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MARTIN MARIETTA

EVALUATION OF THE COMPUTERIZED UTILITIES MONITOR AND CONTROL SYSTEM INSTALLED AT THE U.S. ARMY, EUROPE, 26TH SUPPORT GROUP AT HEIDELBERG, GERMANY

Martin A. Broders and Benjamin W. McConnell
Energy Division

May 1991

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U. S. DEPARTMENT OF ENERGY
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MANAGED BY
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FOR THE UNITED STATES
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EXECUTIVE SUMMARY

Under the provisions of Interagency Agreement DOE No. 1938-B090-A1 between the U.S. Department of Energy (DOE) and the United States Army in Europe (USAREUR), Martin Marietta Energy Systems (MMES), Inc., is evaluating the Computerized Utilities Monitor and Control System/Energy Monitoring and Control System (CUMACS/EMCS) installed at the Headquarters, USAREUR, 26th Support Group in Heidelberg, Germany. The funding necessary to install the existing CUMACS/EMCS at the 26th Support Group was provided in part by the Energy Conservation Investment Program (ECIP). This project was initiated during FY 1976. ECIP projects are designed to make existing defense facilities and buildings more energy efficient and to reduce the cost of installation operations.

The Oak Ridge National Laboratory (ORNL) was selected to evaluate the overall effectiveness and energy efficiency of EMCSs at four U.S. Army installations in Germany. The first of these systems to be evaluated was the CUMACS/EMCS installed at the 26th Support Group in Heidelberg. This evaluation relied upon existing data and information to take an in-depth look at the overall performance and effectiveness of the CUMACS/EMCS to determine if it was achieving its operational objectives and meeting projected energy and cost savings.

The CUMACS/EMCS at Heidelberg is a hybrid supervisory control system with distributed intelligence in local process controllers. The initial EMCS was installed in the mid 1960s and was expanded significantly in 1983 when ECIP Project No. 706 was implemented. The construction contract for this ECIP project was awarded during March 1983 at a cost of approximately $543,000. As of 1990, the CUMACS/EMCS cumulative investment cost is about $950,000, funded primarily by the ECIP program. Overall cost savings resulting from CUMACS/EMCS operation since FY 1979 are reported to be $14,780,401. Cost savings for FY 1990 alone are reported as $1,488,886.

If the CUMACS/EMCS is expected to account for all costs (cable, actuators, sensors, indicators, central control computer, and remote control receivers), a replacement cost of $1000 per point is found to be reasonable. Since cable systems are pre-installed, and the CUMACS actuators, sensors, or indicator costs are included with the local process controller costs, these are not accounted for as CUMACS costs. Under this method of accounting, the cost of replacing CUMACS in FY 1990 dollars is estimated to be about $4.6M with simple payback of 3–4 years.

The present CUMACS/EMCS controls 11,226 data and control points in 551 buildings on twelve installations in the Heidelberg area. A nominal forty system types are monitored or controlled. Equipment from thirty-eight manufacturers is successfully integrated into this hybrid system. The system monitors and/or controls the thermal energy (heating and hot water), electrical energy, water, and sewer systems installed at major Heidelberg area administrative, housing, hospital, and support center installations.

Based on the projected energy and cost savings derived from the project documentation, comparisons can be made for key parameters, such as the savings to

investment ratio (SIR), the simple pay-back period (SPP), and the energy cost (E/C) ratio. The first observation is that the SIR, the SPP, and the E/C ratio attributable to energy and cost savings derived from CUMACS/EMCS operations significantly exceed ECIP project guidance minimum requirements. There is a 15 to 1 SIR betterment (15+ vs 1) and a 10 to 1 SPP betterment (<1 year vs <10 years). Results of recent U. S. Army ECIP project validation and evaluation studies conducted in the United States reveal appreciably less benefit derived from EMCS operations. SIRs for these continental U. S. EMCS projects ranged from 6.6 to 1.1, while SPPs ranged from 1.8 to 9.3 years.

However, the annual energy and cost savings estimates supplied by CUMACS do not take into consideration actual operation and maintenance (O&M) costs, including associated materials and equipment expended in support of CUMACS/EMCS operations. In the opinion of the ORNL principal investigators, these actual O&M costs should be reflected in the estimated cost savings attributable to CUMACS/EMCS operations. Applying estimated annual O&M costs to the above data results in estimated annual savings of $1,071,700, an SIR of 13.54, and an SPP of 0.89 years.

In addition, the evaluation of the system operating data shows a steady decrease in energy consumption in CUMACS/EMCS-controlled buildings between FY 1984 and FY 1990. This decrease in energy consumption can be associated with reduced thermal energy consumption. CUMACS/EMCS-controlled buildings were reduced from 16.41 to 7.72 Btu/ft^2/HDD, which represents a greater than 100% reduction in thermal energy usage during this period. This steady decrease in thermal energy consumption in CUMACS/EMCS-controlled buildings can be attributed to the composite effects of several energy conservation programs that were implemented simultaneously by the USAREUR 26th Support Group in Heidelberg, i.e., installation of the CUMACS/EMCS, installation of a hot water district heating system, retrofit of insulation to building envelopes, and implementation of general conservation measures, such as reduction of domestic hot water heater set temperature.

An appreciable reduction in thermal energy consumption occurred in CUMACS/EMCS-controlled buildings between FY 1984 and FY 1985, the time period when this system was becoming operational. This reduction can most likely be attributed to CUMACS/EMCS operations, since building insulation retrofits had not been started and installation of the hot water district heating system was just getting started. Another significant reduction in thermal energy consumption occurred between FY 1987 and FY 1988. This reduction is probably a direct result of the positive impact of other energy conservation programs such as the building envelope retrofit program, and not primarily a result of CUMACS/EMCS operations.

During FY 1990, energy efficiency (MBtu consumed per 1000 ft^2 of floor space) in CUMACS/EMCS-controlled buildings was less in military housing facilities than in administrative and support facilities. From an overall energy efficiency standpoint, it appears that energy conservation programs sponsored by the USAREUR 26th Support Group have had a greater impact on reducing energy consumption in military housing facilities compared with office, administrative, and support facilities.

During FY 1990, the greatest percentage of energy consumed by military housing facilities was thermal energy for domestic hot water and space heating. The reverse is true for many of the principal USAREUR 26th Support Group office, administrative, and support facilities. In Campbell Barracks, the principal HQ USAREUR and Seventh Army office and administrative facility in Heidelberg, 68% of total energy consumption is electrical, not thermal energy. Part of the reason for this reverse trend is the fact that Campbell Barracks houses several 24-hour-a-day classified operations that are very electric-energy intensive. Similarly, over 65% of the energy consumed by the Community Support Center, one of Heidelberg's principal Army support facilities, is electrical energy. Based on the above observations, it appears that future USAREUR 26th Support Group energy conservation programs should focus on further thermal energy reductions in military housing facilities and on electrical energy reductions in office, administrative, and support facilities.

A very important consideration in evaluating an EMCS is to understand which conservation measures produce the greatest energy and cost savings. Of six general conservation measure categories, only three have been credited with equivalent energy savings as a direct result of CUMACS/EMCS operations: control of space heating systems and equipment, control of domestic hot water heating systems and equipment, and control of electrical energy systems and equipment. It is important to note that over 50% of the reported cost savings is attributable to more energy-efficient operation of space and hot water heating systems and equipment in CUMACS/EMCS-controlled buildings and facilities. This fact is further confirmed by observing that over 95% of reported energy savings attributed to CUMACS/EMCS operations is directly related to more energy-efficient operation of thermal energy (space and domestic hot water heating) systems.

Besides the obvious benefit of energy and cost savings, other benefits are known to exist for utility energy management control systems such as CUMACS. While some of these benefits can be quantified in terms of energy and cost savings, many can only be subjectively assessed. In an effort to gain insight into these issues, the investigators interviewed energy coordinators. In general, these interviews revealed that the CUMACS/EMCS was viewed as a very reliable system that experiences very few end-user complaints. CUMACS/EMCS operations and maintenance personnel were reported to be very responsive if a system problem arose and were supportive of the energy coordinators' overall mission. In addition, discussions with Mr. Juergen Baller, Chief of Utilities, indicate that some CUMACS benefits are difficult to quantify and that additional benefits might be available under slightly different operating guidelines.

Based on the results of this evaluation of the CUMACS/EMCS installed at the USAREUR 26th Support Group in Heidelberg, the following conclusions have been reached:

- The CUMACS/EMCS is well maintained and is managed and operated by a well-trained and dedicated staff.

- Between FY 1984 and FY 1990, CUMACS/EMCS operations have contributed significantly to the overall reduction in energy consumption achieved by the USAREUR 26th Support Group in Heidelberg. Various energy conservation programs that were implemented simultaneously are interrelated and contribute incrementally to the aggregate reduction in installation energy consumption. A significant decrease in installation energy consumption reduces the opportunity for future energy and cost savings.

- The energy and cost savings attributed to CUMACS/EMCS operations are significant, and ECIP military construction project requirements (SIR, SPP, and E/C ratio) have been exceeded by a large margin.

- During FY 1990, energy efficiency in terms of MBtu of energy consumed per 1000 ft^2 of floor space in CUMACS/EMCS-controlled buildings was less in military housing facilities than in administrative and support facilities.

- Most of the energy consumed by military housing facilities during FY 1990 was thermal energy for domestic hot water and space heating. However, partly because Campbell Barracks houses several 24-hour-a-day classified operations that are very electrical-energy intensive, most of the energy consumed during this period by USAREUR 26th Support Group office, administrative, and support facilities was electrical energy.

- A very important consideration in evaluating an EMCS is to understand which conservation measures produce the greatest energy and cost savings. Over 50% of the reported cost savings is attributable to more energy efficient operation of space and hot water heating systems and equipment in CUMACS/EMCS-controlled buildings and facilities. This fact is further confirmed by the fact that over 95% of reported energy savings can be attributed to CUMACS/EMCS operation of thermal energy systems.

- In general, the benefits of CUMACS go beyond the energy and cost savings. Benefits of improved operation are difficult to quantify, but CUMACS personnel have shown an ability for developing techniques that could be constructively shared with other installations.

ABSTRACT

Under the provisions of an Interagency Agreement between the U. S. Army and the Department of Energy, Martin Marietta Energy Systems, Inc., through the Oak Ridge National Laboratory, is evaluating the Computerized Utilities Monitor and Control System (CUMACS/EMCS) installed at the Headquarters, USAREUR, 26th Support Group in Heidelberg, Germany. This evaluation relies upon existing data and information to take an in-depth look at the overall performance and effectiveness of the CUMACS/EMCS to determine if it is achieving its operational objectives and meeting projected energy and cost savings. The evaluation described in this report indicates that the CUMACS/EMCS is well maintained and is managed and operated by a well-trained and dedicated staff. Between FY 1984 and FY 1990, CUMACS/EMCS operations have contributed significantly to the overall reduction in energy consumption achieved by the USAREUR 26th Support Group in Heidelberg. Various energy conservation programs being implemented simultaneously are interrelated and contribute incrementally to the aggregate reduction in installation energy consumption. The energy and cost savings attributed to CUMACS/EMCS operations are significant, and Energy Conservation Investment Program military construction project requirements (savings to investment ratio, simple pay-back period, and energy-to-cost ratio) have been exceeded by a large margin. A very important consideration in evaluating an EMCS is to understand which conservation measures produce the greatest energy and cost savings. Over 50% of the reported cost savings is attributable to more energy-efficient operation of space and hot water heating systems and equipment in CUMACS/EMCS-controlled buildings and facilities. This fact is further confirmed by the fact that over 95% of reported energy savings can be attributed to CUMACS/EMCS operation of thermal energy systems. This report discusses and presents graphically the details of the evaluation. The benefits of CUMACS go beyond energy and cost savings. In addition, CUMACS personnel have shown an ability for developing techniques for accessing these benefits which could be constructively shared with other installations.

1. INTRODUCTION

1.1 BACKGROUND

Under the provisions of Interagency Agreement DOE No. 1938-B090-A1 between the U.S. Department of Energy (DOE) and the United States Army in Europe (USAREUR), Martin Marietta Energy Systems (MMES), 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 calls for the evaluation of utilities energy monitoring and control systems (EMCSs) installed at selected U.S. Army installations in Europe. Plans are currently underway to evaluate the overall performance and energy efficiency of EMCSs installed at U.S. Army installations in Heidelberg, Göppingen, Grafenwöhr, and Baumholder, Germany. This report specifically presents the results of an evaluation of the Computerized Utilities Monitor and Control System/Energy Monitoring and Control System (CUMACS/EMCS) installed at the Headquarters, USAREUR, 26th Support Group in Heidelberg, Germany, which is operated by the Directorate of Engineering and Housing, Utilities Division.

The Energy Conservation Investment Program (ECIP) was initiated during FY 1976 as part of the Department of Defense's Military Construction Program, and was designed both to make existing defense facilities and buildings more energy efficient and to reduce the cost of installation operations. A specified goal of this program was to implement cost-effective energy conservation retrofit projects in existing defense facilities and buildings to reduce their overall energy consumption in 10 years by 12%. One such ECIP project was an FY 1983 military construction project, no. 706, "Extension of Computerized Energy Monitoring and Control Systems." This ECIP project provided a major part of the funding necessary to install the existing CUMACS/EMCS at the 26th Support Group in Heidelberg.

1.2 SCOPE (STATEMENT OF WORK)

The Oak Ridge National Laboratory (ORNL) was selected by Headquarters, USAREUR, Facilities Engineering Division, Utilities and Energy Branch in Heidelberg to evaluate the overall effectiveness and energy efficiency of EMCSs at four U.S. Army installations in Germany. The first of these systems to be evaluated, which is the scope of this report, is the CUMACS/EMCS installed at the 26th Support Group in Heidelberg. This evaluation relies upon existing data and information and does not involve the installation of metering and instrumentation for the purpose of measuring installation energy use.

The primary strategy of this evaluation is to take an in-depth look at the overall performance and effectiveness of the CUMACS/EMCS to see if it is achieving its operational objectives and meeting projected energy and cost savings. CUMACS/EMCS project documentation will undergo a comprehensive review and evaluation in terms of completeness, accuracy, and reasonableness. Energy and cost saving projections derived from actual system operating experience will be compared with energy and cost savings projected for this ECIP project before actual installation, which were used to justify and secure funding for this military construction project. An assessment of site and physical conditions will be performed based on extensive visits to the various 26th Support Group installations, facilities, and buildings served by the CUMACS/EMCS. An in-depth analysis of projected energy and cost savings will endeavor to highlight the most effective energy conservation measures currently being monitored and controlled by the CUMACS/EMCS and to identify additional measures that can be implemented in the future that could improve the overall performance of the CUMACS/EMCS. Finally, this evaluation will focus on a general assessment of CUMACS/EMCS benefits that are not necessarily related to factual energy and cost savings. This assessment will be based on interviews with CUMACS/EMCS management and operation personnel and installation energy coordinators, addressing issues such as system operation and maintenance and human factors such as system end-user acceptance and comfort.

2. PROJECT DESCRIPTION

The CUMACS/EMCS is a hybrid supervisory control system with distributed intelligence in local process controllers. The CUMACS/EMCS central control room was visited and became "home base" for this system evaluation. The chief of CUMACS/EMCS operations, Mr. Holger Grab, served as the travelers' primary contact and host during this system evaluation.

The initial EMCS was installed in the mid 1960s and was expanded significantly in 1983 when ECIP project no. 706, "Extension of Computerized Energy Monitoring and Control System," was implemented. The construction contract for this ECIP project was awarded during March 1983 at a cost of 1,218,683 deutsche mark (DM) (approximately $542,843). As of 1990 the CUMACS/EMCS cumulative investment cost is about $950,000, funded primarily by the ECIP program.

Overall cost savings resulting from CUMACS/EMCS operation since FY 1979 are reported to be $14,780,401. Cost savings for FY 1990 alone are reported to be $1,488,886. Section 5 of this report discusses these savings in detail.

The present CUMACS/EMCS has the following major characteristics:

• Buildings connected	551
• Installations encompassed	12
• Installations, future potential	19
• Analog sensors installed	1,662
• Digital sensors installed	419
• Actuators installed	5,877
• Alarms installed	2,321
• Status points	947
• Total data and control points	11,226

A nominal 40 system types are monitored or controlled. Equipment from 38 manufacturers is successfully integrated into this hybrid system.

The CUMACS system monitors and/or controls the thermal energy (heating and hot water), electrical energy, water, and sewer systems installed at the following major Heidelberg area installations:

- Campbell Barracks (administrative),
- Mark Twain Village (family housing),
- Patrick Henry Village (family housing),
- Tompkins/Kilbourne Barracks (administrative/housing),
- Patton Barracks (administrative/housing),
- U. S. Army Hospital, and
- Community Support Center.

