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ENERGY AUDIT

of the

Helwan Portland Cement Company

Helwan, Egypt

May, 1988

VOLUME 1 of 2

Produced through the joint engineering effort of:

* FOSTER WHEELER USA CORPORATION (FWUSA)
* HELWAN PORTLAND CEMENT COMPANY (HPCC)
* ORGANIZATION FOR ENERGY PLANNING (OEP)

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TABLE OF CONTENTS

	PAGE
Appendices	ii
List of Tables	iii
List of Graphs	iv
Acknowledgment	v
1.0 EXECUTIVE SUMMARY	1
1.1 Introduction	1
1.2 Plant Description	1
1.3 Findings	6
1.4 Recommendations	12
2.0 DISCUSSION	21
2.1 Objectives of the Audit	22
2.1.1 Identify Where Energy is Used	22
2.1.2 Identify Energy Conservation Opportunities	23
2.2 Method of Approach	23
2.3 Goals and Special Considerations	24
2.4 Analysis of Energy Consumption	25
2.4.1 Discussion of Tables	39
2.4.2 Discussion of Graphs	40
2.5 Economic Evaluation	43
2.5.1 Value of Energy Saved	43
2.5.2 Estimating Investment Cost	44
3.0 ENERGY CONSERVATION OPPORTUNITIES (ECO'S)	46
3.1 Summary List	46
3.2 Detailed ECO Presentation	49

Appendices
(Report Volume 2 of 2)

Appendix

1 BASIC ENGINEERING DATA

2 PORTABLE INSTRUMENT LIST

3 ELECTRICAL ONE-LINE DIAGRAMS

4 ECO-36: FORM A COMMITTEE TO PLAN AND IMPLEMENT ECO's (Pg. 269-326)

5 ECO-37: PUBLICITY TO MAKE EMPLOYEES AWARE OF IMPORTANCE OF ENERGY CONSERVATION (Pg. 327-331)

6 TRANSLATION OF REPORT ON EGYPTIAN CEMENT INDUSTRY, EXCERPTS DESCRIBING HPCC (Pg. 1-16)

7 ECO-26: TECHNICAL ARTICLE ON SLURRY THINNERS

8 ECO-34: TECHNICAL ARTICLES REFERRING TO POWER FACTOR CORRECTIONS

9 DISCOUNT CASH FLOW GRAPH

10 ECO-24,31: OXYGEN ANALYZER BROCHURE

List of Tables

Table No.	Description	Page
1.4 A	Housekeeping Items - ECO Summary	16
1.4 B	In-Country Investment Items - ECO Summary	18
1.4 C	Foreign Investment Items - ECO Summary	19
1A	Monthly Energy Consumption - Factory 1 and White Cement - Wet Process	27
1B	Monthly Energy Consumption - Factory 2 Dry Process	28
2A	Monthly Energy Cost - Factory 1 and White Cement - Wet Process	29
2B	Monthly Energy Cost - Factory 2 - Dry Process	30
3A	Monthly Production, Cost and Energy per Unit - Factory 1 and White Cement - Wet Process	31
3B	Monthly Production, Cost and Energy per Unit - Factory 2 - Dry Process	32

List of Graphs

Graph No.	Description	Page
1A	Energy Usage - Factory 1 and White Cement	33
1B	Energy Usage - Factory 2	34
2A	Energy Cost/Unit - Factory 1 and White Cement	35
2B	Energy Cost/Unit - Factory 2	36
3A	Energy/Unit - Factory 1 and White Cement	37
3B	Energy/Unit - Factory 2	38

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

The Organization for Energy Planning, in conjunction with the plant staff of the Helwan Portland Cement Company, and with the technical assistance of Foster Wheeler USA Corporation, have executed an energy audit of the Helwan Portland Cement Company, Helwan, Egypt. The field audit began in February, 1988, and continued through March, 1988. Analysis of all information was performed in the offices of OEP located in Cairo, Egypt.

The energy audit consisted of a detailed review of the wet and dry cement processes and their respective plant performance. All sections of the plants were inspected. Drawings of the processes were reviewed and energy and production data were collected. The energy data has been checked for consistency and accuracy, and supported further by independent field measurements of the necessary process variables.

This report serves to document the consumption of energy, in all its forms, analyze whether this energy is being used efficiently, and, if not, identify opportunities to conserve energy based on quantitative economic analysis.

1.2 Plant Description

Pyroprocessing is the most important part of the cement manufacturing process and is the principal user of energy. With very few exceptions, the rotary kiln is the equipment used for this production phase. The main steps in the manufacturing process are the following: (i) quarrying and extraction of raw materials from deposits; (ii) crushing and preblending of raw materials; (iii) grinding of raw materials in the raw mills; (iv) preparation of kiln feed by homogenization of ground raw materials; (v) burning (pyroprocessing) in kilns to form clinker; (vi) cooling of clinker; (vii) grinding of clinker in finish mills with gypsum to make cement; and (viii) packing and shipping of cement.

The two basic manufacturing processes are the wet and the dry process. These two processes are shown schematically on pages 4 and 5. In the wet process, water is added when the crushed and the proportioned raw materials are ground in the raw mill, so that the kiln feed takes the form of a slurry. In the dry process, the raw materials are dried with hot kiln gases while they are being ground in the raw mill, and

kiln feed becomes a dry powder. In the pyroprocessing phase, the two processes are very similar; the feed moves down through the kiln countercurrent to hot gases drawn through the kiln by powerful fans. In the burning zone the materials are heated to approximately 1500 °C, and the various chemical components interact and form clinker. Downstream of the burning zone, the two processes are identical.

The energy sources in the cement plant are generally classified as primary sources, like oil, coal, gas, other fuels and electricity, and secondary sources, consisting of waste heat from one phase of the process, which can be recovered and utilized in another phase of the process. The two most energy-intensive phases in cement manufacture are pyroprocessing and grinding. Pyroprocessing consumes mainly thermal energy in the form of oil, coal or gas, while grinding consumes mainly electrical power.

Secondary heat contained in the hot kiln exhaust gases is utilized primarily in predrying and preheating materials before introduction into the kiln and raw mill. The waste heat contained in the exhaust gases from the clinker cooler serves to preheat combustion air and also to dry and preheat raw materials before entering the raw mill and kiln. A small amount of thermal energy may be needed as supplemental heat for drying purposes.

The Helwan Portland Cement Company consists of three separate factories: Factory 1 (Grey Cement), the White Cement Plant, and Factory 2.

The first of the six grey cement kilns in Factory 1 began operation in 1929. The two white cement kilns came onstream in 1960 and 1973. The two dry cement kilns in Factory 2 came onstream in 1982 and 1985. Their design capacities are given below.

Factory 1 - Grey Cement, Wet Process, 6 kilns

Kiln		Design Capacity, Tons clinker per day
1		240
2		480
3		330
4		330
5		330
6		640
	Total	2350

White Cement Plant - Wet Process, 2 kilns

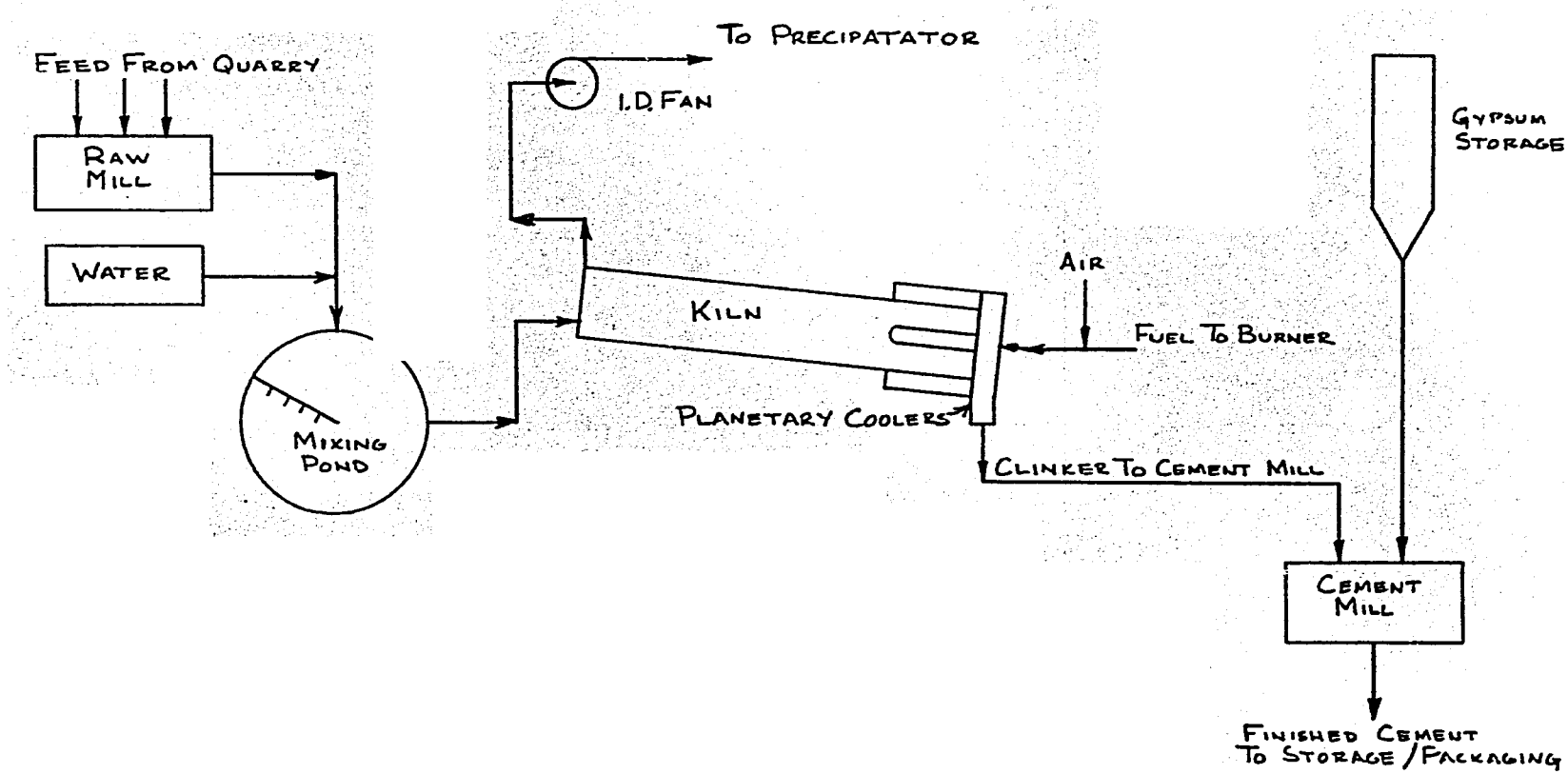
Kiln		Design Capacity, Tons clinker per day
1		100
2		180
	Total	280

Factory 2 - Dry Process, 2 kilns

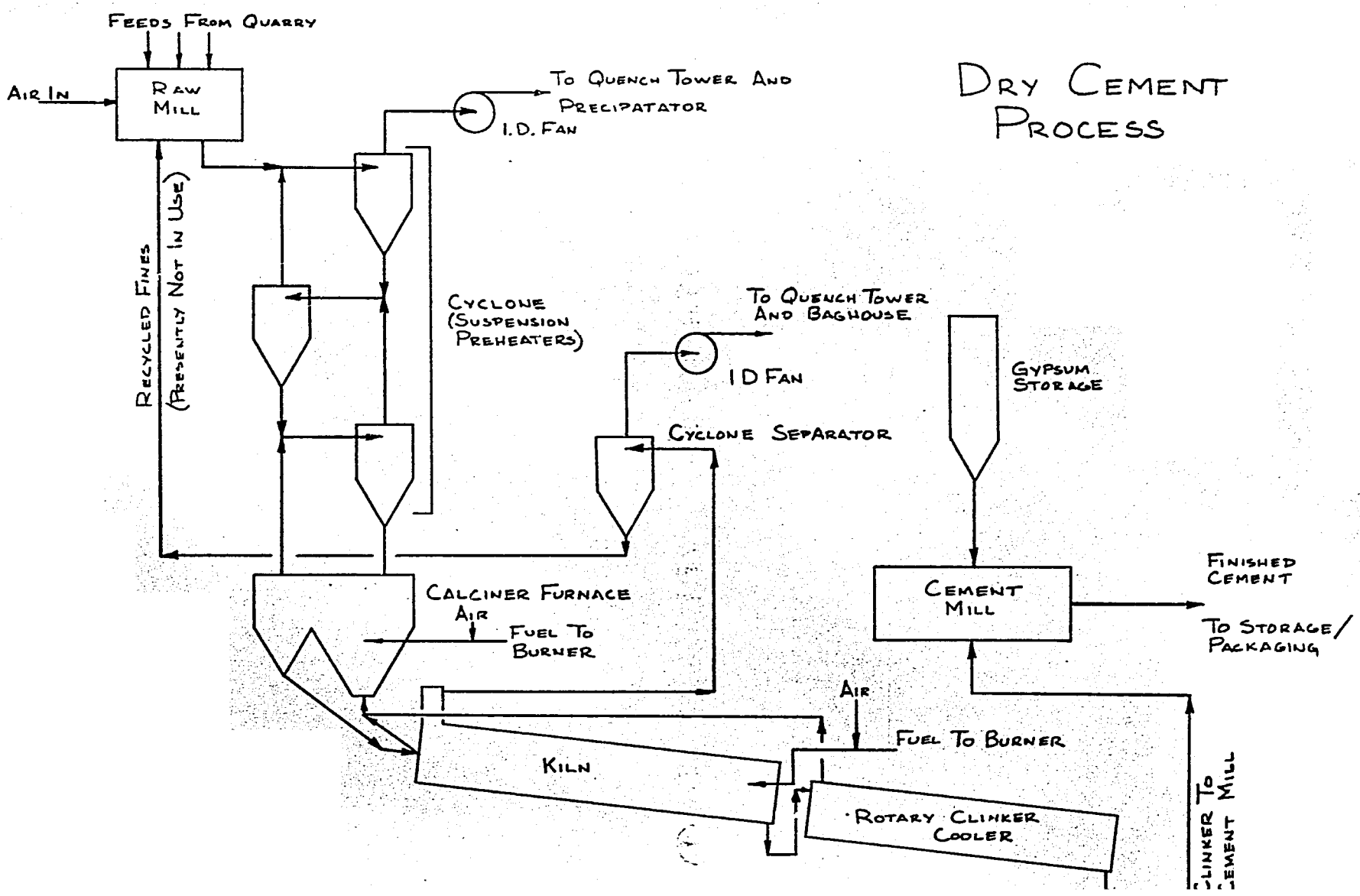
Kiln		Design Capacity, Tons clinker per day
1		4200
2		4200
	Total	8400

The plant has set a production goal of 3 million tons of clinker in 1988. This goal appears to be achievable based upon worldwide production data and onstream factors for plants of similar design.

