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An approach to energy conservation in a manufacturing industry

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AN APPROACH TO ENERGY CONSERVATION IN A MANUFACTURING INDUSTRY

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ABSTRACT

This thesis presents an organized approach to an energy conservation program for a multi-plant electrical manufacturing company.

The approach attacks the problem of control and planning of energy usage via three major categories. These areas are: detection, forecasting and reporting of energy usage.

To initiate any energy program the first step, is the identification of the areas that use the most energy, thus allowing detailed studies to be concentrated in these energy-intensive areas. The author has attempted to show which areas are energy-intensive in his employer's plants.

The second step is the accurate forecasting of energy usage. The author has attempted this via an econometric forecasting model that accurately predicts energy usage based on direct labor hours and degree days.

Thirdly, an energy consumption reporting system has been developed that allows timely energy information to be generated and presented to the factory personnel most able to react to exceptionally high energy usage. The usage figures are presented as ratios of (1) process energy consumption to direct labor hours and (2) heating consumption to degree days. The system utilizes an existing computer and terminal network in the electrical manufacturing company plants.

PREFACE

The purpose of this thesis is to present an organized approach to energy conservation in an industrial environment. Existing energy conservation programs were investigated to determine areas that require improvement. This was accomplished through a thorough research of how industry is presently attacking their energy programs and the problems it has encountered.

Having determined the difficulties with industry's conservation programs an approach was developed that would eliminate problem areas. A program was developed to facilitate a systematic method of planning and controlling energy usage. This was accomplished through the detection, forecasting and reporting of energy usage.

The author wishes to express his appreciation to the many people who helped make this thesis possible particularly to Professor Goldstein for his guidance and to my wife, Maria, for her encouragement and understanding. Also, to Ms. A. Rubano for her patience in typing the thesis.

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INTRODUCTION

Statement of Problem

Industry has historically been a large energy user and this continues to be true. However, with the increasing cost and lack of availability, industry must become more aware of areas of high energy usage and work to decrease waste in these areas. The industry in which the author is employed, is an electrical manufacturing company which used 2.7×10^{12} British Thermal Units (BTU's) of energy in 1975 at an annual cost of $6.5 million. This energy cost represents approximately 15% of the total factory expense and approximately 6.2% of the total inventory cost of products manufactured.

In light of the above figures, the author feels the area of energy usage warrants detailed investigation.

Before energy usage can be controlled, one must become familiar with the areas of manufacturing which are the major consumers of this vital resource. The author will investigate his employer's factories to detect the large users of energy in an attempt to expose areas in which conservation effects should be concentrated.

In addition, an attempt will be made to develop a workable reporting system and consumption forecasting model to help management keep track of the factories' present usage and future requirements.

World Usage

Conservation of energy in an industrial environment can no longer be considered as merely a desired objective to reduce cost. The ability of industry to conserve energy has become one of the major factors in determing whether its products are competively priced and, in the long run, may determine whether required energy sources, such as fuel oil, electricity, propane and natural gas, are available in sufficient amounts to operate its manufacturing facilities.

As stated by Mr. G. A. Lincoln, retired director of the Office of Emergency Preparedness, Executive Office of the President, "Energy conservation can make a substantial contribution in ameliorating or postponing the potential energy shortages faced by the United States over the next several decades".[1.1] To realize this contribution, industry must become increasingly aware of how it is using its energy resources and investigate methods of controlling unnecessary waste.

The United States, as of this writing, consumes about one-third of the world energy production, which is equivalent to about 70×10^{15} British Thermal Unite (BTU) per year. This usage has been projected to double within twenty

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[1.1] G. A. Lincoln, "Energy Conservation," Science, Vol. 180, April 1973.

years to 140 quadrillion BTU's annual consumption. These figures become even more staggering when one considers that the United States accounts for approximately 5% of the world population.

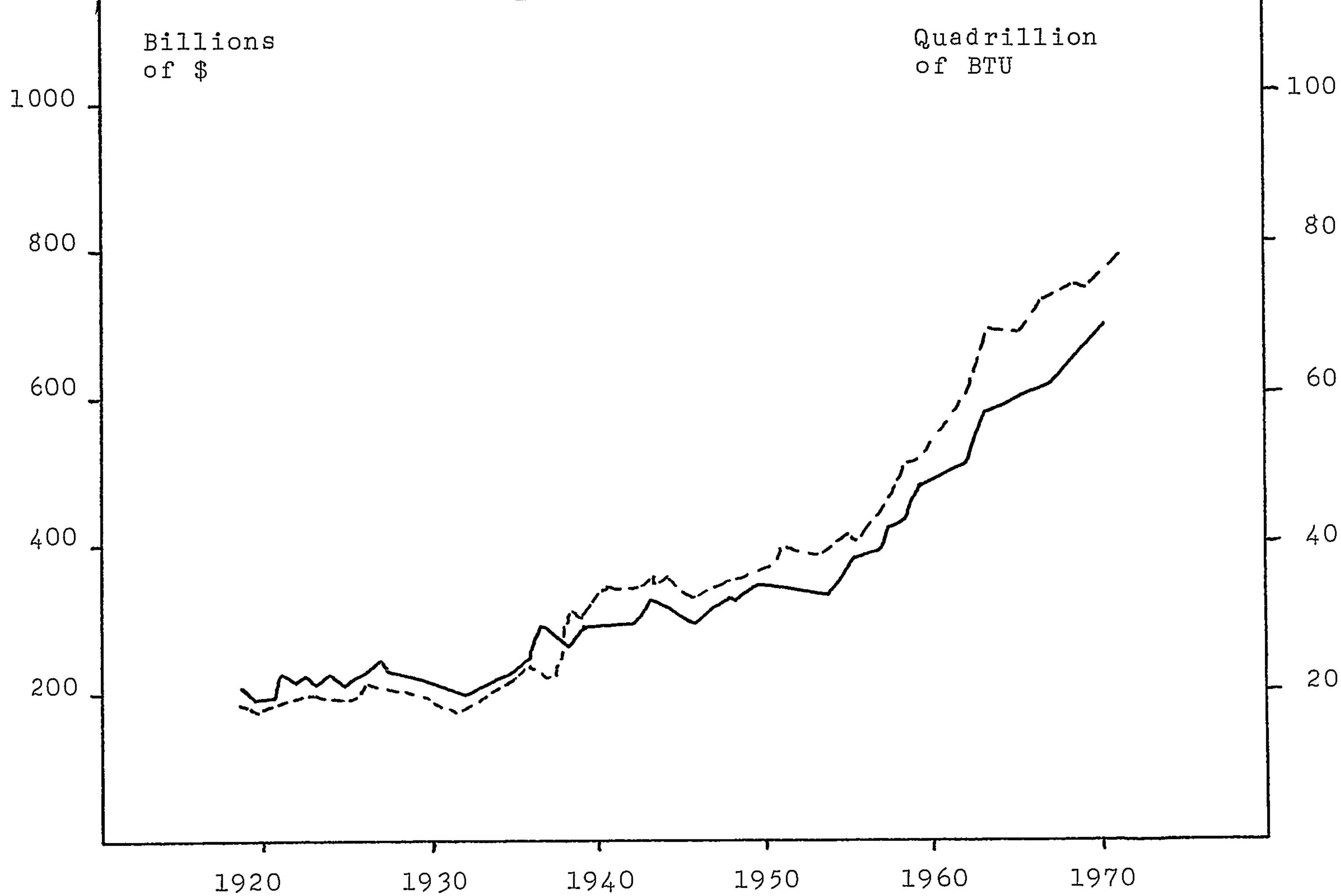
In the past, the United States has had virtually limitless supply of cheap energy. Conservation and energy management were non-existent and the demand for electrical energy was doubling every decade. Energy usage has consistently followed the growth of the Gross National Product (GNP) as shown by Figure 1.1. The energy growth is in spite of the fact that demand is presently outpacing the production of required fuels, "...thus, fuel costs are rising and will continue to do so."[1.2]

The world situation relating to energy is not too different from that of the United States. The annual growth rate for energy demand from 1961 to 1972 has been 5.5%. This is an increase from 132 quadrillion (10^{15}) BTU's in 1962 to 238 quadrillion BTU's in 1972. The real GNP for the same period of time increased at a 5.1% average annual growth and the world population increased at 1.9% annually. The prediction for the future is that, "...energy demand is expected to increase less rapidly

[1.2] G. Friedlander, "Energy: Crisis and Challenge," IEEE Spectrum, May 1973.

FIGURE #1.1

ENERGY USAGE AND REAL GNP



Source: National City Bank
Cleveland, Ohio

through 1985 as population growth declines to 1.8% annually, real GNP growth drops to 5.0% per year: energy conservation practices are instituted and energy costs rise."[1.3]

Sectors of Energy Usage

World energy consumption can be broken down into several sectors of usage: transportation, household, electric power and industrial usage. In the transportation sector, registration of vehicles will increase at an annual rate of 3.8% in the United States. "In 1970, transportation consumed 16.4 x 10^{15} BTU's--one-quarter of the total energy used in this country..."[1.4] On a world-wide basis, 11% of the total energy used in 1972 was for motor vehicles.

Household usage was 14% of the world energy usage and is expected to decline 5% between 1972 and 1985. Usage in the United States for the household sector could possibly be reduced 10-15% due to the availability of better building material, home design changes and the use of solar heating.

[1.3]Warren W. Ware, Andres C. Gross, "World Energy: Demand and Supply," Columbia Journal of World Business, Fall, 1974.

[1.4]G. A. Lincoln, op. cit., p. 157

The most rapid growing consumer of energy among the four major groups listed above is the electric utility sector. Electric power production increased from 2.3 trillion kilowatt hours in 1961 to 5.5 trillion in 1972. In 1985, 145 trillion kilowatt hours will be produced, requiring 145 quadrillion BTU's of energy.

> "The largest user of electrical power is the industrial market, followed by the residential and commercial market. This energy form is necessary to operate heavy industrial machines, lighting devices, commercial office equipment and large and small home appliances."[1.5]

In addition to the usage of the major amount of electrical power, industry is also responsible for 49% of the total primary fuel demand.

> "Industrial energy use increased 6.0% annually between 1961 and 1972, while GNP increased 5.1% Fossil fuels are necessary to maintain industrial growth, but the degree of conservation and efficiency varies significantly from country to country... By 1985, 35,000 BTU's per dollar of GNP will be consumed by world industry with the exception of the United States, where consumption will be decreased to 30,000 BTU's per dollar of GNP."[1.6]

[1.5] Warren W. Ware, op. cit., p. 12

[1.6] Warren W. Ware, op. cit., p. 12

If the 1985 estimates are to be realized, the industry in the United States "...must take a micro-look at production facilities, processes, products, distribution, scheduling and shipping with the word 'conservation' firmly planted in their minds."[1.7]

Major industrial users of energy have always tried to use their resources economically. However, conservation seldom made the top five on an average list of management objectives. Conservation can no longer be ignored by industry. The cost per BTU of energy is increasing at an accelerated rate since the energy crisis in 1973 and the availability of required fuel has become doubtful.

Cost Growth

Natural gas was the most rapidly growing and largest source of industrial energy used in the United States. This source has risen in cost by approximately 93% to industrial users in the North Jersey area between 1973 and 1976. This represents 46% of industries' energy requirements. Coal has also doubled in cost within rougly the same period of time. Petroleum represents 16.8% of the energy needed to keep industry rolling, while electricity

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[1.7]James M. Beattie, "Managing Energy--A New Role for Industry," Iron Age, February 25, 1974.

is 10.6%. Oil costs have grown from $.14/gal. to $.33/gal. and electricity has gone to $.031/KWH from $.0145/KWH in the three year period from 1973 to the present.

Figure 1.2 shows the cost of gas, electric and oil in the northern New Jersey area. An industry the author is familiar with had an annual cost increase of 70% between 1972 and 1976, in spite of a 30% decrease in BTU consumption.

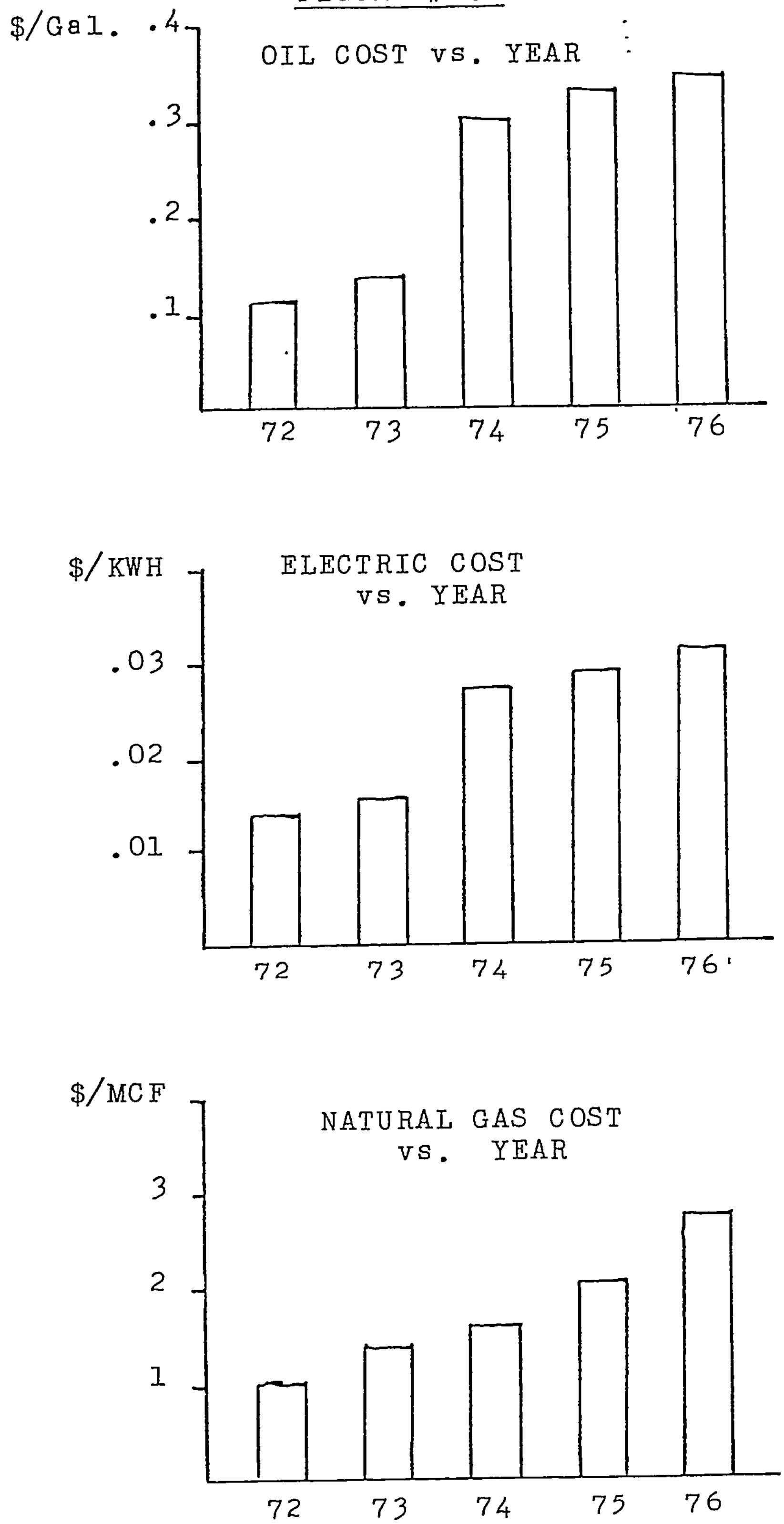
Industry Must Attack Problem

The energy costs and shortages will not disappear for industry. Therefore, methods for reporting, controlling and forecasting energy requirements becomes of prime importance. Reporting areas of energy usage is not only important to industry, but the government will be demanding usage figures from all major manufacturing industries.

> "As the bill now stands before the Interior Committee, it's uncertain exactly what information companies would be required to report...The bill states somewhat foggily, that data would be collected from major energy consuming companies to provide a statistically accurate profile of each line of commerce, by segment of business, which consumes significant 'quantities of energy'... An Interior Committee staff member indicates that the number of firms required to file would depend upon the sampling techniques drawn by the National Energy Information Administration. ...but we're potentially talking about a whole lot of companies, he concedes."[1.8]

[1.8] "Will More Energy Data be Demanded?", *Industry Week,* April 5, 1973.