The present configuration (circa 1983 to date) uses four data transmission media (DTM) or communications channel types (see Fig. 1). The first two DTM types are full

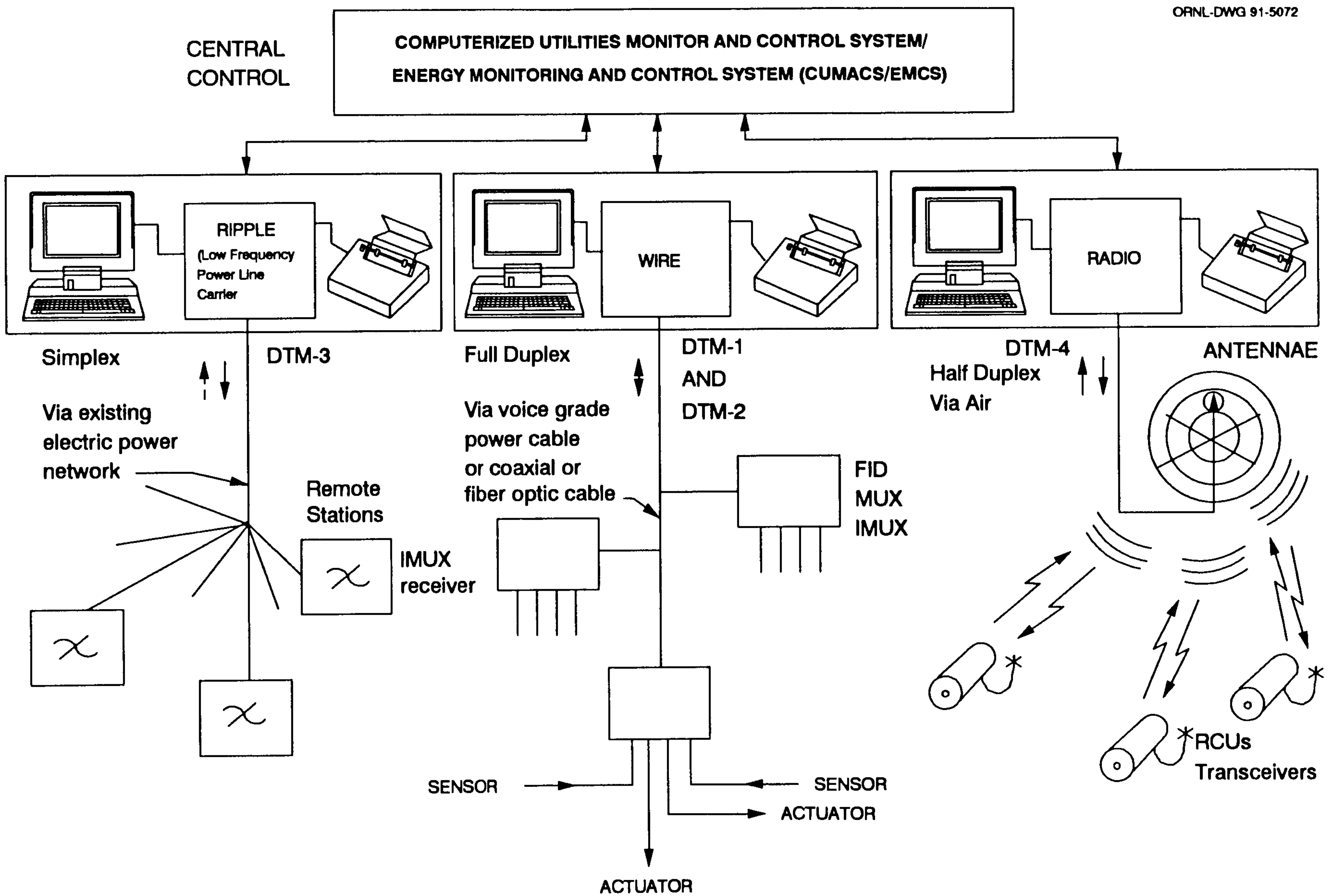

Fig. 1. Computerized Utilities Monitor and Control System (CUMACS) data transmission media (DTM).

duplex, cable-based twisted pair, coaxial, or fiber optic depending upon the application. One of these DTM types (1000 channels) is frequency division multiplex (BBC Indactic FM10b or Landis & Gyr F2/F3) operating under IAW CCITT regulations at 420 to 3300 Hz (25–600 baud). The other type (1120 channels) is time division multiplex (BBC Indactic 21) operating under IAW CCITT regulations with pulse code modulation at 200 to 9600 baud. These media provide simultaneous full-duplex transmission of process data and status and control commands to and from utility plants and associated networks. While these media primarily serve a supervisory data acquisition role, they exercise direct control over certain key utility points.

The third DTM type is a Landis & Gyr 316.7-Hz audio frequency ripple (low-frequency power-line carrier) for simplex transmission of commands and controls. This system is a well-established, highly reliable switching technology, albeit at a very low communications rate. The system is one-way outbound to some 2000 ripple control receivers and associated microprocessors connected to the electric network. Signal injection is accomplished at 400 V, 6 kV, and 20 kV with simultaneous synchronized injection used occasionally for greater channel reliability.

The fourth DTM channel is a small, two-way frequency modulated (FM), half-duplex Motorola radio system that operates at 79 MHz. The present system can process 32 alarm/status inputs or 6 analog inputs per transceiver and is used for remote systems that cannot be connected via ripple or wire network.

The FM system is presently being expanded and will utilize a higher operating frequency (139.65 MHz). The new DTM will also allow up to 128 alarm/status or 32 analog points per transceiver. Present plans call for progressively replacing the ripple system with FM components as the ripple system components become obsolete.

As indicated, the present CUMACS is connected to 11,226 control or data points in 551 buildings on 12 installations in the Heidelberg area. Some 5877 control points are connected, with the majority being activated via the ripple control system (DTM-3). However, some key points are activated via the cable system (DTM-1 and DTM-2). The number of control points can be expanded to more than 50,000. The rest of the control and data points (5349) are alarm and sensor points (analog and digital) that transmit data via the cable system or FM radio system (DTM-4). The alarm and sensor points are capable of expansion to 20,000. Examples of DTM installation are shown in Figs. 2a and 2b. The end points controlled are represented by the equipment shown in Figs. 3a and 3b.

A specific breakdown of the number of points installed and the associated time period were provided by Juergen Baller in response to a letter from B. W. McConnell.[10] This response is included as Appendix B. Figure 4 indicates the point count by DTM type against time period and provides some indication of the system's evolution from ripple to wire with the beginnings of a radio-based DTM underway.

The cost per point provided by Juergen Baller is consistent with the nominal $1000 per point used in most estimations. As indicated in Appendix B, cable installation, sensors, actuators, and indicators are not accounted for as part of the CUMACS because

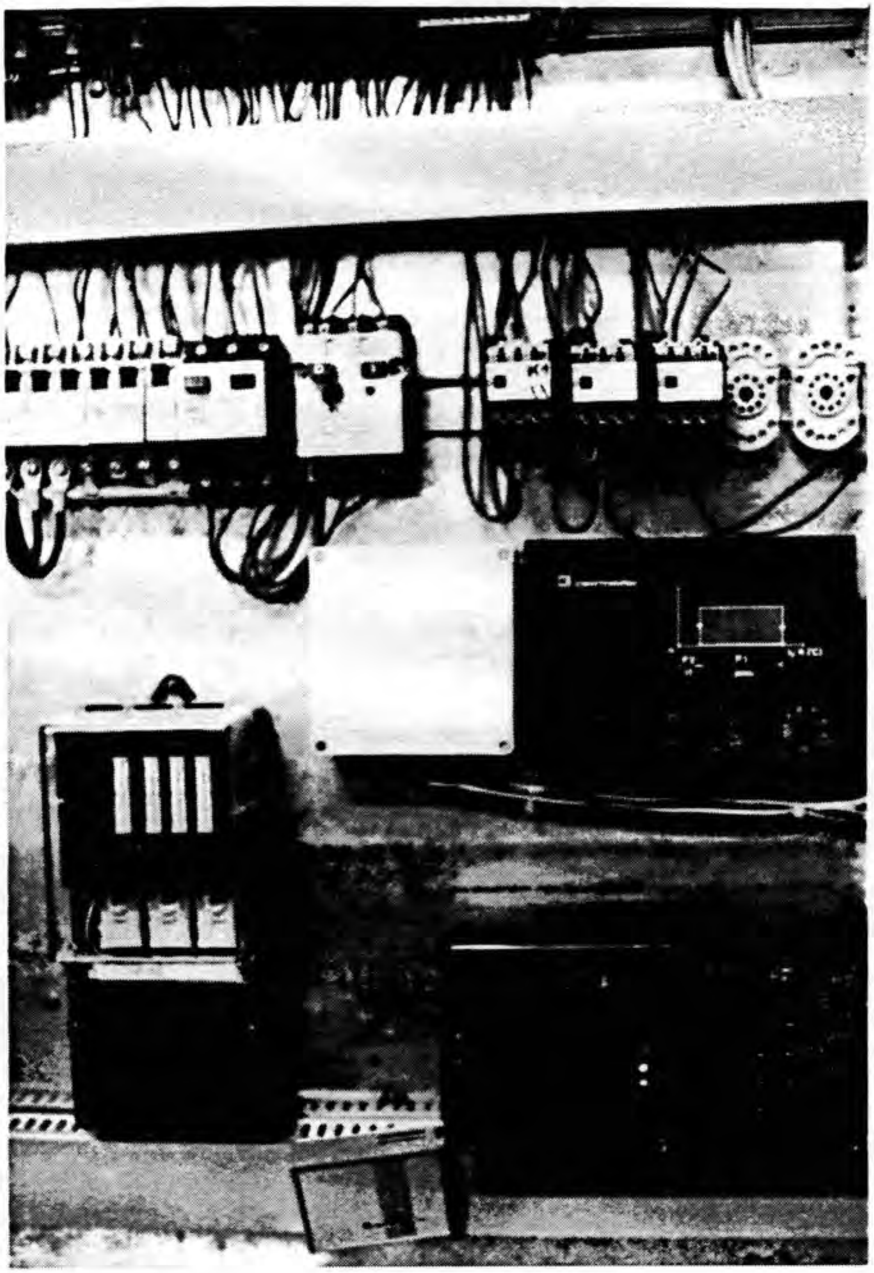

Fig. 2a. Heat system control panel with ripple control receiver, controller, and optimizer and EMCS interface in Building 3702, Mark Twain Village.

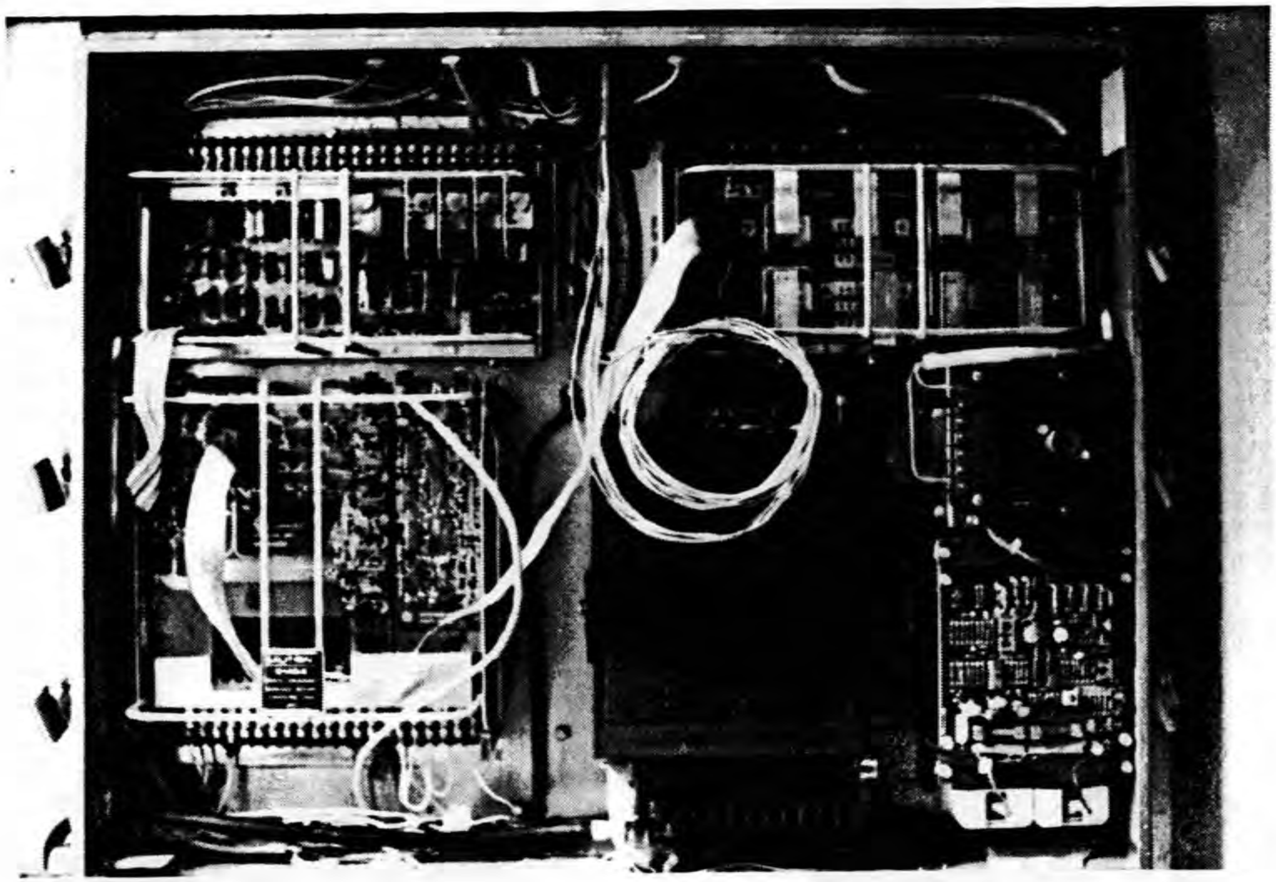

Fig. 2b. Two-way (half duplex) control in Waterplant, Building 4103, Golf Course.

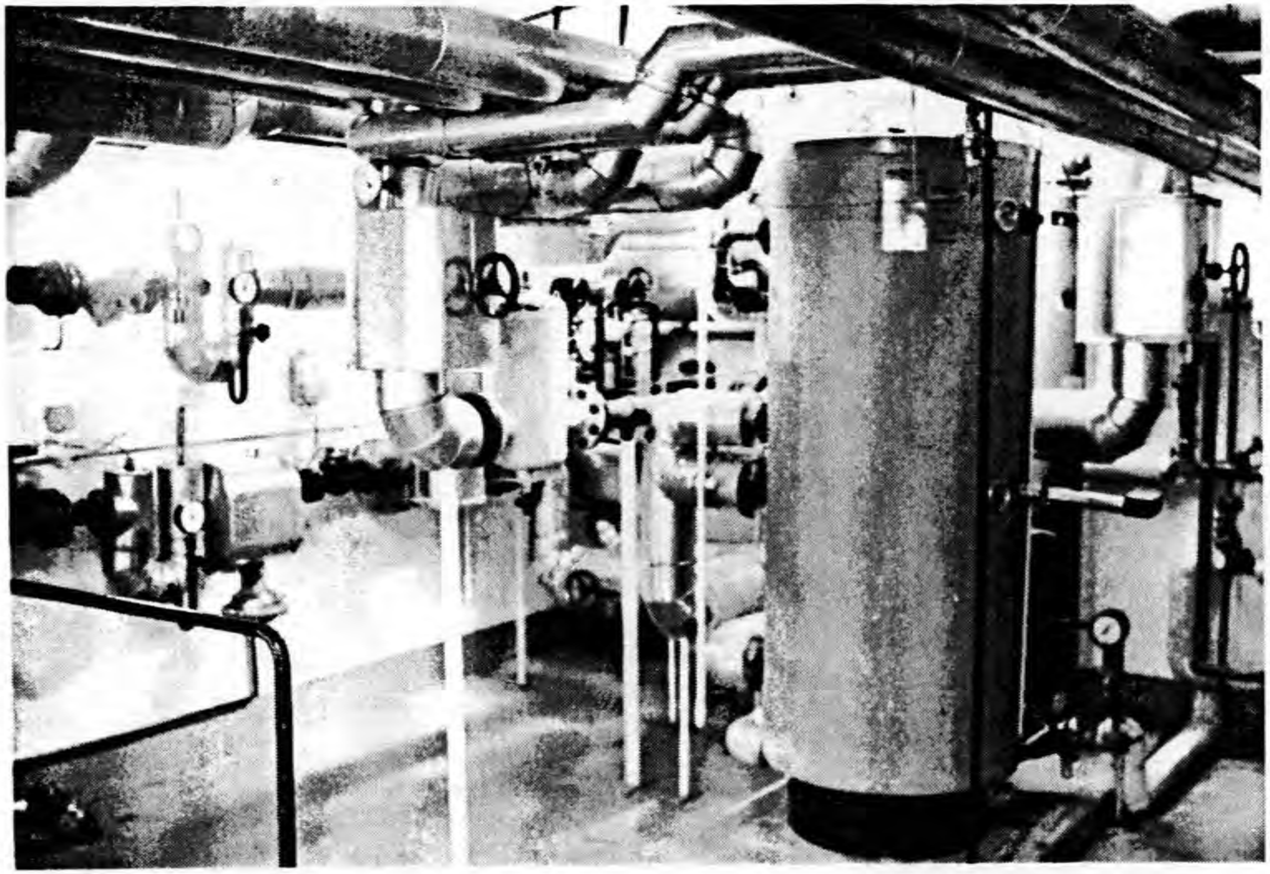

Fig. 3a. District heat transfer station (1 MBtu/h) with heat exchanger in Building 3702, Mark Twain Village.

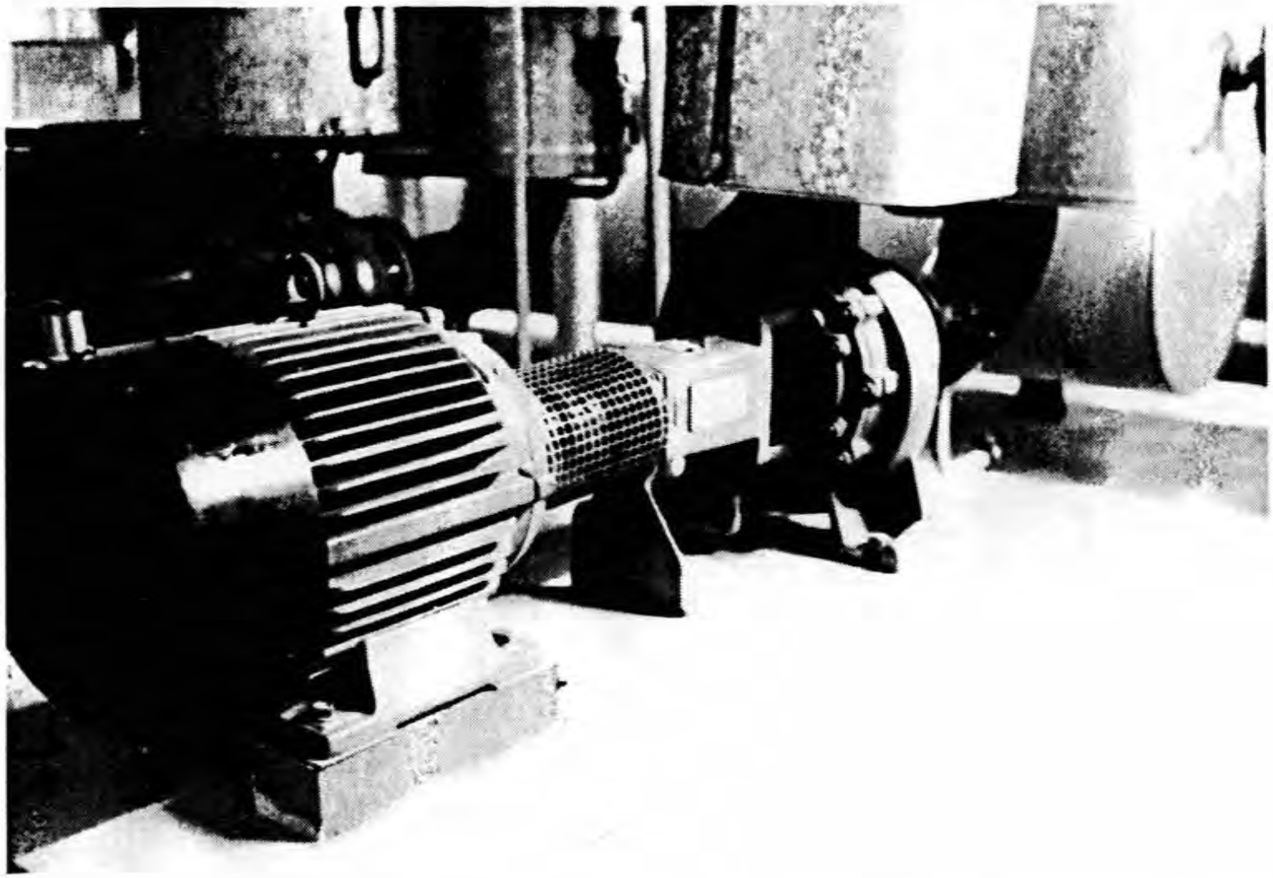

Fig. 3b. Variable-speed heat supply pump (differential pressure controlled) with EMCS connection in Building 3613, U.S. Army Hospital.

