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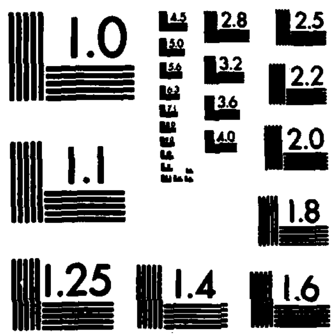
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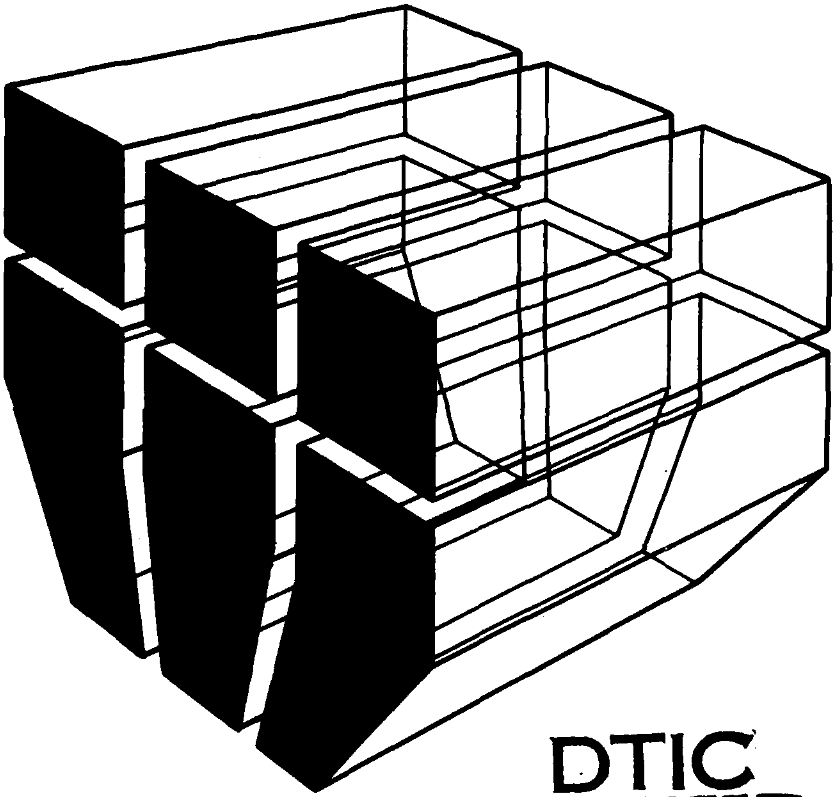
AN ESTIMATE OF PROCESS ENERGY CONSUMPTION IN DARCOM

by
Ben J. Sliwinski



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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This report describes the estimation of the present percentage of process energy consumed by Army Materiel Development and Readiness Command (DARCOM) installations. It is estimated that 46 percent of DARCOM energy consumption is process related. The report also describes the several methods used to arrive at this estimate and provides separate process percentage estimates for 48 DARCOM installations.

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FOREWORD

This work was performed for the Energy Office, Installations and Services Directorate, of the Army Materiel Development and Readiness Command (DARCOM). The work was done by the Energy Systems (ES) Division, U.S. Army Construction Engineering Research Laboratory (CERL). Mr. Gennaro Aveta of the DARCOM Energy Office was the technical monitor. This was done as part of the Industrial Plant Energy Conservation Procedure work unit, funded by the Office of the Chief of Engineers under OMA FAD No. 2-2178.

Appreciation is expressed to Mr. Craig Sambdman and CPT Jeffrey Springer at DARCOM headquarters. Appreciation is also expressed to the energy coordinators at each DARCOM installation for their valuable input to the estimating procedure.

Mr. John Shonder and Mr. William Heflin at CERL provided valuable assistance in the performance of this work.

COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director. Mr. R. G. Donaghy is Chief of CERL-ES.

CONTENTS

AN ESTIMATE OF PROCESS ENERGY CONSUMPTION IN DARCOM

1 INTRODUCTION

Background

Since the inception of the DARCOM energy program, significant decreases in energy consumption have occurred at most DARCOM facilities.[1] How much of this reduction is due to actual conservation measures and how much is due to changes in workload/mission is unknown. For this reason, DARCOM realized the need for a current estimate of what portion of their total energy consumption is used in mission-related manufacturing processes. The Energy Office of the DARCOM Installations and Services Directorate requested the U.S. Army Construction Engineering Research Laboratory (CERL) to develop this estimate.

Objective

The objectives of this study were twofold: (1) develop methods for estimating process energy consumption using the available data, and (2) use these methods to provide DARCOM with a current estimate of process energy consumption.

Approach

The following steps were taken to estimate the percentage of DARCOM energy which is currently used for manufacturing process:

1. Energy Engineering Analysis Program (EEAP) reports were acquired for all DARCOM facilities for which they were available.