FIGURE #1.2



Source: Public Service
Electric & Gas Co.
Newark, New Jersey
1976

The government needs these figures when they consider problems related to balance of payments and amount of fuel required from foreign countries. Industry must gather these figures in an attempt to pinpoint large energy usage areas and once located, investigate ways of decreasing waste and increasing efficient usage of their resources.

Processes that require large amounts of decreasingly available fuel must be made more efficient and/or converted to more readily available sources.

> "An energy audit within a company generally results in pinpointing of waste, but what a company finds may be an expensive discovery in terms of capital investment...Apart from the obvious, certain essential engineering shifts with large investments and an overall change in the way you do things are what's needed."[1.9]

In many cases, it is a matter of making the investment or not having available fuel to continue manufacturing. This becomes obvious when one considers how natural gas suppliers have curtailed industry's usage all over the country. Industry, the interruptible customer, can look forward to more of the same if the coming winter is a severe one. The author is familiar with one plant that lost twelve

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[1.9] James M. Beattie, op. cit., p. 42.

days of three shifts' operations due to lack of natural gas in the winter of 1975.

Mr. Freed, principal of A. T. Kearny, Inc., a Chicago based management consulting firm, emphasizes that "...important moves like site selection or changing from one fuel to an alternative, is not something that can be done without total and credible information being available."[1.10] When the present areas of usage are known, the decision making and control process can proceed.

To be successful when making decisions related to the future, one must first attempt to get a feel for what future needs will be. Industry has been doing this for years in its sales and marketing departments via the use of economic models. This same process should be considered with respect to energy consumption. With an energy model, one could attempt to predict future demands and be in a better position to react to insure that their requirements are fulfilled.

With information made available through reporting and forecasting of energy usage and future needs, management must act to conserve energy today and investigate alternative fuels and processes for tomorrow. It must train workers

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[1.10]IBID., p. 43

to become aware of energy waste and provide services to correct the waste areas. An energy committee should be formed to investigate new processes and alternative energy sources. In the short and long run, conservation is one of the most important ways that industry has to insure its future. The author intends to investigate the areas of reporting, forecasting and conserving of energy in the industrial environment.

Chapter II will investigate what other industries are doing to isolate and control their energy usage. It will also explore what has been accomplished in relationship to use of alternative fuel in manufacturing facilities.

Chapter III will contain the author's investigation into the problems of his employer's conservation efforts.

Chapter IV's discussion will include identification of high energy users in his employer's plant.

Chapter V will develop a forecasting model to predict future energy requirements.

Chapter VI will incorporate a method of reporting energy usage.

Finally Chapter VII will summarize findings and make recommendations pertaining to energy conservation.

Summary

With the realization that industry is such a large user of energy, and that the cost for this resource has increased so significantly in recent years, the author feels that the control of energy is imperative. The author intends to detect energy users within his employer's plants and formulate a forecasting model and reporting system in an attempt to initiate control on energy usage.

CHAPTER II

INDUSTRY'S ACCOMPLISHMENTS TO DATE

Introduction

Energy conservation has not been unknown to industry. In energy intense industries, conservation has been going on for many years in order to maintain a competitive position in the market place. However, conservation effort has taken on a renewed interest since the energy crisis of 1973. The crisis also stimulated interest in industries that have not had organized efforts in this area. Industry as a whole is now in search of ways to conserve energy, thus reducing factory operating costs.

In attacking the problems of conservation, industries must first set objectives and goals and form an organization assigned with responsibility to investigate energy usage. The goals can best be attacked (1) by a breakdown of areas to be investigated via elimination of obvious waste and (2), by the redesign and/or change of machinery and processes.

The author's intention in this chapter is to investigate what has been done by industry to reduce energy usage.

This investigation will be broken down as stated above. The first area, herein called Phase I, will explore wastage and general areas of conservation that most industries can advantageously enter. Phase II will investigate more specific changes that industries have incorporated into machinery and processes to reduce energy usage.

The author will follow the above with the results of a telephone survey of energy coordinators in various industries to show the extent of their involvement in energy conservation. This survey was also used to gather information on the efforts of industry to develop reporting systems and forecasting models in the battle to conserve.

Phase I

Phase I of energy conservation are those areas in which obvious wastes occur and for the most part, are present in all industrial environments. The corrective action required in these areas are usually inexpensive to correct. This phase of the energy conservation effort usually begins with the forming of a committee. Typically, for a large industrial manufacturing facility, the committee members would include a person from top management, (i.e. a plant manager, or energy coordinator who reports to the plant manager) department heads or representatives, (i.e. line supervisors), and representatives of the plant engineering department.

In the typical factory, each committee member is assigned the responsibility of detecting wastes in his or her area of responsibility. The types of conservation recommendations that the members usually suggest are those which fall within the Phase I category. These could include such acts as simply turning off unnecessary lighting to the redistribution of peak electrical energy loads.

One may challenge the fact that redistribution of electrical load does not conserve energy. However, if peak loads were reduced industry-wide, the utilities would be in a position to use only their more efficient generating equipment, thus conserving fuel. In addition, the companies reducing their peaks are rewarded with lower energy bills.

The author at this time will investigate what industry has done to conserve energy in specific categories within Phase I areas.

Lighting

Lighting is usually the first item to be suggested as an energy saver. It does save energy, but the amount is not significant. For example, if every light at General Motors was turned off, it would result in an energy consumption cut of approximately 3% for that company. However, as stated by Mr. Neil DeKoker, manager of energy conservation, energy management section of General Motors, "our consumption pattern is made up of many small elements. To conserve energy, we have to work on all of them and this is what we are doing."[2.1] Therefore, although small, lighting savings should be investigated.

One method of saving via lighting changes as explained in a Westinghouse Electric Corp. advertisment would be to

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[2.1] "Making Production Pay through Energy Conservation", Automotive Industries, August 1, 1976, p. 23

replace mercury vapor lamps with ceramalux lamps. A 400 watt ceramalux lamp can replace a 1,000 watt mercury vapor lamp without changing the lighting level. This is a 600 watt per lamp savings in energy consumption. With the national industrial average power cost of 2.5¢ per kilowatt hour, this would result in 1.5¢ per hour in savings. This seems insignificant until one multiplies it by the hours of use in a year and the number of lamps. Savings and applications of this type are most readily utilized by high bay factory buildings.

The lighting project above was subjected to an engineering cost analysis by Westinghouse Electric Corporation's engineers, and with all costs considered, the project proved to be not only an energy saver, but also a money saver.

"Task lighting" represents another illumination change that can save energy and dollars for industries willing to employ it. A simple example of task lighting is a desk lamp. Due to the close proximity to the work surface, a lower wattage lamp can give as much light as a high wattage ceiling-mounted ambient light-producing fixture. This same approach can be utilized in an industrial environment.

Electrical Demand and Power Factor Correction

To satisfy the peak demands required by it's customers, utility companies must have available enough capacity in generating equipment. Often, the equipments that are utilized at peak periods are not as efficient as those normally used.

Therefore, to decrease energy usage during peak periods would conserve energy and save money. Power companies bill customers on the basis of two factors: (1) actual power consumed; and (2) a peak power demand factor reflecting the fact that the power company needs to have facilities available to supply power at peak rate.

Industry has used many methods to reduce the peak power demands of their factories. These actions include computer systems that monitor the demand factor and keep it under a previously determined peak value. If the demand attempts to increase beyond this peak value, the computer system automatically turns off non-essential electrical loads. The electrical loads removed from the lines may include air compressors, electric furnaces and/or air conditioner loads. Included in the computer program is a factor that determines how long each removed load can remain off without hindering the process of which it is a part.

One such system that has been employed is the IBM System/7 which monitors power-demand and has resulted in a 11-15% savings.[2.2]

Computer systems can be expensive; however, this does not eliminate the possibility of reducing peak demand. Some companies have installed timers which automatically turn equipment off everyday at a given time. This off-time period occurs at the factories' peak load period.

This was accomplished at a Westinghouse Electric Corporation on air conditioning units and resulted in a $2,500 annual cost reduction.[2.3]

Another item that should be corrected with respect to electrical energy demand is the power factor. The power factor is the rate of true watts to volt-amperes or the phase relationship between the voltage and current. Correction of a low power factor can reduce system losses and avoid a billing penalty.

[2.2] Kember, D. R. and Spector, M., "Control Peak-Load Demand and Cut Your Power Bill", Stores, June 1973, p. 27

[2.3] Westinghouse Electric Corp., 1975

Most utilities penalize companies that have power factors below a given value (usually around 90%). Therefore, to decrease utility cost, most companies maintain at least this power factor value. However, since no reward is received for high power factors, many companies are unwilling to go any further. An energy conscious manager at the Campbell Soup Company,[2.4] whom the author interviewed, suggested a billing system in which utilities penalize lower power factor, i.e. below 90% and reward higher power factor companies up to the maximum value of 100%, thus giving industry an incentive to correct to the maximum value or as close as possible.

Maintenance Items

In the past, industry has had a tendency to ignore maintenance items that can save fuel. This attitude has changed and represents another area of conservation that energy committee members usually suggest as part of Phase I.

The government has not been inactive in this area. It has published many pamphlets with maintenance areas that would conserve energy.

[2.4]Telephone interview conducted by author

One useful publication is the United States Department of Commerce's National Bureau of Standards in cooperation with the Federal Energy Administration's Conservation Program Guide for Industry and Commerce"; NBS Handbook #115. Maintenance items included were numerous. For example: repair cracked doors, faulty louvers and dampers, provide proper lubrication of motor driven equipment, repair poor pipe insulation, check and correct steam leaks, clean filters, etc.

Good maintenance does save energy. For example, the Burroughs Corporation took a survey to locate all existing bare steam lines in a plant in New Jersey. This survey was aimed at identifying energy wastes that could be corrected by in-plant maintenance. The survey results showed the following size and lengths of bare steam lines:

6 ft. of bare 1 inch pipe
120.5 ft. of bare 1.25 inch pipe
309.5 ft. of bare 1.50 inch pipe
280 ft. of bare 2.0 inch pipe
66 ft. of bare 2.5 inch pipe
156 ft. of bare 3.0 inch pipe
28 ft. of bare 4.0 inch pipe

It was suggested that if the above bare steam lines were insulated, a yearly potential savings of $4,587.00 would be realized. The insulation cost would be $907.00.[2.5] Data figures required for the calculations were obtained by Burroughs from the above mentioned U. S. Commerce Department Publication.

Miscellaneous Items

Numerous miscellaneous items can be investigated to reduce factory energy costs including cutting heating to unoccupied space, lowering thermostat settings, reducing ventilating air, using photocell switching on exterior lighting, etc.

All Phase I suggestions should be thoroughly studied for their potential savings. This will encourage further suggestions from both committee members and factory personnel.

Reporting and Forecasting

Most industries include, and the government suggests as part of Phase I for conserving energy, a reporting system that will reflect the progress that has been made. In a

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[2.5] Internal Survey Burroughs Corporation, August 1976.

publication released from the Office of Petroleum Fuels Affairs, Office of the Governor, Puerto Rico, the following was suggested under the heading of measuring results:

"--chart energy use per unit of production by department.

--chart energy use per unit of production of whole plant.

--monitor and analyze charts of BTU per unit of product, taking into consideration effects of complicating variables, such as outdoor ambient air temperature, level of production unit with past performance and theoretical BTU per unit.

--observe the impact of energy savings actions and project implementation on decreasing BTU/unit of product.

--investigate, identify, and correct the cause for increases that may occur in BTU units of product, if feasible."[2.6]

The author intends to discuss this area further in a succeeding chapter.

[2.6]"Puerto Rico's Uncommonly Good Energy Conservation Checklist", Industrial Development, September/October, 1975, p. 19.

Phase II - Objective

With the obvious waste under control as accomplished in Phase I, it is time to investigate other areas that can be modified to save energy. These new areas are those which required larger capital expenditures and detailed analysis of ways in which to modify manufacturing equipment, process changes and plant layouts and design. This is the phase that must be justified by an adequate return on investment so as to successfully compete and obtain its share of the capital budget.

Upon entering Phase II, many problems are encountered. One of these is the "lack of comprehensive energy policy at the national level."[2.7] For example, policies of the Environmental Protection Agency and regulations dealing with OSHA often work in conflict with the goals of energy conservation.

"Perhaps the most troublesome is the lack of price policy that would tilt energy usage away from scarce energy sources to more abundant ones."[2.8] To accomplish this, the pricing policy must motivate capital expenditures in

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[2.7] "Making Production Pay Through Energy Conservation", Automotive Industries, August 1, 1976, p. 21.

[2.8] Ibid. p. 21.

industry. In many cases, the present policy doesn't do this as stated by Chrysler's Mr. Harbour, "Due to the present energy price structure... It's our position to maintain our reliance on gas, oil and coal and reduce usage on all of them. That's the best we can do."[2.9]

In spite of the large increase in energy costs, industry is not motivated to spend large amounts of money on saving. Here's why:

> "If there is a cloud on the horizon of the effectiveness of higher energy prices as a new and major driving force for energy conservation, however, it lies in a realistic look at what is happening to energy prices. Despite all the talk about the quadrupling of oil prices, we must be at least as realistic as OPEC spokesmen. It is a fact that energy prices, and especially oil prices, have been declining in real terms quite sharply for the past 16 months.
>
> This is an unfortunate and counterproductive development which both the Administration and the Congress find objectionable and are seeking to reverse. Declining real oil prices, hence declining real energy prices, tend to reduce the added pressures to accelerate the natural and observable trends to lower energy consumption per unit of output already noted. Whether higher real prices are achieved by OPEC increases, import excise taxes, gasoline and other fuels excise taxes, or elimination of depletion allowances and foreign tax credits, the objectives appear to be the same. The aim seems to be to build higher pressures via higher prices to induce lower consumption and greater efficiency of utilization.[2.10]

[2.9] Ibid., p. 22.

[2.10] W. A. Hamilton, "Hastening What Comes Naturally in Saving Energy", The Conference Board Record, August, 1975, p. 19.

Since the writing of the above statement, government has moved to change price structures as an incentive to conserve. Government has also required that certain energy intense industries meet energy decreases per unit of production, i.e., the chemical industry is required to decrease its energy consumption per pound of product by 15% by the year 1980.(with 1972 as a base year).

Automotive Industries

"Large manufacturing companies with more at stake - and more money to spend - are attacking the problem (energy conservation Phase I and II) in a big way."[2.11]

General Motors, according to its chairman, Richard D. Gerstenberg, in 1974 stated that he has set a 20% energy conservation goal for the high usage winter months. "Each (GM) unit should ensure that the adequate staffing and funds are available to achieve positive results."[2.12]

> "Total management, the development of new technology, major commitments to capital and management resources...setting energy goals, educating employees, suppliers and customers... these concepts are becoming as common today as labor availability, costs or productivity were

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[2.11] James M. Beattie, "Managing Energy - A New Role for Industry", Iron Ages, Feb. 25, 1974, p. 44.

[2.12] Ibid., p. 44.

yesterday."[2.13]

Accomplishments by the auto industry to date have been impressive. "Chrysler Corporation for example is now reclaiming 100% of its process oil - cutting, coolant and hydraulic. Coolant and cutting oil is re-refined by Chrysler itself and hydraulic oil is refined outside. Chrysler previously used close to 7 million gallons of such oil per year."[2.14] Today their virgin oil purchases are nil. This allows the conserved 7 million gallons to be used elsewhere in industry.

> "Chrysler also...controls 124 air intake and exhaust fans automatically from a central environment control center. It adjusts weather load energy requirements as well as work load energy requirements.
>
> For example, on third shift, there is no welding and so the associated air moving equipment is shut down automatically."[2.15]

Heat recuperation on foundry furnaces, elimination of unnecessary heat treatment, movement to cold and warm forming away from hot forging and extensive use of thermographic analysis (infrared photography) are other areas in which Chrysler is working to conserve.

General Motors, the largest manufacturer of automobiles, consumed 206.9 trillion BTU's of energy in 1974

[2.13]Ibid., p. 44.

[2.14]"Making Production Pay Through Energy Conservation, op. cit. p. 22.