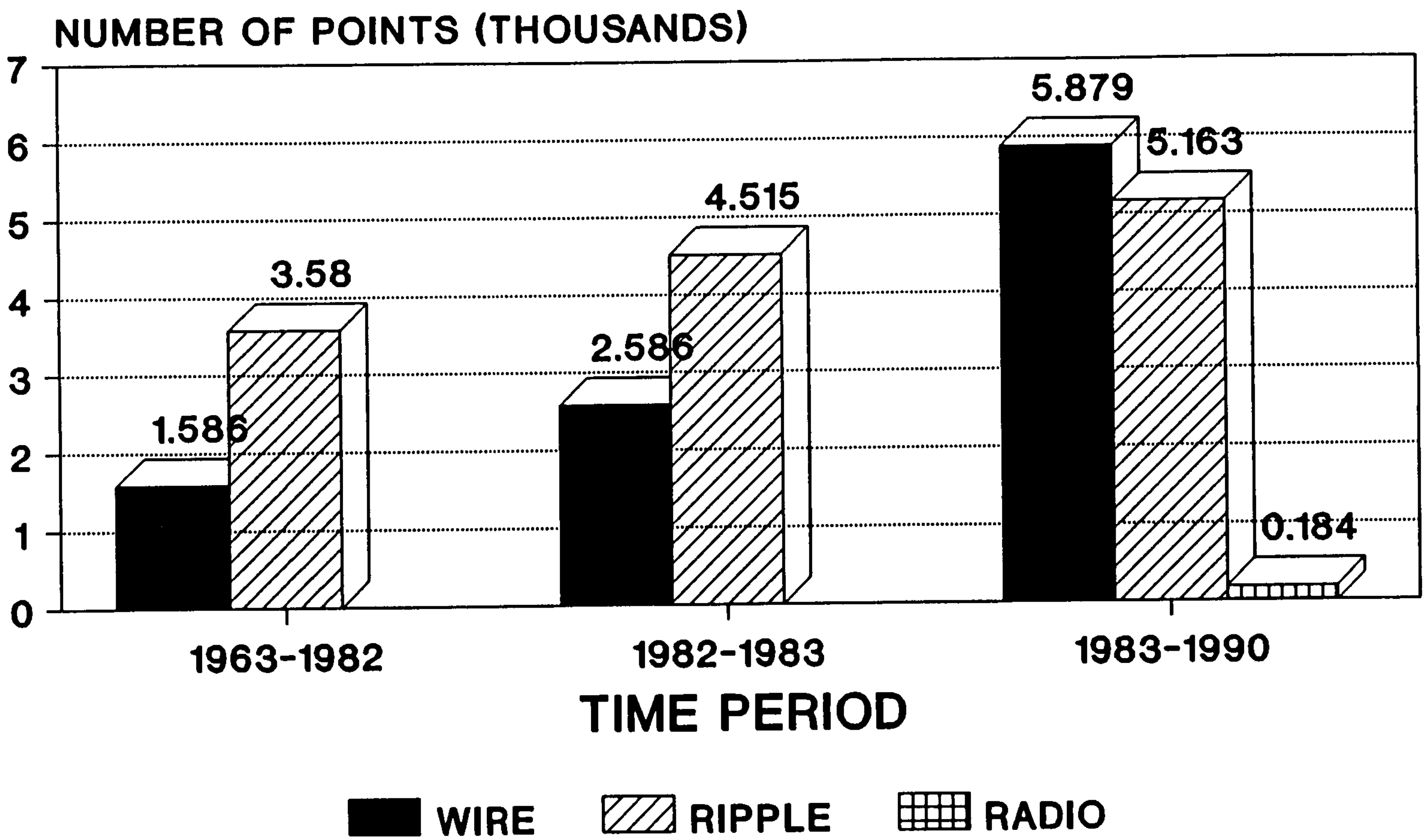

Fig. 4. Computerized Utilities Monitor and Control System (CUMACS) point count by type and date.

these are either installed as a part of a required system upgrade (cables) or are required by the local process controllers. This practice is consistent with the concept of having the EMCS account for only the cost difference.

For comparison, if the cost per point provided in Appendix B and the present point breakdown are used to estimate the FY 1990 replacement costs (assuming 1.5 DM = $1), a system cost of $3.55M for the remote points is obtained. Adding $1M for the central control computer and support facilities and dividing by the present point count gives a cost of $405 per point. As suggested by Appendix B, this does not include cable, actuator, sensor, or indicator costs. Therefore, if the EMCS is expected to account for all costs, a $1000 per point figure is appropriate. It is, however, much more consistent to have the EMCS account only for differential costs.

The CUMACS control center is shown in Figs. 5a and 5b and is located in Building 4 at Campbell Barracks. It consists of several 6800 and 8080 microprocessors, an FPR-1 microcomputer for the ripple control DTM (Landis & Gyr), a Mauell 5005 microcomputer for the cable DTM, a Hewlett-Packard 87 XM microcomputer for the FM radio DTM, a DEC PDP 11/23 minicomputer for integrated systems control, and a stand-alone IBM XT clone for data processing and evaluation. A small amount of external magnetic memory consisting of floppy discs and magnetic tape systems is available. The primary operator interfaces are CRTs and a pair of CONRAC 7119 graphic display monitors. System software currently consists of about 510 programs requiring 4.5 megabytes of memory which can be expanded to 10,220 programs in 50 megabytes. In addition, the system is connected to alphanumeric printers, a plotter, numeric printers, and eight display cabinets with multiple indicating and recording instruments for logging of data and alarms. A remote teletype is available in the Utilities Division office, and a closed-loop television system provides additional surveillance for the Chief of the Utilities Division. Automatic telephone dialers with prerecorded text are used to advise key personnel of high-level alarms and failures during off-duty hours. The FM voice communication system was replaced in December 1990 by a new two-way twelve-channel communication system including pagers and portable and mobile radios, which allows CUMACS control center operators to contact field personnel.

While the CUMACS system is dynamic in terms of its growth and day-to-day operation, the present number of points and building interfaces has remained constant during the last year. CUMACS is clearly a mixture of technologies from a variety of manufacturers. Presently the system is essentially a supervisory control system with "islands" of processing and control capability. The layout of CUMACS should allow the system to evolve toward the structure and characteristics described in the USAREUR reference and design handbook;[1] however, CUMACS may never actually match these requirements in detail.

Future plans, beyond the FM expansion to the seven communities not presently served by CUMACS, call for an upgrade of the central control computer from the present DEC PDP 11/23 to a DEC VAX-based system. This move will allow for system expansion, more graphic display screens, and greater data handling capability. Moreover, the system should allow for more data archival capability and for the ability to analyze data on-line or to download the information to PC-type machines for further analysis. The present data analysis capability is limited by the hand transfer of data.

Fig. 5a. Computerized Utilities Monitor and Control System (CUMACS) master control room (front view) in Building 4, Campbell Barracks.

Fig. 5b. Computerized Utilities Monitor and Control System (CUMACS) master control room (rear view) in Building 4, Campbell Barracks.

3. EVALUATION OF PROJECT DOCUMENTATION

On September 28, 1990, a letter was sent to Headquarters USAREUR requesting that copies of selected ECIP project documentation and other pertinent CUMACS/EMCS records be made available for review by ORNL personnel during their scheduled visit to the 26th Support Group in Heidelberg.[2] Upon arrival in Heidelberg on November 26, 1990, a majority of the information requested, plus detailed backup information, was assembled at the CUMACS/EMCS operations center for use by ORNL personnel during their two-week site visit to evaluate the overall effectiveness and energy efficiency of this system. It was obvious that CUMACS/EMCS management and operations personnel had made an extra effort to comply with ORNL's request for information and to provide whatever other information would be useful in support of this evaluation. During the two-week site visit, the ORNL principal investigators posed many questions and asked for pertinent supplemental data and information. All questions were answered in a forthright and open manner. Whenever supplemental information was available, it was quickly prepared (including its graphic presentation) and made available to the ORNL principal investigators. In many cases, the data and information requested was immediately made available in the CUMACS/EMCS operation center on a computer terminal visual display and/or hard copy printout. Overall, the quality of project documentation was excellent, and the cooperation of CUMACS/EMCS management and operations personnel could not have been better.

U. S. Army ECIP project guidance[3,4,5] in effect during the process of securing funding for, and actually constructing, the major part of the existing CUMACS/EMCS stipulates that qualifying projects must meet the following criteria:

- Savings to investment ratio (SIR)[a] > 1
- Simple pay-back period (SPP)[b] < 10 years
- E/C ratio (for FY 83 projects)[c] > 18

These ECIP project guidance performance criteria establish a baseline against which projected and actual energy and cost savings attributed to CUMACS/EMCS operations can be compared.

During 1980, an FY 1983 Military Construction Project Data Sheet (Form DD-1391) was prepared and issued for an extension of the EMCS installed at Heidelberg.[6] This data sheet established ECIP project number 706, and it documents the original energy and cost savings projections and associated justification for the current CUMACS/EMCS. It should be noted that the present system was actually started before ECIP project 706 was implemented, and it has undergone iterative expansion since that time. Nevertheless, a significant part of the system that exists today (2000 points and a major portion of the

[a]Total net discounted savings/ECIP project investment cost.
[b]ECIP project investment cost/first-year dollar savings.
[c]Annual MBtu of energy saved/($K) ECIP project investment cost.

central control facility) was installed using FY 1983 ECIP project funds. Figure 6 is a copy of the actual ECIP Economic Analysis Summary that accompanied the original justification and funding request (Form DD-1391) for ECIP project 706. Highlights from this original project documentation are summarized as follows:

• Estimated investment (construction) cost	$892,000
• Projected annual energy savings	80,319 MBtu
• Projected annual (first year) $ savings	$701,163
• SIR	9.65
• SPP	1.2 years
• E/C ratio	94.6

On March 30, 1983, a construction contract was awarded for this project. The contract was awarded for 1,218,683 DM or the equivalent of $542,843 based on the prevailing 1983 exchange rate of 1 U.S. dollar = 2.245 DM. At this juncture an updated ECIP Life Cycle Cost Analysis Summary (see Fig. 7) was prepared by the 26th Support Group to reflect the actual contractual costs to install this major extension to the CUMACS/EMCS. Highlights from this updated project documentation are summarized as follows:

• Estimated investment (construction) cost	$604,154
• Projected annual energy savings	80,319 MBtu
• Projected annual (first-year) $ savings	$755,728
• SIR	15.24
• SPP	0.8 years
• E/C ratio	147.96

Starting in FY 1979, the 26th Support Group, Directorate of Engineering and Housing, Utilities Division prepared and issued annual energy and cost savings summaries that estimate energy and cost savings attributable to CUMACS/EMCS operations. Supporting documentation including detailed calculations, estimating assumptions, current fuel costs, and prevailing currency exchange rates were on file and were readily available to the ORNL principal investigators during the two-week site visit to evaluate CUMACS/EMCS operations. Appendix A is a typical CUMACS/EMCS energy and cost savings summary for FY 1990. Table 1 is an overall summary of estimated energy savings attributable to CUMACS/EMCS operations between FY 1979 and FY 1990. Table 2 is a similar table for estimated cost savings. Data for these tables were extracted directly from the annual energy and cost savings summaries discussed in Appendix A.

Based on the projected energy and cost savings derived from the aforementioned project documentation, comparisons can now be made for the key parameters listed in Table 3. The first observation is that the SIR, SPP, and E/C ratio attributable to energy and cost savings derived from CUMACS/EMCS operations significantly exceed ECIP project guidance minimum requirements. There is a 15 to 1 SIR betterment (15+ vs 1) and a 10 to 1 SPP betterment (<1 year vs <10 years). Results of recent U. S. Army ECIP project validation and evaluation studies conducted in the United States reveal appreciably less benefits derived from EMCS operations.[7,8] SIRs for these continental U. S. EMCS projects ranged from 6.6 to 1.1, while SPPs ranged from 1.8 to 9.3 years. The best stateside performance was for ECIP project number 428, which

ECIP ECONOMIC ANALYSIS SUMMARY

Location: U.S. Military Community Activity, Heidelberg FY 1982
Project: No. 706, Extension of Computerized Energy Control System in Bldg. No. 4, Campbell Barracks, Heidelberg, APO New York 09102 (O&MA and Schools)
Economic Life: 15 Yrs. Date Prepared 3/28/80 Prepared by Juergen Bäller

COSTS	
1. Non-recurring Initial Capital Costs:	
a. CWE	$ 849,400
b. Design	$ 55,400
c. ______	$ - 12,800
d. Total	$ 892,000
BENEFITS	
2. Recurring Benefit/Cost Differential Other Than Energy:	
a. Annual Labor Decrease (+)/Increase (-)	$ 28 547 /Yr.
b. Annual Material Decrease (+)/Increase (-)	$ /Yr.
c. Other Annual Decrease (+)/Increase (-)	$ /Yr.
d. Total Costs	$ 28 547 /Yr.
e. 10% Discount Factor	$ 7.98
f. Discounted Recurring Cost (d x e)	$ 227,805
3. Recurring Energy Benefit/Costs:	
a. Type of Fuel: Electricity	
(1) Annual Energy Decrease (+)/Increase (-)	10,349 MBTU
(2) Cost per MBTU	$ 10.24 /MBTU
(3) Annual Dollar Decrease/Increase ((1)x(2))	$ 105,923 /Yr.
(4) Differential Escalation Rate (7 %) Factor	12.278
(5) Discounted Dollar Decrease/Increase (3)x(4)	$ 1,300,517
b. Type of Fuel: Electric: Demand Charge Reduction	
(1) Annual Energy Decrease (+)/Increase (-)	Negligible MBTU
(2) Cost per MBTU	$ ./. /MBTU
(3) Annual Dollar Decrease/Increase ((1)X(2))	$ 109,382 /Yr.
(4) Differential Escalation Rate (7 %) Factor	12.278
(5) Discounted Dollar Decrease/Increase ((3)x(4))	$ 1,342,992
c. Type of Fuel: Distillate Fuel Oil	
(1) Annual Energy Decrease (+)/Increase (-)	36,638 MBTU
(2) Cost per MBTU	$ 9.37 /MBTU
(3) Annual Dollar Decrease/Increase ((1)x(2))	$ 343,298 /Yr.
(4) Differential Escalation Rate (8%) Factor	13.122
(5) Discounted Dollar Decrease/Increase ((3)x(4))	$ 4,504,757
d. Type of Fuel: Anthracite Coal	
(1) Annual Energy Decrease (+)/Increase (-)	33,337 MBTU
(2) Cost per MBTU	$ 3.42 /MBTU
(3) Annual Dollar Decrease/Increase ((1)x(2))	$ 114,013 /Yr.
(4) Differential Escalation Rate (5%) Factor	10.798
(5) Discounted Dollar Decrease/Increase ((3)x(4))	$ 1,231,307
e. Discounted Energy Benefits (3a(5)+3b(5)+3c(5)+3d(5))	$ 8,379,573
4. Total Benefits (Sum 2f+3e)	$ 8,607,378
5. Discounted Benefit/Cost Ratio (Line 4÷Line 1d)	9.65
6. Total Annual Energy Savings (3a(1)+3b(1)+3c(1)+3d(1))	80,319 MBTU
7. E/C Ratio (Line 6 ÷ Line 1a/1000)	94.6
8. Annual $ Savings (2d+3a(3)+3b(3)+3c(3)+3d(3))	$ 701,163
9. Pay-back Period ((Line 1a - Salvage)÷Line 8)	1.2 years

Fig. 6. Energy Conservation Investment Program (ECIP) Economic Analysis Summary prepared March 28, 1980.