2. Energy coordinators were contacted at each installation and asked for their best estimate of the percentage of energy attributable to processes.

3. Energy use data were obtained from the following three sources: (a) the Directorate of Military Programs, OCE, Annual Summary of Operations[2]; (b) a report titled Army Energy Data Analysis by Computer Sciences Corporation[3]; and (c) process information supplied by installation personnel. These data were analyzed to develop methods for estimating process energy consumption.

4. Estimates were calculated for each installation using as many of the methods for which adequate data were available. The results of each method were compared; if large differences were found, efforts were taken to resolve them. The estimates from each method were then averaged to determine a final estimate.

2 METHODS OF ANALYSIS

The information provided by energy coordinators at the installations varied in both the types and quantities. Consequently, a number of different methods had to be developed to insure an estimate could be provided for each facility.

Linear Regression

The energy consumption for a facility can be assumed to be a function of both weather-related and production-related variables. A good first approximation of this relationship can be obtained by expressing it as a linear function of heating degree days and some measure of total production. It was assumed that if such a function could be obtained through the regression of energy consumption, heating degree days, and production data, the process energy could be identified as that portion of the total energy which correlated to production.

As an example, this linear function was developed using the energy use data from Holston Army Ammunition Plant (AAP) (Table 1). A regression analysis was performed on these data using the Statistical Package for the Social Sciences (SPSS).[4] The following equation was developed:

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[1]DARCOM, "DARCOM Industrial Energy Plan," Proceedings of the Annual DARCOM Energy Seminar, 26 October 1981.

[2]Office of the Chief of Engineers, Annual Summary of Operations–Fiscal Year 1981 (Department of the Army), pp 241-310.

[3]Computer Sciences Corporation, Army Energy Data Analysis (Department of Energy, June 1981), pp A140-A265.

[4]Norman H. Nie, C. Hadlai Hull, Jean G. Jenkins, Karin Steinbreunner, and Dale H. Bent, SPSS: Statistical Package for the Social Sciences (McGraw-Hill, Inc., 1975).

Table 1
Yearly Energy Consumption and Production Data for Holston AAP

FY	Total Energy Consumption (MBtu)	Product Output (Equivalent #RDX)	Heating Degree Days
1975	7.851×10^6	6.839×10^7	4034
1976	5.136×10^6	3.532×10^7	3774
1977	4.323×10^6	2.328×10^7	5068
1978	4.251×10^6	2.308×10^7	4979
1979	3.916×10^6	2.538×10^7	4372
1980	3.629×10^6	2.500×10^7	4498
1981	3.595×10^6	2.598×10^7	4723

$$E = (0.09259)P + (243.6)HDD + 582130 \quad \text{[Eq 1]}$$

where

E = total energy consumption

P = production

HDD = heating degree days.

The coefficient for production was statistically significant to the 99.7 percent confidence level, and the overall r-squared for the regression was 0.9116. For FY81, the energy used in production processes at Holston AAP is estimated as $(.09259)(2.598 \times 10^7) = 2.405 \times 10^6$ MBtu, or about 67 percent of the total consumption. As another example, a regression analysis was performed using energy use data from the Louisiana AAP for FY 81 (Table 2). A regression analysis of this data gave the following equation:

$$E = (249.7)S + (79.59)HDD + 26630 \quad \text{[Eq 2]}$$

where S is shipments, and the other variables are developed as in Equation 1. In this case, the coefficient for shipments is significant only to the 54 percent confidence level. The coefficient for heating degree days, however, is significant to the 99.7 percent confidence level. It was assumed that the production energy for the Louisiana AAP could be determined by subtracting the heating energy from the total energy consumption. The total heating energy is calculated as (79.59)(1507) = 119,942 MBtu. The process energy is then 536,119 − 119,942 = 416,177 MBtu, or about 78 percent of the total consumption.

A regression approach was also used by personnel at Scranton AAP. The regression equation developed using the Scranton data is:

$$E = 642.15 + 21.661\ DDO + 7.1\ TO + 8.22\ T2 + 1466.85\ WO \quad \text{[Eq 3]}$$

where

E = estimated energy consumption in MBtu

DDO = heating degree days (monthly)

TO = tons shipped present month

Table 2
Monthly Energy Consumption and Production Data for Louisiana AAP, FY81

Month	Total Energy Consumption (MBtu)	Shipments (tons)	Heating Degree Days
Oct	27,259	24	35
Nov	51,719	10	195
Dec	53,219	18	363
Jan	64,688	30	504
Feb	73,366	35	275
Mar	58,562	33	123
Apr	39,491	43	12
May	31,093	45	0
Jun	39,507	38	0
Jul	35,725	36	0
Aug	26,646	33	0
Sep	34,744	42	0
Total	536,119	387	1,507

T2 = tons shipped 2 months prior

WO = work days.

