calculated earlier in this section), an annual cost savings of $101,365 can be attributed to UEMCS operations based on FY 1992 fuel rates and official exchange rates.

Provided that the low bid price of $494,300 for the UEMCS is accurate, a new, simple payback period of 4.88 years is calculated. Although this is not as good as the 0.9 year simple payback period shown at the beginning of this section, it still satisfies ECIP guidelines of 10 years. However, because good cost records are lacking, there is no guarantee that the system cost was limited to $494,300. The new energy-saved-to-cost ratio is found to be 19.2 rather than 105, just barely over ECIP guidelines of 18. It is difficult to say what the SIR is, since only FY 1992 costs were investigated, but it is safe to say that SIR > 1, which satisfies ECIP guidelines.

The official exchange rate figures into the cost-savings calculation. In terms of the FY 1982 official exchange rate of 2.26 DM to $1, the average costs savings is $127,269. (The project was conceived in 1982.) At the peak of dollar strength against the Deutsche Mark in FY 1986, the average cost savings would be $210,051. In fact, FY 1992 is the worst year for the dollar against the DM for the duration of this project.

Fuel costs were not available to the investigation team for any other years; therefore, the effect of changing fuel prices throughout the years cannot be evaluated.

6. GENERAL ASSESSMENT OF BENEFITS

6.1 OPERATIONS AND MAINTENANCE

Operation of the UEMCS is centered in the UEMCS control room, which is housed in building 329 of the MPA. The control room contains an operator's video display, a programming and maintenance terminal, a PC with special software to interface to the UEMCS like a programming and maintenance terminal, and four printers. PCs equipped with the special interfacing software are also located in the stove shop maintenance area and in the utilities office area. Monitoring of data occurs mainly at the operator's video display but is controlled by one of the programming and maintenance terminals. The UEMCS continuously monitors the entire system, scanning all FIDs nominally every minute. If there is an abnormal situation or failure in the FID or any of its satellite buildings, the resulting alarm will be printed out on one of the printers.

Typical data monitored at the operator's video display include building heated-space temperatures; thermal and electrical energy consumption; status of equipment (on/off), valves (open/closed), and field auto/manual switches (on/off); and alarm conditions. The four printers are divided as follows: one for field camp alarm use, two for main post alarm use, and one for special reports and program listings. Four priority levels of alarms are printed on the alarm printers.

Control programs for the new FIDs originate in the control room at one of the terminals. When the program is fully developed, it is downloaded to the target FID over the system network. Control parameters for remote buildings can be modified from the control room. Because of the sporadic occupancy of the field camps, it is necessary to change control parameters often. It is much more convenient to modify temperature set points and switching conditions for pumps from the control room than to schedule vehicles, equipment, and manpower to travel to the field camp and modify parameters there.

The UEMCS is manned by three people 5 days a week during normal shift hours. On a typical day, the chief of UEMCS will begin by reviewing the alarm printers for problems. If more information about a particular problem is required, it is obtained through one of the video displays or maintenance terminals. For items requiring maintenance, a service order is placed. UEMCS failures are, in general, rectified by the UEMCS staff. An apparent weakness with this system operations scenario is that an alarm failure can go unattended from Friday evening to Monday morning.

During unattended operation, if a problem occurs, the end users call the fire department and complain. If the problem is serious, the fire department attempts to call the chief of UEMCS at home (but he is never officially on call). Plumbing shop craftsmen work off-shifts and they are trained to turn FID units to manual for a temporary fix when the UEMCS FID is at fault. The craftsmen can diagnose valve and piping problems, but not UEMCS troubles. For convenience to the craftsmen, a UEMCS terminal is located in the stove shop maintenance area.

The supply water temperature from the DH supply company is considered to be the highest priority point monitored by the UEMCS. If this temperature falls too low, an automatic dialer attached to the UEMCS calls the fire department and plays a recorded message. The fire department telephone operator takes appropriate action. Other points could be added to the list that actuate the automatic dialer, but the low supply temperature is the only point considered necessary at this time.

A UEMCS terminal is also located in the energy conservation manager's office. Although not in use when this report was written, the terminal will be used by the manager not only to monitor current data, but also to review monthly or yearly summary data. Trend analysis and comparisons with previous data can be done to spot potential problems and provide data to develop a basewide energy strategy and help justify new energy-conservation projects.