LIFE CYCLE COST ANALYSIS SUMMARY
ENERGY CONSERVATION INVESTMENT PROGRAM (ECIP)

LOCATION: Heidelberg, Germany REGION NO. 11 PROJECT NUMBER 706

PROJECT TITLE Extend CUMACS/EMCS System FISCAL YEAR 1983

DISCRETE PORTION NAME Summary

ANALYSIS DATE 7/28/83 ECONOMIC LIFE 15 YEARS PREPARED BY Juergen Bäller

1. INVESTMENT
   - A. CONSTRUCTION COST $ 609,342
   - B. SIOH $ 25,380
   - C. DESIGN COST $ 36,560
   - D. ENERGY CREDIT CALC (1A+1B+1C)X.9 $ 604,154
   - E. SALVAGE VALUE - $ -0-
   - F. TOTAL INVESTMENT (1D-1E) $ 604,154

2. ENERGY SAVINGS (+) / COST (-)
   ANALYSIS DATE ANNUAL SAVINGS, UNIT COST & DISCOUNTED SAVINGS

FUEL	COST $/MBTU/YR(1)	SAVINGS MBTU/YR(2)	ANNUAL $ SAVINGS(3)	DISCOUNT FACTOR(4)	DISCOUNTED SAVINGS(5)
A. ELEC	$ 7.68	10,344	$ 79,442	11.01	$ 874,656
B. DIST	$ 10.57	36,638	$ 387,264	11.36	$ 4,399,320
C. RESID	$ —	—	$ —	13.29	$ -0-
D. NG	$ —	—	$ —	12.80	$ -0-
E. COAL	$ 6.21	33,337	$ 207,023	15.39	$ 3,186,080
F. TOTAL		80,319	$ 673,728		----------> $ 8,460,050

3. NONENERGY SAVINGS(+) / COST(-)
   - A. ANNUAL RECURRING (+/-) $ 82,000
     - (1) DISCOUNT FACTOR (TABLE A) 9.108
     - (2) DISCOUNTED SAVING/COST (3A X 3A1) $ 746,200
   - B. NONRECURRING SAVINGS(+) / COST(-)

ITEM	SAVINGS(+) COST (-)(1)	YEAR OF OCCURRENCE(2)	DISCOUNT FACTOR(3)	DISCOUNTED SAVINGS(+) COST(-)(4)
(1)	$			$
(2)	$			$
(3)	$			$
(4) TOTAL	$			$ none

   - C. TOTAL NONENERGY DISCOUNTED SAVINGS(+) / COST(-) (3A2+3Bd4) $ 746,200
   - D. PROJECT NONENERGY QUALIFICATION TEST
     - (1) 25% MAX NONENERGY CALC (2F5 X .33) $ 2,791,817
       - a. IF 3D1 IS = OR > 3C GO TO ITEM 4
       - b. IF 3D1 IS < 3C CALC SIR = (2F5+3D1) ÷ 1F = N/A
       - c. IF 3D1b IS = > 1 GO TO ITEM 4
       - d. IF 3D1b IS < 1 PROJECT DOES NOT QUALIFY

4. FIRST YEAR DOLLAR SAVINGS 2F3+3A+(3B1d ÷ YEARS ECONOMIC LIFE) $ 755,728

5. TOTAL NET DISCOUNTED SAVINGS (2F5+3C) $ 9,206,250

6. DISCOUNTED SAVINGS RATIO (IF < 1 PROJECT DOES NOT QUALIFY)(SIR)=(5 ÷ 1F)= 15.24

Fig. 7. Updated Energy Conservation Investment Program (ECIP) Life Cycle Cost Analysis Summary prepared July 28, 1983.

Table 1. Summary of Heidelberg Computerized Utilities Monitor and Control System estimated energy savings (MBtu) by conservation categories

Fiscal Year	Electrical Consumption	Domestic Hot Water	Space Heating	Total MBtu
1979	942	5,651	16,252	22,845
1980	1,139	7,362	20,205	28,706
1981	1,293	9,428	21,693	32,414
1982	5,363	24,713	49,427	79,503
1983	4,228	42,356	71,644	118,228
1984	8,252	52,673	79,927	140,852
1985	6,896	64,687	95,112	166,695
1986	6,311	93,383	102,702	202,396
1987	6,434	96,290	100,699	203,423
1988	7,740	32,551	72,174	112,465
1989	7,876	31,195	69,932	109,003
1990	7,161	28,575	57,679	93,415
Cumulative	63,635	488,864	757,446	1,309,945
Average	5,303	40,739	63,120	109,162

Table 2. Summary of Heidelberg Computerized Utilities Monitor and Control System estimated cost savings ($) by conservation categories

Fiscal Year	Electrical Demand Limiting	Electrical Consump-tion	Domestic Hot Water	Space Heating	Leak Detection	O&M Savings	Total $ Savings
1979	127,539	19,719	36,741	79,571	0	29,286	292,856
1980	138,629	23,839	48,000	94,000	0	125,000	429,468
1981	183,970	35,292	121,236	219,450	0	34,831	594,779
1982	125,249	39,898	238,575	477,160	181,416	28,761	1,091,059
1983	293,251	46,488	432,083	654,857	254,892	26,250	1,707,821
1984	270,602	43,132	341,001	516,815	466,695	28,044	1,666,289
1985	227,743	38,879	355,643	522,908	319,087	25,155	1,489,415
1986	203,558	86,899	449,055	477,728	172,703	42,660	1,432,603
1987	302,398	132,310	602,089	576,146	52,838	35,886	1,701,667
1988	366,573	188,988	227,065	456,766	98,617	59,544	1,397,553
1989	411,012	188,804	224,317	467,582	106,435	89,850	1,488,000
1990	242,914	171,964	257,713	483,054	49,619	283,623	1,488,887
Cumulative	2,893,438	1,016,212	3,333,518	5,026,037	1,702,302	808,890	14,780,379
Average	241,120	84,684	277,793	418,836	141,859	67,048	1,231,700

Table 3. Comparison of key energy and cost savings parameters attributable to Computerized Utilities Monitor and Control System, Heidelberg operations

Key Parameter	ECIP Project Guidance[a]	Original ECIP Economic Analysis,[b] March 28, 1980	Updated ECIP LCCA Summary,[c] July 28, 1983	Annual Energy/Cost Savings Estimates,[d] FY 1979–1990
Investment Cost	n/a	$892,000	$604,154	$950,000 (cumulative)
Annual Energy Savings	n/a	80,319 MBtu	80,319 MBtu	109,162 MBtu (avg.)
Annual Dollar Savings	n/a	$701,163	$755,728	$1,231,700 (avg.)
Benefit/Cost Ratio (SIR)	> 1	9.65	15.24	15.56
Simple Pay-Back Period	< 10 years	1.2 years	0.8 years	0.77 years
E/C Ratio	> 18	94.6	147.96	114.9

[a]See references 3, 4, and 5.
[b]See Fig. 5.
[c]See Fig. 6.
[d]See Tables 1 and 2.

covered the installation of FM-radio-controlled setback thermostats in 851 Army buildings at Fort Bragg, North Carolina.[9] The SIR for this one project was 6.6 and the SPP was 1.8 years. This fact should provide CUMACS/EMCS management and operations personnel with a degree of confidence and comfort in view of the fact that future planned expansion of the CUMACS/EMCS will concentrate on FM radio controls.

The key parameters listed in columns 2 and 3 of Table 3 would, for all practical purposes, be very similar if not for the fact that the actual ECIP project investment cost is significantly lower than originally estimated, i.e., $604,154 (actual) vs $892,000 (estimated). If this actual ECIP project investment cost were to be substituted in the original ECIP economic analysis, then the resultant SIR, SPP, and E/C ratio recorded in column 2 would have become much more closely aligned with the comparable figures listed in column 3, i.e., SIR = 14.73 vs 15.24, SPP = 0.76 years vs 0.8 years, and E/C ratio = 148 vs 147.96. For this reason, subsequent discussion in this section will be limited to comparisons and commentary on the data listed in Table 3, columns 3 and 4.

The key parameter data listed in column 4 is based on annual energy and cost savings estimates attributable to actual CUMACS/EMCS operations over a 12-year period (FY 1979 to FY 1990). Annual CUMACS/EMCS energy and cost savings summary sheets (see Appendix A) were carefully prepared, use reasonable assumptions, and appear to be accurate. In most cases adequate back-up documentation is available to substantiate the energy and cost savings quoted in these annual summaries. The fluctuation in the rate of exchange between the U. S. dollar and the DM in extreme cases tends to portray somewhat synthetic cost savings. For example, the average rate of exchange varied from a high of $1 = 3.73 DM in 1986 to a low of $1 = 1.78 DM in 1981. During the ORNL principal investigators' visit to Heidelberg during the latter part of 1990, the prevailing rate of exchange was $1 = 1.47 DM. The good news is that over a period of 12 years these fluctuations tend to average out. Therefore, the data listed in column 4, which is based on 12 years of cumulative and average figures, tends to be more credible.

The annual energy and cost savings estimates discussed do not take into consideration actual operation and maintenance (O&M) costs including associated materials and equipment expended in support of CUMACS/EMCS operations. In the opinion of the ORNL principal investigators, these actual O&M costs should be reflected in the estimated cost savings attributable to CUMACS/EMCS operations. For example, since 1979 there have been four operating personnel assigned to the CUMACS/EMCS. In addition, trained maintenance personnel from the HVAC Controls Shop (DEH: Utilities Division, Mechanical Branch) respond to calls for CUMACS/EMCS routine maintenance and repair. Although the system components are reported to be very reliable, occasionally an electronic component or other piece of equipment must be replaced. The cost of these materials and equipment should be charged against CUMACS/EMCS operations if the estimated cost savings are to be considered realistic and credible. Finally, an annual maintenance services contract is awarded to cover the costs of an outside contractor to perform major, nonroutine maintenance and repair on this system. A recent annual maintenance services contract was written to cover system maintenance and repairs costing up to approximately $15,000. Reportedly, these maximum contractual amounts are never actually expended. In aggregate these CUMACS/EMCS O&M costs are estimated to be about 10 to 15% of the reported dollar savings based upon the following rough estimates:

CUMACS/EMCS O&M Activity	Estimated Annual Cost
System operation (4 people @ $30,000/year)	$120,000
In-house maintenance (1 person @ $20,000/year)	20,000
Outside maintenance contract ($15,000 max.)	10,000
Materials and equipment	10,000
Estimated annual O&M costs	$160,000

Over a 12-year period these O&M costs would have amounted to approximately $1,920,000, or about 13% of the reported $14,780,400 cumulative cost savings attributed to CUMACS/EMCS operations. Applying these estimated annual O&M costs to the data in Table 3, column 4, we have the following changes:

Key Parameter	Without O&M Costs	With O&M Costs
• Estimated annual $ savings	$1,231,000	$1,071,700
• SIR	15.56	13.54
• SPP	0.77 years	0.89 years

In summary, we can, therefore, say as a rule that energy and cost savings attributable to CUMACS/EMCS operations nominally result in the following:

• Estimated energy savings	>100,000 MBtu/year
• Estimated cost savings	>$1,000,000/year
• SIR	>13
• SPP	<1 year

4. ASSESSMENT OF SITE AND PHYSICAL CONDITIONS

This section presents a brief overview of the physical condition and other energy related observations at the specific sites and facilities visited. In general, all facilities that were visited and that are under CUMACS control were found to be very clean and well maintained. With the installation of district heat and hot water heating, the operating environment for the CUMACS equipment has been made less severe. As a result the equipment should now have an increased life.

4.1 CAMPBELL BARRACKS AND MARK TWAIN VILLAGE

A variety of connected systems and facilities controlled by CUMACS are located in the Campbell Barracks (CB) and Mark Twain Village (MTV) area. The CUMACS Center in Building 4 at CB houses the control computers and equipment described in Section 2, the telephone switching and communications equipment, and the CUMACS maintenance equipment and was found to be exceptionally well organized and well maintained. The backup electrical generators for CB are housed in Building 63 adjacent to the CUMACS control center and are controlled by CUMACS.

The electrical substations visited at CB/MTV are located in Buildings 7 (6 kV to 400 V) and 48 (20 kV to 6 kV). These installations were observed to be exceptionally clean with a strong emphasis on personnel safety. Modern vacuum breakers are used on both the low- and high-voltage electrical buss. The ripple commands are injected at 6 kV in Building 4 and pass through the substations in Buildings 7 and 48 to the 20-kV Heidelberg electrical distribution network and outward to the other facilities controlled from CUMACS via the ripple system.

A typical family housing unit and the auxiliary district heat distribution point in Building 3702 at MTV was also visited. This building had been converted from oil and was controlled by a local controller with switched set points initiated from the CUMACS via the ripple control system. To allow more optimal control, the district heat main distribution point in Building 7 at CB is controlled directly from the CUMACS center. It was observed that, even though many windows and doors were open in this area even when the outside temperature was below freezing, in most cases the buildings were quite warm.

4.2 PATRICK HENRY VILLAGE

Patrick Henry Village (PHV) is a family, bachelor officer, and bachelor noncommissioned officer housing area with supporting facilities such as churches, schools, day care, theater, and clubs. The electrical substation in Building 4749 (20 kV to 400 V) serves the entire PHV. A synchronized ripple control signal is injected at this substation. The substation was observed to have mechanical breakers, which indicates some of the diversity of equipment interfaced with the CUMACS system.

Building 4750 is the district heat distribution point for the 87 buildings of PHV. The system was in the process of being cleaned up and renovated following conversion from coal to district heat. A small backup generator was also present in this building.

Building 4713 in PHV is a typical multifamily housing unit. The common washer-dryer area was visited and is representative of the demand-limiting equipment installed on CUMACS. In addition, the building district heat and hot water systems were visited and found to be similar to those in MTV. In all buildings, the local controller monitors a single temperature sensor for the entire building. The sensor is usually located on a north wall in the middle of the building. Clearly, an open window, small local heater, or malfunctioning thermostat in the room housing the sensor could have significant impact on the building temperature and energy consumption. It was observed that each apartment unit has a separate electric meter; however, the occupants are not billed for the electric service. Occasionally mock bills are provided as a reminder to conserve energy. The total utility service (heat, hot water, electricity, and water) for the building is metered and monitored by CUMACS.

The elementary school in Building 4498 is also a district heat conversion from an oil boiler. For schools, churches, and other fixed-schedule buildings, the CUMACS places the local controller in the setback mode during non-use periods such as weekends and holidays. A typical bachelor enlisted quarters and bachelor officer quarters were also visited. It should again be noted that many doors and windows were found to be open.

4.3 PATTON BARRACKS AND HOSPITAL

At Patton Barracks (PB), which is a typical enlisted barracks area with some administration, the district heat distribution center in Building 104 and a typical enlisted barracks in Building 103 were visited. The facilities were essentially the same configuration as those in CB/MTV and were oil boiler conversions. A typical ripple control receiver for outside lighting was examined. Again, multiple doors and windows were open in unoccupied space and the buildings were overly warm.

At the U. S. Army Hospital, Buildings 3617, 3613, and 3631H were visited. The steam plant in Building 3617 is an example of an "island" control system which could be operated independently of the CUMACS central control. The system provides steam by using natural gas to raise hot water heated by district heat to steam for cleaning and sterilization. In general, a fireman is present at the boilers but CUMACS can operate these systems remotely. The electrical substation, medical gases, vacuum system, and HVAC in Building 3613 were visited. The HVAC system is an example of enthalpy control using local process controllers. The system is monitored closely by CUMACS with temperature set points switched using ripple control. Finally, the chlorine water treatment plant in Building 3631H was visited. The chlorine produced by the plant is used in sewage and water treatment, and the system is controlled with a local process controller which is monitored by CUMACS for proper operation.

4.4 AUTOBAHN KASERNE, KILBOURNE, AND TOMPKINS BARRACKS

The Stem or Autobahn Kaserne (SK) is an example of an oil-fired boiler which is monitored via the existing FM system. The system in Building 1002 uses local process controllers with setback commands from CUMACS via FM plus an alarm to CUMACS on low fuel.

At Kilbourne Barracks (KB) a district heat system is under construction. Buildings 4302, 4347, and 4315 were visited. The layout was similar to that of CB. At Tompkins Barracks (TB) a district heat system has just been installed to replace a large coal boiler in Building 4243. The startling contrast in the two systems was most impressive, the coal system being complex and dirty while the district heat system was simple and clean. A large backup generation unit (1.370 MVA, 5 kV, 50 Hz) was being constructed and tested in Building 4237. The unit will be monitored and controlled with CUMACS.

It was not possible for the principal investigators to visit every building or facility under CUMACS control. Instead, we visited a limited number of key facilities and buildings that were representative of the systems under CUMACS control. In most cases, CUMACS initiates programs in the local controller by using the ripple control system and monitors the facility using the cable system. As noted in Section 2, CUMACS directly controls some key facilities via the cable communications system.

5. ANALYSIS OF ENERGY AND COST SAVINGS

5.1 ENERGY CONSUMPTION IN CUMACS/EMCS-CONTROLLED FACILITIES

ECIP Project No. 706 provided military construction project funding to install the most significant part of the CUMACS/EMCS that exists today. This system was installed during FY 1983 and became operational during FY 1984. Figure 8 shows a steady decrease in total energy consumption in CUMACS/EMCS-controlled buildings between FY 1984 and FY 1990. This decrease in energy consumption cannot be directly attributed to electrical energy usage, which remained fairly constant during this time period. A closer look at thermal energy consumption per ft^2/HDD alone (see Fig. 9) reveals a more meaningful and realistic energy consumption trend. Between FY 1984 and FY 1990, thermal energy consumption in CUMACS/EMCS-controlled buildings was reduced from 16.41 to 7.72 Btu/ft^2/HDD, which represents a 100%+ reduction in thermal energy usage. This steady decrease in thermal energy consumption in CUMACS/EMCS-controlled buildings can be attributed to the composite effects of several energy conservation programs that were implemented simultaneously by the 26th Support Group, i.e.,

- installation of the CUMACS/EMCS;
- installation of a hot water district heating system;
- retrofit of external wall insulation, ceiling/roof insulation, and multiple glazing to building envelopes; and
- general conservation measure implementation including reduction of the set temperature of domestic hot water heaters.

Figure 9 shows an appreciable reduction in thermal energy consumption in CUMACS/EMCS-controlled buildings between FY 1984 and FY 1985, the time period when this system was becoming operational. This reduction can most likely be attributed to CUMACS/EMCS operations, since building insulation and glazing retrofits had not been started and installation of the hot water district heating system was just getting started. As also shown in Fig. 9, another significant reduction in thermal energy consumption occurs between FY 1987 and FY 1988. Based on evidence revealed later in this evaluation, this particular reduction in thermal energy consumption is probably a direct result of the positive impact of other energy conservation programs such as the building envelope retrofit program, and is probably not primarily due to CUMACS/EMCS operations.