The r-squared of this regression was .916. Assuming that the equation constant and the portion of the equation relating to tons shipped represent process energy, an estimate of process energy can be calculated. This calculation was performed using 10 months of data provided by personnel at Scranton AAP for FY81. The resulting average process percentage estimate was 29 percent.

Linear regression seems to be a valid approach to determine the amount of process energy consumed by DARCOM installations. The linear regression technique is already being used to calculate process energy use at several DARCOM facilities for purposes of energy management. The main problem with the regression approach is finding a measure of production output. Some facilities manufacture hundreds of products, all with varying energy demands. Ideally, the regression approach should consider the production output of each specific product as an independent variable, but this is not feasible. Engineers at Holston AAP have had success finding a production measure using equivalent pounds RDX. RDX is a base chemical used in the manufacture of a great majority of their products. The regression analysis using the Louisiana AAP data suggests that total plant shipments provide a somewhat less accurate production measure than obtained at Holston AAP. However, the estimates do agree closely with estimates obtained by the other methods covered in this report.

Fixed Facilities Energy Consumption Investigation (FFECI)

The Fixed Facilities Energy Consumption Investigation (FFECI) was undertaken by CERL personnel in 1976 to study energy consumption at U.S. Army facilities.[5] Data were collected at Forts Carson, Belvoir, and Hood for seven different building categories. Relationships between energy consumption and heating and cooling degree days were developed for each building type using linear regression. These relationships predict nonprocess heating and cooling energy only. It was reasoned that the FFECI relationships could be used to calculate nonprocess energy requirements for DARCOM facilities. The process energy consumption could be estimated by subtracting heating and cooling energy requirements from the total energy requirement.

The FFECI study resulted in the following two equations estimating energy used for the different building types:

$$E_h = a_1 + b_1 (HDD_d) \quad \text{[Eq 4]}$$

$$E_e = a_2 + b_2 (CDD_d) \quad \text{[Eq 5]}$$

where

E_h = daily heating energy consumption per square foot building space

E_e = daily electrical energy consumption per square foot building space

HDD_d = daily heating degree days (annual HDD/365)

CDD_d = daily cooling degree days (annual CDD/365)

a_1, b_1, a_2, b_2 = model parameters for different building types (see Table 3).

[5] B. Sliwinski, D. Leverenz, L. Windingland, A. Mech, *Fixed Facilities Energy Consumption Investigation Data Analysis*, Technical Report E-143/ADA066513 (U.S. Army Construction Engineering Research Laboratory, February 1979).

Table 3
Model Parameters for Different Building Types

	a_1	b_1	a_2	b_2
Family housing	105.6	20.03	.01447	.001683
Troop housing	130.5	15.99	.01516	.001275
Administration/training	76.7	18.97	.03388	0.0
Community facilities	73.79	32.40	.06712	0.0
Production/maintenance	138.4	35.73	.02688	0.0
Medical/dental	254.4	24.31	.04380	0.0
Storage	35.70	36.10	.01384	0.0

This method was applied to data from the Lone Star AAP, FY80 (Table 4).

Applying the FFECI relationships, the following results:

$$E_h = 3.162 \times 10^5 \text{ MBtu}$$

$$E_e = 0.761 \times 10^5 \text{ MBtu}$$

Adding E_n and E_e gives the total predicted nonprocess energy as 392,300 MBtu. Subtracting this from the total energy consumption leaves 234,556 MBtu for process use, or about 37 percent of the total.

Monthly Energy Data (Maximum Process Period Approach)

When energy consumption for any given facility is plotted by month for an entire year, the curve typically shows a maximum near January and a minimum near June. The maximum reflects an increased use of energy due to winter heating requirements. During summer months, however, very little energy is needed for comfort. Some office space may be air conditioned, but office space is usually only a very small part of the overall facility. Therefore, energy consumed during the summer months should represent mostly process energy. If the energy use for some average summer months is assumed to be the monthly average, then the process energy for the entire year can be estimated. This method then rests on two major assumptions: (1) that the energy consumed during some average summer months is entirely process energy, and (2) that production levels remain fairly constant throughout the year.

This method was used to estimate the process energy requirement for Louisiana AAP in FY81. The data for the Louisiana AAP was presented in Table 2 and plotted in Figure 1. The peak energy use occurs during February, while the energy consumption is fairly constant from April through October. The average energy use for June, July, and August is 33,959 MBtu. Using this figure as the average monthly process energy, the annual process energy consumption is estimated as 34,000 × 12 = 408,000 MBtu, or about 76 percent of the total.