[2.15]Ibid., p. 22.

and 195 trillion BTU's in 1975. Their biggest conservation effects "involves product specification changes, process changes, heat recovery applications, improved equipment control and materials conservation."[2.16] For example, in one plant, the paint specification was changed to eliminate a forced curing cycle and resulted in a 1.4 billion BTU per year savings. "Delco Products Division, eliminated normalizing furnaces for large motors and generator frames saving 5 billion BTU's per year."[2.17]

The Buick Division saved 7 billion BTU's per year by providing nitrogen atmosphere to cool furnaces, thus allowing parts to remain in the furnace over the weekend.

In the area of heat recovery, the Guild Lamp Division uses hot exhaust from sealed beam headlight manufacturing and combines it with outside air for building heat during winter months."[2.18] This saves 65.8 billion BTU's per year.

"Part of the problem in energy conservation is making a good audit of where energy is actually being consumed."[2.19] General Motors has completed this as shown in table #2.1 below

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[2.16]Ibid., p. 23.

[2.17]Ibid., p. 23.

[2.18]Ibid., p. 24.

[2.19]Ibid., p. 23.

TABLE #2.1

Total Energy Consumed By GM 1974 Calendar Year		
Process	Trillion BTU	Percent
HVAC	65.6	31.7
Metals Casting (Incl. 18.2 BTU for Coke)	34.4	16.6
Liquid Heating	26.0	12.6
Furnaces	18.0	8.7
Ovens	15.3	7.4
Paint Systems	8.5	4.1
Lighting	6.9	3.3
Metals Machining	5.5	2.6
Plastic, Rubber and Urethane	4.3	2.1
Metals Forming	3.8	1.9
Assembly	3.6	1.8
Product Testing	2.9	1.4
Soldering and Welding	2.5	1.2
Domestic Hot Water	1.3	0.6
Other	8.3	4.0
TOTAL ENERGY USED	206.9	100%

Source: General Motors

as part of their Phase II accomplishments.

Other Industries Approach

Some industries had been working on energy conservation for many years before the energy crunch of 1973. One example is the EI Dupont de Numerours & Co. which "...has been working for 30 years to cut its own personal energy losses. Now the company is in business for itself selling energy saving tips to others."[2.20]

According to Dr. Edward G. Jefferson, Senior Vice President at Dupont, his company works on design of new facilities and modification or additions to old facilities in an attempt to save energy. Retrofitting old facilities with adequate meter and record keeping ability is essential to good energy management and is constantly being done at Dupont. With good metering, Dupont has been able to set "...standard or minimum requirements for various levels of production and other factors...(and) comparisons between standard and actual performance reveal the extent and location of preventable waste."[2.21]

Key areas of waste generally investigated as part of an energy audit as stated by Dr. Jefferson are: combustion efficiency, effective use of steam turbines, decreasing avoidable energy losses and waste energy recovery.

[2.20] James M. Beattie, op. cit., p. 44.

[2.21] W. A. Hamilton, op. cit. p. 19.

Another area often overlooked is transportation and distribution which accounts for 8% of United States gross energy consumption. In Dupont's program, efforts are being made to reduce freight cost by "...increasing the ton mile per unit of fuel consumed in the movement of both raw material and finished products. Approaches include providing flexibility in shipping and receiving dates to enable...(consolidation of) orders into full truckloak shipments."[2.22]

Mr. W. A. Williams, energy conservation coordinator, Union Carbide Chemical & Plastics considers waste-heat management as an area that should be explored and capital invested as a means of decreasing energy usage. The most common and practical available devices in this area are those used as "air preheaters for combustion air to be fed back into the heat source. By reducing the required temperature rise needed in a combustion unit, less fuel is required to operate the unit."[2.23]

Other types of process wastes are also available for

[2.22] Ibid., p. 20

[2.23] J. J. Mullally, "Energy Conservation is Dollar Conservation", Industry Week, June 14, 1976, p. 42

use. One cited by Mr. Williams is that of chemical process residue which was considered a nuisance a few years ago.

"Formerly the volatile waste was simply incinerated to get rid of it. Today, almost 90% of this residue is being burned as boiler fuel at natural-gas-short Gulf Coast chemical plants."[2.24]

Kaiser Aluminum was singled out in 1974 by the U. S. Commerce Department for its energy savings. Their program "...included developing a new technology for applying water-base paint to aluminum coil used in the manufacturing of aluminum house siding, roofing, etc. The technology brought an almost instantaneous drying and a significant savings in natural gas."[2.25]

U. S. Steel is also "looking into facilities that will effectively recover vital by-product gases, oil and tars in energy-consuming operations."[2.26]

Also, a major investment was made by Kaiser to "establish a hot metal transfer system between the companies' aluminum and a wood rolling mill - eliminating the previous

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[2.24] Ibid., p. 42

[2.25] Ibid., p. 44

[2.26] James M. Beattie, <u>op</u>. <u>cit</u>. p.44

method requiring re-melting at high temperature."[2.27]

Another industry with a novel approach to energy conservation is the Republic Steel Corp., located in Cleveland. They "...demand that each request for a capital expenditure include an 'energy impact statement' detailing the type, amount and source of fuel."[2.28]

Minnesota Mining & Mfg. Co. (3M) of St. Paul will spend between $15 million to $20 million over the next four years to retrofit its processing equipment for energy efficiency. They are also buying new equipment on the basis of product efficiency. "When we buy, we want energy efficiency - we do not want to go back and retrofit energy efficiency into a machine two or three years after purchase says R. L. Aspensen, manager of mechanical utilities and energy conservation at 3M."[2.29]

RCA President Anthony Conrad formed an in-house committee to study RCA's use of fuel and electricity. He also set a goal to decrease 15% in energy usage. To accomplish this, the various divisions installed timers to turn equipment off automatically, coated roof tops to

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[2.27] Ibid., p. 44

[2.28] J. J. Mullally, op. cit. p. 45

[2.29] J. Teresko, "Redesign to beat the new costs", Industry Week, May 24, 1976, p. 24

reflect heat to save on air conditioning, reduced furnace temperature on weekends by 20%, and recycled heat which was being discharged into the atmosphere back into dryers.

Hertz, a division of RCA, changed the mix of its automobile fleet. "Management claims to have slashed the percentage of full sized cars from 65 to around 7"[2.30] to help it survive the energy crunch.

Swift Corporation also changed from full-sized to compact cars for its sales force to survive the energy crunch. However, as of today, they have returned to full-sized cars. The money they saved in gasoline was more than consumed by the increased repair bills.

Plants Layout and Design

Dr. Melvin Chiogioji, Director of Industrial Analysis, Energy Research and Development Administration (ERDA) contends that energy saving can be accomplished by simply minimizing the physical separation of individual steps and the storage of inventory between steps.

[2.30] W. Robertson, "RCA Confronts the Energy Crisis," Future, Feb. 1974, p. 157

> "The classic example of the benefits is in the continuous casting of steel, in which fuel-hungry soaking pits are eliminated.
>
> He (Dr. M. Chiogioji) also suggests grouping loads that require direct-process heat. This provides more continuous utilization of equipment and eliminates the heat loss and fuel consumption that occur during repeated heat-up cycle."[2.31]

In addition to layout, many industries are considering all electric plants. "Several large companies...have torn up expansion plans and have gone back to the drawing board again with all-electric plants in mind."[2.32] One such company is Rockwell International Corporation which built a new $18 million automobile leaf spring plant. The new facility is all electric and Charles Fazio, the group's president, claims that the "...unique direct heat induction process will require only a small fraction of the amount of energy used by other leaf spring plants."[2.33]

A. O. Smith's Harvestor Products is also joining the all-electric ranks with "the biggest electric furnace for fusing glass in the U. S....(The) waste heat from the furnace is captured in an 80,000 sq. ft. overhead plenum, to heat the plant in the winter."[2.34] This will result in a

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[2.31] J. J. Mullally, op. cit. p. 39

[2.32] James J. Beattie, op. cit. p. 47

[2.33] "Industry is moving beyond obvious energy-saving moves," Industry Week, June 24, 1974, p. 26

[2.34] K. W. Bennett, "Energy Saving Can Be Built Into Plants", Iron Age, August 18, 1975, p. 31

$200,000 per year savings in space heating.

Interview Survey

In an attempt to obtain additional information on industry's approach to conserving energy, the author conducted a telephone interview survey of several companies in the New Jersey area. Most companies were unwilling to give detailed information on process changes and machine modifications citing the competitive nature of business. Johnson & Johnson, Tenneco Chemical Corporation, BASF Wyandotte Corporation, among other companies that requested not to be mentioned, all stated that Phase I programs had been initiated at the time of or slightly before the energy crunch of 1973.

Most Phase I programs consisted of similar attempts to reduce waste via techniques previously stated in this chapter. Several companies indicated that they were unable to rearrange their electrical demand because of their continuous three shift operations. Energy surveys conducted within the plant consisted of locating obvious waste such as steam leaks, insulation and general housekeeping and maintenance items.

Phase II has been slow in developing according to the companies interviewed. As stated by a Campbell Soup manager, the reason why Phase II results have not materialized is that energy is still cheap and therefore, return of investment is not high enough to compete with other capital expenditure programs. Other problems hindering Phase II is the lack of adequate man-power to investigate processes and machines that are using large amounts of energy. Most companies admit when questioned that little has been done in the way of an organized detection and tabulation of the large energy users in various plants. They agree, however, that this should be accomplished as a first step in an attempt to zero-in on and alter those processes that are energy-intensive.

All of the companies that were interviewed have set up an energy reporting system. The chemical companies stated that through the Manufacturers of Chemicals Association, they are voluntarily supplying the government with energy usage figures through the Manufacturers of Chemicals Association. BASF for example, knows and reports consumption of BTU per pound of product. As with a large number of reports issued to the government, the present energy reports take a tremendous amount of time to compile.

An energy consumption model although not completed, has been discussed in at least one company interviewed. Another company indicated that they simply extrapolate historical data in an attempt to forecast future consumption.

The majority of companies also stated that they have had curtailments of natural gas in some locations. Also, they have called in consultants to help in their energy conservation programs. Industries as large as Tenneco Chemical Corporation have gone outside of their own organization to obtain specialized consulting assistance.

Summary

Industry has and is continuing to enforce Phase I activities. It has begun to consider Phase II, although most companies have not identified their big energy users thus allowing concentrated energy saving effects in these areas.

All areas of conservation must be constantly reviewed to insure continued savings. When new plant location layouts and equipment are considered, one of the categories of decision making must be an energy impact evaulation. Areas such as lighting, demand control, power factor control and heat recovery should be considered. Energy saving efforts must become a continuing program in industry.

CHAPTER III

EXAMINATION OF PRESENT ENERGY CONSERVATION PROGRAM

Introduction

Industry's pursuit of energy conservation has not been without problems. Energy committees have been formed by industry and have begun working on Phase I type conservation projects. Their efforts however, have declined since the original program's conception during 1973 energy crunch. In many cases, Energy committees have not met in a year or more.

Phase II programs have not developed and areas in which to concentrate efforts have not been identified. Communication of energy saving ideas have not been interchanged between factories within the same company. Furthermore, intercompany communications of energy saving ideas have been non-existent due to the competitiveness of industry and the fear of government intervention.

Feedback of energy usage information to individuals and departments most able to correct high energy usage and waste is slow.

The author will, in this chapter, investigate his employer's factories and their system of energy conservation.

The problems with the present system will be pinpointed and discussed.

Energy Committees

When the energy crises came in 1973, industry's first reaction was the formation of an energy committee. The committee, as previously discussed in Chapter II, had the responsibility of coming up with immediate and low cost energy saving ideas. These Phase I ideas were then investigated and implemented where and when savings in energy and/or cost could be realized.

In the author's company, a committee was formed at each location and Phase I ideas were generated. However, since the initial formation, the energy committees have met less and less frequently. Many ideas have been generated but they have not been implemented. Interest in the Phase I program has steadily declined and energy saving maintenance items are beginning to be ignored.

Many times, cost reduction ideas have backfired and resulted in increased cost and increased energy usage. One example of a cost reduction idea that backfired with which the author is familiar occurred when a powerhouse supervisor retired. The annual salary of the individual was approximately $20,000 per year. A cost reduction was suggested that eliminated the job upon his retirement. Within the first six months after the supervisors retirement, approximately $25,000 of fuel oil was consumed unnecessarily. The supervisor's job was to manually control steam valves to the building's heating system. Ten buildings were involved and he regulated the steam, in such a manner, that not more than two buildings were receiving heat simultaneously. After his retirement, this function was not performed resulting in a waste of fuel oil. The fuel waste occurred during the winter months and was detected because the previous year and the year after his retirement had approximately the same number of degree days.

Phase I ideas that are implemented in one plant are not communicated to the other plants in the division for their information and consideration.

For example, one plant had implemented a program to replace fluorescent lamps with econowatt lamps. This program represented a $2,400 annual savings. The program was in progress for approximately one year before it was expanded to the remaining plants. When expanded, the saving for the remaining plants was approximately $11,000.

Also, information on the effects of energy conservation efforts in one factory are not relayed to the other factories. This has the effect of decreasing the enthusiam of the energy committees in the pursuit of new ideas.

Phase II

The Phase II portion of an energy conservation problem is to investigate modifications of manufacturing equipment, process changes and plant layouts, and design changes that would result in decreased energy usage. These changes could, and most probably would, involve large capital expenditures and must be justified on the basis of their return on investment. The present and future costs of energy must be considered as well as the initial cost of required changes.

As stated previously, the interview survey conducted by the author indicates that Phase II progress has been slow. One problem is that Phase II areas require man-hours that are not readily available.

One idea that was generated was that of turning off machinery after a given length of time when no product was run. This economizer was never implemented due to the lack of available man-power to test and document the savings that this device would generate.

Another problem hindering Phase II is that energy is still relatively inexpensive and therefore, return on investment is not high enough to compete with other capital expenditure programs.

Furthermore, there is a lack of knowledge as to what areas should be investigated for energy savings. The companies that the author interviewed indicated that they did not have a program of detection and tabulation of large energy users in various plants.

The author's company has many of the same problems that the interviewed companies have experienced. The Phase II program has not gotten off the ground on the local or corporate level because high energy users have not been pinpointed. The processes that are energy-intensive have to be identified before the available manpower can be efficiently used to minimize consumption.

The energy committees that were formed to handle Phase I have not received direction from management as to whether they are to expand their activities to the Phase II areas. However, if it were prescribed that the committees include Phase II areas, it would require additional members to make the expansion successful. Members of the cost reduction committees in each factory must be included and members of the equipment design section should also be invited to join. What has happened in the author's company to date has been that the energy conservation efforts havenot been incorporated into the main stream of the design and cost reduction process. With the addition of new members, this problem could be reduced.

The Phase II process must become part of the main stream process with a firm commitment from top management.

The local and divisional level management have not submitted areas that are energy-intensive to corporate level engineering. Therefore, no concentrated effort has been made in the research and development of energy saving methods in these most important areas.

Forecasting Energy Usage

Because of the increased cost of energy, it has become a major portion of the factory's operating budget. In one plant, it represents 15% of the total factory expense. This fact has caused it to become a category by which factory management is judged. It is also an important factor in the budgeting, planning and control process.

The present method of energy forecasting is via an extrapolation of historical data. This method is not accurate and does not take into account those factors that could change consumption considerably. Since the forecasted energy consumption figures are compared to actual consumption and used in the evaluation of factory management's performance, the author feels a more accurate and meaningful method of forecasting is required. For example, the present extrapolation method does not take into consideration the impact of automation that may have been introduced into a factory.

An attempt was made and then abandoned in which consumption per product was considered. This was not successful because of the large variety of products manufactured in each facility. There was also the fact that measurement of usage per product required extensive metering in each manufacturing department and such metering was not available.

In relating consumption to products manufactured, the weather factor was ignored. A more meaningful forecasting method would separate process usage, heating usage, and overhead operation usage. This would allow Phase I usage, heating and overhead usage, to be evaluated separately from Phase II consumption which is more closely related to process usage.

Reporting Energy Usage

In reporting actual usage of energy to management, the consumption per product method was also considered. A new method based on consumption per direct labor hour and consumption per degree day has been introduced. There has been an attempt to accurately estimate how much consumption goes in to heating and how much is related to manufacturing.