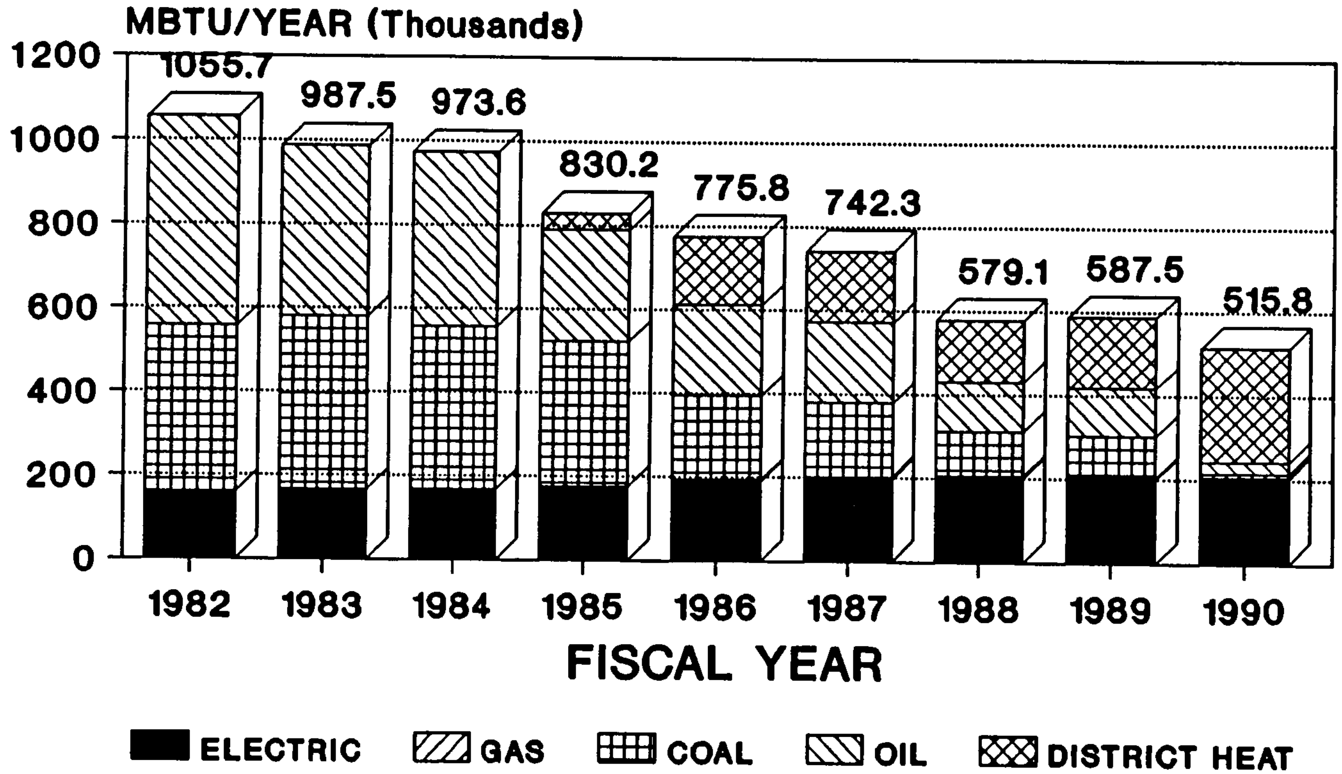

Fig. 8. Computerized Utilities Monitor and Control System/Energy Monitoring and Control System (CUMACS/EMCS), Heidelberg, energy consumption by fuel and energy type, FY 1982 to FY 1990.

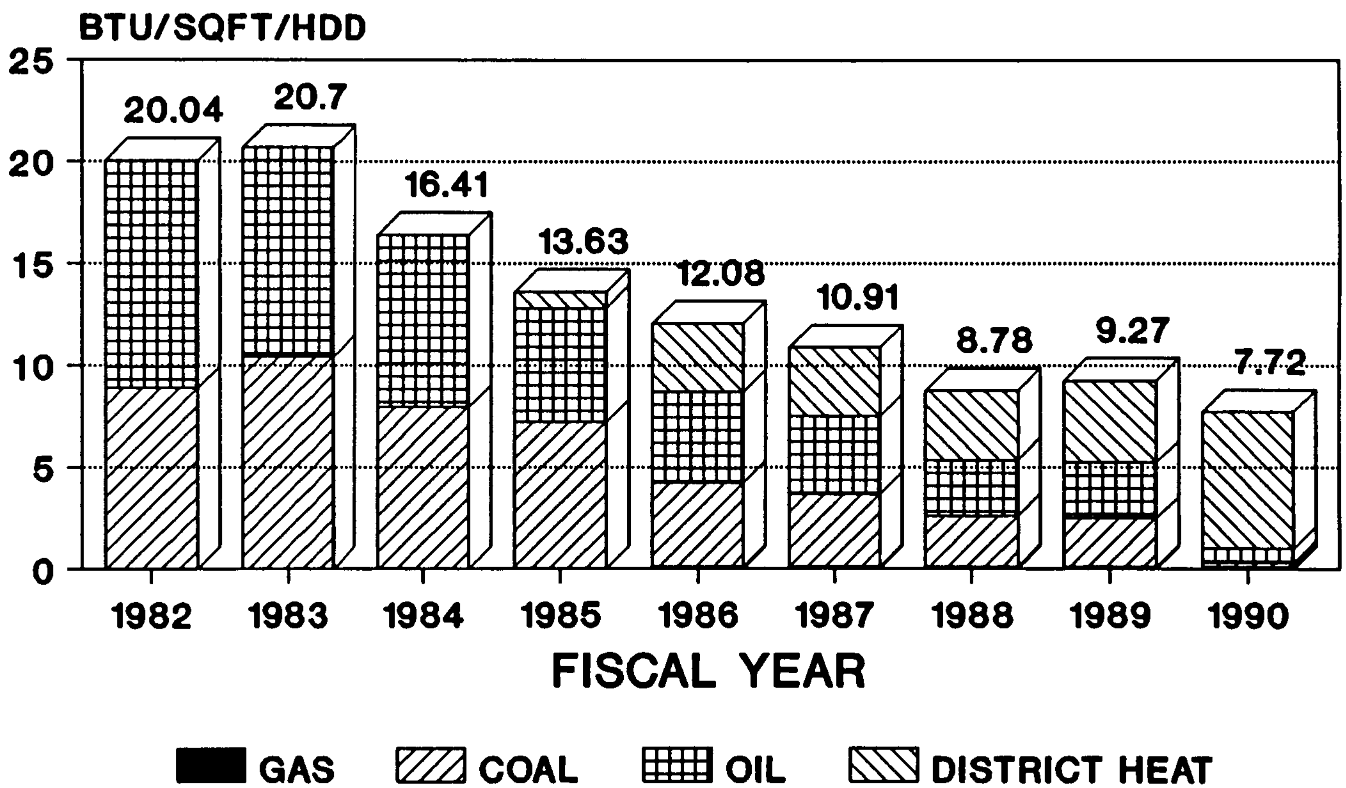

Fig. 9. Computerized Utilities Monitor and Control System/Energy Monitoring and Control System (CUMACS/EMCS), Heidelberg, thermal energy consumption (Btu/ft^2/HDD), FY 1982 to FY 1990.

Figures 10 and 11, which are derived from the data recorded in Table 4, provide interesting comparisons of energy consumption during FY 1990 at the various major installations comprising the 26th Support Group. These installations are identified as follows:

CB	Campbell Barracks (office and administrative)
PB	Patton Barracks (military housing/administrative)
MTV	Mark Twain Village (military housing)
PHV	Patrick Henry Village (military housing)
TB/KK	Tompkins Barracks/Kilbourne Kaserne (military housing/administrative)
HOSP	U. S. Army Hospital (support facility)
CSC	Community Support Center (support facility)
HAAF	Heidelberg Army Air Field (support facility)
SK	Stem Kaserne (support facility)
KSL	Königstuhl (support facility)
GOLF	Golf Course (support facility)
FUT	Future CUMACS/EMCS-Controlled Facilities

In Fig. 10 we see that, for military housing, energy efficiency in terms of MBtu of energy consumed per 1000 ft^2 of floor space in CUMACS/EMCS-controlled buildings was superior to that in administrative and support facilities during FY 1990. For example, during FY 1990, energy consumption in the two primary military housing facilities in Heidelberg, i.e., Mark Twain Village and Patrick Henry Village, was 39.16 and 53.73 MBtu/1000 ft^2, respectively. This compares with 87.2 MBtu/1000 ft^2 for Campbell Barracks, which is the primary HQ USAREUR and Seventh Army office and administrative facility in Heidelberg. Energy consumption in major support facilities such as the U. S. Army Hospital and Community Support Center is approximately 72 MBtu/1000 ft^2 of floor space. From an overall energy efficiency standpoint it appears the 26th Support Group sponsored energy conservation programs have had a greater impact on reducing energy consumption in military housing facilities compared with office, administrative, and support facilities.

Figure 11 provides a different perspective about energy consumption patterns in major 26th Support Group installations. During FY 1990, the greatest percentage of energy consumed by military housing facilities was thermal energy for domestic hot water and space heating. For example, during FY 1990, 70% to 75% of the energy consumed in the two largest military family housing installations, Mark Twain Village and Patrick Henry Village, is attributable to thermal energy for domestic hot water and space heating. The reverse is true for many of the principal 26th Support Group office, administrative, and support facilities. In Campbell Barracks, 68% of total energy consumption is based on electrical usage, not thermal energy usage. Part of the reason for this reverse trend is the fact that Campbell Barracks houses several 24-hour-a-day classified operations that are very electrical-energy intensive. Similarly, over 65% of the energy consumed by the Community Support Center, one of Heidelberg's principal Army support facilities, is electrical energy. Facilities that have a blended occupancy such as the U. S. Army Hospital, Patton Barracks, and Tompkins/Kilbourne Barracks tend to have thermal vs electrical energy use patterns that are between the extremes of pure military housing facilities and pure administrative/support facilities. Based on the above observations, it appears that future 26th Support Group energy conservation programs should focus on

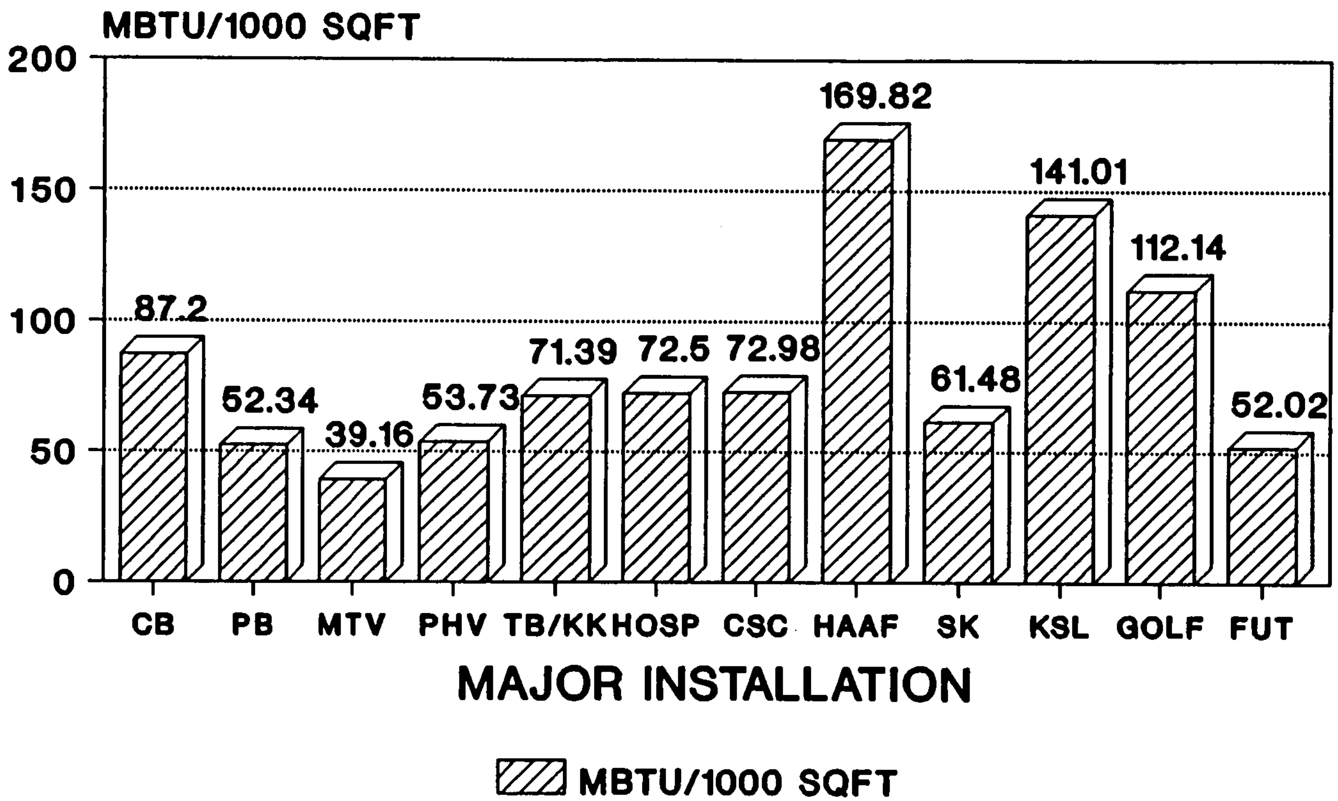

Fig. 10. U.S. Army in Europe (USAREUR), 26th Support Group in Heidelberg, FY 1990 energy consumption (building ft^2) by major installation.

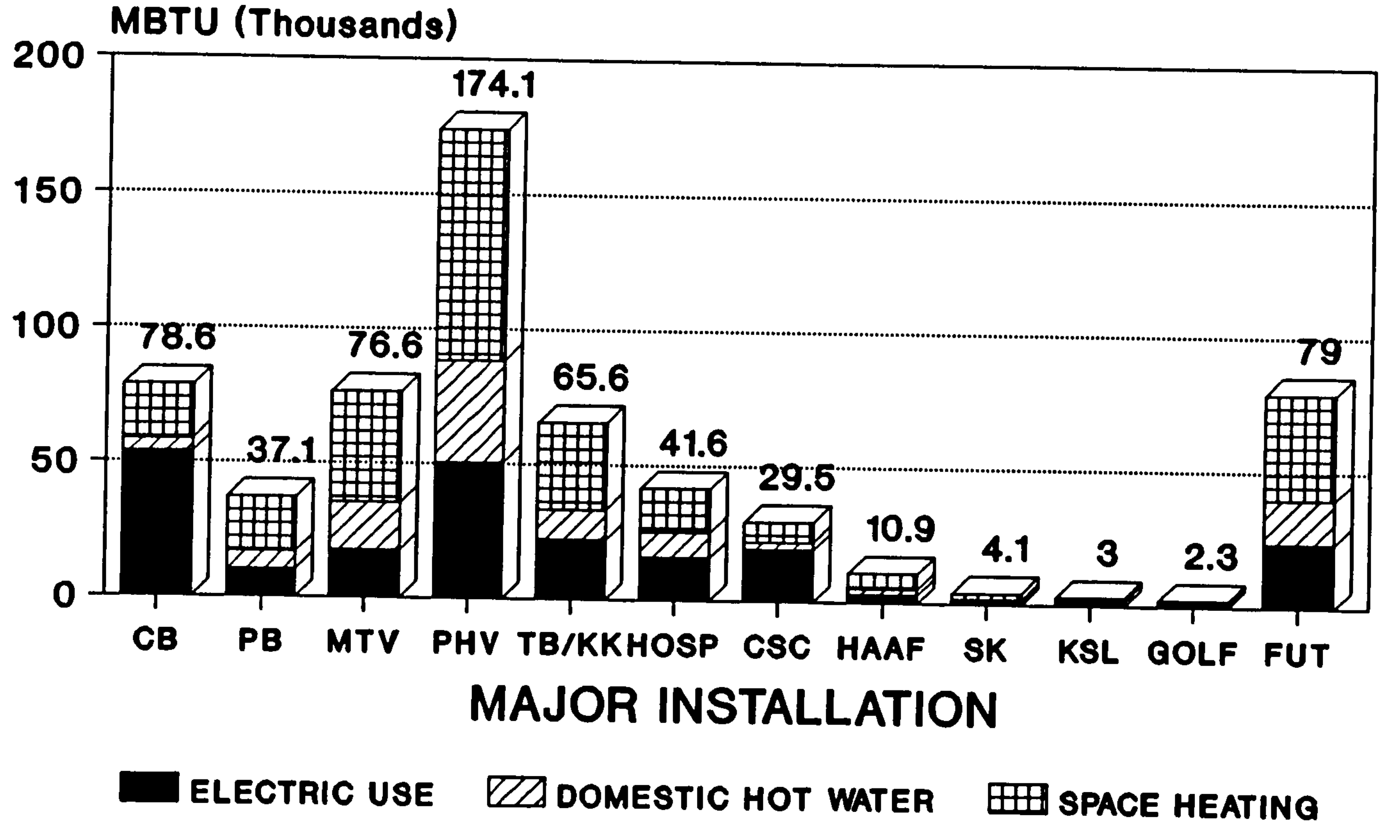

Fig. 11. U.S. Army in Europe (USAREUR), 26th Support Group in Heidelberg, FY 1990 energy consumption by major installation.

Table 4. U.S. Army in Europe (USAREUR) 26th Support Group Heidelberg, FY 1990 energy consumption (by major installation)

Facility	Electrical Energy (MBtu)	Domestic Hot Water (MBtu)	Space Heating (MBtu)	Consumption Total[a] (MBtu)	CUMACS Controlled	Building Area (ft^2)[b,c]	MBtu/ 1000 Ft^2
Campbell Barracks	53,791	4,700	20,148	78,639	Yes	901,857	87.20
Patton Barracks	10,452	6,468	20,173	37,093	Yes	708,706	52.34
Mark Twain Village	17,801	17,645	41,173	76,619	Yes	1,956,637	39.16
Patrick Henry Village	50,619	37,782	85,699	174,100	Yes	3,240,567	53.73
Tompkins/Kilbourne	22,153	37,782	32,351	65,616	Yes	919,139	71.39
Army Hospital	15,974	9,248	16,336	41,558	Yes	573,217	72.50
Community Support Center	19,338	2,632	7,446	29,466	Yes	403,760	72.98
Army Air Field	3,005	2,254	5,653	10,912	Yes	64,256	169.82
Stem Kaserne	1,056	740	2,282	4,078	Yes	66,334	61.48
Königstuhl	1,513	343	1,148	3,004	Yes	21,304	141.01
Golf Course	1,143	384	788	2,315	Yes	20,643	112.14
Leased Facilities	18,331	14,430	31,814	64,575	Future	1,195,529	52.02
Hammond Barracks	4,025	1,654	6,826	12,505	Yes/Future	269,239	
RSEDI	830	89	428	1,347	Future	3,256	
Rheinau Kaserne	566	0	0	566	Future	50,339	
TOTAL	220,647	109,481	272,265	602,393		10,394,843	

[a]Total energy (electrical and thermal) consumed by buildings and facilities under the control of CUMACS/EMCS.
[b]Total ft^2 of buildings and facilities under the control of CUMACS/EMCS.
[c]Of the 10,394,843-ft^2 total, 8,849,420 ft^2 is under CUMACS/EMCS control.

further thermal energy reductions in military housing facilities and electrical energy reductions in office, administrative, and support facilities.