Wet Cement Process



Dry Cement Process



1.3 Findings

The qualitative and quantitative findings at the Helwan Portland Cement Company are below. These findings have been divided into categories deemed most appropriate to this energy audit.

Accuracy of Plant Data

The plant energy consumption data for calendar year 1987 was supplied by the plant from their log sheets, and is the basis for this audit. The accuracy of the energy data supplied by the plant was not verified. Any obvious indiscrepencies in this raw data were resolved to the best of our (FWUSA, OEP, HPCC) abilities.

Energy consumption rates for various pieces of equipment or systems were obtained during the data collection phase of this energy audit. This data was used as a basis for calculating future energy savings for a particular item or system and is not meant to be a check of the 1987 energy data.

Energy

The primary sources of energy are natural gas in Factory 1 and No. 6 fuel oil in the white cement plant. These are the fuels that are used to fire the kilns and account for approximately 87% of the energy consumed in the respective plants.

The total energy consumption for calendar year 1987 was 1.50×10^{16} joules. Approximately 58% of this energy was consumed in the dry process of Factory 2 where approximately 75 % of the total plant clinker is produced. The overall plant energy cost to produce one ton of clinker is US $19.15.

Total energy consumption for Factory 1 and the White Cement Plant, both wet processes, averages 5.2×10^{14} joules per month. The average energy consumption per ton of clinker is 9.57×10^{9} joules. This value is 19% higher than similar present day figures in the U.S., and 60% higher than similar figures in Europe and Japan. The low present day worldwide energy figures are due to significant improvements in the cement industry since the 1940's, while the wet process at the Helwan Portland Cement Company started operation in 1929. The energy consumption per ton of clinker at the Helwan Portland Cement Company

compares favorably against wet U.S. cement plants built during the same era.

The kilns of Factory 2 are designed to fire either natural gas or No. 6 fuel oil, but at present are firing No. 6 fuel oil. Again, the energy derived from the fuel oil is the primary source of energy into the process, accounting for approximately 88% of the total energy consumption for Factory 2.

Total energy consumption for Factory 2 averages 7.3×10^{14} joules per month. The energy consumption per ton of clinker in the dry kilns averages 4.53×10^{9} joules. However, values of 4.25×10^{9} joules per ton were experienced from March to October. This value is 11% to 22% higher than similar figures for Japan and Europe respectively. Energy consumption figures for the U.S. are significantly higher than those of Europe and Japan due to a lack of commitment to state-of-the-art dry processing innovations developed and implemented in Europe and Japan. The dry kilns at the Helwan Portland Cement Company are of European (Danish) design and should be compared against European energy figures.
An excessive amount of energy is being consumed in Factory 2 in order to produce sufficient quality cement product from high impurity raw materials. It is anticipated that the energy required to produce a ton of clinker will drop to levels equal to those in Europe once a source of acceptable, higher quality, raw materials can be developed and fed to the kilns.

Electricity is the second largest energy contributor in both factories. Electricity contributes less than 6% to the total energy consumption of Factory 1 and the White Cement Plant, and approximately 11% to the total energy consumption of Factory 2.

In addition to the energy directly used to manufacture cement is the energy consumed in the utility areas. The Power House consumes 12,861 tons of No. 6 fuel oil annually; the White Cement Factory steam boiler consumes 671.2 tons of diesel fuel annually, and the Factory 2 steam boiler consumes 11,051 tons of diesel annually. The total energy consumed in these utility areas is equal to 9.00×10^{13} joules per month.

One of the largest sources of potential energy savings lies with improving the quality of the raw materials to Factory 2. The Helwan Portland Cement Company states that this will begin in approximately two years; a better site for raw materials has been found but the site must still be developed. At that time, the energy used to fire the kiln should fall and the Helwan Portland Cement Company overall energy picture will improve dramatically.

Pollution and Pollution Control

The primary source of pollution at Helwan Portland Cement Company is cement dust. The most significant source of this dust is the new Factory 2 dry cement process. At the present time, feed materials to Factory 2 are very high in impurities, such as sulfates and alkalis. Feed impurities have reached levels which the unit was not designed to accommodate. In order to maintain production requirements and product quality, these impurities are driven out of the raw materials in the kiln at rates and temperatures that exceed the design limits of the cyclones and precipitators installed to collect cement dust from the stack gases. As a result, significant amounts of cement dust are ejected out of the stacks and onto the equipment, buildings, machinery, and the general surroundings.

The most effective way to eliminate Factory 2 as a pollution source lies with providing higher grade raw materials to the kilns of Factory 2. The Helwan Portland Cement Company has stated that a new source of raw materials has been found. Development of this source will take two years. At that time the pollution should be significantly reduced and Factory 2 should operate near design specifications.

Factory 1 and the White Cement Plant are fitted with electrostatic precipitators at the outlet of each kiln. None of these precipitators are in operation due to lack of available parts to repair them. The ductwork leading up to the precipitators has been disconnected and any cement dust leaving the wet kilns flows freely to the atmosphere.

The primary source of cement dust is Factory 2. This is due to the size of the unit and the nature of the dry cement process. Although Factory 1 has six kilns and the White Cement Plant has two

kilns, they have only 30% of the production capability of Factory 2, and are fed wet raw materials which inherently result in low cement losses. There is no doubt that the abundance of cement dust on equipment and machinery is adversely affecting energy consumption, maintenance intervals, equipment life, and production stability.

Instrumentation

The instrumentation in Factory 1 and the White Cement Plant is in a state of disrepair. Existing instrumentation is either broken or in need of recalibration. Instrumentation that once worked properly and served a purpose towards the production of cement has not been maintained, and as a result is no longer used. Furthermore, this plant was never fitted with the instrumentation necessary to properly monitor the flow of energy throughout the process.

Factory 2 was brought onstream in the 1980's. The condition of instrumentation is already being overlooked, and those instruments that are not "crucial" to the ultimate goal of producing cement are being left in this state. Factory 2 is a state-of-the-art dry process cement facility that has the means to operate as efficiently and effectively as those in operation in Europe and Japan.

Electrical

The disrepair state of the plant's electrical metering system does not allow for an accurate check of electrical energy consumption. Even though Factory 1 and the White Cement Plant only consume 6% of their total energy in electricity and Factory 2 consumes 11%, good electrical monitoring is essential for energy consumption, tracking and cost control.

Factory 1 possesses a steam boiler/turbine generation system which is not fully utilized during normal operation. In addition, electrical outages and load shedding affect the production figures of Factory 2 each year. During these outages the full capacity of the Factory 1 generator cannot be used to assist Factory 2 at these times of need.

Housekeeping

The majority of the electrical and mechanical equipment maintenance calls are a result of the high concentration of cement dust that accumulates on them. There does not appear to be a coordinated effort to keep these items clean. Instead, attention is focused only in those areas where there is a need for immediate repair. No effort is being made to clean the surroundings of the cement dust; consequently, no improvement in useful equipment life can be expected.

The number of steam, condensate, and boiler feedwater leaks are few. The plant, as a whole, does not suffer in this area of energy loss.

Insulation in the power house is quite good. Even so, there are some items of equipment and piping that require the addition or repair of insulation. Insulation at the local steam boiler houses (used to heat mazout) is sporadic and in other cases, totally ineffective due to damage, deterioration, or improper installation.

There are only a dozen or so steam traps at the Helwan Portland Cement Company. Of these, only two were found to be functioning properly. Items such as these, although few, can lead to significant energy loss over the course of a year. Considering the low number of steam traps and the small amount of time involved in checking, cleaning, and repairing steam traps, it should be relatively easy to improve procedures in order to have all of the steam traps functioning properly all of the time.

Maintenance

The ability of the Helwan Portland Cement Company to execute maintenance on items in need of repair is good. Downtime is an inherent part of the cement industry. Onstream factors worldwide are roughly 85% for the wet process and 70 to 75% for the dry process. Helwan Portland Cement Company is running about 15% lower than these onstream factors (approximately 72% and 62% for wet and dry respectively) when one compares unit design capacity with annual unit production. Actual running time may be greater; however, adverse conditions, such as power shortages or poor raw materials, prevent the Helwan Portland Cement Company from producing clinker at design rates throughout the year.

Management and Personnel

The priority of management appears to be production-oriented. Energy conservation is second, at best, to this goal. The management and personnel are, however, quite aware of where energy is being consumed and how it could be improved. The ability of the personnel to concentrate their effort towards energy conservation without losing sight of production goals is already present at the Helwan Portland Cement Company.

It is reasonable to state that energy conservation measures are directly related to production rates over an extended period of time. A piece of equipment that is used in its most efficient manner will out-perform and out-live a piece of equipment that is not used efficiently and effectively. The savings in both energy and money per equal production of clinker can be very significant over a period of just one year. Production need not suffer as a result of energy conservation measures. A large percentage of energy conservation measures do not alter the process in any way. Furthermore, energy conservation measures generally pay for themselves in periods of three years or less, after which the company receives the profit from these measures at the cost of a minimum amount of maintenance.

1.4 Recommendations

Tables 1.4A, 1.4B, and 1.4C list those Energy Conservation Opportunities (ECO) having a simple payout of five years or less.

Housekeeping Items

Under the category of housekeeping ECO's, are items requiring better maintenance, better operations and improved scheduling. The total installed cost for housekeeping ECO's is less than LE 40,000. In developing a list of these items, attention was paid to leaks of steam, air, condensate and water, poor combustion efficiency of various fired devices, poor insulation of hot or very cold (refrigerated) lines or equipment, operating procedures, instrumentation, etc.

Table 1.4A, Housekeeping, lists those ECO's having a simple payout of 5 years or less based on local costs to implement the ECO and local utility costs to calculate savings.

> Note: Housekeeping ECO's having a simple payout exceeding five years based on local costs, but having a payout of less than five years based on worldwide equipment and utility costs have been shifted to Table 1.4B, In-Country Investment, and noted with an asterisk (*).

The implementation of all of the housekeeping items identified would result in a minimum of 959.9 T.O.E. saved annually, and represents 3.7% of the total energy used in the production of steam for electricity generation, mazout heating, and white cement quenching. This savings does not take into account the energy savings possible through the implementation of ECO's 32,36 and 37. While it is impossible to quantify the energy savings realizable from these latter three ECO's, it is expected that they will result in significant continuing energy savings.

These ECO's should be implemented as soon as possible, as they can be done with a minimum amount of in-country labor, manufactured equipment and money.

In-Country Investment Items

Items in this category are similar in nature to housekeeping items; however, an expenditure of

over LE 40,000 is required to implement a particular ECO, except as noted above in "Housekeeping Items." All materials, labor and engineering can be purchased in-country.

Table 1.4B, In-Country Investment, lists those ECO's having a simple payout of less than five years based on worldwide equipment and utility costs.

The implementation of all of the in-country investment items would save a total of 41,427 T.O.E. per year, or 13% of the fuel fired in the entire cement plant.

The largest energy savings will come from final implementation of ECO-22. This ECO requires that a better, higher quality, source of raw materials be developed. At that time, the dry kilns will then be able to operate at reduced heat rates. The plant has stated that the implementation of this ECO is already in progress. The estimated energy savings for ECO-22 is 40,868 T.O.E. per year.

Foreign Investment

Items in this category require an investment of foreign (hard) currency to purchase materials, engineering and/or manpower from outside the country.

Table 1.4C, Foreign Investment, lists those ECO's having a simple payout of less than five years based on worldwide equipment and utility costs.

These ECO's have a good potential for the most energy saving, but also require the greatest investment cost. While the energy savings from the items in this category are not strictly additive, the energy savings that can be expected is 35,984 T.O.E. per year if all non-redundant ECO's were implemented.

Improving, adding and repairing instrumentation alone would result in an indirect energy savings of 2,082 T.O.E. per year. This investment would pay out in less than one year.