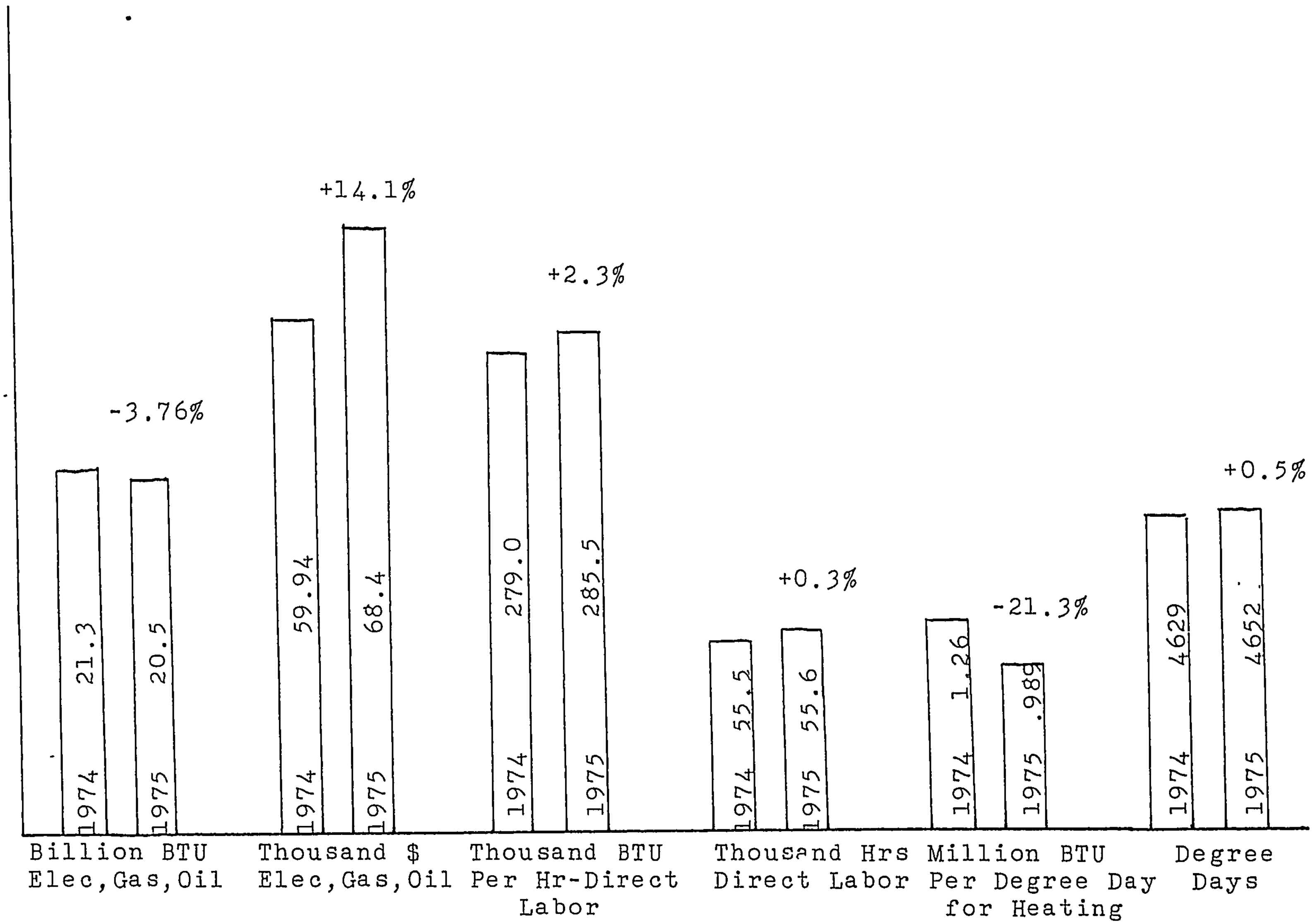
Once the estimates of heating and manufacturing are made, an annual report relating the respective usage is published. A typical bar chart as presently used is shown in Figure 3.1.

The present method of determining heating usage is to consider the summer months consumption as only process usage. Thus, in winter months, anything above this value is considered heating. This method is not accurate since it is assumed that process usage is uniform throughout the year. Nor does the present system allow energy consumption for overhead operations. Since the present system divides usage between process and heating, the overhead consumption is absorbed into these categories.

Further, since the bar charts are published on an

FIGURE #3.1

PRESENT ANNUAL ENERGY BAR CHART



Source: Factory Data Obtained By the Author

annual basis, the factories do not receive the data in time to correct the factors that may be responsible for higher usage.

Summary

The energy problem will not disappear for industry and it therefore must make the conservation program a continuing one. The author's company, as well as several other companies, have let the Phase I program slowly decline and become ineffective. The Phase II program has not been effectively organized to identify areas where major conservation efforts can be made. Because of this lack of detection, any Phase II energy conservation efforts have been on a hit-and-miss basis.

While the measurement of energy usage has been formulated, this information has not been circulated in a timely fashion so as to initiate immediate corrective action.

To date, the forecasting, and therefore the planning and control, of energy usage has been inaccurate. The forecasting, based on naive forecasting methods, cause factory management to be judged on predictions that do not reflect business conditions that affect energy consumption.

CHAPTER IV

DETECTION OF ENERGY-INTENSIVE AREAS

Introduction

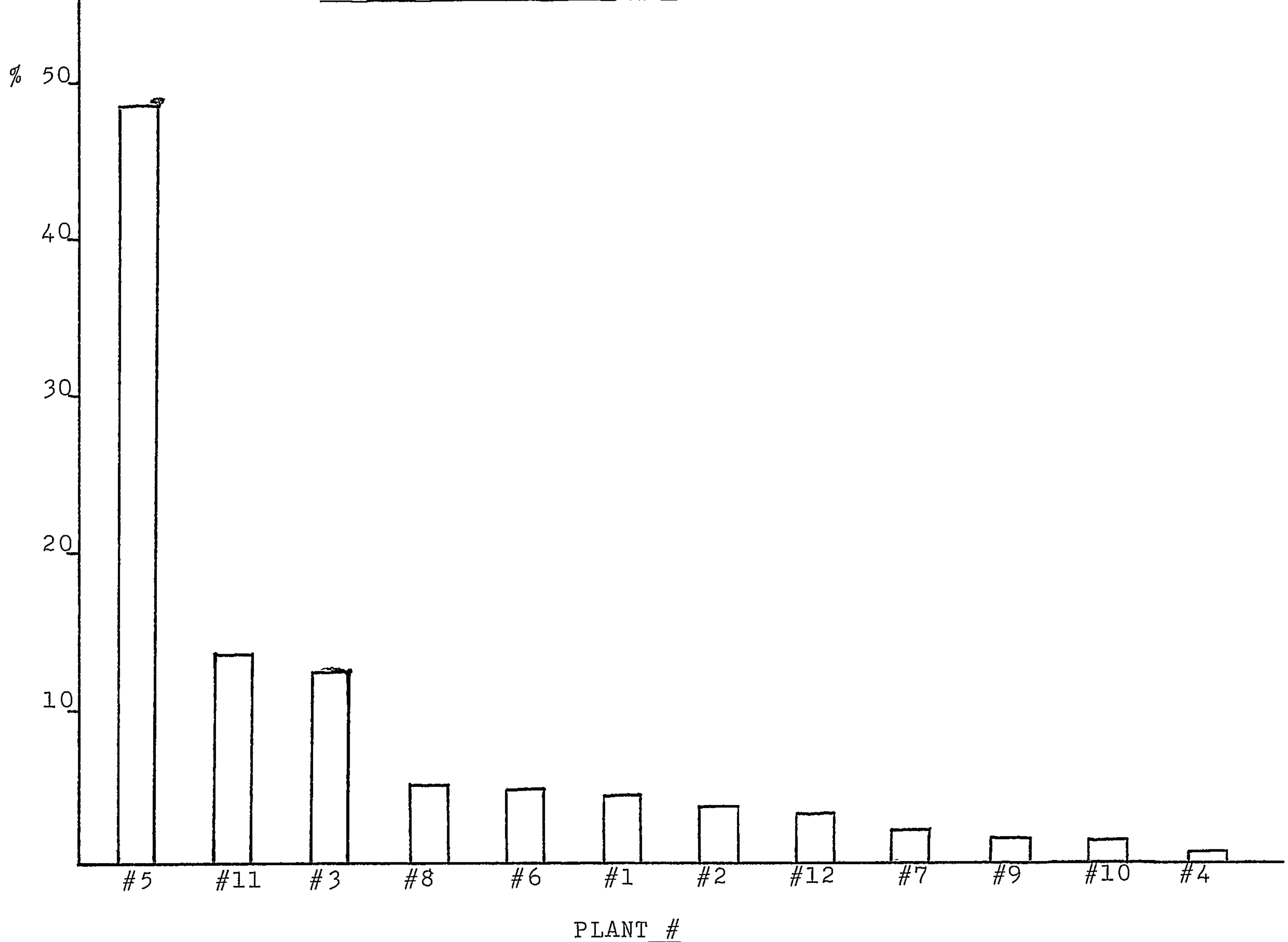
In an attempt to get a more organized approach to the Phase II conservation program, the author has conducted a study of his employer's plants and processes. The study will be used to determine which plants and subsequently, which processes are most energy-intensive and therefore, are areas in which detail analysis and conservation efforts should be applied.

This detection of large energy users should be the first step in any Phase II program. When the survey is completed and submitted to management, it gives them an opportunity to choose the energy-intensive processes and identifies areas where research and development can produce the biggest savings.

Plant Identification

The author obtained energy consumption figures from all of the twelve plants in his division. In addition, the total BTU consumption for each plant has also been plotted with respect to each other. (See Figure 4.1). In an attempt to locate the highest energy users, he separated

FIGURE #4.1
PLANT BTU USAGE AS PERCENTAGE OF
TOTAL DIVISION BTU USAGE FOR 1976



gas, electric and oil usage for each plant and plotted them with respect to each other (See Figures 4.2, 4.3 and 4.4).

From Figure 4.1, it can easily be seen that Plants #5, #11 and #3 are the factories in which major conservation efforts should be concentrated.

Considering only gas consumption, it is apparent that Plants #5, #11 and #8 are the larger users compared to the remaining plants, as can be seen on Figure 4.2.

With respect to the electrical consumption as shown on Figure 4.3, Plant #11 is the biggest users with Plants #3 and #5 close behind.

With this information, it can be determined which plants should be studied first by the division's engineering section as part of the Phase II program.

Other factors which aid in choosing those plants in which to concentrate energy saving efforts are the availability of the fuels used and the cost of the energy sources. With the gas shortage situation being what it is today (1977), the plants that the author has chosen to analyze further are the three largest gas users in the division.