5.2 ENERGY SAVINGS ATTRIBUTED TO CUMACS/EMCS OPERATIONS

Energy savings attributed to CUMACS/EMCS operations compared with total energy consumption in controlled buildings ranges from a low of 7.5% in FY 1982 to a high of 27.4% in FY 1987. In recent years reported energy savings have been about 18%. For example, during FY 1990 approximately 93,400 MBtu energy savings were reported compared with a total annual energy consumption in CUMACS/EMCS-controlled buildings of approximately 515,500 MBtu.

Figure 12 (also see Table 1) plots annual energy savings attributed to reduced thermal energy consumption for space and hot water heating as well as electrical energy use. Again, reported electrical energy savings remain fairly constant and are small in comparison with reported thermal energy savings. Referring again to Fig. 12, a steady increase in annual energy savings is observed from FY 1979 through FY 1987. Then, during FY 1988 reported energy savings plummeted to around 112,500 MBtu/year from a high of approximately 203,500 MBtu/year during FY 1987. This represents an almost 50% reduction in energy savings in just one year. The fact that energy savings associated with building space heating dropped approximately 28% from over 100,000 MBtu in FY 1987 to just over 72,000 in FY 1988 can be attributed to two major factors[11] (see Appendix C). First, the winter of FY 1988 was 14% warmer (4,860 HDD) than the winter of FY 1987 (5,647 HDD). Second, before the FY 1988 heating season, retrofit of external wall insulation, ceiling/roof insulation, and multiple glazing was completed on 229 26th Support Group buildings in Heidelberg. The good news is that this building envelope retrofit program has had a very positive impact by reducing thermal energy consumption for space heating. Unfortunately, the net effect has also been to reduce the opportunity for energy savings from interrelated conservation measures such as CUMACS/EMCS operations.

The significant reduction in energy savings associated with domestic hot water heating is not as easily explained. During FY 1987 CUMACS/EMCS-related energy savings attributed to reduced thermal energy consumption for domestic hot water heating was over 96,000 MBtu. This figure dropped to approximately 32,500 MBtu during FY 1988, representing a two-thirds overall reduction in reported energy savings in just one year. Further analysis of the CUMACS/EMCS energy savings calculations for these two fiscal years reveals no increase or decrease in the number of domestic hot water heating units under CUMACS/EMCS control or changes in the type of equipment used. In view of this anomaly, CUMACS/EMCS management personnel were contacted to explain this significant reduction in energy savings attributed to reduced thermal energy consumption for domestic hot water heating.[11] Their response (see Appendix C) offers the following reasons:

- Ten dining facilities were closed.
- The temperature setpoint for domestic hot water was reduced from 125°F (51.7°C) to 105°F (40.6°C).
- Shutoff time for domestic hot water circulation pumps in family housing buildings was reduced from 6 hours to 5 hours.

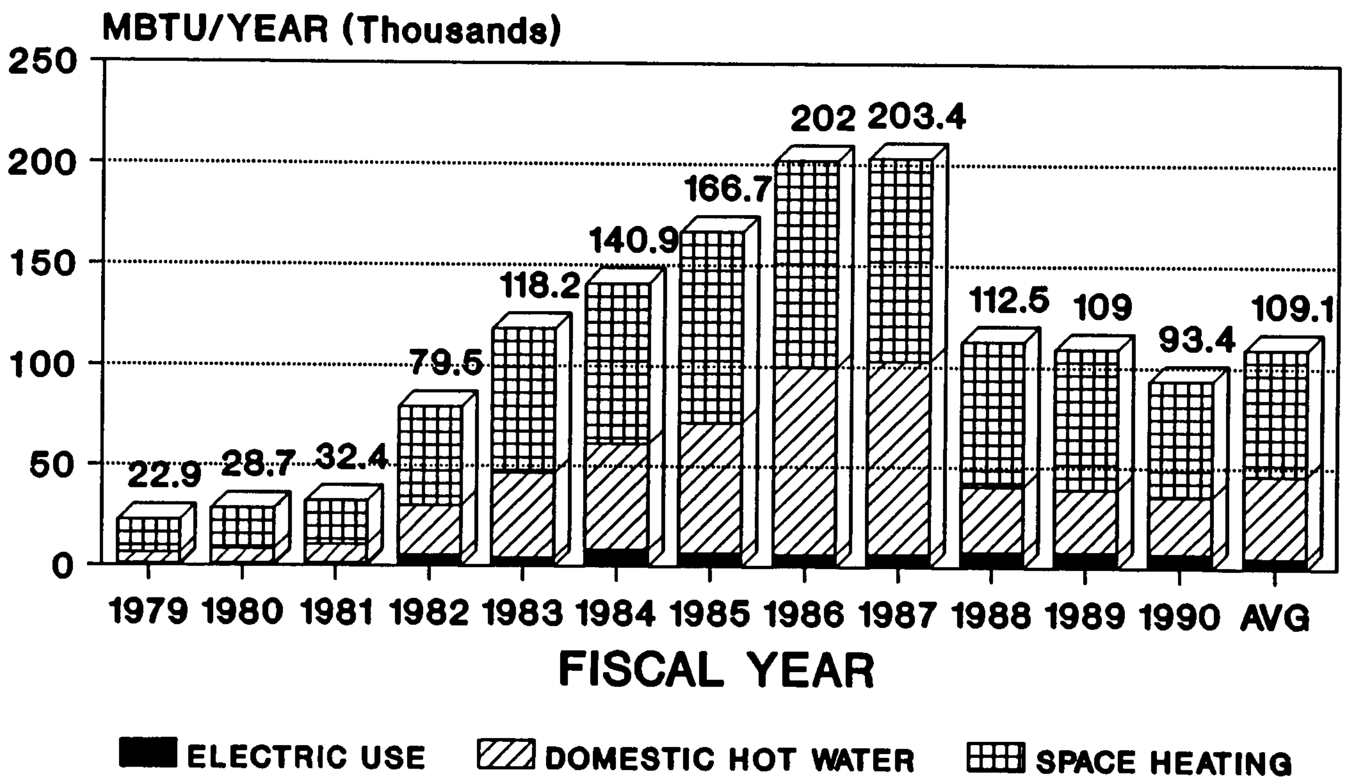

Fig. 12. Computerized Utilities Monitor and Control System/Energy Monitoring and Control System Heidelberg, energy savings by conservation measure, FY 1979 to FY 1990.

- One hundred forty-eight buildings in Patrick Henry Village and Tompkins Barracks were converted from coal-fired steam-heated domestic hot water heaters to low-temperature hot-water-heated (district heat) domestic hot water generators.

- The change in temperature between the supply and the circulation line of the domestic hot water systems in buildings without external insulation was 18 K (32.4°R). Since external insulation was applied to these buildings (FY 1988), the change in temperature has been 7 K (12.6°R). This represents an 11 K (19.8°R) lower change in temperature when compared with uninsulated buildings.

5.3 COST SAVINGS ATTRIBUTED TO CUMACS/EMCS OPERATIONS

Figure 13 plots cumulative cost savings reported from FY 1979 through FY 1990 attributed to CUMACS/EMCS operations, and is based on the data recorded in Table 2. As stated previously in Section 3, the fluctuations in the rate of exchange between U. S. dollars and the deutsche mark in extreme cases tends to portray somewhat synthetic cost savings. For example, the average rate of exchange varied from a high of $1 = 3.73 DM during FY 1986 to a low of $1 = 1.78 DM during FY 1981. To demonstrate the effect of these fluctuating exchange rates let us assume for the moment that the average rate of exchange during FY 1987 was not actually $1 = 2.46 DM, but instead was the same average rate that prevailed during FY 1986, namely $1 = 3.73 DM. This means that the reported cost savings during FY 1987 would have been $1,122,280 (assuming the FY 1986 exchange rate), instead of the actual reported cost savings of $1,701,667 (see Table 2). This represents a 34% decrease in reported cost savings solely because of a difference in the rate of exchange. Fortunately, over a period of 12 years these fluctuations tend to average out.

As discussed in Section 3, the estimated cost savings recorded in Table 2 do not consider actual O&M costs including associated materials and equipment expended in support of CUMACS/EMCS operations. These costs were estimated to average about $160,000 annually, or $1,920,000 over the 12-year reporting period. If these O&M costs are considered, the 12-year cumulative cost savings figure recorded at the end of FY 1990 would be reduced approximately 13% from $14,780,400 to $12,860,400. Figure 13 also shows the effects when estimated O&M costs are included in the cumulative cost savings attributed to CUMACS/EMCS operations.

A very important consideration in evaluating an EMCS is to understand which conservation measures produce the greatest energy and cost savings. Figure 14 shows how various conservation measures under the control of the CUMACS/EMCS have produced cost savings over a 12-year period. These reported cost savings attributed to CUMACS/EMCS operations have been summed for the 12-year reporting period and an overall average calculated (refer to Table 2 and the last bar in Fig. 14). These overall averages are tabulated as follows in the order of maximum estimated cost savings:

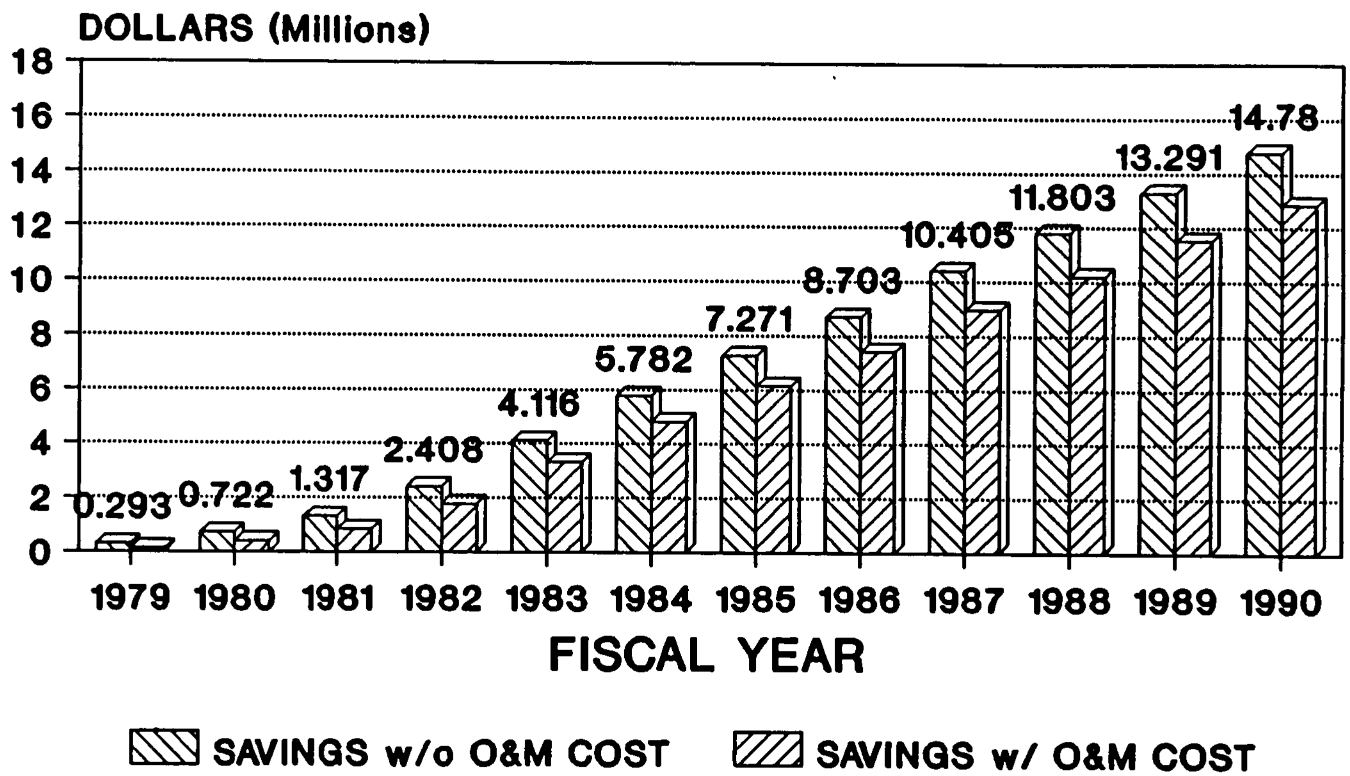

Fig. 13. Computerized Utilities Monitor and Control System/Energy Monitoring and Control System Heidelberg, cumulative cost savings, FY 1979 to FY 1990.

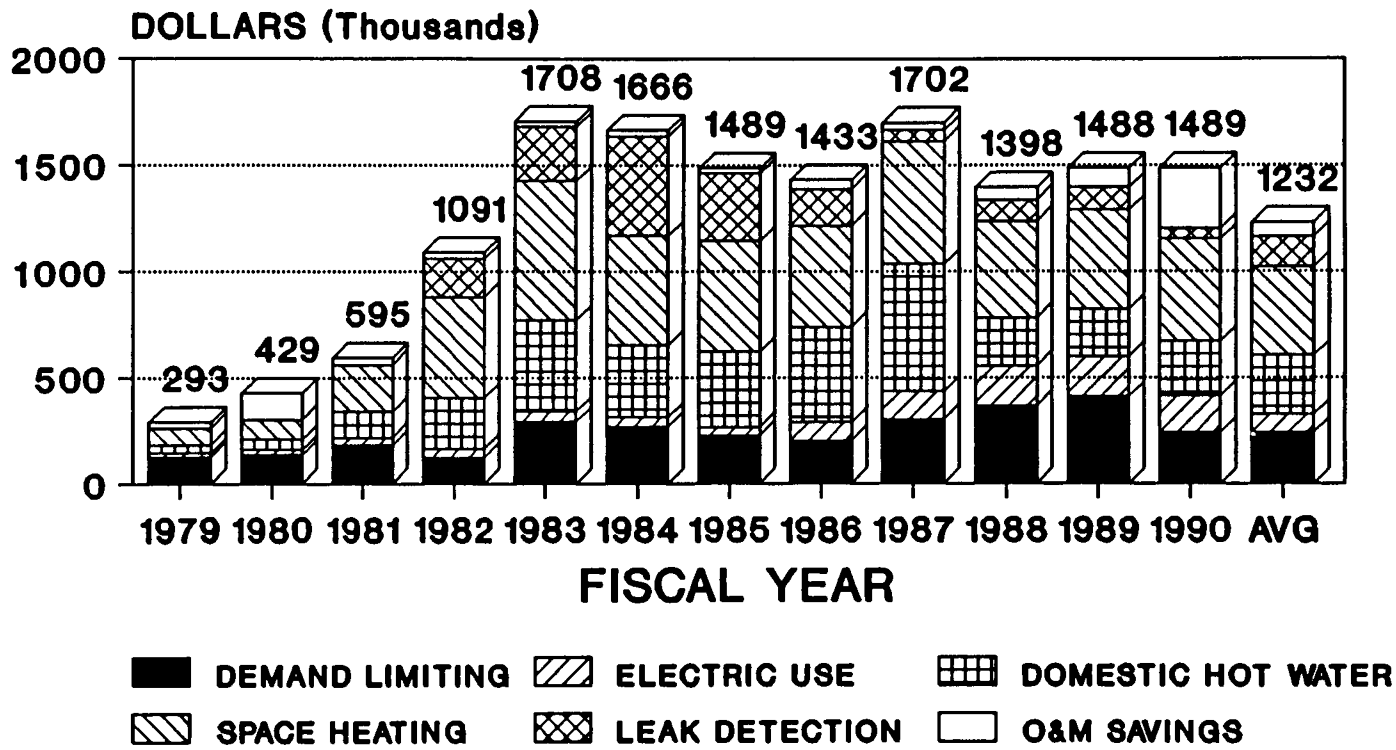

Fig. 14. Computerized Utilities Monitor and Control System/Energy Monitoring and Control System Heidelberg, annual cost savings by conservation measure, FY 1979 to FY 1990.

Conservation Measure	Average Annual Cost Savings	% of Total Average Savings
Space Heating	$418,836	34.0%
Domestic Hot Water	277,793	22.6%
Demand Limiting	241,120	19.6%
System Leak Detection	141,859	11.5%
Electric Energy Use	84,684	6.9%
O&M Savings	67,408	5.4%

Of these six general conservation measure categories only three have been credited with equivalent energy savings as a direct result of CUMACS/EMCS operations, i.e.,

- control of space heating systems and equipment,
- control of domestic hot water heating systems and equipment, and
- control of electrical energy systems and equipment.

It is important to note that over 50% of the reported cost savings are attributable to more energy efficient operation of space and hot water heating systems and equipment in CUMACS/EMCS-controlled buildings and facilities. This fact is further confirmed in the previous discussion of energy savings (see Table 1 and Fig. 12), where over 95% of reported energy savings attributed to CUMACS/EMCS operations are directly related to more energy-efficient operation of thermal energy systems (space and domestic hot water heating).

6. GENERAL ASSESSMENT OF BENEFITS

Beyond the obvious benefit of energy and cost savings, other benefits are known to exist for utility energy management control systems such as CUMACS. While some of these benefits can be quantified in terms of energy and cost savings, many can only be subjectively assessed. In an effort to gain insight into these issues, the energy coordinator for the U. S. military community in Heidelberg, Mr. John Doherty, and the energy coordinator for Patrick Henry Village, Sgt. Peter Contreras, were interviewed. In general, these interviews revealed that the CUMACS/EMCS was viewed as a very reliable system, experiencing very few end-user complaints. CUMACS/EMCS operations and maintenance personnel were reported to be very responsive if a system problem arose, and were supportive of the energy coordinators' overall mission. In addition, discussions with Mr. Juergen Baller, Chief of Utilities, indicate that some CUMACS benefits are difficult to quantify and that additional benefits might be available under slightly different operating guidelines.