The contractor that originally installed the UEMCS (not AEG) provided a 2-year warranty for system maintenance. This contractor would involve AEG in maintenance as required, not the Army directly. New contracts were awarded to perform UEMCS system upgrades and expansions. Each subcontract went through the bid process and was awarded to the low bidder. Each contract involved its own warranty period. The contracts were scheduled to expire in September 1992. Theoretically, if there is a major failure, there will be no outside help to fix it. If UEMCS service and maintenance is to be received from the outside, a new contract must be issued. In reality, the three UEMCS staff members perform their own routine maintenance and repair. They also keep basic spare parts for maintenance.

6.2 ENERGY CONSERVATION PROGRAM

Roland Repper is the energy conservation manager for the Grafenwöhr base, reporting to Werner Ohla of the Utilities Division. The energy conservation program was recently moved from the Environmental and Energy Division to the Utilities Division. The energy conservation manager interfaces functionally with Angie Graf, a person with the same title in the 100th Area Service Group (ASG). The responsibility at the 100th ASG involves coordination with other 100th ASG installations such as Hohenfels, Vilseck, and Wildflecken. A staff member at USAREUR in Heidelberg has overall energy conservation responsibility for all USAREUR installations in Europe. Special energy conservation training programs are held under USAREUR sponsorship. The programs, which all installation energy conservation managers attend, occur once or twice a year.

Repper thinks he can get more done in the Utilities Division than he could in the Environmental and Energy Division. The office resources were very limited there (e.g., transportation, typing), and Repper was the only energy-oriented person in the division. He believes he has more support now, since operation of the UEMCS is a major activity in the Utilities Division. However, he is the only person assigned to the energy conservation task, and he fears there is much more to do than he has time for.

An energy conservation monitor assigned to each MPA building checks the building with a list provided by Repper. The list contains checks of appropriate window and door status, light usage and wattage, building temperature, etc. There are no building conservation monitors in the field camp area. The building inspector for the field camps is responsible for energy awareness in the field camp buildings; however, this is not a formal task, only an informal agreement. Repper provides training sessions twice a year to ensure that each building energy conservation monitor receives training at least once a year.

Other features of the energy conservation program are as follows:

- Each October, there is an installation-wide energy awareness week.

- Building energy monitor contests are held in which energy monitor performance, including record keeping, is evaluated and prizes are awarded.

- Repper tries to visit personally a cross-section of buildings on the base each year. Because there are more than 1000 buildings, visiting each one is not feasible; but he thinks he knows which areas to concentrate on because he has had time to see most of the buildings over the years.

- During a summer energy inspection program, energy monitors use a checklist to inspect energy features of their respective buildings and report the results. Items checked include bad radiator valves, windows that do not close, and broken windows.

- The energy conservation manager is responsible for updating and maintaining a USAREUR-required energy contingency plan. The plan states responsibilities, provides historical energy consumption data, and lists fuel types used in each building in the previous 2 years. The plan is used to outline a contingency for major energy outages. For example, if the DH supplier, FGL, went down, the plan states that boilers at the heat islands would be fired to provide heat to the MPA.

- Special energy award programs for designated building types, such as bachelor enlisted quarters and the barracks, are conducted.

- Informal programs are conducted, such as rewards for children who spot cars and tanks idling for excessive periods in parking lots.

Many housing buildings have lights that would remain on all day if energy awareness were not stressed by the energy conservation manager. It would be difficult to have the UEMCS switch these lights on and off without interfering with the residents' activities. Street lights, on the other hand, can be controlled on a routine basis. About 90% of the street lights in the MPA have twilight switches.

Repper will have a UEMCS terminal in his office to help him monitor base energy consumption activities. The fact that the energy conservation manager reports to the Utilities Division is good. There should be close coordination with UEMCS personnel, who could serve as a resource for energy-consumption data. Conversely, the energy conservation manager could advise UEMCS staff members on how and where energy could be saved.

7. CONCLUSIONS

Based on the results of the evaluation of the UEMCS at Grafenwöhr, the following conclusions have been reached:

- The AEG UEMCS appears to be operating without major difficulty, and it has a well rounded capability with potential for future expansion and upgrading. Plans for UEMCS expansion and increased application appear to be appropriate and should result in increased energy and cost savings. However, these plans do not appear to be backed up by convincing energy and cost savings analysis.

- The UEMCS staff is knowledgeable of and dedicated to efficient system operation and future improvements and upgrades. The Grafenwöhr Energy Conservation program is staffed by a full-time energy conservation manager and incorporates many features to promote energy awareness and conservation.