FIGURE #4.2

NATURAL GAS CONSUMPTION (MCF) vs. PLANT LOCATIONS FOR 1976

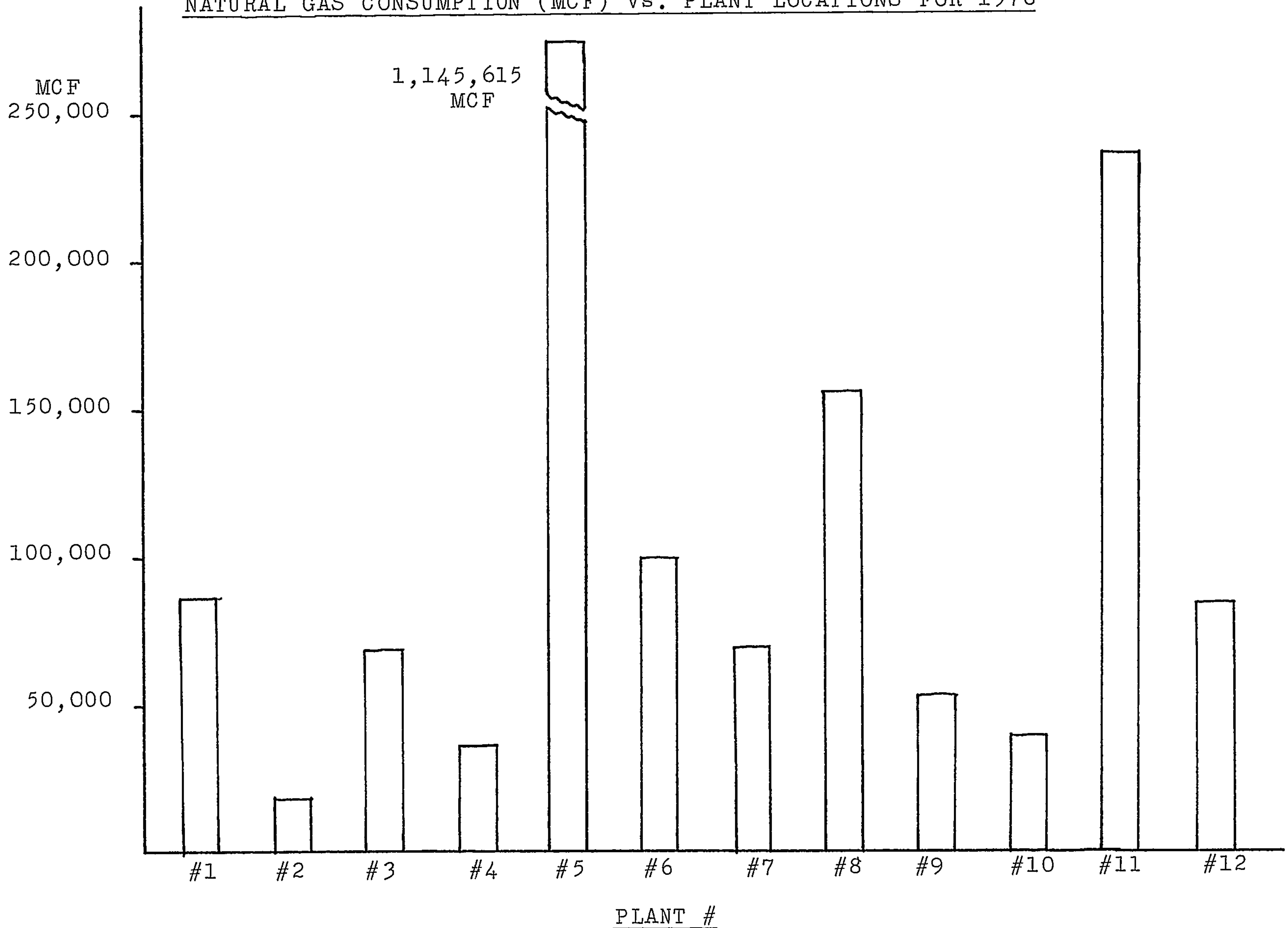


FIGURE #4.3

ELECTRIC POWER CONSUMPTION (KWH) vs. PLANT LOCATIONS FOR 1976

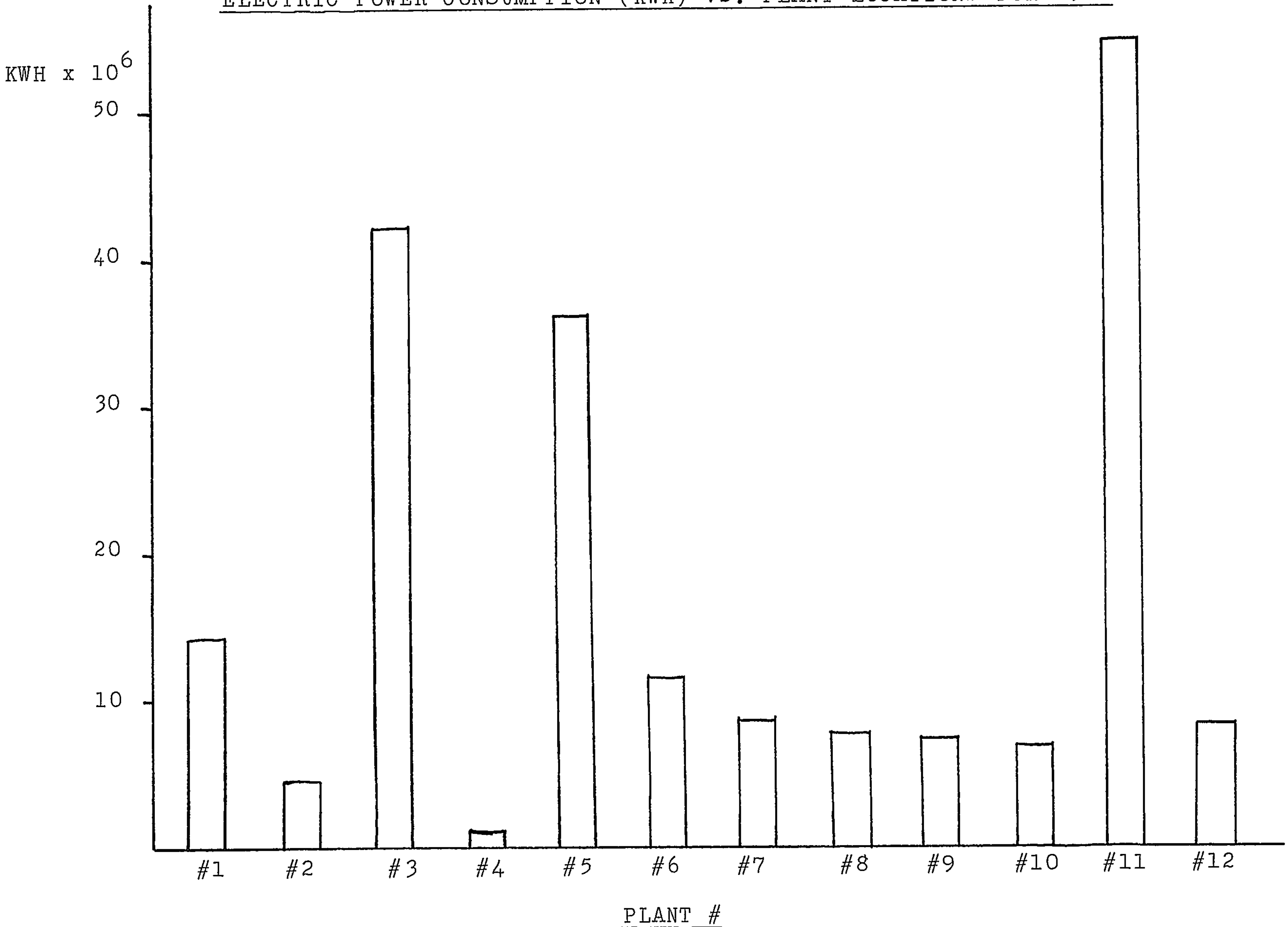
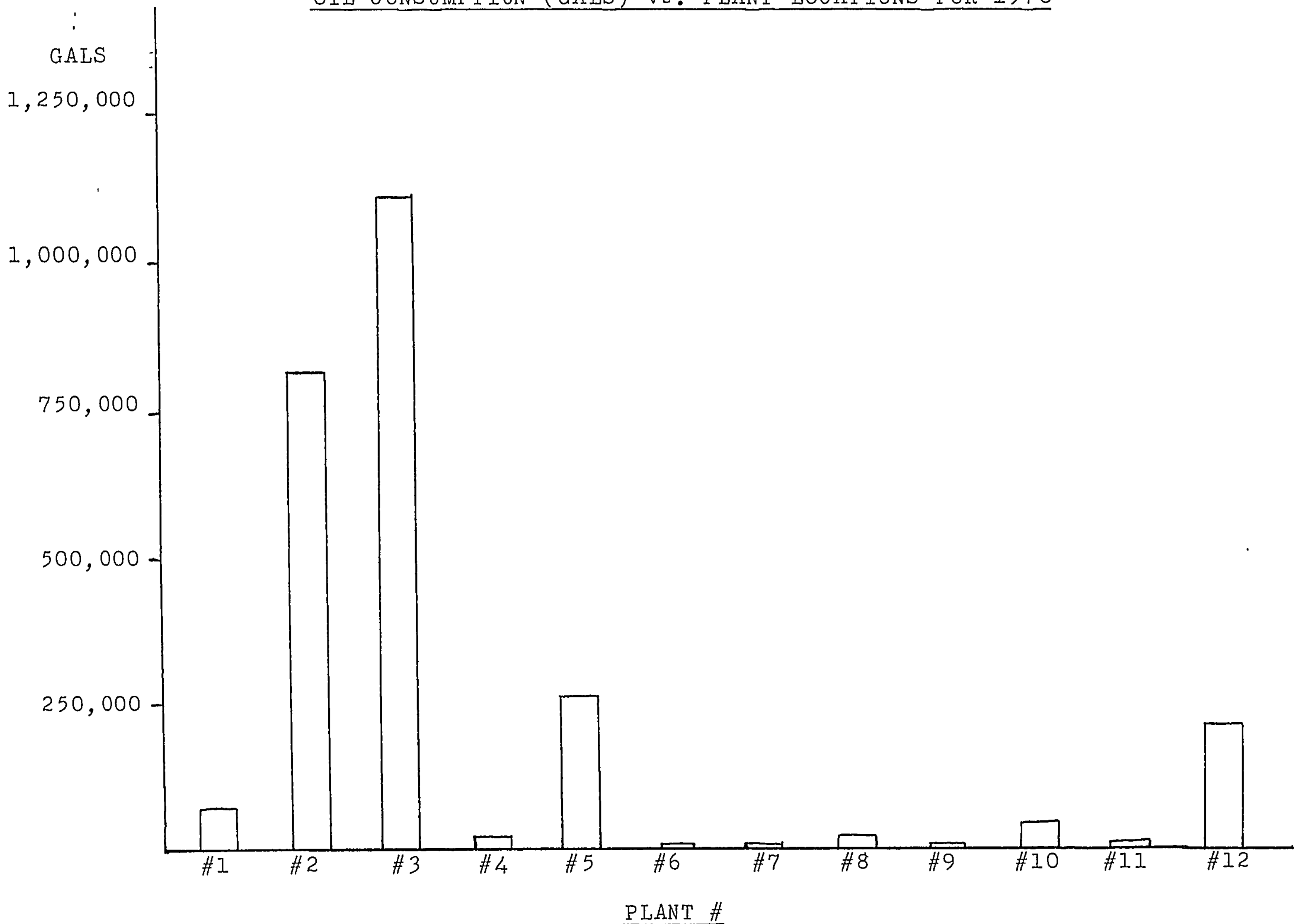


FIGURE #4.4

OIL CONSUMPTION (GALS) vs. PLANT LOCATIONS FOR 1976



Analysis of Plant Usage

Having selected the plants for further analysis, the author developed an energy usage form. This form is a classification of areas of usage for natural gas, fuel oil and electrical power. The natural gas and oil sections have been further divided into process and heating consumption.

The results of a detailed study of the three plants in question for 1976 are included as Tables #4.1, #4.2 and #4.3 for plants #5, #11 and #8 respectively. Due to the confidentiality of the information obtained, the processes have been given a numerical identification.

The purpose of this graphical analysis is to identify the large energy users in each of the three plants in question. With those processes identified, one can then easily proceed to investigate these energy-intensive areas. For instance, in Plant #5, Process #1 consumes 56% of all the natural gas used at that location. Therefore, if any process changes are to be investigated to determine means in which to conserve energy, Process #1 becomes the obvious place to start. This does not mean that Process #2, which consumes only 8.3% of the natural gas at Plant #5, should be ignored. This approach simply sets priorities by which

TABLE # 4.1 ENERGY USAGE FORM

LOCATION PLANT # 5 YEAR 1976

NATURAL GAS - ANNUAL CONSUMPTION ________ MCF	
Process 98 %	Process Uses Describe Process
Annual Consumption 1,122,761 MCF	Process #1 56 % Process #2 8.3 % Process #3 23.5 %
Building Heating 2 %	Process #4 - %
Annual Consumption 22,913 MCF	Steam Generation 11 %

FUEL OIL - ANNUAL CONSUMPTION 379,000 GALS.	
Process 100 %	Process Uses Describe Process
Annual Consumption 379,000 GALLONS	Process #1 - % Process #2 - % Process #3 100 %
Building Heating - %	Process #4 - %
Annual Consumption - GALLONS	Steam Generation - %

ELECTRIC POWER - ANNUAL CONSUMPTION 34,403,000 KW HR	
Lighting 9 %	Process Uses Describe Process
	Process #1 23 % Process #2 13 % Process #3 35 % Process #4 20 % Process #5 - % Process #6 - %
	MISC. - %

TABLE #4.2 ENERGY USAGE FORM

LOCATION PLANT #11 YEAR 1976

NATURAL GAS - ANNUAL CONSUMPTION 220,715 MCF	
Process 70 %	Process Uses Describe Process
Annual Consumption 154,500 MCF	Process #1 8.2 % Process #2 34.3 % Process #3 27 % Process #4 - %
Building Heating 30 %	
Annual Consumption 66,214 MCF	Steam Generation 0.4 %

FUEL OIL - ANNUAL CONSUMPTION - GALS.	
Process - %	Process Uses Describe Process
Annual Consumption - GALLONS	Process #1 - % Process #2 - % Process #3 - % Process #4 - %
Building Heating - %	
Annual Consumption - GALLONS	Steam Generation - %

ELECTRIC POWER - ANNUAL CONSUMPTION 44,079,600 KW HR	
Lighting 6.4 %	Process Uses Describe Process
	Process #1 6.5 % Process #2 4.2 % Process #3 8.4 % Process #4 8.8 % Process #5 4.6 % Process #6 - %
	MISC. 2.6 %

TABLE #4.3 ENERGY USAGE FORM

LOCATION PLANT # 8 YEAR 1976

NATURAL GAS - ANNUAL CONSUMPTION 118,956 MCF

Process	90 %	Process Uses Describe Process	
Annual Consumption	107,060 MCF	Process #1	80.7 %
		Process #2	9.6 %
		Process #3	.6 %
Building Heating	10 %	Process #4	- %
Annual Consumption	11,895 MCF	Steam Generation	- %

FUEL OIL - ANNUAL CONSUMPTION - GALS.

Process	- %	Process Uses Describe Process	
Annual Consumption	- GALLONS	Process #1	- %
		Process #2	- %
		Process #3	- %
Building Heating	- %	Process #4	- %
Annual Consumption	- GALLONS	Steam Generation	- %

ELECTRIC POWER - ANNUAL CONSUMPTION 4,189,300 KW HR

Lighting	10.6 %	Process Uses Describe Process	
		Process #1	40.4%
		Process #2	- %
		Process #3	- %
		Process #4	17 %
		Process #5	32 %
		Process #6	- %
		MISC.	- %

a more organized and straight forward approach to Phase II areas can be attacked.

The Plant #11 usage form (Figure Table 4.2) presents two processes that are energy-intensive. Process #2 representing 34% of the natural gas usage and Process #1 representing 65% of the electrical energy consumed. However, since the usages are for different engineering specialties, it may be possible to investigate these processes simultaneously.

In similar manner, Plant #8 has Process #1 that requires detailed study because of its large usage (80.7%) of gas. (See Table 4.3)

Obtaining and Analyzing Data

The identification of the large energy users represents inputs from all of the energy committee members. Sometimes however, the information is not readily available and either an educated guess or an on-site metering is required. Often times, equipment specifications have to be consulted. However, much of the data can be obtained from factory operating personnel in a department by department survey.

The author chose to categorize the data by processes, that is, a grouping of equipment that represents the complete manufacturing cycle from raw materials to a finished or salable product. Another method that could be utilized would be to group similar operations regardless of the process of which they are a part. For example, the grouping of all welding operations and subsequently, the study of how welding could be made less energy-intensive.

Regardless of the approach, the areas of large energy usage must be determined before Phase II of the energy program can be initiated.

Once the major processes are considered, an analysis of each will reveal areas within the specific process that would be considered first. For example, it may be determined that within a given process, a gas oven consumes the largest amount of natural gas. This would suggest an engineering study to determine if it would be feasible to convert the oven from gas to electric. In such a study, initial cost, operating cost and availability of the required fuel must be considered by the energy committee.

Summary

An attempt has been made to identify the energy-intensive plants owned and operated by the author's company. Then the major energy-intensive are identified so that these areas can be subjected to a detailed engineering analysis. The thought is that if each factory within the division identified these large energy users, a more organized Phase II program could be initiated which would most efficiently use available engineering manpower to decrease energy waste. Also, by concentrating on the larger energy usage areas, enough may be saved to justify a large capital expenditure.

CHAPTER V

ENERGY CONSUMPTION MODEL

Introduction

In conjunction with any Phase II energy program, a reliable method of forecasting energy usage should be considered. The forecast will be useful in determining future energy requirements so that contract agreements can be initiated in anticipation of increased usage. In addition, since management is judged on its ability to meet objectives in energy consumption, it becomes important to forecast accurately.

The objective of this chapter is to determine the econometric relationship that will accurately predict the level of energy consumption in an electrical manufacturing plant. The model that is developed will be applicable to only the factory that is being investigated. However, if successful correlation is demonstrated between the independent and dependent variables of the model, the author feels that with variations in the coefficient values, the model could be applied to other facilities within the same division or any other similar industrial environment.

Most industries at this point in time are very interested in energy consumption and are required to forecast their future usage. The price of energy has become an ever-increasing portion of a plant's direct operating cost. One factory in the author's company has an energy cost that represents 40% of the direct operating cost. With such a high percentage, it becomes important to accurately predict consumption for both planning and controlling purposes.

In an attempt to determine what manufacturing industries have done to-date in the way of predicting future energy requirements, the author conducted a telephone interview survey of several New Jersey companies as reported in Chapter II. The results indicated that at least one company is attempting to develop a computerized energy forecasting model. The energy manager of that company explained that his industry was very energy-intensive and had been required by the government to report their energy usage per unit of production.

Other industries that were interviewed believed that a forecasting model would be helpful but because of manpower problems, havenot attempted to develop such models. These industries simply extrapolate from current data to determine future requirements.

One energy coordinator felt that as the government became more active indemanding industry forecasts of future energy usage, his company would investigate development of an econometric model for consumption.

Forecasting Models

Of all the forecasting methods available, the author feels that econometric modeling is most appropriate in this forecasting situation.

The mechanical extrapolation used by many industries is useful for short run predicting but it doesn't allow for adjustments that a qualified person may be able to supply. Neither are opinion polling or barometric techniques suitable for this type of problem.

The econometric model however allows pertinent information to be taken into account and terms added or deleted from the model as the necessity arises.

The model that will be developed does require input information that may be determined via these other forecasting methods. For example, in the model, direct labor hours per quarter is a required input. Direct labor hours are forecasted by the accounting department. Upon receiving a sales forecast made by the sales and marketing departments, the accounting group forecasts the hours required to produce the required products. The sales forecast is based on 1) an opinion polling of the sales force and 2) predictions based on headquarter analysis of economic conditions.

Another required input in degree days per quarter. This information can be obtained for historical data and extrapolated. The extrapolated data can be adjusted upward or downward depending on information and forecasts provided by such sources as the National Weather Bureau.

Other Energy Models

There have been energy models formulated in the past. One such model which focused on the output level as an indication of energy input required was developed by the National Petroleum Council.[1] Still another model was developed by E. R. Berndt and O. Wood in 1974. The developers of the latter model were critical of previous work stating that none took into consideration the price of non-energy resources as a substitute for energy.

> "The absence of studies on substitution possibilities between energy and non-energy inputs becomes particularly apparent if one is interested in deriving implications of increasingly scarce and higher priced energy inputs."[2]

The results on the Berndt-Wood model indicated that:

"(i) energy demand is price-responsive-the (energy) price elasticity is about .5

(ii) energy and labor are slightly substitutable...

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[1]Berndt, E. R. and Wood, O., "Technology, Prices and the Derived Demand for Energy", The Review of Economics and Statistics, Aug. 1975. p. 259

[2]Ibid. p. 259

the elasticity of substitution between energy and labor is about .65 .

(iii) energy and capital are complementary - (cross elasticity) is about -. 3.2"[2]

Also indicated in this model was the fact that at the individual firm level the input prices can be taken as a fixed value.

Manufactures Energy Consumption Model

The author has been asked on many occasions at his place of employment to predict energy uses in various factories. In the past, extrapolation methods have been utilized. In an attempt to get a more reliable method of forecasting the following econometric model has been developed.

The objective is to find an appropriate relationship between energy consumption in an electrical manufacturing facility and direct labor hours and degree days. Energy consumption is the dependent variable with direct labor hours and degree days being independent variables. Historical data has been obtained from one of the author's employers' factories for the years 1972 to 1976. The information has been collected on a quarterly rather than on an annual basis to(1) give more points of data to be analyzed, and(2) to allow seasonal energy consumption variations to be observed. The data has been tabulated in Table #5.1.