6.1 OPERATING AND HUMAN FACTORS

In the Heidelberg Directorate of Engineering and Housing, the building occupants are passive in that they do not control the temperature setting in their quarters other than by use of the individual thermostat controls on radiators. A single temperature measurement for the building is located on a central apartment's north wall. In general, building occupants do not complain about temperature. There have been no complaints about being cold, but a few consider the control temperature too high (too hot), which may account for some of the open doors and windows. Because of a change in Army regulations, the upper set-point temperature was raised to 72°F (22.5°C) and the CUMACS system adjusted accordingly. This resulted in a decrease in electrical energy consumption which is probably attributable to the shutting off of the small electric heaters and stove ovens. In general, if the commanding officer feels comfortable at the higher temperature, then the system temperature is set accordingly. Under these circumstances setback cannot be easily reduced.

The CUMACS aids the energy coordinators (ECs) in that it gives feedback to them on energy consumption and provides supporting information in energy awareness programs. A CUMACS-related failure gets maintenance attention faster and with less paperwork and can focus attention on a problem before the end-user even realizes a problem exists. CUMACS is very reliable, and if problems occur in systems under its control, the CUMACS mobile maintenance crew can either repair the problem or alert appropriate service personnel in one day. Conversely, if the problem is not a CUMACS-related maintenance problem, maintenance work can take several days, since the conventional maintenance procedures are not as responsive. The value of some early warning response has been quantified and included in CUMACS cost savings.

Building occupants in family housing do not pay their own energy bills. Furthermore, family housing units are individually metered for electricity, but not for heat and hot water. Building occupants randomly receive "mock" bills telling them how they compare with building or area averages, but this action probably provides conservation incentive for only a very short period. Presently no penalty exists for excess consumption of energy or any utility service.

The current situation in the Middle East is resulting in some short-term nonoccupancy. In the long term (the next 5 years), occupancy should increase overall because military members and civilians living off-base will be asked to move back into existing on-base family housing. John Doherty indicated that he did not have good occupancy figures and was reluctant to estimate any percentages. In most cases, building occupancy is dynamic and does not lend itself to a continuing CUMACS control scenario, e.g., a special control monitor for unoccupied apartments. In this situation, the occupants and energy coordinators must be relied upon to promote effective energy conservation. In Juergen Baller's opinion, energy conservation is 50% energy awareness.

In general, the ECs feel that people cannot be counted on to implement energy conservation as reliably as can a system like CUMACS. Also, personal response to energy conservation varies from area to area. Personnel billeted at PHV, for example, respond better than those at MTV. The difference between MTV's and PHV's energy conservation effectiveness can probably be attributed to the attitude of the military personnel in charge. If those in charge do not care, then energy conservation and awareness programs become less effective.

Currently, electrical energy consumption in family housing is not controlled except for (1) the CUMACS control of exterior lighting and (2) the selective control (one day off per week per predefined area) of the clothes dryer load from 1700 to 1900 hours between October 1 and March 31 if demand limits are exceeded. Presently there is considered to be no major system energy conservation other than night setback of district heat and hot water in family housing space. Since very few complaints are received about present control strategies, occupants seem pleased with CUMACS. While daytime setback is probably not practical in family housing, it may be prudent to consider temperature setback in BOQ, BEQ, or other single soldier barracks during working hours. If cost effective, occupancy sensors or window interlocks would be used. Since CUMACS already performs weekend and off-duty setback of administrative buildings and all special facilities such as schools, churches, etc., the system capability exists.

The biggest problems observed by the ECs are open outside doors and windows, outside water left running, and the overall problem associated with the location of the building temperature sensor in one room of a building. As noted earlier, a functioning electric heater or a window open in this one room affects the comfort of the entire building.

The opportunity for energy and associated cost savings went down significantly after 1987 because of the addition of wall insulation (60 mm of styrofoam) to all family housing and to about 45% of non-family housing buildings. Ceiling or roof insulation was added to these buildings at the same time, and the boiler systems were replaced with hot water district heating. These factors contributed to a significant decrease in energy consumption over the entire system, which also results in significant reductions in opportunity for energy and cost savings.

The principal investigators observed that electrical consumption is high in Campbell Barracks even on weekends. The major reason for high, relatively constant electrical energy consumption in Campbell Barracks is several 24-hour-a-day classified facility operations that are very intense electrical energy users. These operations are the RAPIDE site (900 kW or 21,600 kWh/day), the Army Multimedia Exchange (AME) Communications Center in Building 22, the USAREUR Command Center in building 12M, and the Communications and Electronics (C&E) Building (CENTAC/NATO). It was also observed that Kilbourne Kaserne is an administrative facility that has numerous around-the-clock operations.

6.2 MAINTENANCE AND TRAINING

CUMACS operator and maintenance personnel training effectively started in 1970 with the advent of the first full-time person dedicated to CUMACS. In the late 1970s, five people were authorized (billeted) for CUMACS operations. CUMACS personnel develop, document, and continually update their own O&M procedures. A maintenance philosophy has evolved to perform preventive maintenance on significant items based on hours of operation. Minor items are replaced after failure. CUMACS O&M documentation and procedures keep pace with and may stay ahead of that generated by Huntsville.

The training of CUMACS personnel is accomplished in several ways. On-the-job training is the number one method. Beyond on-the-job training, EMCS equipment manufacturers conduct training programs that CUMACS personnel attend, and some vendors conduct on-site training, e.g., the HVAC control vendors. The U. S. Army Corps of Engineers, Huntsville Division, conducts training about every two years in Europe. Mr. Baller observes that this training is usually a relaxed meeting with not too much substantive technical information communicated. There appears to be a lack of "lessons learned" information at these meetings, but there are valuable personal contacts during off-duty discussions. In addition, the U. S. Army European Utilities organization sponsors an annual meeting with one-half day usually devoted to EMCS business.

Energy and cost savings figures quoted in the evaluation sheets do not include O&M personnel but include material, equipment, and subcontracted maintenance. The following rationale was provided for this practice:

- The four persons assigned to CUMACS fill four Utilities Division billets ($30,000/year jobs). There are four empty billets elsewhere in the organization. If CUMACS did not exist, the same number of billets would still be filled. How people are used or assigned is at the discretion of Utilities management. For example, if Mr. Grab were not assigned to CUMACS, he would probably be assigned to the Exterior Electric Section; therefore, no operations costs are attributable to CUMACS.

- Miscellaneous materials cost $1,500 annually and are counted.

- The maintenance service contract is charged as needed. Most installed equipment is very reliable and probably has a 10-year (recurring) life. Minor costs have been incurred to date.

- In-house maintenance personnel operate under the same billet scenario described for CUMACS operators above; i.e., if the HVAC Controls Shop personnel were not semi-dedicated to CUMACS maintenance, they would fill another billet. These maintenance personnel also do work that is not CUMACS dedicated.

- The test and diagnostic equipment, on which 100,000 DM has been spent, has other uses.

- Repair and replacement part costs are very small (because of high reliability), and installation maintenance is performed with CUMACS or maintenance forces (which are billeted).

- The initial installation of CUMACS included replacement of worn-out mechanical equipment as well, eliminating a lot of old maintenance problems. These savings were credited to CUMACS in the initial LCCA.

Many of the problems encountered by CUMACS operations personnel are related to communications among CUMACS, field forces, end users, etc., rather than to technical problems. A new, portable communications system with both mobile and fixed (base) units was installed in December 1990.

EMCS equipment manufacturers generally do not install CUMACS equipment. A general contractor installs the equipment, but does not make electrical or communications connections. CUMACS and specially trained maintenance personnel (Mechanical Branch, HVAC Controls Shop) do CUMACS interconnection and system check-out. The HVAC Controls Shop is an organization separate from the normal shop, with better-trained personnel. These 4 or 5 technicians are not dedicated solely to CUMACS but are trained in the CUMACS system. They receive both on-the-job and specialized training.

7. CONCLUSIONS

Based on the results of this evaluation of the CUMACS/EMCS installed at the USAREUR 26th Support Group in Heidelberg, the following conclusions have been reached:

- The CUMACS/EMCS is well maintained and is managed and operated by a well-trained and dedicated staff. The system stands out as a laudable example of U. S. Army EMCS installations.

- Between FY 1984 and FY 1990, CUMACS/EMCS operations have contributed significantly to the overall reduction in energy consumption achieved by the USAREUR 26th Support Group in Heidelberg. Evaluations of this EMCS demonstrate the fact that various energy conservation programs being implemented simultaneously are interrelated and contribute incrementally to the aggregate reduction in installation energy consumption. It also follows, however, that a significant reduction in installation energy consumption reduces the opportunity for future energy and cost savings that can be achieved by a specific energy conservation measure such as the operation of an EMCS.

- The energy and cost savings attributed to CUMACS/EMCS operations are significant, and ECIP military construction project requirements (SIR, SPP, and E/C ratio) have been exceeded by a large margin. Reported cost savings do not, however, take into consideration actual O&M costs. Even after O&M costs (estimated to be about 10 to 15% of the reported dollar savings) are taken into consideration, the resultant net cost savings attributed to CUMACS/EMCS operations are still sizable and impressive.

- During FY 1990, energy efficiency in military housing facilities in terms of MBtu of energy consumed per 1000 ft^2 of floor space in CUMACS/EMCS-controlled buildings is superior to that in administrative and support facilities. For example, during FY 1990, energy consumption in the two primary military housing facilities in Heidelberg, Mark Twain Village and Patrick Henry Village, was 39.16 and 53.73 MBtu/1000 ft^2, respectively. This compares with 87.2 MBtu/1000 ft^2 for Campbell Barracks, the primary HQ USAREUR and Seventh Army office and administrative facility in Heidelberg.

- During FY 1990, the greatest percentage of energy consumed by military housing facilities was thermal energy for domestic hot water and space heating. For example, during FY 1990, 70 to 75% of the energy consumed in the two largest military family housing installations, Mark Twain Village and Patrick Henry Village, is attributable to thermal energy for domestic hot water and space heating. The reverse is true for many of the principal HQ USAREUR and Seventh Army office, administrative, and support facilities. In Campbell Barracks, the principal 26th Support Group office and administrative facility in Heidelberg, 68% of total energy consumption is based on electrical demand, not thermal energy demand. Part of the reason given for this reverse trend is the fact that Campbell Barracks houses several 24-hour-a-day classified operations that are very electrical-energy intensive.

- A very important consideration in evaluating an EMCS is to understand which conservation measures produce the greatest energy and cost savings. An analysis of reported cost savings during the 12-year period between FY 1979 and FY 1990 reveal the following average annual cost savings attributed to the various conservation categories under the control of the CUMACS/EMCS:

Conservation Measure	Average Annual Cost Savings	% of Total Average Savings
Space Heating	$418,836	34.0%
Domestic Hot Water	277,793	22.6%
Electrical Demand Limiting	241,120	19.6%
System Leak Detection	141,859	11.5%
Electric Energy Use	84,684	6.9%
O&M Savings	67,408	5.4%

It is important to note that over 50% of the reported cost savings are attributable to more energy efficient operation of space and hot water heating systems and equipment in CUMACS/EMCS-controlled buildings and facilities. This attribution is further confirmed by the fact that over 95% of reported *energy* savings attributed to CUMACS/EMCS operations are directly related to more energy efficient operation of thermal energy (space and domestic hot water heating) systems.

- While the CUMACS system is "dynamic" in terms of its growth and day-to-day operation, the present number of points and building interfaces has remained constant during the last year. The specific number of points associated with energy conservation and control has probably stabilized while the number of supervision and control points for other functions is growing. In general, the benefits of CUMACS go beyond the energy and cost savings. Benefits of improved operation are difficult to quantify, but CUMACS personnel have shown an ability for developing techniques which could be constructively shared with other installations.

- Future plans, beyond the FM expansion to the seven communities not presently served by CUMACS, call for an upgrade of the central control computer from the present DEC PDP 11/23 to a DEC VAX-based system. This move will allow for system expansion, more graphic display screens, and greater data handling capability. Moreover, the system should allow for more data archival capability and for the ability to analyze data on-line or to download the information to PC-type machines for further analysis.

8. RECOMMENDATIONS

Based on the results of this evaluation of the CUMACS/EMCS installed at the USAREUR 26th Support Group in Heidelberg, the following recommendations are being made:

- The CUMACS/EMCS is a laudable example of a well-maintained and effectively managed and operated U. S. Army utilities energy management and control system. The many "lessons learned" since initial system installation should be documented and communicated to other U. S. Army installations worldwide. These lessons learned should cover the full spectrum of system procurement, installation, operation, and maintenance.

- Headquarters USAREUR in Heidelberg has a network of ECs assigned to major 26th Support Group installations that promote energy awareness and conservation practices among the major facility and building end-users (energy consumers). The importance and emphasis given to these activities cannot be overstressed. No conservation measure or energy system such as the CUMACS/EMCS can achieve its full potential unless building occupants (energy consumers) consider energy conservation a good thing. It is recommended that this program receive continued and increased emphasis and that observations, insights, and suggestions of ECs serve as a "feedback loop" for the overall energy conservation program being implemented by the 26th Support Group. An observation: A system such as the CUMACS/EMCS cannot achieve its full energy and cost saving potential if the end-user does not make a conscientious attempt to keep windows and doors closed, turn off lights, and practice other reasonable energy conservation measures.

- A representative number of doors and windows in family housing units were observed to be left open, indicating that the occupants were perhaps too warm. It is recommended that the living-space temperature setpoint be reduced in small increments to achieve a more comfortable and energy efficient operation.

- In Campbell Barracks, the principal HQ USAREUR and Seventh Army office and administrative facility in Heidelberg, 68% of total energy consumption is based on electrical energy use, not thermal energy use. Similarly, over 65% of the energy consumed by the Community Support Center, one of Heidelberg's principal support facilities, is electrical energy. It is therefore recommended that future USAREUR 26th Support Group energy conservation programs focus on energy conservation measures that can <u>reduce electrical energy consumption in office, administrative, and support facilities</u>.

- In contrast, during 1990, 70 to 75% of the energy consumed in the two largest military housing installations, Mark Twain Village and Patrick Henry Village, is attributable to thermal energy for domestic hot water and space heating. It is therefore recommended that future USAREUR 26th Support Group energy conservation programs also focus on energy conservation measures that can <u>reduce thermal energy consumption in military housing facilities</u>. Several suggestions include:

  — Consider a daytime temperature setback in BEQ, BOQ, and other military housing units that are routinely unoccupied during the daytime operating hours.

- Since a representative number of family housing unit doors and windows were observed to be left open, consider gradually and incrementally lowering the space-heating temperature setpoint in multifamily housing units where this practice is a problem.

- Consider the evaluation and possible use of energy conserving devices such as occupancy sensors, door/window interlocks, and other area/room energy control devices in buildings and facilities that are unoccupied for extended periods of time. These energy conserving devices can be effectively applied in selected military housing applications as well as in other non-housing applications such as warehouses and classrooms.

- The FM expansion to the seven communities not presently served by CUMACS and the upgrade of the central control computer from the present DEC PDP 11/23 to a DEC VAX-based system will allow for system expansion, more graphic display screens, and greater data handling capability. It is recommended that the system allow for more data archival capability and for the ability to analyze data on-line or to provide a hard and secure interface to PC-type machines for further analysis. If successful, this analysis capability will enhance further the "lessons learned" documentation.

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APPENDICES

APPENDIX A

FY 1990 Summary of Energy and Cost Savings from CUMACS/EMCS Operation

31 October 1990

26th SUPPORT GROUP, HEIDELBERG
FY90 SAVINGS
DUE TO CUMACS/UEMCS-OPERATION

1. **Electrical Demand Limiting: 946 KW = DM 493.116.- = $ 242,914.-**

   1.1 CB/MTV/PB: 258 KW x DM 58.- x 11 months = DM 164,604.- = $ 81,086.-

   1.2 PHV: 212 KW x DM 58.- x 7 " = DM 86,072.- = $ 42,400.-

   1.3 CSC: 186 KW x DM 58.- x 10 " = DM 107,880.- = $ 53,143.-

   1.4 Hospital: 118 KW x DM 58.- x 8 " = DM 54,752.- = $ 26,971.-

   1.5 TB/KB: 172 KW x DM 58.- x 8 " = DM 79,808.- = $ 39,314.-

2. **Electrical Consumption Control: 2,099,130 KWH = DM 349,086.- = $ 171,964.-**

   2.1 **Full-night exterior lights:** 487.040 KW x 2.5h x 365d =
   444,424 KWH (1,516 MBTU) x DM .1663 = DM 73,908.- = $ 36,408.-

   2.2 **Half-night exterior lights:** 18.630 KW x 2,558h =
   47,656 KWH (163 MBTU) x DM .1663 = DM 7,925.- = $ 3,904.-

   2.3 **DHW-Pumps AFH:** 206 x .23 KW x 5h x 365d =
   86,469 KWH (295 MBTU) x DM .1663 = DM 14,380.- = $ 7,084.-

   2.4 **DHW-Pumps OMA:** 143 x .305 KW x 5,196h =
   226,624 KWH (773 MBTU) x DM .1663 = DM 37,688.- = $ 18,566.-

   2.5 **Electric Domestic Hot Water Generators:**
   32 x 6 KW x 2h x 365d =
   140,160 KWH (478 MBTU) x DM .1663 = DM 23,309.- = $ 11,483.-

   2.6 **Electric Space Heaters:**
   12 x 2 KW x 9h x 235d =
   50,760 KWH (173 MBTU) x DM .1663 = DM 8,441.- = $ 4,158.-

   2.7 **Window-Airconditioners:** 68 x 3.4 KW x 6h x 130d =
   180,336 KWH (615 MBTU) x DM .1663 = DM 29,990.- = $ 14,773.-

   2.8 **CFE-Program:** 39 x 1,415 KWH =
   55,185 KWH (188 MBTU) x DM .1663 = DM 9,177.- = $ 4,521.-

   2.9 **Airconditioning Enthalpy:** 156 KW x 5,561h =
   867,516 KWH (2,960 MBTU) x DM .1663 = DM 144,268.- = $ 71,068.-