ECO-30 B gives the economics of continuously generating 30 MW of electricity from a gas

turbine. The cost of this type of system is estimated to be $14,629,100 and results in a simple payout of 3.06 years based on energy cost savings alone. As stated above, the actual payout period will be less than 3.06 years when the value of increased revenues due to increased cement production is taken into account. The advantages of short-term operating periods are also possible using a gas turbine.

ECO-30 C gives the economics of generating 30 MW of electricity from a gas turbine with waste heat recovery facilities. A gas turbine with waste heat recovery provides a more efficient means of generating electricity than using a gas turbine alone. The fuel consumption of a gas turbine with waste heat recovery is two-thirds that of a gas turbine alone; however, there is the addition of electrical requirements for the waste heat recovery facilities.

A gas turbine package with waste heat recovery would be required to operate continuously. It is not practical to start-up and shut-down the waste heat recovery facilities in short intervals. A gas turbine package alone, as discussed above, is able to be operated "on demand" if required.

The payout period for such a gas turbine package with waste heat recovery facilities is 5.0 years, based on energy cost savings alone. This payout excludes the additional income generated from being on-stream a higher percentage of time and thus producing more saleable product.

The present electrical metering system for both factories should be repaired, cleaned weekly and recalibrated on a regular basis in order to accurately determine electrical energy consumption. Switchgear modifications should be investigated before the next planned modification to the overall plant's electrical system as described to FWUSA by Helwan Portland Cement Company's Electrical Department. It would be the most efficient use of existing equipment if the generators of Factory 1 could be used to feed Factory 2.

Other Items for Consideration

Considering the disruption of cement production during the summer months and the anticipated

decrease in hydro-electric generating capacity in Egypt, the installation of a 30 MW electrical generating package (ECO-30 A,B and C) should be considered. Such a package would allow the plant to operate without disruption and thereby increase the cement production rate. During periods of shutdown or turnaround, excess electricity generated could be supplied to the national grid.

ECO-30A gives the economics of generating 30 MW of electricity from a steam boiler/turbine system. The cost of this type of system is estimated to be $22,045,800, and results in a simple payout of 10.4 years based on energy cost savings alone. The actual payout period will be less than 10.4 years when the value of increased revenues due to increased cement production is taken into account.

Preference, at this time, would be towards a gas turbine generating package (ECO's 30 B and 30 C) as the economics are more attractive. Refer to the Foreign Investment category of this section.

Conclusions

It is important that the Housekeeping items listed in Table 1.4A be implemented as soon as possible. These energy conservation opportunities can be implemented by plant personnel using locally available materials.

The total estimated annual energy savings that can be derived through implentation of all non-redundant ECO's listed in Tables 1.4 A, B, and C is 78,370 T.O.E. This annual energy savings has a corresponding value of U.S. $13,589,958. The investment cost to implement all non-redundant ECO's is U.S. $19,383,528 and results in an overall simple payout of 1.43 years.

Table 1.4A HOUSEKEEPING ITEMS - ECO Summary

Plant: Helwan Portland Cement Company

ECO #	TITLE	WORLDWIDE ANNUAL ENERGY SAVINGS FUEL	WORLDWIDE ANNUAL ENERGY SAVINGS T.O.E.	WORLDWIDE INVESTMENT COST, $	WORLDWIDE ANNUAL COST SAVINGS, $	WORLDWIDE SIMPLE PAYOUT, YRS	LOCAL INVESTMENT COST, LE	LOCAL SIMPLE PAYOUT, YRS
Power House								
01	Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.	125.2 tons mazout	121.6	110	14,031	IMMEDIATE	245	IMMEDIATE
08	Test, repair, replace steam traps.	203.9 tons mazout	198.0	2,410	22,851	IMMEDIATE	5,400	0.94
Mazout Steam Boiler White Cement								
10	Add new or repair existing insulation on steam and mazout lines.	34.3 tons diesel	36.5	2,782	5,167	0.54	4,034	1.96
11	Insulate boiler feed water tanks.	8.7 tons diesel	9.3	1,410	1,315	1.07	2,045	3.90
14	Test, repair, replace steam traps.	32.5 tons diesel	34.6	2,410	4,895	0.50	5,400	2.77
Mazout Steam Boiler Factory 2								
15	Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.	211.0 tons diesel	224.4	750	31,785	IMMEDIATE	1,690	IMMEDIATE
16	Add new or repair existing insulation on steam and mazout lines.	134.7 tons diesel	143.3	10,949	20,291	0.54	15,876	1.96

Table 1.4A HOUSEKEEPING ITEMS - ECO Summary (continued)

Plant: Helwan Portland Cement Company

ECO #	TITLE	WORLDWIDE ANNUAL ENERGY SAVINGS FUEL	WORLDWIDE ANNUAL ENERGY SAVINGS T.O.E.	WORLDWIDE INVESTMENT COST, $	WORLDWIDE ANNUAL COST SAVINGS, $	WORLDWIDE SIMPLE PAYOUT, YRS	LOCAL INVESTMENT COST, LE	LOCAL SIMPLE PAYOUT, YRS
17	Insulate boiler feed water tanks.	22.8 tons diesel	24.3	4,329	3,435	1.26	6,277	4.59
18	Insulate mazout day tank.	57.3 tons diesel	60.9	11,150	8,632	1.29	16,167	4.70
21	Test, repair, replace, add steam traps.	101.0 tons diesel	107.0	625	15,214	IMMEDIATE	1,400	IMMEDIATE
General								
32	Show the effect of insulation on heat loss from pipes.	--	--	--	--	IMMEDIATE	--	IMMEDIATE
36	Form a committee to plan and implement an energy conservation program in plant.	--	--	--	--	IMMEDIATE	--	IMMEDIATE
37	Use of publicity, memos, newsletter, etc. to implement an energy program and make personnel aware of the importance of energy conservation.	--	--	--	--	IMMEDIATE	--	IMMEDIATE
TOTAL		--	959.9	36925.0	127616.0	0.29	58534.0	1.29

NOTES: 1. Currency conversion 2.25 LE/$
2. Boiler efficiency 75%
3. Energy conversion 42.0 x 10E9 J/T.O.E.
4. Payout periods of less than 3 months have been labelled "IMMEDIATE"

Table 1.4B IN-COUNTRY INVESTMENT ITEMS - ECO Summary

Plant: Helwan Portland Cement Company

ECO #	TITLE	WORLDWIDE ANNUAL ENERGY SAVINGS FUEL	WORLDWIDE ANNUAL ENERGY SAVINGS T.O.E.	WORLDWIDE INVESTMENT COST, $	WORLDWIDE ANNUAL COST SAVINGS, $	WORLDWIDE SIMPLE PAYOUT, YRS	LOCAL INVESTMENT COST, LE	LOCAL SIMPLE PAYOUT, YRS
Power House								
02 *	Add new or repair existing insulation on steam and mazout lines.	49.3 tons mazout	47.9	5,702	5,525	1.03	(8,268) *	(5.99) *
03 *	Insulate boiler feed water tanks.	67.7 tons mazout	65.7	15,187	7,587	2.00	(22,021) *	(11.61) *
05	Recovery of heat from continuous boiler blowdown.	217.0 tons mazout	211.0	43,360	24,319	1.78	--	--
07	Installation of a condensate recovery system for existing mazout heater and drip legs.	216.0 tons mazout	210.0	36,730	24,198	1.52	--	--
Dry Kilns Factory 2								
22	Improve combustion efficiency of kilns.	42,094 tons mazout	40,868	0 (6)	4,717,475	IMMEDIATE	--	--
General								
35 *	Institute a permanent program for steam trap testing.	24.7 tons mazout	24.0	3,754	2,768	1.36	(8,447) *	(12.21) *
TOTAL		--	41427	104,733	4,781,872	0.02	--	--

NOTES:
1. Currency conversion 2.25 LE/$
2. Boiler efficiency 75%
3. Energy conversion 42.0 x 10E9 J/T.O.E.
4. Payout periods of less than 3 months have been labelled "IMMEDIATE"
5. An asterisk * represents a Housekeeping ECO that has a simple payout exceeding five years based on local costs, but has a payout of less than 5 years based on worldwide equipment and utility costs.
6. ECO-22 is already being implemented at HPCC. No additional investment cost is required.

Table 1.4C FOREIGN INVESTMENT ITEMS - ECO Summary

Plant: Helwan Portland Cement Company

ECO #	TITLE	WORLDWIDE ANNUAL ENERGY SAVINGS FUEL	WORLDWIDE ANNUAL ENERGY SAVINGS T.O.E.	WORLDWIDE INVESTMENT COST, $	WORLDWIDE ANNUAL COST SAVINGS, $	WORLDWIDE SIMPLE PAYOUT, YRS	LOCAL INVESTMENT COST, LE	LOCAL SIMPLE PAYOUT, YRS
Power House								
06	Improve combustion efficiency of steam boilers.	1,728 tons mazout	1,678	174,600	193,656	0.90	--	--
Mazout Steam Boiler White Cement								
12	Improve combustion efficiency of steam boilers.	4.6 tons diesel	4.9	1,060	693	1.53	--	--
Mazout Steam Boiler Factory 2								
19	Improve combustion efficiency of steam boilers.	3.4 tons diesel	3.6	1,060	512	2.07	--	--
Wet Kilns Factory 1 & White								
24	Improve combustion efficiency of kilns.	21,738,685 M3-nat. gas 4,519 tons mazout	23,670	64,600	2,202,062	IMMEDIATE	--	--
25	Energy savings through the use of slurry thinner to reduce water content in the feed.	4,703,205 M3 nat. gas 982 tons mazout	5,125	388,100	295,040	0.76	--	--
28	Energy savings by changing cement and raw mill drive controls to variable frequency (speed) controllers.	13,560 MWh	3,420	2,310,000	583,080	3.96	--	--

Table 1.4C FOREIGN INVESTMENT ITEMS - ECO Summary (continued)

Plant: Helwan Portland Cement Company

ECO #	TITLE	WORLDWIDE: ANNUAL ENERGY SAVINGS: FUEL	WORLDWIDE: ANNUAL ENERGY SAVINGS: T.O.E.	WORLDWIDE: INVESTMENT COST, $	WORLDWIDE: ANNUAL COST SAVINGS, $	WORLDWIDE: SIMPLE PAYOUT, YRS	LOCAL: INVESTMENT COST, LE	LOCAL: SIMPLE PAYOUT, YRS
General								
29	Run generators in power house at or near nameplate capacity and send excess kW to main power supply grid.	--	--	1,589,200	372,603	4.27	--	--
30 B	Use of a 30 MW gas turbine electric generator.	--	--	14,629,100	4,784,000	3.06	--	--
30 C	Use of a 30 MW gas turbine electric generator with waste heat recovery.	--	--	31,610,000	6,256,000	5.00	--	--
31	Improve, add, or fix instrumentation to be able to properly monitor and control energy consumption. (NOTE 5)	1,754 MWh 1,092 tons mazout 650,000 M3 nat. gas 2.32 tons diesel	2,082 (5)	84,150	248,824	0.34	--	--
34	Installation of capacitors as required to improve power factor.	3,122 MWh	787	103,620	134,261	0.77	--	--
TOTAL	(Excluding ECO's 30C and 34 - NOT ADDITIVE)	--	35,984	19,241,870	8,680,470	2.22	--	--
GRAND TOTAL	(Tables 1.4 A, B, and C)	--	78,370	19,383,528	13,589,958	1.43	--	--

NOTES:
1. Currency conversion 2.25 LE/$
2. Boiler efficiency 75%
3. Energy conversion 42.0 x 10E9 J/T.O.E.
4. Payout periods of less than 3 months have been labelled "IMMEDIATE"
5. Energy savings shown represent an indirect savings. Proper instrumentation will enhance the energy savings due to implementation of the other ECO's.

2.0 DISCUSSION

The Organization for Energy Planning in conjunction with the Helwan Portland Cement Company and Foster Wheeler USA Corporation have conducted an energy audit of the HPCC plant to develop, formulate, and rank ECO's. These energy conservation opportunities are presented in three categories, entitled:

- Housekeeping.

  These are items which require low cost/no cost solutions and can be implemented by the personnel at the plant.

- In-country - Investment.

  These are items which require an investment of over LE 40,000 of local currency to implement. All equipment necessary to implement this type of ECO can be made and purchased in-country.

- Foreign Investment.

  These are items which require foreign (hard) currency, to purchase materials, engineering, and/or manpower from outside the country.

The overall program to evaluate the energy conservation opportunities in the HPCC plant was performed in three steps, namely,

- Screening
- Preaudit
- Audit

The initial phase, screening, resulted in the selection of the HPCC plant as a reasonable candidate for an energy audit.

Upon completion of the screening activity, the preaudit phase was undertaken, the energy consumption of the plant was evaluated, and a list of ECO's was prepared.

This report documents the results of the preaudit and audit activities, and includes:

- An overall energy picture for 1987
- A discussion of the approach taken
- A detailed description of each ECO
- Supporting documentation as required

2.1 Objectives of the Audit

The dual objectives of the energy audit are:

- o identify and measure where energy is used, and
- o identify, evaluate, and list in order of priority each housekeeping ECO and each capital investment ECO. The capital investment ECO's are presented in two categories, in-country investment and foreign investment.

2.1.1 Identify Where Energy is Used

The achievement of this objective requires the evaluation, in some detail, of all features of energy consumption in the plant.