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[2]op. cit. p. 260

TABLE #5.1

ENERGY CONSUMPTION

Year	Qtr.	KWH($X10^3$) Process	MCF Process	MCF Heating	Direct Labor Hours	Degree Days	BTU($X10^6$) Process	BTU($X10^6$) Heating	Total BTU($X10^6$)
72	1	199	2531	3592	14729	2635	3210.187	3592	6802.2
	2	198	3972	778	16379	556	4647.7	778	5425.8
	3	178.1	3594	0	13197	22	4201.9	0	4201.9
	4	197.8	4000	2370	14611	1731	4675.1	2370	7045.1
73	1	187.3	3325	3185	13849	2292	4500.3	3185	7685.3
	2	192.6	3861	699	15400	503	4518.3	699	5217.3
	3	188.5	3640	0	12409	18	4283.4	0	4283.4
	4	191.6	2375	2244	13738	1615	3028.9	2244	5272.9
74	1	215.2	3142	2634	13869	2491	3876.5	2634	6510.5
	2	208.8	3562	648	15421	412	4275.6	648	4923.6
	3	186.2	3364	0	12425	62	3999.5	0	3999.5
	4	189.1	2915	1323	13757	1664	3560.4	1323	4883.4
75	1	203.8	2566	3080	13858	2471	3261.6	3080	6341.6
	2	212	3691	850	15469	614	4414.6	850	5264.6
	3	182.7	3321	125	12510	59	3944.6	125	4069.6
	4	183	2940	1766	13779	1508	3564.6	1766	5330.6
76	1	198.1	2669	2560	13768	2560	3345.1	2560	5905.1
	2	214.2	3311	632.4	15312	496	4042.1	632.4	4674.5
	3	177.4	3235	0	12336	56	3840.5	0	3840.5

Source: Factory Data Obtained By the Author

The energy consumption figures (Kilo-watt Hours & MCF) have been obtained from the monthly bills from the utility companies. These figures were then converted to BTU units thus eliminating the need of conversion factors to be included in the model. The direct labor hours were obtained from accounting records while the degree days were supplied by the local weather bureau.

Having tabulated the necessary information, plots of the variables over time were constructed. This was desirable to show the seasonal fluctuations of consumption. Total consumption varied seasonally as would be expected because of the heating component (See Figure 5.1).

Figure 5.2, as a plot of process energy vs. time, also appears to have a seasonal variation, with the low usage periods being between the fourth and first quarters.

The last of the time related graphs, Figure 5.3, indicates drastic variation in heating energy consumption as would be expected.

In Figure 5.4, the scatter diagram of heating energy consumption vs. degree days was plotted and a visually determined regression line was constructed. As can be seen, the relationship between degree days and heating consumption seems to be linear.

Figure 5.5 is the scatter diagram and regression line of process consumption vs. direct labor hours. Although the points are more closely grouped and are less obviously related than Figure #5.4, the author has also visually determined and constructed a linear regression line. The regression line intercepts the BTU consumption line at approximately 300 x 10^6 BTUs. Thus with no direct labor hours consuming energy, this value of BTUs is used and can be attributed to overhead operations, for example, miscellaneous pilot lights, furnace heating, product preservation equipment and office usages.

From the above charts, the energy consumption model can be developed into a multi-linear regression model in the form:

$$Y = a + b X_1 + c X_2$$

where: Y = total factory energy consumption in BTUs ($\times 10^6$) per quarter

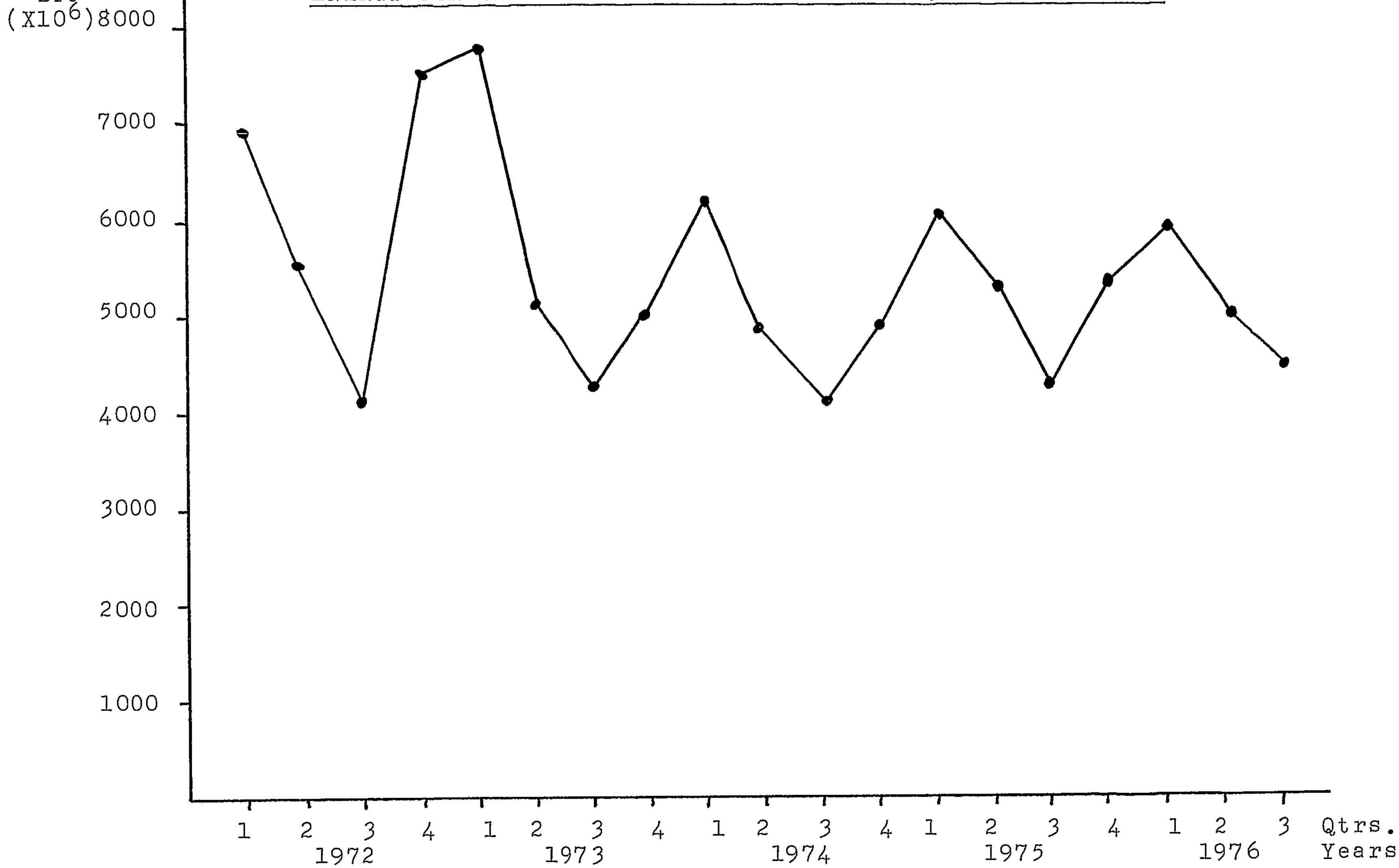
X_1= degree days per quarter at factory location

X_2= direct labor hours per quarter

The values of a, b, and c could be calculated via Figure 5.4 and Figure 5.5, however, a more straight-forward and accurate estimate can be accomplished via a multi-linear computer analysis of the data.

FIGURE #5.1

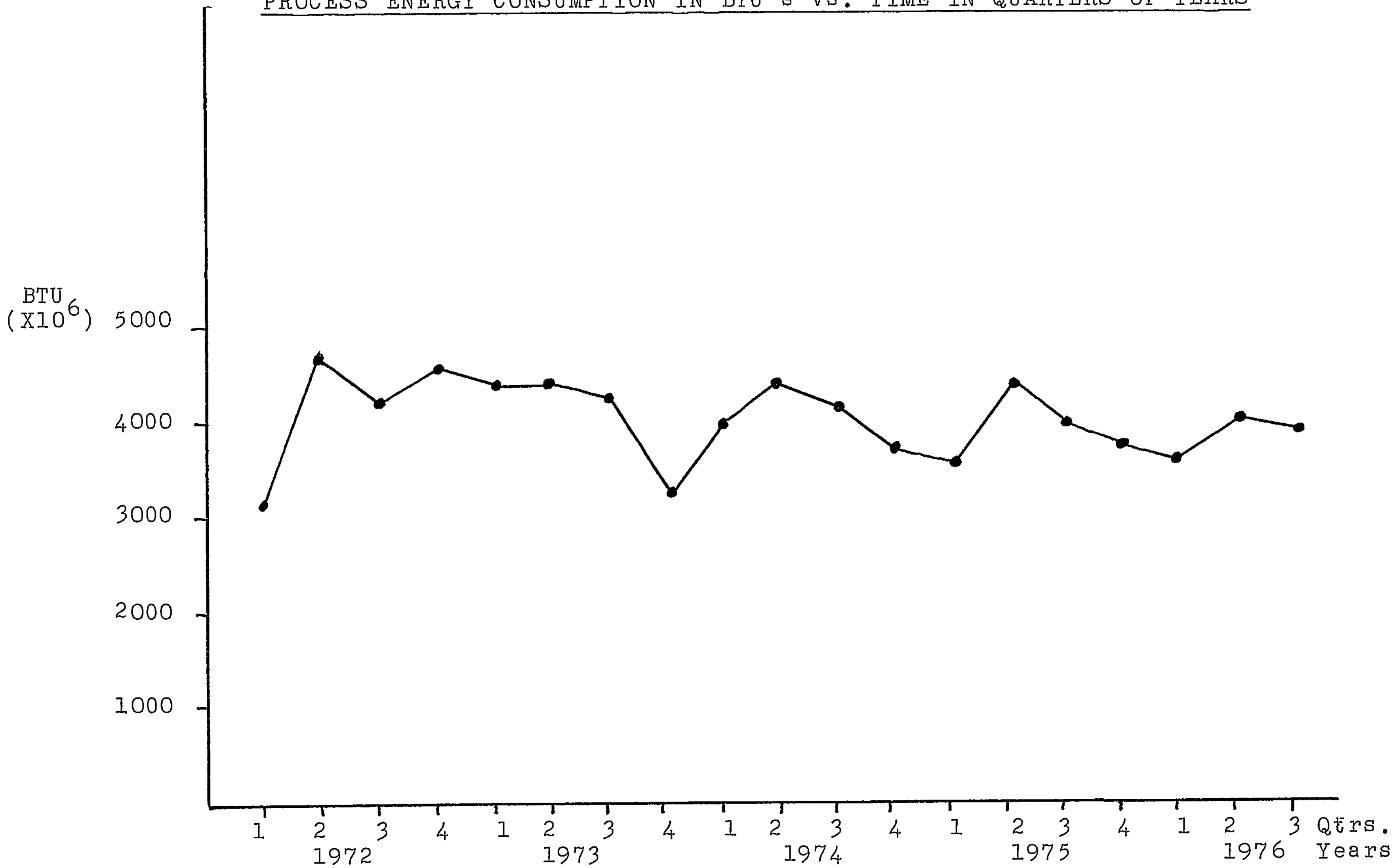
ENERGY CONSUMPTION IN BTU's vs. TIME IN QUARTERS OF YEAR



Source: Factory Data Obtained
By the Author

FIGURE #5.2

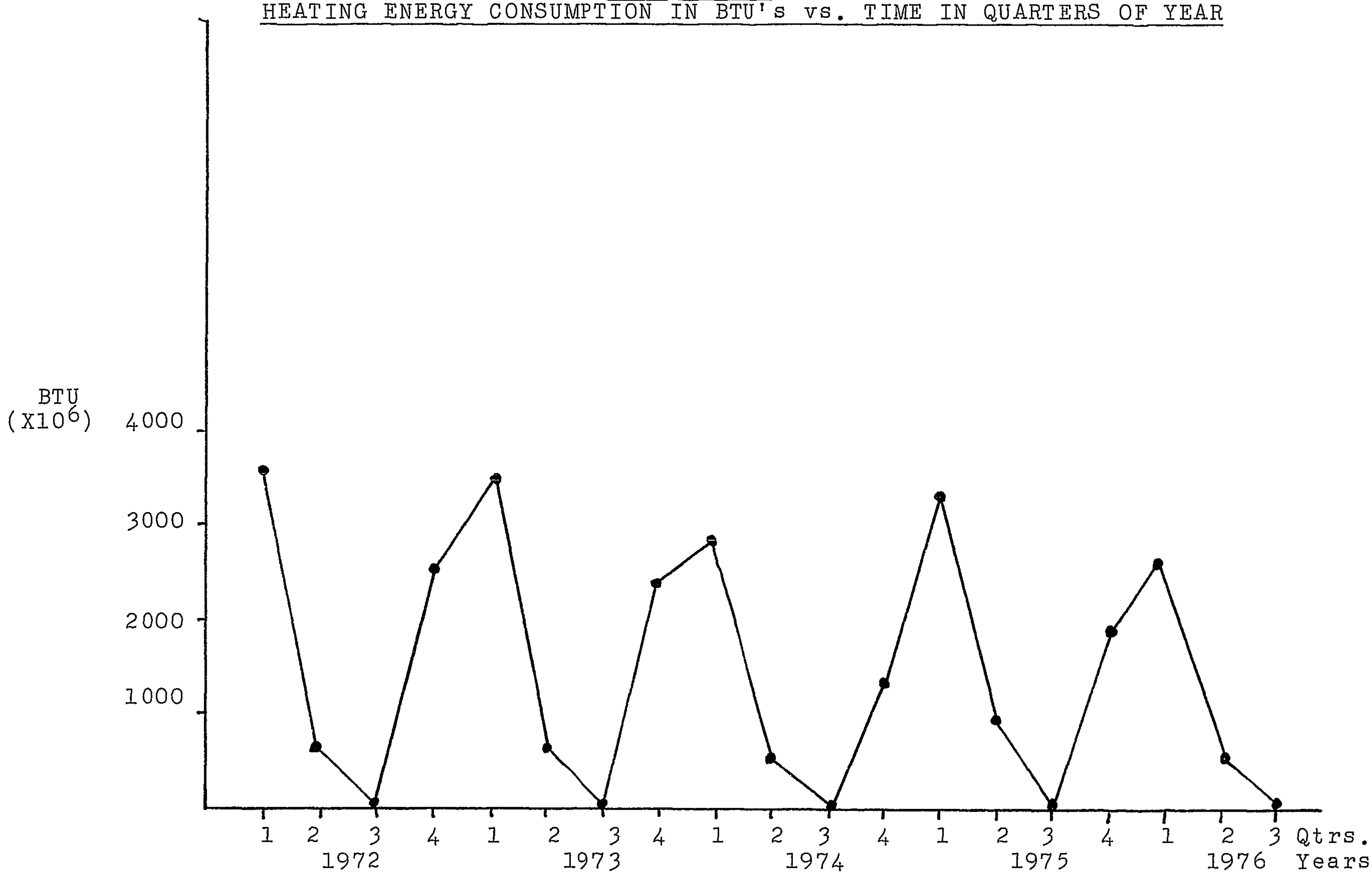
PROCESS ENERGY CONSUMPTION IN BTU's vs. TIME IN QUARTERS OF YEARS