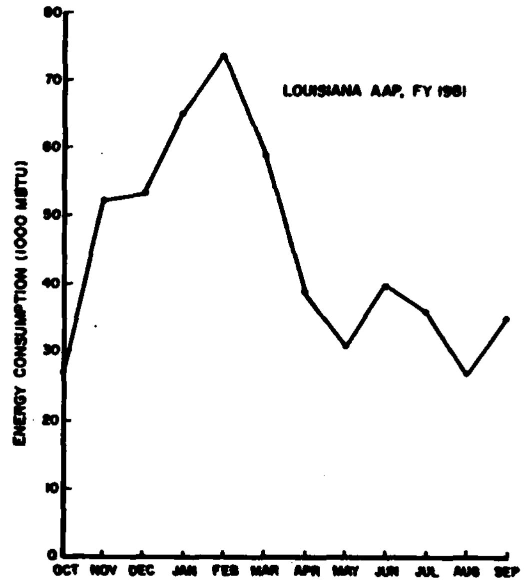

Figure 1. Louisiana AAP FY81 Energy Consumption.

This is the simplest method of estimating process energy use. This method can be used for any facility by simply finding the average energy used during the summer months.

The Phone Contacts and EEAPs

In addition to the estimating methods described above, energy coordinators at each installation were asked to give their best estimate of the installation's process energy use.

Results of the EEAP were reviewed for those installations for which studies were completed. The reports were examined to determine if any estimate had been made of process energy; if available, this estimate was included in the current study.

Table 4
Energy Data for Lone Star AAP, FY80*

HDD: 2531 = 6.40 daily heating degree days
CDD: 2245 = 6.72 daily cooling degree days
Energy consumption: 626,856 MBtu
Admin/training: 132,000 sq ft
Community facilities: 56,000 sq ft
Maintenance/production: 1,585,000 sq ft
Medical/dental facilities: 13,000 sq ft
Storage facilities: 722,000 sq ft

*Computer Sciences Corporation, pp A194-195.

3 OVERALL RESULTS

The estimating methods were applied to each installation for which sufficient information was available. The results are shown in Table 5. The overall

Table 5
Percentage Estimates of Process Energy Consumption by Installation—FY81 Data

Installation	EEAP & Phonecons	Regression	FFECI E-143	Max. Process	Avg Estimate
Redstone	29		72		50
Radford	82	29	81	80	68
Holston		67	88	56	70
Aberdeen	34		48		41
Picatinny	12		42		27
Fort Monmouth	30		16		23
White Sands	36		42		39
Detroit	46		72		59
Rock Island	40			38	39
Iowa	12		17	28	19
Lake City	6		27		16
Red River		84	60	71	71
Sunflower	72			61	67
Letterkenny			47		47
Anniston			60		60
Tooele	24		18		21
New Cumberland			61		61
Watervliet	40		23	42	35
Scranton	37	29	42	59	42
Twin Cities*					8
Lone Star			36	36	36
Longhorn			64	66	65
Yuma			54		54
Dugway	29		0		15
Lima	57				57
Pine Bluff				75	75
Harry Diamond	27		61		44
Joliet*	0				0
Lexington	27		10		19
Louisiana	72	78		76	75
Milan	27	55	48	47	44
Indiana		44		52	48
Sacramento	61		63		62
Seneca			41	43	42
McAlester				57	57
Hawthorne				48	48
Natick	24				24
Riverbank				34	34
Sierra	39		12		26
Kansas			47	51	49
Savannah	8				8
AMMC	8				8
Newport*				35	35
Ravenna*				41	41
Jefferson	16				16
Volunteer				80	80
Pontiac	0				0
FSTC	40				40

*Plant inactive.

estimate for each installation was determined by averaging the estimates obtained by each method. The estimate for each installation was used with the FY81 energy use data for each installation[6] to determine an overall DARCOM process percentage estimate. The estimate was calculated by multiplying each installation's energy consumption by its process percentage, summing for all installations, and dividing the total by the total energy consumption.

4 CONCLUSIONS AND RECOMMENDATIONS

Four methods were developed and used to calculate process energy use for each DARCOM installation. These methods generally provide similar process energy estimates for each installation. In cases where estimates differ, it is likely that the basic assumptions behind one of the methods is incorrect for the installation in question.

The results of the analysis indicate that for the FY81 levels of production, 46 percent of the total energy use by DARCOM facilities is process related. This estimate is correct, ± 15 percent, and is the best estimate possible based on the available information.

It is recommended that the estimates in this report be used by DARCOM for planning where process and building energy conservation efforts may best be applied. Energy coordinators at DARCOM installations will be able to use the methods presented to develop estimates of process energy use for Defense Energy Information System (DEIS) reporting.

METRIC CONVERSIONS

$$1 \text{ Btu} = 1.055\,06 \times 10^{+3} \text{ J}$$

[6]DARCOM, 26 October 1981.

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