- Several UEMCS operations and maintenance vulnerabilities were identified. UEMCS maintenance is not always covered by outside expert support, depending upon whether a UEMCS support services subcontract is in place. Also, UEMCS operational failures may go unnoticed since the UEMCS staff work only 8 h per day, 5 days a week.

- Reasonably detailed energy consumption and estimated energy and cost savings records are not maintained; for example, there are

  - no records of electrical energy consumption by major facility,
  - no thermal energy consumption records for individual MPA hot water DH system substations (heat islands) nor facility and building types, and
  - no actual or projected energy and cost savings records.

- Based on the results of this analysis, it appears that the Grafenwöhr UEMCS is not achieving the level of energy and cost savings originally projected for this project in the FY 1982/1983 Military Construction Project Data sheets (DD Form 1391). When the UEMCS becomes fully operational and is operated in an optimal manner, it should meet or exceed minimum energy and cost savings guidance for ECIP construction projects (SIR > 1, SPP < 10 years, E/C > 18).

- Expansion and optimal use of the UEMCS offer many opportunities for increased energy and cost savings, for example,

  - reduction in the domestic hot water supply temperature,
  - shutdown of domestic hot water circulation at night,
  - implementation of an electric demand limiting program,
  - increased application of night setback/weekend shutdown in the MPA,
  - addition of motor pool buildings in the field camps to the UEMCS, and
  - late-night shutdown of selected exterior lighting.

8. RECOMMENDATIONS

Based on the results of the evaluation of the UEMCS at Grafenwöhr, the following recommendations are made:

- Optimize UEMCS control of the domestic hot water systems by reducing the hot water supply temperature from 122–140°F (50–60°C) to 104–113°F (40–45°C), and shut down circulation for 5 to 6 hours during the night in family housing and other buildings that do not use hot water during the late night hours.

- Evaluate the policy of using high temperature set points (158°F) in the shower and latrine buildings in the field camps to overcome the under-capacity problem of the hot-water system. Consider varying the temperature set point based on the number of troops utilizing the facility and perhaps increasing the capacity of the hot-water system if it is continuously over utilized.

- Implement an electric demand limiting program under UEMCS control considering the following candidate loads:

  - air conditioners: 26 unitary air conditioners (~480 total kW)
    21 window air conditioners (~110 total kW)

  - Refrigeration systems in cold storage building 295, which includes five 22 kW compressor units.

  - Refrigeration units in field camp mess halls.

  - Family housing dryers (schedule day-of-week operations).

- Increase application of night setback/weekend shutdown in the MPA, which is currently being practiced in <50% of the buildings. NOTE: AS AN INDICATION OF POTENTIAL SAVINGS, AT THE MILITARY COMMUNITY IN HEIDELBERG, 58% OF THE ENERGY SAVINGS AND 34% OF THE COST SAVINGS WERE ATTRIBUTED TO UEMCS CONTROL OF SPACE HEATING (REF. 5).

- In the field camps, expand UEMCS operations to include approximately 20 motor pool buildings that reportedly abuse energy use. Use interlocks that ensure energy system operation only during actual motor pool operations and when garage doors are shut.

- Use the UEMCS to optimize operation of exterior lighting.

  - In the MPA and field camps, consider scheduling every other street light to go off between 11:00 and 05:00.

  - In the field camps, incorporate provisions to shut off exterior building lights during the day.

- Continue to emphasize the overall Grafenwöhr Energy Conservation Program and the important role of the energy conservation manager.

- Promote closer coordination between the energy conservation manager and the UEMCS staff.

- Improve energy monitor coverage in the field camps.

- Increase "end-user" involvement in the overall Energy Conservation Program.

- Coordinate DEH Utility Division energy activities more closely with training area personnel.

• Several years ago, CERL installed elaborate metering in selected MPA and field camp buildings and facilities. It is recommended that DEH personnel use this metering to record selected facility energy performance and determine the potential energy and cost savings resulting from selected conservation measures.

• Reconsider the impact and consequences of not having a UEMCS maintenance and repair subcontract in place at all times. Also, consider the adverse affects of not staffing the UEMCS central control station during the evening and night shifts and on weekends.

• Finally, improve the documentation and reporting of energy consumption and of actual and estimated energy and cost savings. This should include

  - Electrical energy consumption for each major Grafenwöhr facility.

  - Thermal energy consumption for each MPA hot water DH system substation (heat island) or building/facility type.

  - Estimated energy and cost savings attributed to UEMCS operations (by major energy conservation measure).

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