Subactivities to this objective include:

- o the creation of a "base case", as a reference for savings, corresponding to the most current calendar year operation.
- o the careful scrutiny of records, and their supplementation by field measurements, as necessary to establish the utility consumption.
- o particular attention to the energy consumption of large users, with the reasonable assumption that major utility consumption devices offer much greater opportunities for savings.
- o a review of all sources of lost or wasted energy, such as leaks in steam, air, or water systems, and missing or insufficient insulation.
- o a review of all losses which can be recovered, and an appraisal of those which cannot be recovered.

One important aspect of energy conservation is being able to document plant energy consumption and how it varies with time. In order to do this properly it is necessary that the plant assign an individual to keep and maintain a system of records which document both past and present energy consumption. These records should be kept in an active file which goes back a minimum of

five years. Records older than five years should be stored in an inactive file for an additional five years, after which they may be discarded. In this way a plant can carefully study and monitor the improvements which will occur in terms of reduced energy usage as attractive ECO's are implemented within the plant.

2.1.2 Identify Energy Conservation Opportunities

This objective is based upon the proper and effective completion of the identification of all locations in which energy is currently consumed. After this definition is complete, the task of completing the identification and the economic justification, or lack thereof, of each ECO can be completed.

Again, the achievement of the objective includes several sub tasks, which include:

- evaluation of ECO's which relate to housekeeping items.
- evaluation of ECO's which require an investment for implementation.
- development of all significant data to prioritize the ECO's; highlight attractive investments, and provide a basis for rejection of unsatisfactory ECO's.

2.2 Method of Approach

A detailed schedule for carrying out the preaudit and audit work was developed. The time frame for the overall audit work was set at sixteen weeks, including reports and presentation.

Personnel from OEP, HPCC, and FWUSA specialists were all deployed in a coordinated effort to accomplish this task.

This first day started with a planning meeting between OEP and FWUSA personnel. A detailed measurement plan was set up, followed by a visit to the plant to acquaint the plant personnel with the plan. Energy consumption data, required penetrations, and any comments and ideas which plant personnel might have were collected and discussed.

During the first four weeks, after the necessary preparations were made by plant personnel, instrument

measurements, visual observations and all necessary information required for the audit report was gathered. In addition to the FWUSA team already present, the audit staff was augmented by FWUSA specialist personnel, which included an additional energy systems operations engineer, combustion and electrical experts. These personnel worked with other audit team members and assisted in instrument measurements as well as in the gathering and analysis of other relevant data.

After the first seven weeks, a cost estimating specialist joined the team, and started the estimating work required for each of the ECO's. During this period sketches were prepared for the various systems, as well as listings of equipment and other technical data, as necessary for complete definition of each of the ECO's.

The major part of the work, after the first four weeks of the audit, was carried out in OEP's offices in Cairo, with plant coordination as necessary to produce a complete, coherent and usable report.

During the latter part of the eighth week report preparation began and continued through the eleventh week.

Weeks fourteen and fifteen were reserved for presentations to OEP and then to the plant, culminating with the finished report at the end of the sixteenth week.

2.3 Goals and Special Considerations

In order to have an effective energy conservation program it is necessary to establish a goal, as a target for which everyone in the plant strives. This goal should be realistic and also somewhat conservative, rather than overly optimistic, in order to ensure that it can be achieved. A goal which we would recommend is a reduction in yearly energy consumption of 8 percent at the end of two years, following partial implementation of housekeeping and in-country investment items, and 15 percent at the end of a five year program of implementation of foreign investment related items.

The results achieved each year are to be plotted and compared against the base case (energy consumption before any implementation was started) in order to demonstrate the actual reduction in consumption versus the predicted goal. Any deviation in energy consumption must be accounted for in terms of increased production, new products, new units, etc.

It is necessary that the scheduling of planned shutdowns be coordinated in such a way that energy conservation recommendations can be implemented.

2.4 Analysis of Energy Consumption

The audit provided a review of the energy consumption of the plant, including an examination of the various types of energy consumed, and their cost impact on production. This energy consumption analysis, as further described below, provides the baseline for the audit, and the implementation of its recommendations.

The basic analysis of these variables is accomplished through the use of a specialized computer program developed by FWUSA, and employed in the preaudit and audit phases of the work.

This program requires, as input, the quantities, unit cost, and energy equivalent of all energy forms supplied to the plant. This includes fuel oils, electricity, natural gas, and other fuels, as applicable. These data, which include production quantities, are entered on a monthly basis, for one recent calendar year. Through systematic calculations the program produces a variety of results in tabular form. These include monthly cost of the energy sources themselves in units of currency or energy consumption, as well as the relationship of energy cost and consumption to production units.

Each of the tables contained in this section is produced with both domestic energy prices and worldwide prices to permit a true evaluation of cost and cost savings.

Pricing basis is per the Basic Engineering Data, which is included in Appendix "1" of this report. The worldwide energy prices and T.O.E. (ton oil equivalent) are of particular value in this analysis, as they reflect the value of the energy, if used as an export product.

The existence of these tables permits direct graphs to be made on the computer, to exhibit a graphic display of the table's data, and to aid in analysis.

The choice of graphs to be presented is generally made after a careful review of the tables, to detect trends which would be meaningful as curves when plotted. The graphs of greatest interest will be energy consumption, production costs per production unit and energy consumption per production unit, plotted against calendar time.

Table 1A reflects the energy consumption for Factory 1 and the White Cement Plant. Table 2A reflects the cost of energy for Factory 1 and the White Cement Plant in both the domestic and the worldwide price structure, as discussed above. Table 3A gives the monthly production figures for 1987 of Factory 1 and the White Cement Plant as well as energy and cost figures per ton of clinker. Tables 1B, 2B, and 3B reflect similar data for Factory 2.

Six graphs have been plotted by the computer for the Helwan Portland Cement Company. Energy consumption has been plotted in joules. A comparison of the energy consumption figures per ton of clinker to worldwide energy consumption in the cement industry has been made and is shown on Graphs 3A and 3B. The conclusions drawn from the six energy consumption tables and the six graphs follow the presentation of the tables and graphs.

TABLE 1A - MONTHLY ENERGY CONSUMPTION

CLIENT: U.S. AID/OEP
DATA: JAN-DEC 1987

COMPANY: HELWAN PORTLAND CEMENT COMPANY
UNIT : FACTORY 1 AND WHITE CEMENT - WET PROCESS

		ELECTRICITY *			# 6 FUEL OIL			NATURAL GAS			DIESEL			TOTAL ENERGY	
		PURCHASED ENERGY	EQUIVALENT ENERGY		PURCHASED ENERGY	EQUIVALENT ENERGY		PURCHASED ENERGY	EQUIVALENT ENERGY		PURCHASED ENERGY	EQUIVALENT ENERGY			
		MWH	J x 10E9	T.O.E.**	TONS	J x 10E9	T.O.E.	CU. M.	J x 10E9	T.O.E.	TONS	J x 10E9	T.O.E.	J x 10E9	T.O.E.**
1	JAN	7469.8	26891	1883.1	2447.0	99768	2375.7	11601804	432240	10291.7	27.0	1205.2	28.7	560104	14579.2
2	FEB	7120.2	25633	1794.9	2163.0	88189	2100.0	11257729	419421	9986.5	25.5	1139.3	27.1	534382	13908.5
3	MAR	6816.9	24541	1718.5	2318.0	94508	2250.5	11320637	421765	10042.3	27.3	1218.9	29.0	542033	14040.3
4	APR	6346.2	22846	1599.8	2337.0	95283	2268.9	10554973	393239	9363.1	26.8	1199.1	28.6	512567	13260.4
5	MAY	5946.2	21406	1499.0	2230.0	90921	2165.0	11426311	425702	10136.0	27.0	1206.3	28.7	539235	13828.8
6	JUN	6912.9	24886	1742.7	2415.0	98463	2344.7	10450280	389338	9270.2	26.9	1199.6	28.6	513888	13386.1
7	JUL	6467.3	23282	1630.4	2247.0	91614	2181.6	11981394	446382	10628.4	26.6	1186.5	28.3	562465	14468.6
8	AUG	6835.8	24609	1723.3	1996.0	81380	1937.9	11418101	425396	10128.7	26.5	1185.9	28.2	532571	13818.1
9	SEP	6101.5	21965	1538.2	2267.0	92429	2201.0	9570294	356553	8489.6	26.5	1184.5	28.2	472132	12256.9
10	OCT	6426.3	23135	1620.0	2318.0	94508	2250.5	10147492	378058	9001.6	26.6	1186.1	28.2	496887	12900.3
11	NOV	5630.7	20271	1419.5	2327.0	94875	2259.2	10178497	379213	9029.1	27.2	1215.0	28.9	495574	12736.7
12	DEC	5984.7	21545	1508.7	1963.0	80035	1905.8	10108546	376607	8967.0	24.9	1110.5	26.4	479297	12408.0
ANNUAL TOTALS		78059	281011	19678	27028	1101973	26241	130016058	4843913	115334	318.7	14237	339.0	6241134	161592
MONTHLY AVERAGE		6505	23418	1640	2252	91831	2187	10834672	403659	9611	26.6	1186.4	28.2	520094.5	13466.0
NOTES		3.6 x 10E9 J/MWH			40.7715 x 10E9 J/TON			37256270 J/CU. M.			44.6687 x 10E9 J/TON			42.00 x 10E9 J/T.O.E.	

* INCLUDES 500 MWH/MONTH FOR NORMAL QUARRY ELECTRICAL CONSUMPTION.

** ELECTRICAL T.O.E. VALUES INCLUDE A TYPICAL 34% EFFICIENCY FACTOR AND CORRESPOND TO GENERATING ELECTRICITY USING A CONDENSING STEAM TURBINE SYSTEM.

TABLE 1B - MONTHLY ENERGY CONSUMPTION

CLIENT: U.S. AID\OEP
DATA : JAN-DEC 1987

COMPANY: HELWAN PORTLAND CEMENT COMPANY
UNIT : FACTORY 2 - DRY PROCESS

		ELECTRICITY *			# 6 FUEL OIL			NATURAL GAS			DIESEL			TOTAL ENERGY	
		PURCHASED ENERGY	EQUIVALENT ENERGY		PURCHASED ENERGY	EQUIVALENT ENERGY		PURCHASED ENERGY	EQUIVALENT ENERGY		PURCHASED ENERGY	EQUIVALENT ENERGY			
		MWH	J x 10e9	T.O.E. **	TONS	J x 10E9	T.O.E.	CU. M.	J x 10E9	T.O.E.	TONS	J x 10E9	T.O.E.	J x 10E9	T.O.E.**
1	JAN	26847.1	96649.6	6768.0	19934.0	808663	19256.3	0.0	0.0	0.0	2.7	121.3	2.9	995434	26027.2
2	FEB	20821.4	74957.2	5249.0	17229.0	702453	16727.2	0.0	0.0	0.0	68.4	3057.1	72.8	780467	22048.9
3	MAR	25057.1	90205.5	6316.7	18345.0	747954	17810.7	0.0	0.0	0.0	26.2	1171.5	27.9	839331	24155.3
4	APR	20849.3	75057.6	5256.0	16266.0	663190	15792.2	0.0	0.0	0.0	4.8	214.7	5.1	738462	21053.3
5	MAY	19140.2	68904.7	4825.1	13361.0	544748	12971.8	0.0	0.0	0.0	5.7	256.7	6.1	613910	17803.1
6	JUN	22803.0	82090.9	5748.5	15297.0	623682	14851.5	0.0	0.0	0.0	2.2	98.0	2.3	705871	20602.3
7	JUL	19893.0	71614.8	5014.9	13034.0	533455	12702.9	0.0	0.0	0.0	3.3	149.4	3.6	605219	17721.4
8	AUG	20048.7	72175.3	5054.1	12097.0	493213	11744.7	0.0	0.0	0.0	5.0	224.0	5.3	565613	16804.1
9	SEP	23684.6	85264.4	5970.7	17927.0	730911	17404.9	0.0	0.0	0.0	3.3	149.3	3.6	816325	23379.1
10	OCT	24275.0	87390.2	6119.6	16306.0	664821	15831.1	0.0	0.0	0.0	0.2	9.3	0.2	752220	21950.9
11	NOV	24643.3	88715.[illegible]	6212.4	16653.0	678968	16168.0	0.0	0.0	0.0	3.7	163.4	3.9	767847	22384.3
12	DEC	24764.2	89151.[illegible]	6242.9	14939.0	609086	14503.9	0.0	0.0	0.0	18.3	816.8	19.4	699054	20766.2
ANNUAL TOTALS		272827	982177	68778	191338	7801143	185765	0	0	0	144.0	6431.6	153.1	8789752	254696.1
MONTHLY AVERAGE		22736	81848	5731	15945	650095	15480	0	0	0	12.0	536.0	12.8	732479	21224.7
NOTES		3.6 x 10E9 J/MWH			40.7715 x 10E9 J/TON			37256270 J/CU. M.			44.6687 x 10E9 J/TON			42.00 x 10E9 J/T.O.E.	

* ENERGY USED IN THE QUARRY FOR HANDLING RAW MATERIALS FOR THE WET KILNS IS 500 MWH/MONTH. THE ELECTRIC METER FOR THE DRY PROCESS INCLUDES THIS VALUE. THE 'PURCHASED ENERGY' COLUMNS DOES NOT INCLUDE ELECTRICITY USED FOR THE WET PROCESS.