Source: Factory Data Obtained By the Author

FIGURE #5.3

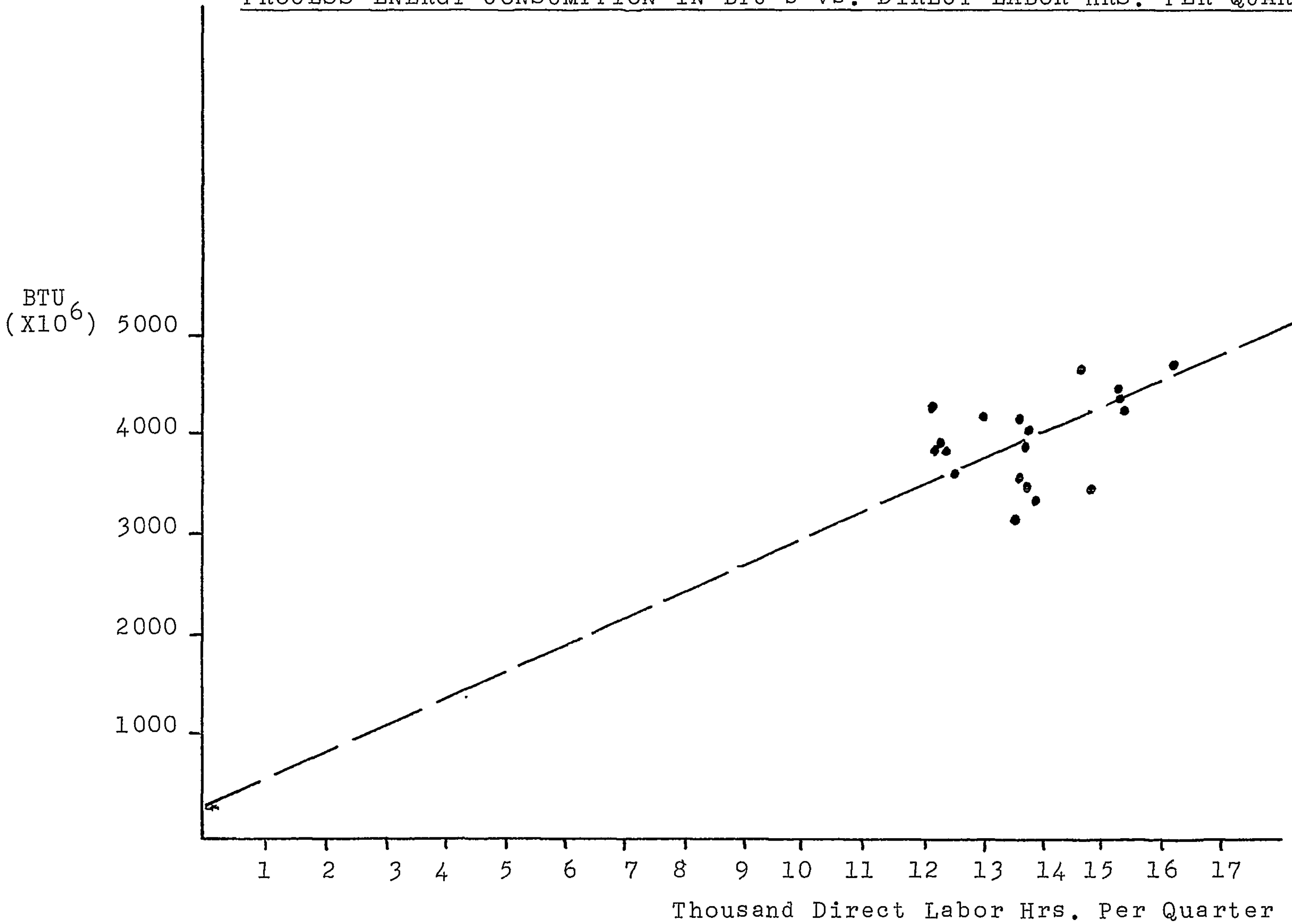
HEATING ENERGY CONSUMPTION IN BTU's vs. TIME IN QUARTERS OF YEAR



Source: Factory Data Obtained
By the Author

FIGURE #5.4

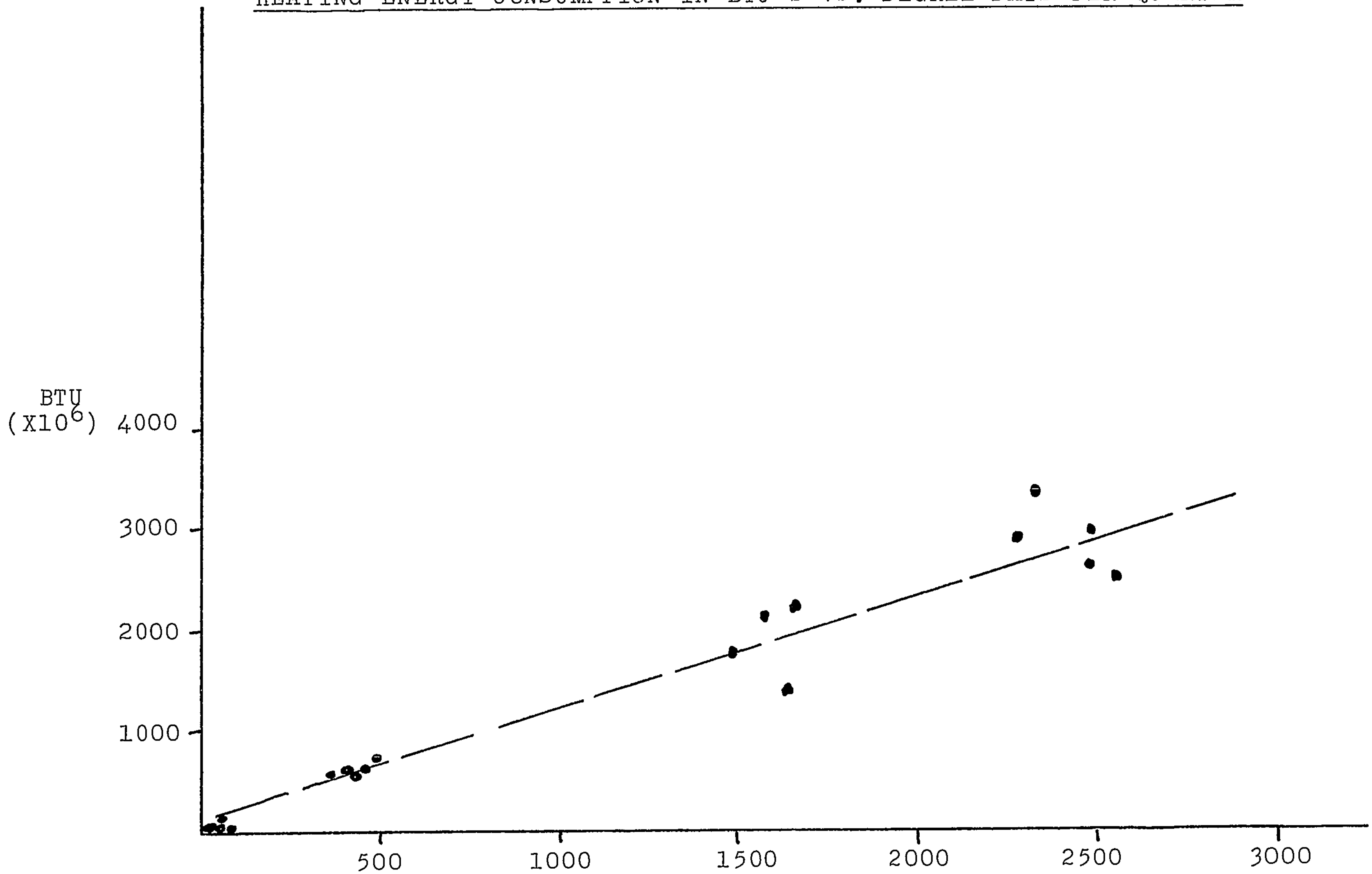
PROCESS ENERGY CONSUMPTION IN BTU's vs. DIRECT LABOR HRS. PER QUARTER



Source: Factory Data Obtained
By the Author

FIGURE #5.5

HEATING ENERGY CONSUMPTION IN BTU's vs. DEGREE DAYS PER QUARTER



Source: Factory Data Obtained
By the Author

The computer analysis also indicates the standard error of estimate and coefficient of correlation. The resulting computer determined equation; the standard error, Sy; and the coefficient of correlation, r are:

$$Y = 878.55751 + .89716x_1 = .2453x_2$$

$$Sy = 540.4$$

$$r = .888$$

In developing the model, the author attempted to keep it simple, easy to apply and used inputs that were readily available. Perhaps a more accurate method would be to report energy consumption as so many BTUs per product. This approach was considered. However, after the initial attempts, it was abandoned because of the large number of different types of product manufactured in the facility and the lack of adequate metering of each department. Thus the assumption that the product mix was stable at the facility was essential to the model development.

The factory which was used for the model had a relatively stable consumption of energy vs. degree days. However, it should be mentioned that in other factories for which the author had energy data, the energy consumption per degree day was substantially reduced immediately after the 1973 energy crunch. This conservation effort leveled off and maintained itself at a new lower level of BTUs per degree days after several quarters. For factories in which this leveling phenomenon occurs, an exponential term can be substituted into the model. This term would be exponential with the years (or quarters) since the energy crunch affected the rate of decrease. The new term would affect the heating consumption figure considerable at the time of the energy crunch and become almost non-existent as time continued. For example, at the time of the energy crunch, the factories began adding economizers to their boilers, thus reducing temperatures and decreasing wastes due to poor maintenance.

The model will require modification if the technology of manufacturing machinery changes such that the number of direct labor hours decreases or increases with respect to the number of products produced. For example, more automation would cause direct labor hours to decline.

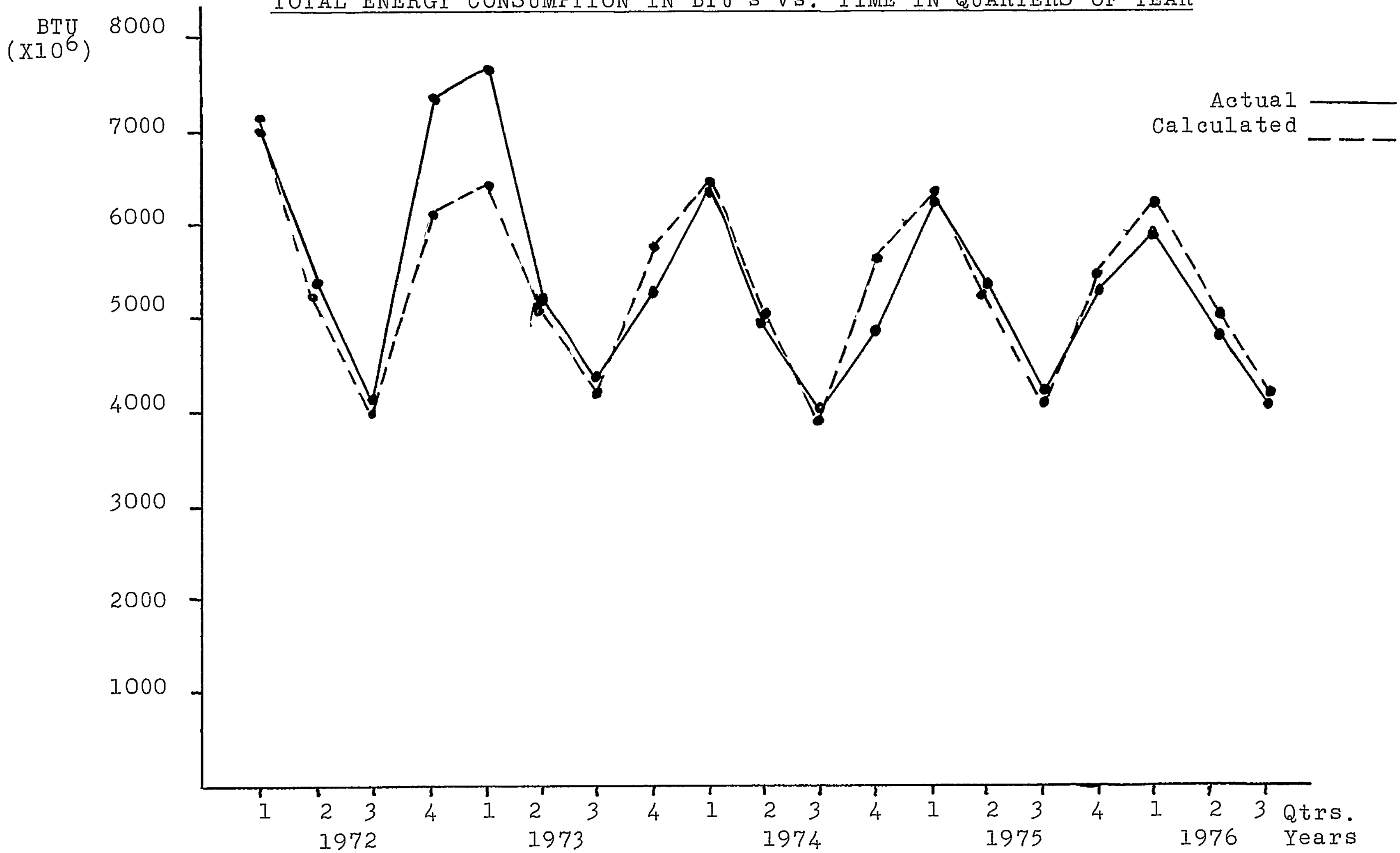
Result of Computer Analysis

The model of energy consumption developed in this chapter has been tested via a multi-linear regression computer program. The results are included as Figures 5.7 and 5.8.

The coefficient of determination (multiple correlation) is .88836 or 88.8%. Thus this percentage of the dependent energy consumption variable is explained by

FIGURE #5.6

TOTAL ENERGY CONSUMPTION IN BTU's vs. TIME IN QUARTERS OF YEAR



Source: Factory Data Obtained
By the Author

FIGURE # 5.7

MULTIPLE REGRESSION

V1=CONSUMPTION,V2=DEGREE DAY,V3=DIRECT LABOR HOURS WM.POLIGNANO DEPT1541

SELECTION 1

VARIABLE NO.	MEAN	STANDARD DEVIATION	CORRELATION X VS Y	REGRESSION COEFFICIENT	STD. ERROR OF REG.COEFF	COMPUTED T VALUE
2	1145.52632	1003.94629	0.84964	0.89716	0.12823	6.99634
3	14042.94737	1186.12579	0.37980	0.24530	0.10854	2.26005
DEPENDENT						
1	5351.00000	1109.71678				

INTERCEPT 878.55751

MULTIPLE CORRELATION 0.88836

STD. ERROR OF ESTIMATE 540.42734

ANALYSIS OF VARIANCE FOR THE REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE
ATTRIBUTABLE TO REGRESSION	2	17493496.69777	8746748.34889	29.94829
DEVIATION FROM REGRESSION	16	4672987.30223	292061.70639	
TOTAL	18	22166480.00000		

FIGURE #5.8

MULTIPLE REGRESSION

V1=CONSUMPTION,V2=DEGREE DAY,V3=DIRECT LABOR HOURS WM.POLIGNANO DEPT1541

SELECTION 1

TABLE OF RESIDUALS

CASE NO.	Y VALUE	Y ESTIMATE	RESIDUAL
1	6802.00000	6855.58203	-53.58203
2	5425.00000	5395.12891	29.87109
3	4202.00000	4135.50781	66.49219
4	7045.00000	6015.60156	1029.39844
5	7685.00000	6331.99219	1353.00781
6	5217.00000	5107.43359	109.56641
7	4283.00000	3938.62354	344.37646
8	5272.00000	5697.38672	-425.38672
9	6510.00000	6515.43359	-5.43359
10	4923.00000	5030.94531	-107.94531
11	3999.00000	3982.02344	16.97656
12	4883.00000	5746.00781	-863.00781
13	6341.00000	6494.78906	-153.78906
14	5264.00000	5223.94531	40.05469
15	4069.00000	4000.18213	68.81787
16	5330.00000	5611.44922	-281.44922
17	5905.00000	6552.56250	-647.56250
18	4674.00000	5079.56641	-405.56641
19	3840.00000	3954.80859	-114.80859

the independent variables, namely degree days and direct labor hours.

The intercept, as calculated by the computer, is 878.5575×10^6 which represents zero direct labor hours and zero degree days. This amount is higher than originally estimated via the free-hand regression lines in Figures 5.4 and 5.5. The 878×10^6 BTU figure represents overhead operation energy consumption.

The standard error of estimate was 540.42734×10^6. The main contributors to this error were concentrated in cases #4, #5 and #12. Upon examination of the data, no clear reason for this large error in the indicated quarters is apparent. It is possible that with further investigation, a disturbance term may have to be added to these quarters.

Summary

The author feels that the model developed in this chapter can be helpful in correlating and forecasting energy consumption in his employer's manufacturing facility. The author also feels that the model could be expanded to other manufacturing facilities.

The correlation was good and the information required was easily obtainable. And with this more accurate method of forecasting energy usage, any anticipated changes in usage can be planned for by management.

In addition, factory managerment, which is judged on its ability to limit energy consumption to objectives can feel confident that these goals have been determined via a forecasting model that reflects factory conditions.

CHAPTER VI

ENERGY REPORTING FOR CONTROL OF CONSUMPTION

Introduction

With the energy situation of today, more and more companies are becoming concerned with conservation of energy. The conservation programs in many companies have been inefficient due to the lack of suitable reporting and control system.