3. Dom. Hot Water, Time-Prg.: 28,575 MBTU = DM 523,157.- = $ 257,713.-

3.1 Oil-AFH: 47 x .0183 MBTU x 5h x 104d =
447 MBTU x DM 7.41 = DM 3,312.- = $ 1,632.-

3.2 District Heat-AFH: 47 x .0183 MBTU x 5h x 261d =
1,122 MBTU x DM 19.82 = DM 22,238.- = $ 10,955.-

3.3 District Heat-AFH: 159 x .0183 MBTU x 5h x 365d =
5,310 MBTU x DM 19.82 = DM 105,244.- = $ 51,844.-

3.4 Oil-OMA: 20 x .0292 MBTU x 5,196h =
3,034 MBTU x DM 7.41 = DM 22,482.- = $ 11,075.-

3.5 District Heat-OMA: 123 x .0292 MBTU x 5,196h =
18,662 MBTU x DM 19.82 = DM 369,881.- = $ 182,207.-

4. Space Heat, Set-Back & Optimizing: 57,679 MBTU = DM 980,600.- = $ 483,054.-

4.1 Oil-fired-AFH:
28,461 MBTU x 16% = 4,554 MBTU x DM 7.41 = DM 33,745.- = $ 16,623.-

4.2 Coal-fired-AFH:
8,948 MBTU x 16% = 1,432 MBTU x DM 11.04 = DM 15,809.- = $ 7,788.-

4.3 District Heat-AFH:
83,663 MBTU x 16% = 13,386 MBTU x DM 19.82 = DM 265,311.- = $ 130,695.-

4.4 Oil-fired-OMA:
27,908 MBTU x 27% = 7,535 MBTU x DM 7.41 = DM 55,834.- = $ 27,504.-

4.5 District Heat-OMA:
113,971 MBTU x 27% = 30,772 MBTU x DM 19.82 = DM 609,901.- = $ 300,444.-

5. Water-Pipe Leak-Detection: DM 100,726.- = $ 49,619.-

24,178 CBM x DM 2.23 (Water) = DM 53,917.- = $ 26,560.-
21,277 CBM x DM 2.20 (Sewer) = DM 46,809.- = $ 23,059.-

6. O&M Savings (Labor, Equipment, etc.): DM 575,754.- = $283,623.-

6.1 Low level alarms: Breaker trip, clogged filter, pump failure, chlorine + fluor level low, engine pre-heater, electrolyzer, fuel + etc tanks, maintenance schedules, etc. Savings: 2 manhours each = DM 68.97/alarm

Mech	Elec	Sani	Total	Sav/each	Total	Total
214	93	68	375	DM 68.97 =	DM 25,864.-	$12,741.-

6.2 Normal level alarms: Water leak, heat pipe leak, tampering, space heat too high, etc. Savings: DM 1,141.-/alarm

Mech	Elec	Sani	Total	Sav/each	Total	Total
181	92	39	312	DM 1,141.- =	DM 355,992.-	$175,366.-

6.3 Hot/high level alarms: Elevator breakdown, boiler + heat transfer, sewer treatment, power failure, ground fault (high + low tension), Buchholz, trafo overtemp., aircon failure, converter + UPS, emergency generator, battery chargers (UPS + generator), cold storage, breaker trip (high tension + emergency power), meter reading (differences), distribution (networks) coordination, medical gas systems, etc. Savings: 6 manhours = DM 207.- + prevention of food spoilage, equipment damage, longer power interruptions = DM 1,240.- = DM 1,447.-/alarm

Mech	Elec	Sani	Total	Sav/each	Total	Total
67	46	21	134	DM 1,447.- =	DM 193,898.-	$95,516.-

7. TOTAL SAVINGS: = 13.28% of J-Account = DM 3,022,439.- = $ 1,488,886.-

7.1	DEMAND:	946 KW	=	8.63% of Demands (10,968 KW)
7.2	ELECTRICITY:	2,099,130 KWH/ 7,161 MBTU	=	3.54% of Consumption (59,277,550 KWH)
7.3	HEAT:	86,254 MBTU	=	27.51% of Consumption (313,480 MBTU)
7.4	WATER/SEWER:	24,178/21,277 CBM	=	2.00% of Consumption (1,206,090 CBM)
7.5	TOTAL ENERGY SAVINGS:	93,415 MBTU	=	18.11% of Consumption (515,735 MBTU)

8. Back-up Data:

8.1	Fullnight hours (lights)	=	3,654 (on)
8.2	Halfnight hours (lights)	=	2,558 (off)
8.3	Heating hours	=	5,640 = 235 days
8.4	AFH-Setback-hours	=	1,880
8.5	OMA-Setback-hours	=	3,636
8.6	Heating Degree Days 65	=	4,582
8.7	Enthalpy-hours	=	5,561
8.8	Rainfall	=	663 mm = 663 l/m² (26.1 inch)

R A T E : $ 1 = D M 2 . 0 3

Baller

JÜRGEN BALLER
Chief, Utilities Division

31 October 1990

10 Apr 91

Explanation of Cost and Energy Savings FY 90, dtd. 31 Oct 90

To 1. Electrical Demand Limiting: Five major metering points are connected to demand limiting controllers. The cost for one kW exceeding the ordered demand is DM 58.--. During 11 months in CB/MTV/PB, during 7 months in PHV, during 10 months in CSC and during 8 months in Hospital and TB/KB a total of 946 kW (see detailed computation under para 1.1 to 1.5) was saved (preventing demands from exceeding ordered demands) due to load shed. CUMACS-connected are 6,740 kW (See list of connected equipment). The load shedding programs were able to shut-off 14.03% demand kW's from all electrical equipment and appliances connected to CUMACS during FY 90.

To 2. Electrical Consumption Control:

2.1 Full-night exterior lights: The total load of all CUMACS-connected exterior lights is 487.040 kW. During FY 90 2.5 hrs of daily on-time of all exterior lights were saved compared to local manual or time clock controls.

2.2 Half-night exterior lights: 18.630 kW of exterior lights are connected to half-night and special time programs. For example: Every second street light is turned off after 2200 hrs. During 2,558 night hours (during darkness) 18.630 kW of exterior lights were shut-off.

2.3 Domestic hot water circulation pumps in Family Housing: 206 pumps with a load of .23 kW each are connected and turned off daily between 2300 and 0400 hrs.

2.4 Domestic hot water circulation pumps in Non-Family Housing: 143 pumps with a load of .305 kW each are connected and turned off during 5,196 hours in FY 90 (nights, weekends, holidays).

2.5 Electric domestic hot water generators: 32 each hot water heaters with 6 kW each were shut-off 2 hours daily.

2.6 Electric space heaters: 12 each space heaters 2 kW each were shut-off 9 hours daily during the heating season of 235 days in guard shacks and similiar facilities.

2.7 Window airconditioners: 68 each window airconditioners 3.4 kW each were shut-off 6 hours daily during the non-heating season.

2.8 CFE program: 39 each vending machines for soft drinks (Cola, Fanta, etc.) were shut-off during nights, weekends and holidays, saving 1,415 kWH each.

2.9 Airconditioning enthalpy: During 5,561 hours of enthalpy time (outdoor air colder than the rooms to be airconditioned) 156 kW of cooling compressor drive motors were shut-off. Outdoor air was cool enough to maintain required room temperatures.

To 3. Domestic Hot Water Time Programs:

3.1 Oil fired domestic hot water heating systems in Family Housing: Circulation line temperature-losses in our Family Housing buildings amount to .0183 MBTU per hour (metered). In 47 buildings during 104 calendar days the line losses were saved because of circulation pump shut-off.

3.2 District heat heated domestic hot water systems in Family Housing: Same as above, however in 47 buildings during 261 calendar days.

3.3 District heat heated domestic hot water systems in Family Housing: Same as above, however in 159 buildings during 365 calendar days.

3.4 Oil fired domestic hot water systems in Non-Family Housing: Circulation line temperature losses in our non-Family Housing buildings amount to .0292 MBTU per hour (metered). Same as above, however in 20 buildings during 5,196 hours.

3.5 District heat heated domestic hot water systems in Non-Family Housing: Same as above, however in 123 buildings during 5,196 hours.

To 4. Space Heat (set-back and optimizing):

4.1 Oil fired heating systems in Family Housing: 16% of space heat energy were saved (metered), due to temperature set-back (4°F) during 8 hours daily (2200-0600 hrs) in 235 heating days.

4.2 Coal fired heating systems in Family Housing: Same as above.

4.3 District heat heated heating systems in Family Housing: Same as above.

4.4 Oil fired heating systems in Non-Family Housing: 27% of space heat energy were saved (metered), due to temperature set-back (13°F) and optimum start/stop (up to 2 hours before close of business and up to 6 hours before start of business.

4.5 District heat heated heating systems in Non-Family Housing: Same as above.

To 5. Water Pipe Leak Detection: 8 major water metering points are connected to the CUMACS leak detection monitors. Leak detection monitors check the water flow continuously, and between 0200 and 0215 hrs daily the water flow is compared against the computed (acceptable) leakage target. Should the water flow be greater than the pre-set leakage, the monitors provide alarm and print-out of a possible water leak in the water distribution. Water distribution maintenance personnel then checks the distribution for leaks. During FY 90 7 water leaks were found and repaired immediately resulting in 24,178 cbm of water and 21,277 cbm of sewer (88% of water consumed is charged as sewer) saved.

To 6. Operation and Maintenance Savings:

6.1 Low level alarms: An average of 2 manhours is saved per alarm. Trip of small breakers, clogged filters, failures of small pumps, alarming of low fuel oil levels in tanks, announcement of required maintenance on equipment, alarming of water and sewer treatment values, etc. are considered low level alarms (early warning alarms). A total of 375 low level alarms were received during FY 90.

6.2 Normal level alarms: Alarming of water distribution leaks, heating distribution pipe leaks, tampering with thermostates and controls, space heat temperature to high, etc. are considered normal level alarms. Example of a normal level alarm: Cost to heat one squarefeet of floorspace is approx. DM 0.58 per year; average size of one of our buildings is 16,400 SF; therefore cost to heat one building is DM 9,512.-- per year. If the space temperature is 2°C warmer than required, the energy wasted is approx. 12% more, which represents DM 1,141.-- per heating season/year. If, however, the alarm is received and immediate adjustment performed, DM 1,141.-- are saved per alarm.

6.3 Hot/high level alarms: Alarming of elevator break downs, boilers, heat exchangers, power failures, ground fault (high and low tension), transformers, airconditioners, converters/uninterruptable power supplies, cold storage facilities, tripping of breakers in high tension and emergency power distributions, medical gas systems, etc. are considered high level alarms. The average savings due to immediate response and required repair/restauration of service are DM 1,447.-- per alarm, which represents prevention of food spoilage, equipment damage, longer power interruptions and approx. 6 manhours per alarm.

Baller

JUERGEN BALLER
Chief, Utilities Division

UEMCS

Connected Systems

1. Electrical Networks (high and low tension)
2. Stand-by Generators
3. Power Plants
4. Uninterrupted Power Supplies (UPS)
5. Exterior Lights (Street-, Fence-, Flood- and Security)
6. Transformer Sub-Stations
7. Switching Stations
8. Frequency Converters
9. Elevators
10. Venetian Blinds

11. Water Plants and Networks
12. Sewer Plants and Networks
13. Sewer Treatment Plants
14. Chlorination and Fluoridation Plants
15. Electrolytic Chlorination Systems
16. Booster Stations
17. Water Pumping Stations
18. Sewer Pumping Stations
19. Irrigation Systems
20. POL Separators/Interceptors
21. Ground Water

22. Boiler Plants (Coal, Oil and Gas)
23. District Heat Connections
24. Heating Distributions
25. Heating Systems (Hydronic-Heating with Radiators)
26. Domestic Hot Water Generators
27. Cold Storage and Refrigeration Plants
28. Window Air Conditioners
29. Air Conditioners
30. Ventilation Systems
31. High Pressure Steam Plants (for Process)
32. Heat Pumps (Air to Water) (for Domestic Hot Water)
33. Medical Gas Systems
34. Compressed Air Systems
35. Tanks (Heating Oil, Waste Oil, etc.)

36. Laundry Rooms (Clothes Dryers)
37. Vendomats (Vending Machines)
38. Sauna's
39. Humidifiers
40. Weather Station

ELECTRIC EQUIPMENT CONNECTED TO

LOAD-SHED/DEMAND LIMITING

1. MOTORS ON COOLING COMPRESSORS OF AIR CONDITIONERS
2. WINDOW AIR CONDITIONERS
3. MOTORS ON COLD STORAGE COMPRESSORS
4. MOTORS ON AIR COMPRESSORS
5. ELECTRIC CLOTHES DRYERS
6. HOT WATER CIRCULATION PUMPS
7. LARGE BATTERY CHARGERS
8. ELECTRIC HOT WATER GENERATORS
9. ELECTRIC PRE-HEATERS FOR STAND-BY GENERATORS
10. ELECTRIC BOOSTERS IN DISH WASHERS
11. LARGE COFFEE URNS
12. ELECTRIC SPACE HEATERS IN GUARD SHACKS
13. HEAT PUMPS
14. BOOSTER PUMPS IN WATER NETWORKS
15. SEWER PUMPS
16. SAUNA'S
17. ELECTRIC HUMIDIFIERS

APPENDIX B

Answer to ORNL Letter, Jan 28, 1991

February 18, 1991

1. Costs for DTM underground cables are not charged nor accounted/added to UEMCS installation cost since we providing all DTM underground cables as part of underground power cable and underground heating distribution projects (new and replacement projects).

See VDEW guidelines for power cables, dtd. May 7, 1962,
and para 10c.m. USAREUR Suppl # 1 to AR 420-43, dtd. Dec 6, 1977,
and para 7.7 USAREUR Suppl # 1 to AR 420-43, dtd. Jan 31, 1984,
and para 15.i USAREUR Regulation 420-43, dtd. Sep 20, 1990,

Since 1963 (with the start of voltage conversions from 5 and 6 KV to 20 KV) we installed 55,970 meters of underground control cables in conjunction with power and heating distribution projects.

2. FY 1990 average cost for connection of UEMCS points was as follows:

Alarm/status/counters	=	DM 600.00/point
Analog (measuring value, i.e. temperature, pressure, voltage, etc.)	=	DM 1,380.00/point
Ripple control	=	DM 85.00/point

3. Local process controllers with sensors, actuators, status indicators, etc. are not accounted for as part of UEMCS/CUMACS since they are required for the operation of utilities systems. Only the interface at the local process controllers to the UEMCS are accounted to CUMACS. Projects for renovation of buildings, replacement or new installation of HVAC's, elevators, heating systems, etc. include always the local process controllers with required sensors and actuators and we provide the UEMCS interface only.

[illegible] BALLER
Chief, Utilities

18 FEB 1991

4. Connected UEMCS/CUMACS points:

Time frame of connection	Wire System (full duplex)				Ripple (simplex) Control	Radio (half duplex)				T O T A L
	Status Alarm Counters	Control	Analog	Total		Status Alarm Counters	Control	Analog	Total	
1963-1982	933	128	525	1,586	3,580	0	0	0	0	5,166
ECIP 1982-1983	400	250	350	1,000	935	0	0	0	0	1,935
1983-1990	1,836	315	1,142	3,293	648	99	21	64	184	4,125
T O T A L	3,169	693	2,017	5,879	5,163	99	21	64	184	11,226

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REMARKS: With the ECIP project 935 ripple control points and 1,000 wire points were connected. Most of the local processors and sensors, etc. were in place already and required connection only. The UEMCS-ADP equipment in the master control room Bldg. # 4, Campbell Barracks was provided under the ECIP project also.

Currently approx. 2,000 more points (at local processors) are installed ready to be hooked-up to one of the three DTM types (mainly radio). Connecting work is partially ongoing.

BALLER
Chief, Utilities

APPENDIX C

Answer to ORNL Letter, Feb 5, 1991

February 18, 1991

1. Reduction in Energy Savings for space heating from FY 87 (100,699 MBTU) to FY 88 (72,174 MBTU) was a result of:

a. 14% warmer winter (FY 87 = DD 65: 5,647 versus FY 88 = DD 65: 4,860)

b. External building insulation (walls, roofs and thermopane windows on 229 OMA and AFH buildings)

2. Reduction in Energy Savings for domestic hot water from FY 87 (96,290 MBTU) to FY 88 (32,551 MBTU) was a result of:

a. 10 dining facilities (# 18, Campbell Bks; # 110 and 115, Patton Bks; # 1000, Stem Kas; # 3860, CSC; # 3622, Hospital; # 4236, 4251 and 4253, Tompkins Bks; and # 4316, Kilbourne Bks) were closed.

b. Setpoint for domestic hot water temperature at faucets was reduced from 125°F (51.7°C) to 105°F (40.6°C).

c. Shut-off time for domestic hot water circulation pumps in family housing buildings was reduced from 6 hours (2200-0400 hrs) to 5 hours (2300-0400 hrs).

d. Conversion of coal-fired, steam heated, domestic hot water generators to low temperature hot water heated (district heat) domestic hot water generators in 148 buildings in Patrick Henry Village and Tompkins Barracks.

e. The ΔT between supply and circulation lines of the domestic hot water systems in buildings without external insulation was 18°K (32.4°R). After external insulation the ΔT is 7°K (12.6°R) only. This represents a 11°K (19.8°R) lower ΔT compared to uninsulated buildings.

Baller

[illegible] BALLER
Chief, Utilities

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46. H. Frank Carlen, Chief of Electronic Technology Branch, U.S. Army Corp of Engineers, HNDED-ME, P.O. Box 1600, Huntsville, AL 35807

47. Millard Carr, Assistant for Energy Policy, Office of the Secretary of Defense, DASO(L)EP, Washington, DC 20301-8000

48. Floyd J. Collins, Department of Energy, CE-141, 5E-066/FORSTAL, 1000 Independence Avenue, SW, Washington, DC 20585

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55. Richard Karney, U.S. Army Engineering and Housing Support Center, Attn: CEHSE-FU-M, Ft. Belvoir, VA 22060-5580

56. John P. Millhone, DAS, Office of Building Technologies, Department of Energy, CE-40, 6A-081/FORSTAL, 1000 Independence Avenue, SW, Washington, DC 20585

57-66. Jeff Mitchell, Electronics Engineer, HQ, U.S. Army, Europe, AEAEN-FE-U, APO, New York 09403

67. J. W. Nehls, Sr., DOE-OR

68-77. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831

78. J. A. Reafsnyder, Assistant Manager, Energy Research and Development, DOE/ORO

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