** ELECTRICAL T.O.E. VALUES INCLUDE A TYPICAL 34% EFFICIENCY FACTOR AND CORRESPOND TO GENERATING ELECTRICITY USING A CONDENSING STEAM TURBINE SYSTEM.

TABLE 2A - MONTHLY ENERGY COSTS

CLIENT: U.S. AID/OEP
DATA : JAN-DEC 1987

COMPANY: HELWAN PORTLAND CEMENT COMPANY
UNIT : FACTORY 1 AND WHITE CEMENT - WET PROCESS

		ELECTRICITY *			# 6 FUEL OIL			NATURAL GAS			DIESEL			TOTAL ENERGY COST	
		PURCHASED ENERGY MWH	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	PURCHASED ENERGY CU. M.	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	TOTAL COST LE	TOTAL COST US $
1	JAN	7469.8	186744	321200	2447.0	68516	274235	11601804	350374	904941	27.0	1619	4064	607253	1504440
2	FEB	7120.2	178004	306166	2163.0	60564	242407	11257729	339983	878103	25.5	1531	3843	580082	1430520
3	MAR	6816.9	170422	293126	2318.0	64904	259778	11320637	341883	883010	27.3	1637	4111	578846	1440024
4	APR	6346.2	158655	272887	2337.0	65436	261908	10554973	318760	823288	26.8	1610	4043	544462	1362126
5	MAY	5946.2	148655	255637	2230.0	62440	249916	11426311	345075	891252	27.0	1621	4069	557790	1400924
6	JUN	6912.9	172822	297254	2415.0	67620	270649	10450280	315598	815122	26.9	1612	4046	557652	1387071
7	JUL	6467.3	161684	278096	2247.0	62916	251821	11981394	361838	934549	26.6	1594	4001	588031	1468467
8	AUG	6835.8	170896	293941	1996.0	55888	223692	11418101	344827	890612	26.5	1591	3995	573202	1412240
9	SEP	6101.5	152538	262365	2267.0	63476	254063	9570294	289023	746483	26.6	1593	3999	506630	1266910
10	OCT	6426.3	160657	276330	2318.0	64904	259778	10147492	306454	791504	26.6	1593	3999	533608	1331612
11	NOV	5630.7	140768	242121	2327.0	65156	260787	10178497	307391	793923	27.2	1632	4097	514947	1300928
12	DEC	5984.7	149619	257344	1963.0	54964	219993	10108546	305278	788467	24.9	1492	3745	511352	1269549
	ANNUAL TOTALS	78059	1951464	3356518	27028	756784	3029028	130016058	3926485	10141253	318.7	19124	48013	6653856	16574812
	MONTHLY AVERAGE	6504.9	162622	279710	2252.3	63065	252419	10834672	327207	845104	26.6	1594	4001	554488	1381234
	NOTES	25.0 LE/MWH 43.0 US $/MWH			28.0 LE/TON 112.07 US $/TON			0.0302 LE/CU. M. 0.078 US $/CU. M.			60.0 LE/TON 150.64 US $/TON				

INCLUDES 500 MWH/MONTH FOR NORMAL QUARRY ELECTRICAL CONSUMPTION.

TABLE 2B - MONTHLY ENERGY COSTS

CLIENT: U.S. AID/OEP
DATA: JAN-DEC 1987

COMPANY: HELWAN PORTLAND CEMENT COMPANY
UNIT : FACTORY 2 - DRY PROCESS

		ELECTRICITY *			# 6 FUEL OIL			NATURAL GAS			DIESEL			TOTAL ENERGY COST	
		PURCHASED ENERGY MWH	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	PURCHASED ENERGY CU. M.	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	TOTAL COST LE	TOTAL COST US $
1	JAN	26847.1	671178	1154426	19834.0	555352	2222796	0.0	0	0	2.7	68	117	1226598	3377339
2	FEB	20821.4	520536	895322	17229.0	482412	1930854	0.0	0	0	68.4	1711	2943	1004659	2829119
3	MAR	25057.1	626427	1077455	18345.0	513660	2055924	0.0	0	0	26.2	656	1128	1140743	3134506
4	APR	20849.3	521233	896521	16266.0	455448	1822931	0.0	0	0	4.8	120	207	976801	2719659
5	MAY	19140.2	478505	823028	13361.0	374108	1497367	0.0	0	0	5.7	144	247	852757	2320643
6	JUN	22803.0	570076	980530	15297.0	428316	1714335	0.0	0	0	2.2	55	94	998447	2694959
7	JUL	19893.0	497325	855399	13084.0	366352	1466324	0.0	0	0	3.3	84	144	863761	2321867
8	AUG	20048.7	501217	862094	12097.0	338716	1355711	0.0	0	0	5.0	125	216	840059	2218020
9	SEP	23684.6	592114	1018436	17927.0	501956	2009079	0.0	0	0	3.3	84	144	1094154	3027659
10	OCT	24275.0	606876	1043827	16306.0	456568	1827413	0.0	0	0	0.2	5	9	1063449	2871249
11	NOV	24643.3	616082	1059661	16653.0	466284	1866302	0.0	0	0	3.7	91	157	1082457	2926120
12	DEC	24764.2	619104	1064859	14939.0	418292	1674214	0.0	0	0	18.3	457	786	1037853	2739859
ANNUAL TOTALS		272827	6820674	11731559	191338	5357464	21443250	0	0	0	144.0	3600	6191	12181738	33181000
MONTHLY AVERAGE		22736	568389	977630	15945	446455	1786937	0	0	0	12.0	300	516	1015145	2765083
NOTES		25.0 LE/MWH 43.0 US $/MWH			28.0 LE/TON 112.07 US $/TON			0.0302 LE/CU. M. 0.078 US $/CU. M.			60.0 LE/TON 150.64 US $/TON				

* ENERGY USED IN THE QUARRY FOR HANDLING RAW MATERIALS FOR THE WET KILNS IS 500 MWH/MONTH. THE ELECTRIC METER FOR THE DRY PROCESS INCLUDES THIS VALUE. THE 'PURCHASED ENERGY' COLUMNS DOES NOT INCLUDE ELECTRICITY USED FOR THE WET PROCESS.

TABLE 3A - MONTHLY PRODUCTION, COST AND ENERGY PER UNIT

CLIENT: U.S. AID\OEP
DATA : JAN-DEC 1987

COMPANY: HELWAN PORTLAND CEMENT COMPANY
UNIT : FACTORY 1 AND WHITE CEMENT - WET PROCESS

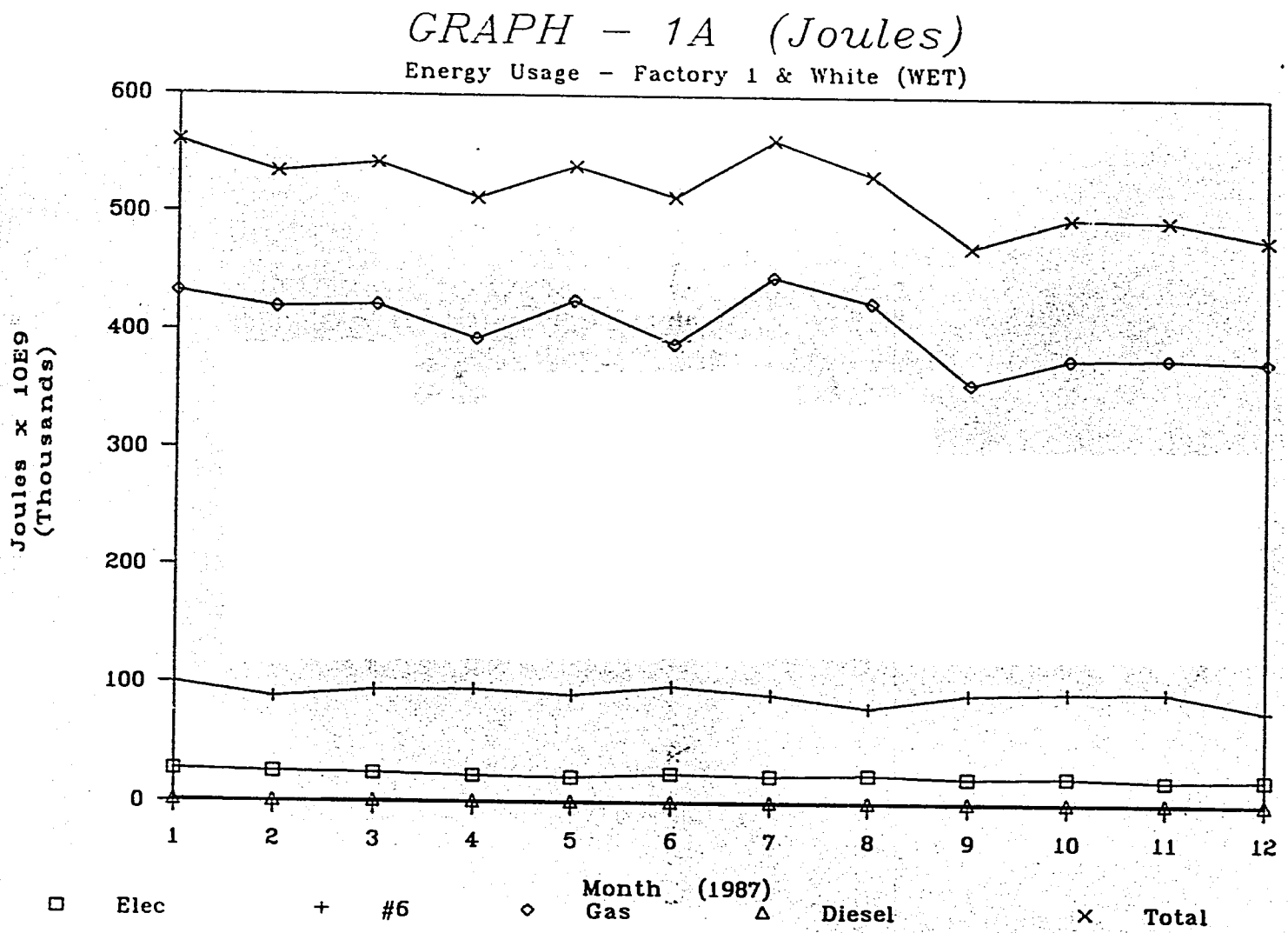
		CLINKER PRODUCTION	ENERGY COST PER UNIT		ENERGY PER UNIT	
		TONS	LE / TON	US $ / TON	J x 10E9/TON	T.O.E./TON
1	JAN	60600	10.02	24.83	9.24	0.241
2	FEB	59150	9.81	24.18	9.03	0.235
3	MAR	59200	9.78	24.32	9.16	0.237
4	APR	54830	9.93	24.84	9.35	0.242
5	MAY	57251	9.74	24.47	9.42	0.242
6	JUN	52094	10.70	26.63	9.86	0.257
7	JUL	53000	11.09	27.71	10.61	0.273
8	AUG	51800	11.07	27.26	10.28	0.267
9	SEP	49300	10.28	25.70	9.58	0.249
10	OCT	52300	10.20	25.46	9.50	0.247
11	NOV	52200	9.86	24.92	9.49	0.244
12	DEC	51500	9.93	24.65	9.31	0.241
	ANNUAL TOTALS	653225				
	MONTHLY AVERAGE	54435	10.20	25.41	9.57	0.248