Factory management has not received information that is suitable for evaluating the energy conservation efforts. The information that the factory management has received has been untimely and therefore, not suitable as a tool for controlling usage.

This chapter will investigate what has been done in the author's company and the ways in which the reporting system could be modified to become a more effective control tool. The chapter will also explore the distribution of energy reports to management.

Reporting

As it now stands, the reporting process begins with outlying factories receiving the monthly utility bills and then submitting them to the division's headquarters accounting department for payment. In this manner, the actual electrical and gas usage for a given month is determined. The oil consumption is determined by direct readings of oil levels in the tank taking into consideration any deliveries that may have occurred. The propane usage is based on the amount of propane delivered in a given month. Admittedly, this method is inaccurate; however, it is the only method available at this time.

Copies of the electrical and gas bills are sent to the division headquarters plant engineering department after they have been processed by the accounting department.

To obtain the amount of oil and propane used, the plant engineering department calls each factory once a month and receives verbal information on usage and cost.

Once the energy consumption figures are obtained, the division headquarters plant engineering department prepares and submits to the corporate headquarters monthly usage figures. Further, on a quarterly basis, the division engineering department prepares a report comparing the usage and cost of the present quarter to the same quarter of the previous year. This is done for each plant and for the division as a whole. This report is submitted to the manager of the

Manufacturers Services. Finally, on an annual basis, the total usage, the total cost, along with data on "process consumption to direct labor hours" and "consumption to degree days" for each factory and the division as a whole are prepared. This report is distributed to the operations managers for their review.

When looking at a system such as the present reporting system, one must ask oneself if the ultimate decision maker is receiving information that is helpful in the decision making process. Another consideration is whether the pertinent information is in lanaguage which is easily understood and in the best form for management's use.

The most obvious problem with this reporting procedure as it stands, is that the pertinent information required at the factory level is not available. That is, the report that most accurately shows the energy usage in relevant ratios (that is, the process consumption to direct labor hours and the heating consumption to degree days) is not tabulated until the end of the year.

Even when this information is obtained, it does not reach the plant manager until the middle of March of the following year. It is impossible to use this information since it is completely outdated.

The author feels that the annual report as now issued (see Figure 3.1) is a good report and as such, should be continued. However, this report should not wait to be published on an annual basis as it is now, but should be tabulated and plotted on a monthly basis. This would allow the plant management to evaluate the plant's performance twelve times a year. The information would be timely and could be used to detect any exceptionally high energy usage within weeks of its occurrence. The report should make comparisons on a month-to-month basis that is, January of this year to January of the previous year. Corresponding months of subsequent years could be added, thus giving a trend curve for the same month over a period of many years. With this procedure, trends and exceptions could be easily noted and corrected in a timely manner.

This monthly report should be issued to the plant manager as well as to the individual plant's energy committees since these are the people most able to determine why changes have occurred and who can provide answers on how they could be corrected. Also the division's headquarters plant engineering section should receive the report and should subsequently assign engineers to assist the factory in determining exceptionally high usage problems.

Quarterly reports similar to the monthly reports should be issued to operations managers for their review and use in evaulation of energy consumption.

Annual reports as they are now presented should be continued and submitted to upper management within the division for their information and evaulation.

Computer Usage in Reporting

The present reports require a lot of time to tabulate and the chance of errors is high because of the numerous and tedious calculations that are required. The proposed reporting procedure would also require careful calculations and time and would therefore, delay reporting of the pertinent information to the plant managers.

To reduce the paper work and time required to tabulate and issue the energy reports, the author feels that a computer should be utilized.

In addition to decreasing the time to publish the report, the computer would be utilized in forecasting energy usage. Furthermore, with the government requesting more and more information from manufacturing companies, the time to obtain the required information has increased. However, if the computer was used, the data base would include all the pertinent information related to energy consumptions. It could conceivably decrease the time required to accumulate the needed information.

With the energy information availability, one could also compare energy consumption to the products which are made and attempt to get better correlation between products and product mix as related to energy consumption.

At the present time, each factory has a computer terminal which is connected to the division headquarters. A procedure could be set up whereby the factory accountants, upon receiving the energy figures, could enter them, along with the direct labor hours and degree days for a given month, into the terminal. The terminal, which is capable of storing up to 50,000 characters, could receive and store the information until the computer is able to procede with the energy program.

Upon receiving the new input for the given month, the computer could begin to process and within seconds return to the terminal the monthly report that is presently being computed by hand.

An example of what a typical monthly report is like, is shown in Table #6-1 and #6.2.

TABLE #6-1

EXAMPLE OF MONTHLY ENERGY REPORT

Location: Plant # ; Date: ____________

Month		Previous Year	Present Year	% Change
January	Natural Gas	______ MCF	______ MCF	______ %
		$ ______	$ ______	______ %
	Electricity	______ KWH	______ KWH	______ %
		______ KW	______ KW	______ %
		$ ______	$ ______	______ %
	Oil	#6 ______ GALS	#6 ______ GALS	______ %
		$ ______	$ ______	______ %
		#4 ______ GALS	#4 ______ GALS	______ %
		$ ______	$ ______	______ %
		#2 ______ GALS	#2 ______ GALS	______ %
		$ ______	$ ______	______ %
	Propane	______ GALS	______ GALS	______ %
		$ ______	$ ______	______ %
	Direct Labor Hours	______	______	______ %
	Degree Days	______	______	______ %
	BTU x 10^6 per Direct Labor Hours	______	______	______ %
	BTU x 10^6 per Degree Days	______	______	______ %
	Total BTU's x 10^6 Total	______	______	______ %

TABLE #6-2

CONTINUATION OF MONTHLY ENERGY REPORT

Year to Date

	Previous Year	Present Year	% Change
Natural Gas	______ MCF	______ MCF	______ %
	$ ______	$ ______	______ %
Electricity	______ KWH	______ KWH	______ %
	______ KW	______ KW	______ %
	$ ______	$ ______	______ %
Oil	#6 ______ GALS	#6 ______ GALS	______ %
	$ ______	$ ______	______ %
	#4 ______ GALS	#4 ______ GALS	______ %
	$ ______	$ ______	______ %
	#2 ______ GALS	#2 ______ GALS	______ %
	$ ______	$ ______	______ %
Propane	______ GALS	______ GALS	______ %
	$ ______	$ ______	______ %
Direct Labor Hours	______	______	______ %
Degree Days	______	______	______ %
BTU x 10^6 per Direct Labor Hours	______	______	______ %
BTU x 10^6 per Degree Days	______	______	______ %
Total BTU's x 10^6 Total	______	______	______ %

As a check on the system, the billings could continue to be circulated as is presently being done.

This new procedure would require no additional hardware purchases. The investment related to this change would be that of the initial programming of the computer and the training of the factory personnel in the use of the new energy program.

The benefits would be more timely information for the people most involved in energy conservation and most responsible for controlling its usage. In addition, most of the clerical work required to generate the reports would be eliminated.

Summary

It is obvious that a more timely report does nothing to conserve energy but this does not render it useless. It becomes a measuring tool to indicate results of good conservation. Further, it indicates when energy usage is out of control.

The energy committee and plant manager should review on a monthly basis the total usage and ratios of usage and determine whether there are justifiable reasons for changes, and note whether or not a conservation effort has affected a given utility usage.

This monthly report could also be used to compare actual usage to a forecasted usage via the energy model developed in Chapter V.

Finally, with a terminal in each plant, it would be possible for each factory to ask the computer for results in other plants as a comparison to their energy usage.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Introduction

As stated in Chapter I, energy consumption growth in recent years has outpaced the production of required fuels thus causing the cost of fuel to increase. And with industry using about 49% of the total primary fuel demand of the United States' annual consumption of over 250 quarrillion BTU's (as of 1976) there has been an increased concern with methods of decreasing usage wherever possible.

This has become even more important because of the gas curtailments that have occurred throughout the country during the winter of 1976-1977. Due to the severe cold weather, many industries were 100% curtailed from the use of natural gas. To substitute for normal gas supplies, many industries purchased propane and natural gas at the well for higher costs. Therefore, to offset some of the additional costs, energy waste must be controlled.

Chapter II has shown that most industries do indeed have conservation programs, and have made progress in saving via decreased energy usage.

Also discussed in Chapter II, it was indicated that Phase II programs have been slow in materializing due to the still cheap cost of energy, and therefore, the inability of energy related projects to compete with other capital expenditure programs. However, as curtailments continue and costs increase, this situation will change.

Most industries interviewed indicated that a first step in Phase II conservation efforts would be to detect and tabulate large energy users in an attempt to zero in and alter those processes that are energy intense. These industries also felt that a good reporting system and forecasting model were necessary tools for control and measuring of energy consumption.

Conclusions and Recommendations

The author has attempted in this thesis to present an approach to the Phase II energy program in an industrial environment. The thesis has been developed for his employer's plants; however, the approach could be adapted to many manufacturing facilities.

The first step was to study the consumption figures for each utility (natural gas, electricity and oil) at each plant. With these figures plotted, it is easy to determine which locations should be studied more closely. The author chose those plants that used the highest natural gas consumption to consider in more detail.

The detailed approach was an attempt to indicate what processes (or departments) were responsible for the largest energy usage at each location. Having identified these areas, the procedure would be to concentrate conservation efforts in these areas and break the process into components.

Those components which use the most energy should be subjected to a detailed engineering study to investigate ways in which energy can be more efficiently used.

Depending on the areas to be investigated, the study could be completed by one engineer or a small group of engineers on a part-time basis. In any case, the engineers involved should be those most familiar with the process under consideration. Because the areas being investigated use the largest amount of energy, the chances of producing savings are more likely then exploration of less energy intense areas.

In conjunction with any Phase II energy program, a method of reliable predicting energy consumption should be considered. The author has developed and tested such a model in Chapter V of this thesis. In the author's opinion, the model is feasible in successfully forecasting energy usage. The correlation indicated 88.8% of the energy consumed was determined by the direct labor hours and degree days. The input information for the model was total energy consumption in BTU's direct labor hours and degree days. The model also determined a BTU consumption that is directly applicable to the overhead operations at the factory involved.

The multi-linear regression computer program that was used determined total BTU consumption based on direct labor hours and degree days. The same type of approach could be employed in determining consumption of each utility. This would allow gas, electricity and oil to be forecasted by the independent variables, direct labor hours and degree days.

The forecasting model would allow more reliable predicting of energy consumption by which objectives for the factories could be determined.

Lastly, the author developed a reporting system for energy usage. This procedure, with the use of an existing computer and terminal, would allow more timely information in energy consumption to be presented to the factory management. The proposed system would allow investigation into exceptionally high usage before it is continued for a prolonged and costly period of time. To make this reporting process suitable for factory usage separate monitoring should be provided for process and heating energy usage, particularly for natural gas consumption.

The author suggests that with the adoption of the stated approach to energy conservation, a more organized, measurable, and hopefully, controllable Phase II program would be employed in many industrial factories.

REFERENCES

Beattie, James M., "Managing Energy--A New Role for Industry", Iron Age, Feb. 25, 1974.

Bell, A. R., "Industrial Electricity Consumption--An Example of An Intermediate Good", The Journal of Industrial Economics, April, 1973.

Bennett, K. W., "Energy Savings Can Be Built Into Plants", Iron Age, Aug. 18, 1975.

Berndt, E. R. and Wood, D. O., "Technology, Prices, and the Derived Demand for Energy", The Review of Economics and Statistics, Aug. 1975, Harvard University Press.

Brookes, L. G., "More on the Output Elasticity of Energy Consumption", The Journal of Industrial Economics, Nov. 1972.

Burchard, D., "A Systematic Approach to Energy Conservation", Plant Engineering, March 20, 1975.

Friedlander, G., "Energy: Crisis and Challenge", IEEE Spectrum, May 1973.

Hamilton, W. A., "Hastening What Comes Naturally in Saving Energy", The Conference Board Record, Aug. 1975.

"How One Man Copes with Energy", Factory, July, 1976.

Industry is Moving Beyond Obvious Energy Saving Moves", Industry Week, June 24, 1974.

Jacobson R. A., "Resource Conservation: The Coming Design Parameter", Machine Design, July 25, 1974.

Jefferson, E. G., "Energy Management in Industry", The Conference Board Record, May 1974.

Kemler, D. R. and Spector, M., "Control Peak-Load Demand and Cut Your Power Bill", Stores, June 1973.

Kendell, M.G., Mathematical Model Building in Economics and Industry, second edition.

Lincoln, G. A., "Energy Conservation", Science, Vol. 180, April 1973.

"Making Production Pay Through Energy Conservation", Automotive Industries, Aug. 1, 1976.

Minich, Q., "Energy Costs Demand Further Study", Skyscraper Management, March 1974.

Mullally, J. J., "Energy Conservation is Dollar Conservation", Industry Week, June 14, 1976.

Puerto Rico's Uncommonly Good Energy Conservation Checklist", Industrial Development and Manufacturers Record, Sept./Oct. 1975.

Robertson, W., "RCA Confronts the Energy Crisis", Fortune, Feb. 1974.

"Senate Vote Due on Mandatory Fuel Conservation by Industry", Industry Week, April 7, 1975.

Spencer, M. H., Seok, K., and Simkin, M. G., Managerial Economics, fourth edition.

Teresko, J., "Redesign to Beat the New Costs", Industry Week, May 24, 1974.

Ware, Warren W., and Andrew C. Gross, "World Energy: Demand and Supply", Columbia Journal of World Business, Fall 1974.

"Will Energy Efficiency Sell Products?", Industry Week, Nov. 10, 1975.

"Will More Energy Data be Demanded?", Industry Week, April 5, 1973.

"$10 Lamp Sparks Controversy", Factory, April 1976.

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One Westinghouse Plaza
Bloomfield New Jersey 07003

April 29, 1977

Mr. William Polignano
923 Ridgewood Road
Millburn, New Jersey 07041

Dear Mr. Polignano:

I read your thesis with great interest.

Our business of making lamps consumes a large number of B.T.U.s for the manufacturing process as well as for heating. During this past winter, we had plant shutdowns and had to convert to propane gas for our manufacturing processes.

The high cost of energy has cut into our profit margin. There is a whole new emphasis on conserving energy in our industry today. We have converted gas furnaces to oil. We have installed large electric glass furnaces. You are correct in saying that we have attempted to conserve energy on a "hit or miss basis".

At the present time, we have special cost reduction bogies for energy conservation. We have energy committees and energy newsletters. Your assumptions and statements are very apropos. It is true that we do have a reluctance to spend large amounts for conservation that give little return on investment for conservation's sake.

One of the most interesting chapters in this thesis is your model of forecasting energy usage. We do not at present do this in that manner, however, we will be asking you for this model for our industry. We need a better way than our present forecasting method.

I think your approach to this particular subject was logical and practical and I enjoyed reading it very much. The only critism I can offer to you is the minor attention given to the high cost of energy and the relationship of conservation to cost.

The thesis presented a detailed and practical guideline that will be useful for our industry and I felt the subject was very well handled.

S.M. Dyangeid

Manager-Manufacturing Services
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May 5, 1977

Mr. William Polignano
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Milburn, New Jersey 07041

Dear Mr. Polignano:

Thank you for asking me to review your thesis. I think you have presented a very complete picture on our present energy situation and the problems that we will face in the future. I am particularly impressed when I consider the fact that this thesis must have been started months before our country's latest energy crisis and yet what you have detailed is still valid.

You requested that I read and critique this thesis. In response to this request, I offer the following general comments.

1. In forecasting future energy requirements, Industry may be able to guess at future production and/or unit requirements, however, the forecasting of degree days is not a forecast. Forecasting of degree days is just an average of historical data. I believe that we must improve our ability to forecast and/or control the weather before accurate forecasting of energy usage will be valid.

2. I agree with your sentiments that industrial management is not overly concerned with the costs of energy. I believe that as long as the costs can be passed on to the consumer, Industry will not be overly concerned. Industry is more concerned with availability and conservation will be accomplished only thorough shortage.

3. A Government commitment must be made to develope new sources of energy. Similar to the commitment that was made in the early 1960's when we set a goal to land man on the moon within 10 years. Without this commitment, and with costs being passed on to the

consumer, very little will be accomplished.

Congratulations on a very thorough project and if I may be of any further assistance please feel free to call on me.

Very truly yours,

R. J. Bazaral
Purchasing Section Supervisor

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