TABLE 38 - MONTHLY PRODUCTION, COST AND ENERGY PER UNIT

CLIENT: U.S. AID\OEP
DATA : JAN-DEC 1987

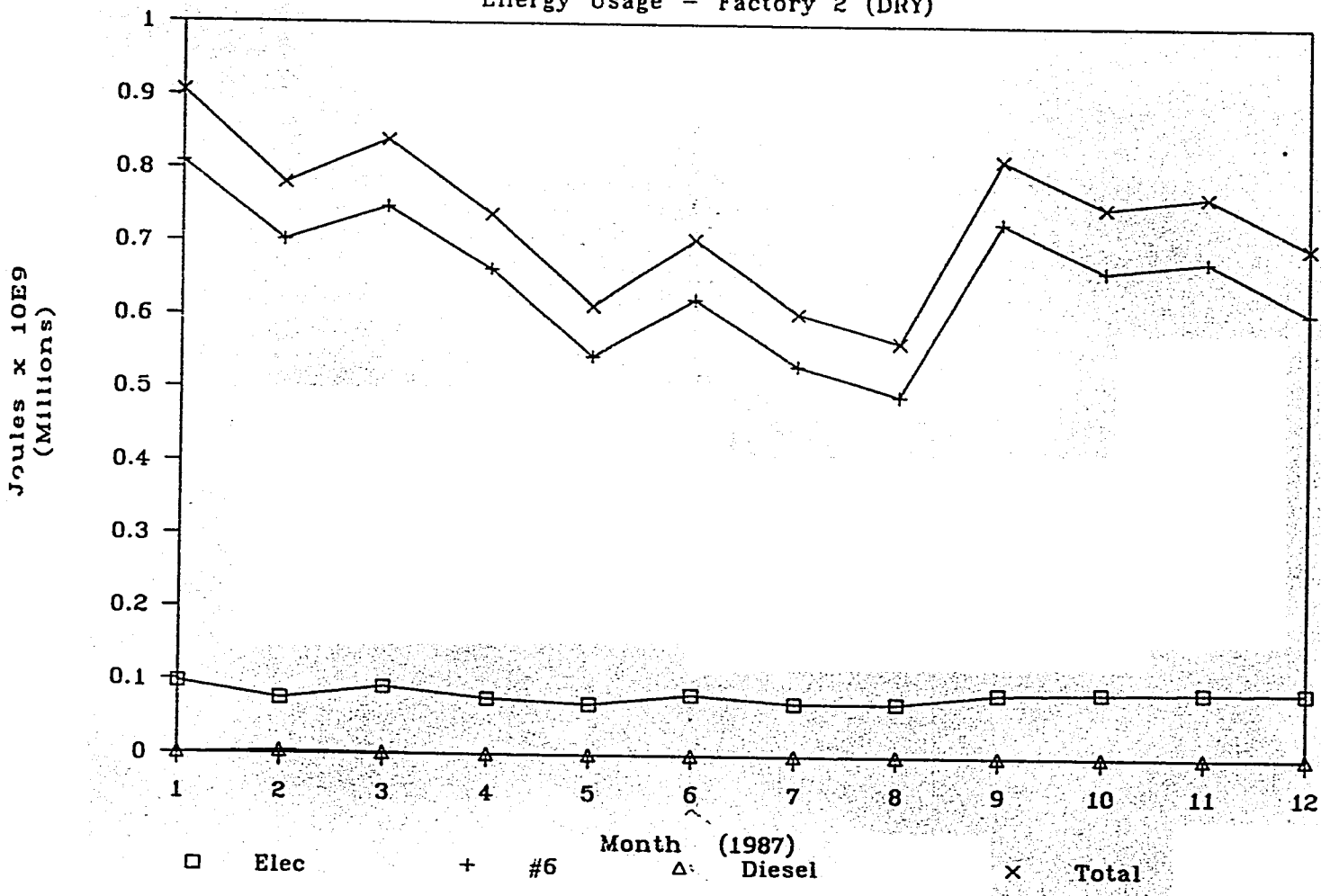
COMPANY: HELWAN PORTLAND CEMENT COMPANY
UNIT : FACTORY 2 - DRY PROCESS

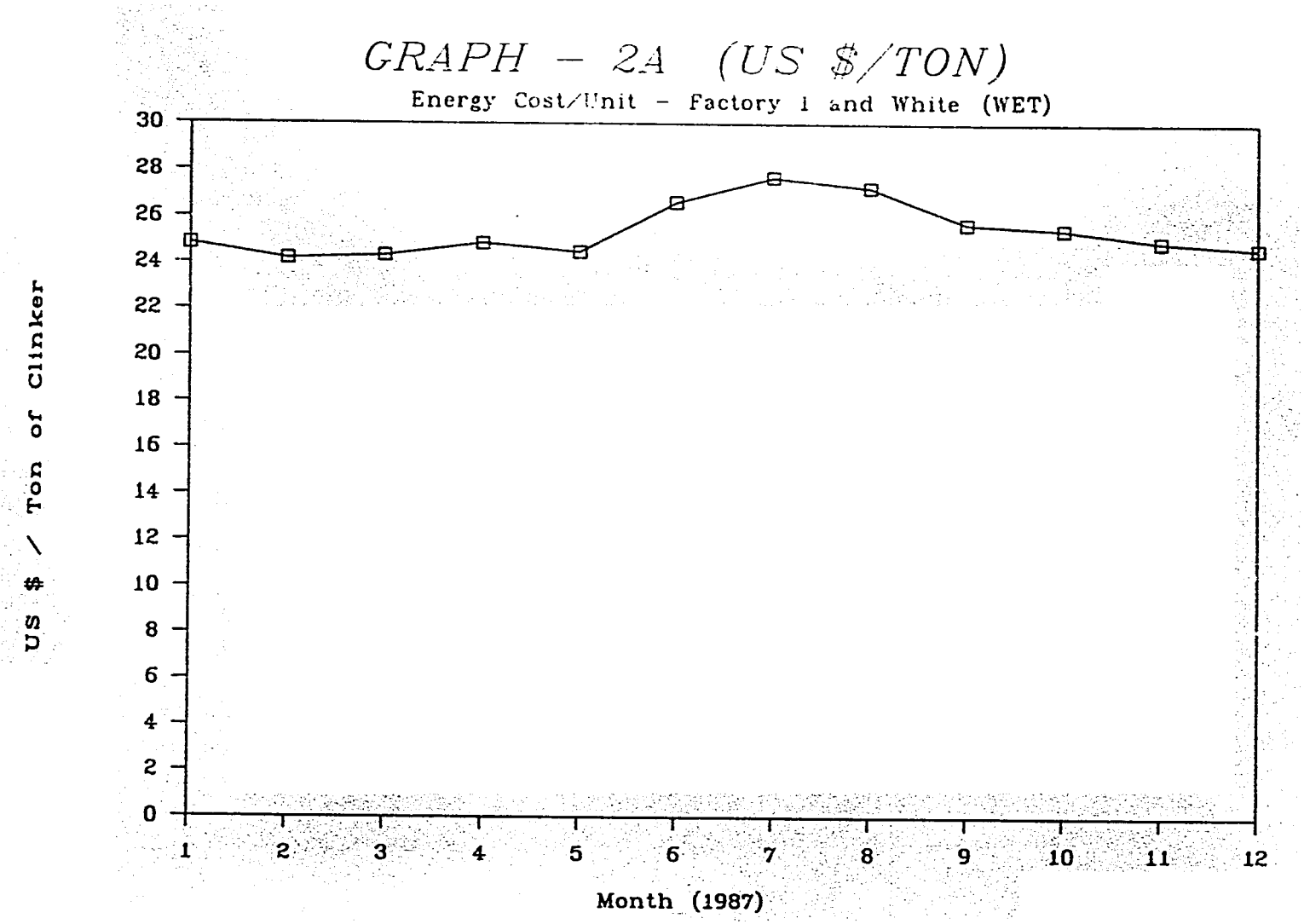
		CLINKER PRODUCTION	ENERGY COST PER UNIT		ENERGY PER UNIT	
		TONS	LE / TON	US $ / TON	J x 10E9/TON	T.O.E./TON
1	JAN	180960	6.78	18.66	5.00	0.144
2	FEB	142812	7.03	19.81	5.46	0.154
3	MAR	193388	5.90	16.21	4.34	0.125
4	APR	173487	5.63	15.68	4.26	0.121
5	MAY	144441	5.90	16.07	4.25	0.123
6	JUN	165400	6.04	16.29	4.27	0.125
7	JUL	142600	6.06	16.28	4.24	0.124
8	AUG	128200	6.55	17.30	4.41	0.131
9	SEP	196206	5.58	15.43	4.16	0.119
10	OCT	179047	5.94	16.04	4.20	0.123
11	NOV	152744	7.09	19.16	5.03	0.147
12	DEC	146169	7.10	18.74	4.78	0.142
	ANNUAL TOTALS	1945454				
	MONTHLY AVERAGE	162121	6.30	17.14	4.53	0.132

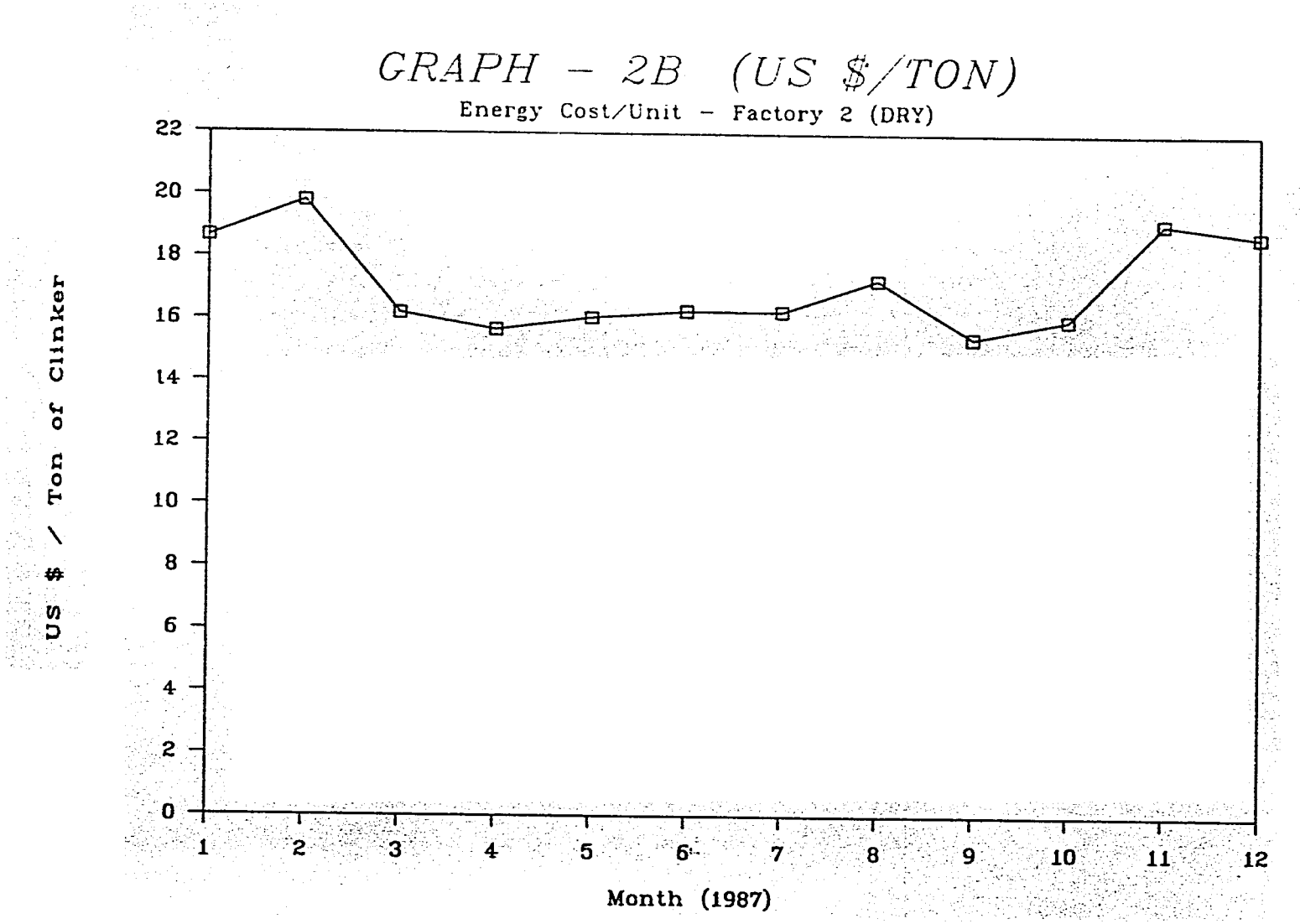

GRAPH - 1A (Joules)
Energy Usage - Factory 1 & White (WET)
Joules x 10E9 (Thousands)
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
12
Month (1987)
Elec
#6
Gas
Diesel
Total

GRAPH – 1B (Joules)

Energy Usage – Factory 2 (DRY)

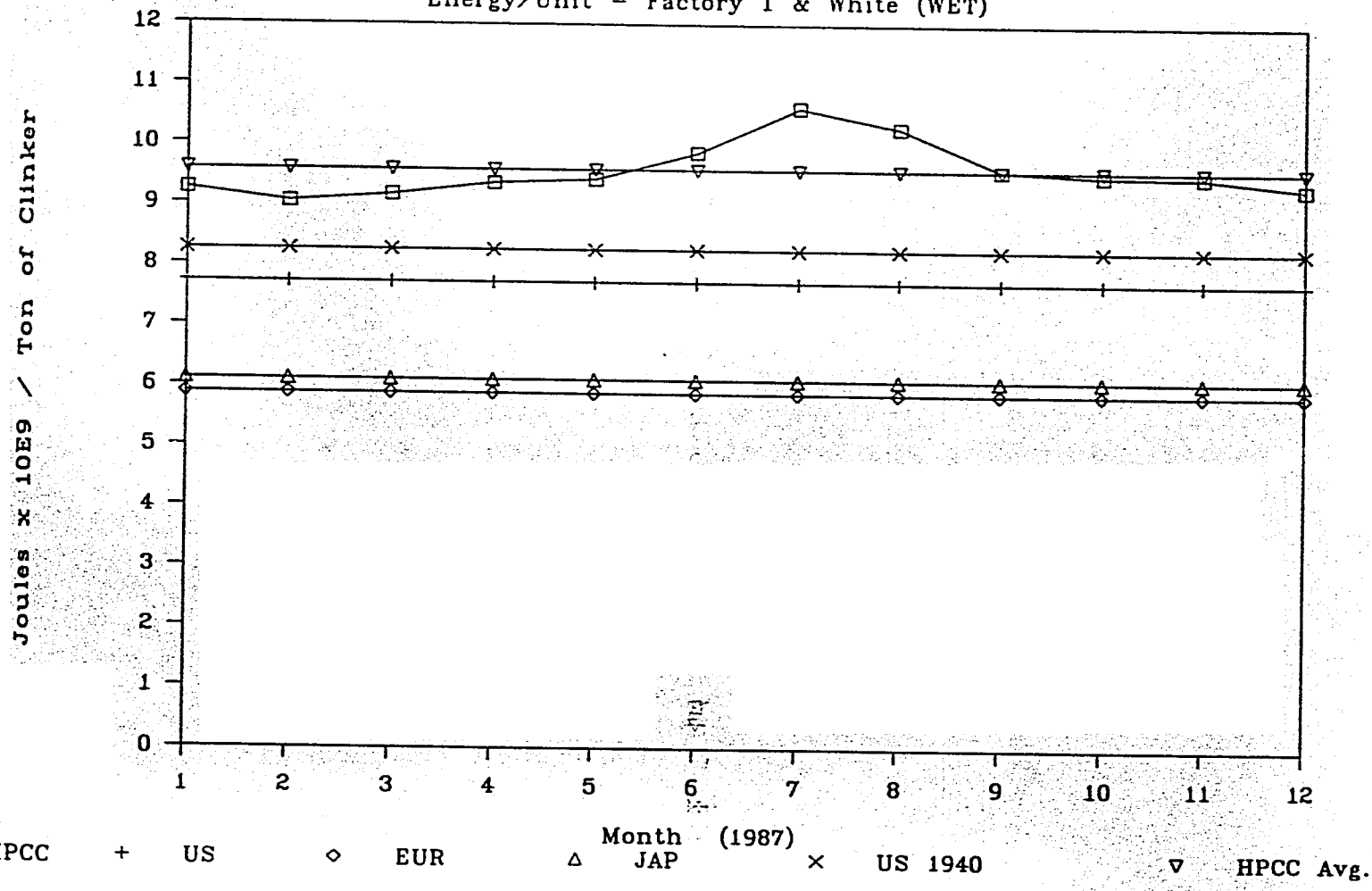



GRAPH – 2A (US $/TON)
Energy Cost/Unit - Factory 1 and White (WET)
US $ / Ton of Clinker
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
Month (1987)


GRAPH - 2B (US $/TON)
Energy Cost/Unit - Factory 2 (DRY)
US $ / Ton of Clinker
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
Month (1987)

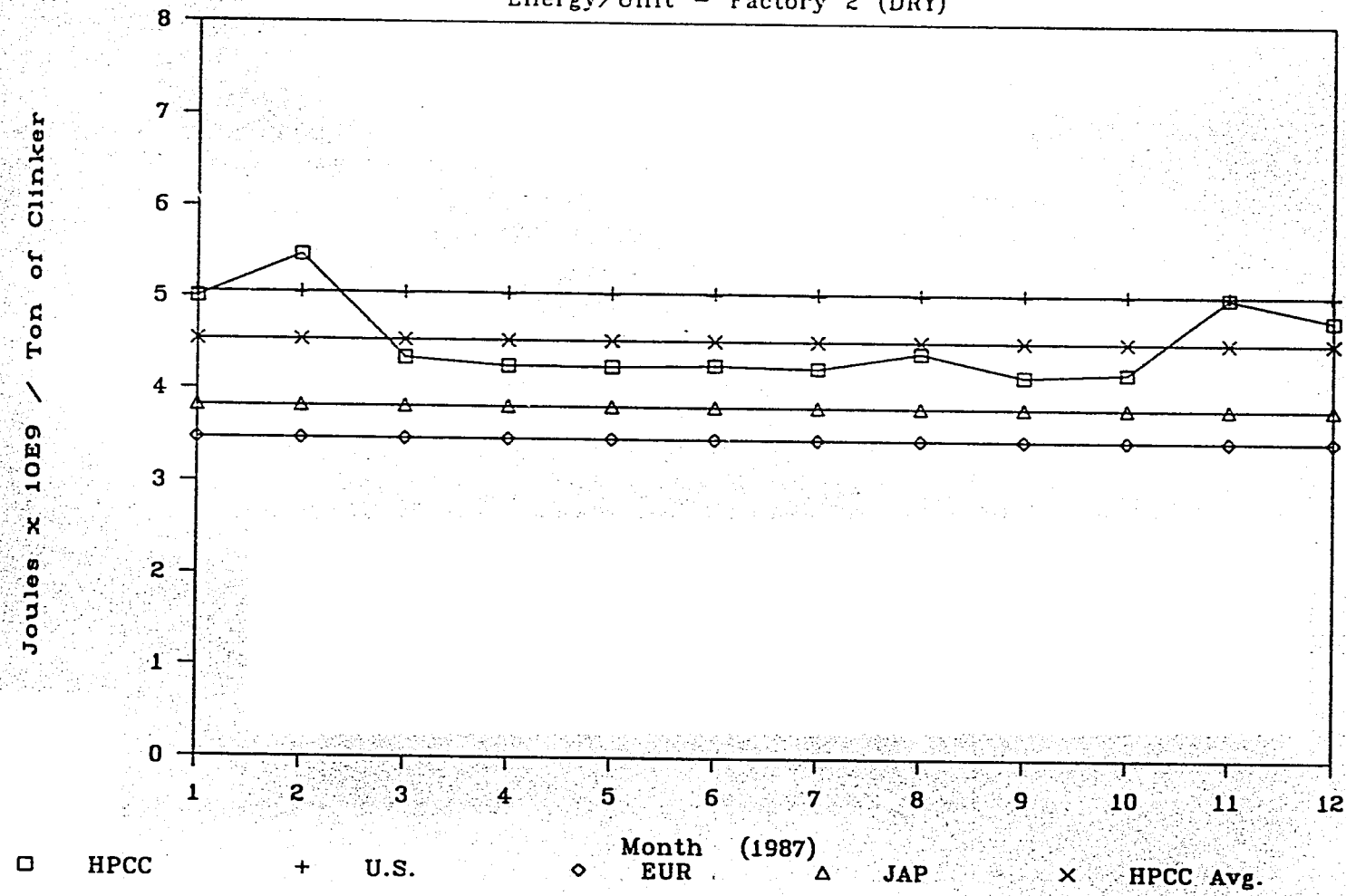
GRAPH – 3A (JOULES/TON)

Energy/Unit – Factory 1 & White (WET)



GRAPH – 3B (JOULES/TON)

Energy/Unit – Factory 2 (DRY)



2.4.1 Discussion of Tables

Table 1A

The monthly energy consumption for Factory 1 and White Cement Plant varied from a low of 472,132 x 10^9 joules in September to a high of 532,465 x 10^9 joules in July. The majority of fuel used is natural gas, accounting for 78% of the average total monthly energy usage. This is expected, since natural gas is fired in 6 of the 8 kilns located in these two areas. Attention should therefore be focused primarily on saving natural gas, as it would provide a significant energy savings as a percentage of overall energy consumed in Factory 1. The diesel fuel used represents an insignificant amount of the total energy used.

Table 2A

The energy costs show that the local annual electricity cost is approximately one-half the annual natural gas cost, even though the equivalent energy derived from the natural gas consumption, in joules, is 17 times that of electricity. This indicates that significant cost savings would result by substituting less expensive energy for electricity, or by generating electricity at the plant at a cost per MWH lower than the cost to purchase the same electricity from the electric company.

Table 3A

The clinker production rates show a low of 49,300 tons in September and a high of 60,600 tons in January. The energy consumption per ton ranges from 9.03 to 10.61 x 10^9 joules, while the cost per ton varies from LE 8.84 to LE 10.12. The highest costs per ton and energy usage per ton are during the summer months of July and August where monthly production is below the yearly average due to frequent power failure problems.

Table 1B

The monthly energy consumption for Factory 2 varied from a low of 565,613 x 10^9 joules in

August to a high of 905,434 x 10^9 joules in January. Fuel oil #6 is the major energy source; its usage is approximately 89 percent of the average total monthly energy consumed. Electric consumption is less than one-tenth the # 6 fuel oil consumption. Diesel fuel usage varies greatly from month to month but is always an extremely small quantity compared to the total energy used.

Table 2B

The factory consumed 7,801,143 x 10^9 joules of #6 fuel oil, and 982,177 x 10^9 joules of electricity; therefore the annual energy usage for #6 fuel oil is approximately eight times that of electricity. However, the annual #6 fuel oil cost was 5,357,464 LE vs. 4,638,058 LE for the annual electric cost, a cost difference of only 13 percent. These figures are justified by the significantly higher cost per joule of electricity vs. #6 fuel oil. This indicates that significant cost savings would result by substituting less expensive energy for electricity, or by generating electricity at the plant at a cost per MWH lower than the cost to purchase the same electricity from the electric company.

Table 3B

The monthly cost varied from a low of 4.61 LE/ton in September to a high of 5.86 LE/ton in February. The energy consumption per ton ranged from a low of 4.16 x 10^9 joules in September to a high of 5.46 x 10^9 joules in February. The clinker production rate ranged from 128,200 tons in August to 196,206 tons in September. Although the product rates for the summer months of July and August are each much below the monthly average for the rest of the year, the energy costs per ton for these months are do not reflect an inefficient operation due to power failure problems.

Discussion of Graphs

Graph 1A

This graph illustrates the contribution of the various forms of energy in Factory 1 and the White Cement Plant to the total energy

picture. It graphically shows the large usage of natural gas as an energy source when compared to #6 fuel oil, electricity, and diesel.

Graph 2A

The cost per ton of clinker in Factory 1 and White Cement Plant shows a rise during the summer months. This increase is most likely due to inefficiencies that occur during times of load shedding, required by the electric company, and a lack of plant generated electricity to compensate for this occurrence.

Graph 3A

In this graph, energy consumed per ton of clinker in Factory 1 and White Cement Plant is compared to worldwide published figures for the wet process in the United States, Europe, and Japan. These figures show the energy savings that would be realized by improvements designed to bring the plant up to current worldwide standards.

The curve labelled "US 1940" most likely represents the wet process at HPCC. Curves for the US, Europe, and Japan represent present day energy consumption per ton of clinker.

Graphs 1B

This graph shows the contribution of the various forms of energy in Factory 2 to the total energy picture. It graphically shows the large usage of #6 fuel oil as an energy source when compared to diesel and electricity.

Graph 2B

The cost per ton of clinker in Factory 2 is plotted based on worldwide energy costs. The high cost per ton of clinker in the winter months of January, February, November and December reflects the significant consumption increases in No. 6 fuel oil per ton of clinker for the same time period. This is most likely weather related due to increased steam usage for heating the fuel oil above its pour point during these cold months.

Graph 3B

In this graph, energy per ton of clinker in Factory 2 is compared to worldwide published figures for the dry cement process in the United States, Europe, and Japan. Factory 2 was started up in 1982 and incorporates modern, European, state-of-the-art dry kiln design technology. Therefore, comparing Factory 2 with the European figures for energy consumption would be most appropriate. When this comparison is made, however, it can be seen that the monthly average of 4.53 x 10^9 joules/ton of clinker for Factory 2 is currently 18% higher than the European consumption. This is due to the current need in Factory 2 to bypass large quantities of impurity laden gas from the system in order to produce a sufficiently pure cement product from highly impure raw materials. Under current plans, it is anticipated that, within a year or two, high quality raw materials will begin to be used. At that time, the need to bypass large amounts of hot kiln gas will no longer exist. It is then expected that the energy consumption for Factory 2 will drop approximately 18% to match current European consumption.

2.5 Economic Evaluation

In carrying out economic evaluations for each of the potential energy conservation opportunities involving an investment, the following steps must be taken:

- Establish utility costs/economic criteria
- Develop energy savings
- Estimate investment cost
- Decide if project is attractive

For this energy audit the utility costs are defined in the Basic Engineering Data contained in Appendix "1".

Both the worldwide and the local cost of the utilities involved are used in each case being evaluated in order to establish a realistic value for the energy savings. The criteria for evaluation which are used in each case is simple payout, defined as estimated investment cost divided by annual savings and discounted cash flow (DCF). The DCF method assumes a 32% tax rate, 3% operating cost, 2.5% salvage value on investment, 30% yearly escalation on investment, a 10 year life, and a constant yearly value for the annual energy savings over the life of the project. These criteria are simple to use and very effective in establishing a priority listing for a group of potential projects.

As a part of the evaluation a simplified design and/or equipment list is developed which contains enough detail to establish an estimated investment cost. The key information needed for any evaluation is an estimate of the energy saved and an estimate of the investment cost. Since these two topics are so crucial to an effective audit, each of them are discussed separately in the sections which follow.

2.5.1 Value of Energy Saved

The first step in predicting the value of the energy saved for any ECO is to establish the energy consumption of the current operation or the so called "base case". Once the base case is established, the ECO must be compared to it to determine exactly what energy savings would take place if the ECO were to be implemented. The savings are initially calculated on an hourly basis in terms of the units of energy normally used.

The next step is to calculate the energy savings on an annual basis taking into account the number of days per year the plant operates, shutdowns for

maintenance, and the number of shifts used for each operating day.

Once this is done, the annual energy savings is converted into U.S. dollars ($) through the use of the worldwide cost data for utilities given in Appendix "1".

2.5.2 Estimating Investment Cost

Each ECO which requires the expenditure of money, regardless of whether it is a housekeeping, in-country investment, or foreign investment ECO, has been provided with an individual estimate of costs. These estimates are of a preliminary nature. Definitive estimates are only possible following detailed engineering.

The majority of the estimates, especially those which are well defined, are estimated using a "definitive" type format enumerating and quantifying, where possible, each discipline of work. Material and installation manhours are estimated separately. In those cases in which the process equipment represents the large majority of the cost, and the bulk materials cannot be accurately defined, the estimate was done using a factored technique for bulk materials and labor.

Engineering data and technical information used in preparation of each estimate is based on the equipment list and technical description provided for each ECO as prepared by the responsible engineer as shown with sketches or schematic drawings when required.

The estimates are done using United States material pricing and United States standard construction manhours as a base line. The material costs are adjusted for a worldwide pricing basis and then the dollar (US) value has been converted to Egyptian pounds at the rate of 2.25 LE / $1.00 (US). The worldwide pricing adjustment is based on historical data and experience in worldwide procurement and construction. It represents a sampling of purchased materials from engineering offices in England, France, United States, Italy and Spain which includes Far East manufactured materials purchased from these locations.

Construction manhours have been adjusted from a baseline representing a U.S. Gulf Coast location to the productivity realized in previous Foster

Wheeler projects carried out in Egypt. Once again, worldwide experience was used as the primary determinant on productivity adjustment. Other factors were considered such as the size and complexity of each item of work, the amount of engineering that will be provided, the amount and type of supervision and who will be executing the work (in plant personnel, contractor, etc.).

Labor rates for construction crafts in Egypt were obtained from Foster Wheeler's Labor Relations Dept., local Egyptian contractors, and rates published in Engineering News magazine.

Each estimate includes:

a) Indirect costs. These include construction supervision, major tools, temporary facilities, subcontractor's requirements.

b) Home office costs. These include engineering, purchasing, drafting and project management. Home office costs were estimated on a factored basis.

All estimates are based on instant execution (No escalation has been applied). Labor is based on a straight time normal work week. It has been assumed that all construction work can proceed with continuity and without interruption or delay due to plant operation interference. It is anticipated that plant shutdowns of sufficient duration will be available, when necessary, to install the needed equipment to implement a particular ECO.

No provision is made for import duties or taxes, as these items require detailed information which is normally not available until the project (or ECO) execution plan is developed.

All estimates for engineering assume execution by local Egyptian engineering contractors, with engineering supervision and/or assistance from an international contractor's staff. This assistance will involve local supervision on all projects, and a "front end" engineering package, as a technical basis, on major projects.

3.0 ENERGY CONSERVATION OPPORTUNITIES (ECO's)

3.1 Summary List

Following is a list of ECO's identified and studied at the Helwan Portland Cement Company.

Power House

ECO 01. Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.

ECO-02. Add new or repair existing insulation on steam and mazout lines.

ECO-03. Insulate boiler feed water tanks.

ECO-04. Combustion air preheat through stack gas heat recovery.

ECO-05. Recovery of heat from continuous boiler blowdown.

ECO-06. Improve combustion efficiency of steam boilers.

ECO-07. Installation of a condensate recovery system for existing mazout heater and drip legs.

ECO-08. Test, repair, replace steam traps.

Mazout Steam Boiler - White Cement

ECO-09. Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.

ECO-10. Add new or repair existing insulation on steam and mazout lines.

ECO-11. Insulate boiler feed water tanks.

ECO-12. Improve combustion efficiency of steam boilers.

ECO-13. Combustion air preheat through stack gas heat recovery.

ECO-14. Test, repair, replace steam traps.

Mazout Steam Boiler - Factory 2

ECO-15. Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.

ECO-16. Add new or repair existing insulation on steam and mazout lines.

ECO-17. Insulate boiler feed water tanks.

ECO-18. Insulate mazout day tank.

ECO-19. Improve combustion efficiency of steam boilers.

ECO-20. Combustion air preheat through stack gas heat recovery.

ECO-21. Test, repair, replace, add steam traps.

Dry Kilns - Factory 2

ECO-22. Improve efficiency of kilns.

ECO-23. Recover heat lost through clinker cooler shell to preheat combustion air to kiln.

Wet Kilns - Factory 1 (Grey and White)

ECO-24. Improve efficiency of kilns.

ECO-25. Evaluate energy savings of feed preheat using waste heat from stack gas.

ECO-26. Investigate the use of slurry thinner to reduce water content in feed.

ECO-27. Investigate the use of roller mills to save energy in processing clinker.

ECO-28. Investigate energy savings by changing cement and raw mill drive controls to variable frequency (speed) controllers.

General

ECO-29. Run generators in power house at or near nameplate capacity and send excess kw to main power supply grid in Factory 1.

ECO-30A Investigate the use of an electrical generating boiler package to supplement the power supply.

ECO-30B Investigate the use of a gas turbine electrical generator to supplement the power supply.

ECO-30C Investigate the use of a gas turbine electrical generator with waste heat recovery to supplement the power supply.

ECO-31. Improve, add, or fix instrumentation to be able to properly monitor and control energy consumption.

ECO-32. Study the effect of insulation on heat loss from pipes.

ECO-33. Provide automatic fuel/air ratio controllers for steam boilers.

ECO-34. Installation of capacitors as required to improve power factor.

ECO-35. Institute a permanent program for steam trap testing.

ECO-36. Form a committee to plan and implement an energy conservation program in plant.

ECO-37. Use of publicity, memos, newsletters, etc. to implement an energy program and make personnel aware of energy conservation.

3.2 Detailed ECO Presentation

For each of the ECO's summarized in Section 3.1, a detailed ECO description and evaluation has been developed. All of this information is now presented in the pages which follow.

Note that each ECO is given an identification number, such as ECO-01, which ties it directly to the list of ECO's, as shown in Section 3.1. Additionally, each ECO is written in such a way that it can be "self standing", and contains, at the bottom of each of its pages, an identifier and page number for that ECO alone. This step is taken so that the full text which defines that ECO, including its technical description, investment cost, savings, and payback can be removed for easy use elsewhere in project definition documents, financing discussions, and the like.

POWER HOUSE

REPAIR OF STEAM, AIR, WATER AND CONDENSATE LEAKS FROM PIPING.

Annual Savings, TOE	:	121.6
Annual Savings, $	:	14,031.0
Investment Cost, $	:	110.0
Payout: Simple, Yrs	:	3 days
DCF, %	:	--

ECO-01

1.0 PURPOSE

The purpose of this ECO is to repair steam, air, water and condensate leaks from valves, lines, flanges, etc. to minimize energy losses.

2.0 PROCESS DESCRIPTION

A detailed survey was made of the steam, air, water and condensate leaks in the plant. All leaks were tagged and identified during the preaudit phase. The size of each leak was estimated as either small, medium, large or extra large. No steam or air leaks were noticed. Only one definite BFW/condensate leak was present.

3.0 NUMBER OF STEAM LEAKS

Steam	:	0
Air	:	0
BFW/condensate	:	1 (overflow line between BFW tanks)

Total Leakage 227 kg/hr or 1689 tons/yr (310 days/yr)

4.0 PREDICTED ENERGY SAVINGS

The anticipated energy savings, after repairing all of the leaks, is below:

ANNUAL ENERGY SAVINGS

T.O.E.	Tons Mazout
121.6	125.2

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for repairing the above leaks is below. Figures are based on worldwide and local equipment and utility costs.

INVESTMENT COST		ANNUAL ENERGY COST SAVINGS	
$	LE	$	LE
110	245	14,031	3,506

-50

6.0 CONCLUSIONS

For very little investment this ECO pays out extremely fast.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

51

POWER HOUSE

ADD NEW OR REPAIR EXISTING INSULATION ON STEAM AND MAZOUT LINES.

Annual Savings, TOE	:	47.9
Annual Savings, $	:	5,525
Investment Cost, $	:	5,702
Payout: Simple, Yrs	:	1.03
DCF , %	:	--

ECO-02

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on piping in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine locations of hot piping that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to provide new insulation where none is currently installed on the piping and to replace existing insulation in those locations where this insulation is judged to be in bad condition and is visibly not effective for heat conservation.

The pipe sizes and lengths to be insulated were measured. The lengths include flanges and valves that were not presently insulated. The required insulation thicknesses were then determined by use of the "Heatalyzer" Economic Insulation Thickness computer program. The "Optimum Insulation Thickness and Energy Savings" table is included in this report as a separate ECO titled, "Study the Effects of Insulation on Heat Loss From Pipes."

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by pipe size, length and service.

Steam Piping - Header Conditions: 1863 kPa (19 kg/cm2)
400 °C Superheated

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
0.75	3	127,550,000

Steam Piping - Header Conditions: 1863 kPa (19 kg/cm2)
210 °C Saturated

-5V

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
1	151	346,092,000 (1000 Hr/Yr)
1.5	2	47,625,000
2	2	58,525,600
3	2	83,028,900

Condensate Return - Header Conditions: 70 kPa, 120 °C (0.7 kg/cm2)

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
0.75	50	846,014,500

TOTAL ENERGY SAVINGS : 1.509×10^9 kJ
(Based on 7446 Hr/Year unless otherwise stated)

Insulation to be mineral wool. Jacketting to be galvanized steel.

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer" Economic Thickness" computer program determines the heat saved in $/ft. of pipe for various line sizes and at different operating fluid temperatures. It also calculates the economic insulation thickness. These heat savings are summarized as follows based on worldwide costs:

Annual Savings	
T.O.E.	Ton mazout
47.9	49.3

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to all piping is below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
5,702	8,268	5,525	1,38[illegible]

6.0 CONCLUSIONS

Insulation should be applied to bare lines in plants including those where insulation is in poor condition.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

-84

POWER HOUSE

INSULATE BOILER FEEDWATER TANKS

Annual Savings, TOE	:	65.7
Annual Savings, $	:	7,587
Investment Cost, $	:	15,187
Payout: Simple, Yrs	:	2.00
DCF , %	:	33

ECO-03

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on the boiler feed water tanks in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine the locations of vessels that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to determine the energy savings by providing new insulation where none is currently installed on the vessels.

The vessels to be insulated were measured for size and temperature. The required insulation thicknesses were then determined by use of the "Heatilizer" Economic Insulation Thickness computer program.

The results of this program are summarized in this ECO.

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by vessel surface.

BFW Tank
Vessel Temperature - 50 C Design

	Per Tank	
Location	Estimated Area, M2	Annual Energy Savings, kJ
Sides	57	586,472,400
Bottom	20	201,258,700
Top	20	247,449,200
		1,035,180,300

TOTAL ENERGY SAVINGS : 2.070×10^9 kJ (2 Tanks)
(Based on 7446 Hr/Year)

55

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer Economic Thickness" computer program determines the heat saved in $/sq.ft. of vessel surface at different operating fluid temperatures. It also calculates the economic insulation thickness. These heat savings are summarized as follows based on worldwide costs:

Annual Savings	
T.O.E.	Ton mazout
65.7	67.7

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to the vessels is below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
15,187	22,021	7,587	1,896

6.0 CONCLUSIONS

Insulation should be applied to these bare vessels.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

50

POWER HOUSE

INVESTIGATE THE FEASIBILITY OF AIR PREHEAT SYSTEMS FOR STEAM BOILERS

Annual Savings, TOE	:	549
Annual Savings, $	:	63,459
Investment Cost, $	:	1,200,000
Payout: Simple, Yrs	:	18.9
DCF, %	:	<1.0

ECO-04

1.0 PURPOSE

The purpose of this ECO is to investigate the feasibility of air preheat systems for the power house steam boilers. Overall combustion efficiency is improved by preheating the combustion air and thus reducing the fuel consumption of the boiler.

2.0 PROCESS DESCRIPTION

High temperature flue gases exiting the boiler contain a considerable amount of energy that can be recovered using combustion air preheaters. The preheaters recover heat from the hot flue gases to the combustion air, but do not allow leakage of the flue gases into the combustion air or visa versa. Sensible heat from the flue gas is passed to the combustion air and therefore the amount of fuel that must be fired is reduced. This reduction of fuel consumption occurs because the increase in combustion air temperature from ambient to flame temperature is decreased.

Air is forced through the air side of the air preheater and the burners with a forced draft fan. Flue gas is drawn through the flue gas side of the air preheater and expelled up the stack with an induced draft fan. Forced draft fans must be larger than those supplied with the original boiler having no air preheat system on account of the increased volume of the air passing through the burners, the added duct work, and the air preheater itself. Induced draft fans must also be larger to overcome the air preheater and ductwork.

The feasibility of an air preheat system is dependent on the amount of heat that is available for recovery to offset the new equipment cost. In general high stack temperatures and high load boilers are the best candidates for air preheaters. As either the stack temperature or the boiler load become smaller, it is more difficult to justify investment in such equipment.

97

3.0 EQUIPMENT LIST/SIZE

Please note that the equipment listed is for only one air preheat system, although the above investment represents the price for both air preheat systems:

1 (one) forced draft fan

1 (one) induced draft fan

5 (five) forced draft oil burners

1 (one) cast iron recuperative air preheater

Air and flue gas duct work

Associated instrumentation

4.0 PREDICTED ENERGY SAVINGS

A reduction in the stack temperature of the powerhouse boilers from approximately 282 oC to 177 oC would increase the boiler efficiency from 84.77 percent, assuming the excess air is controlled, to 89.82 percent. The figures shown below represent the total for the two boilers:

ANNUAL ENERGY SAVINGS	
T.O.E.	TONS MAZOUT
549	566

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for purchasing and installing the equipment listed above is listed below for both worldwide and local equipment and utility costs.

INVESTMENT COST	ANNUAL ENERGY COST SAVINGS	
$	$	LE
1,200,000	63,459	15,848

6.0 CONCLUSIONS

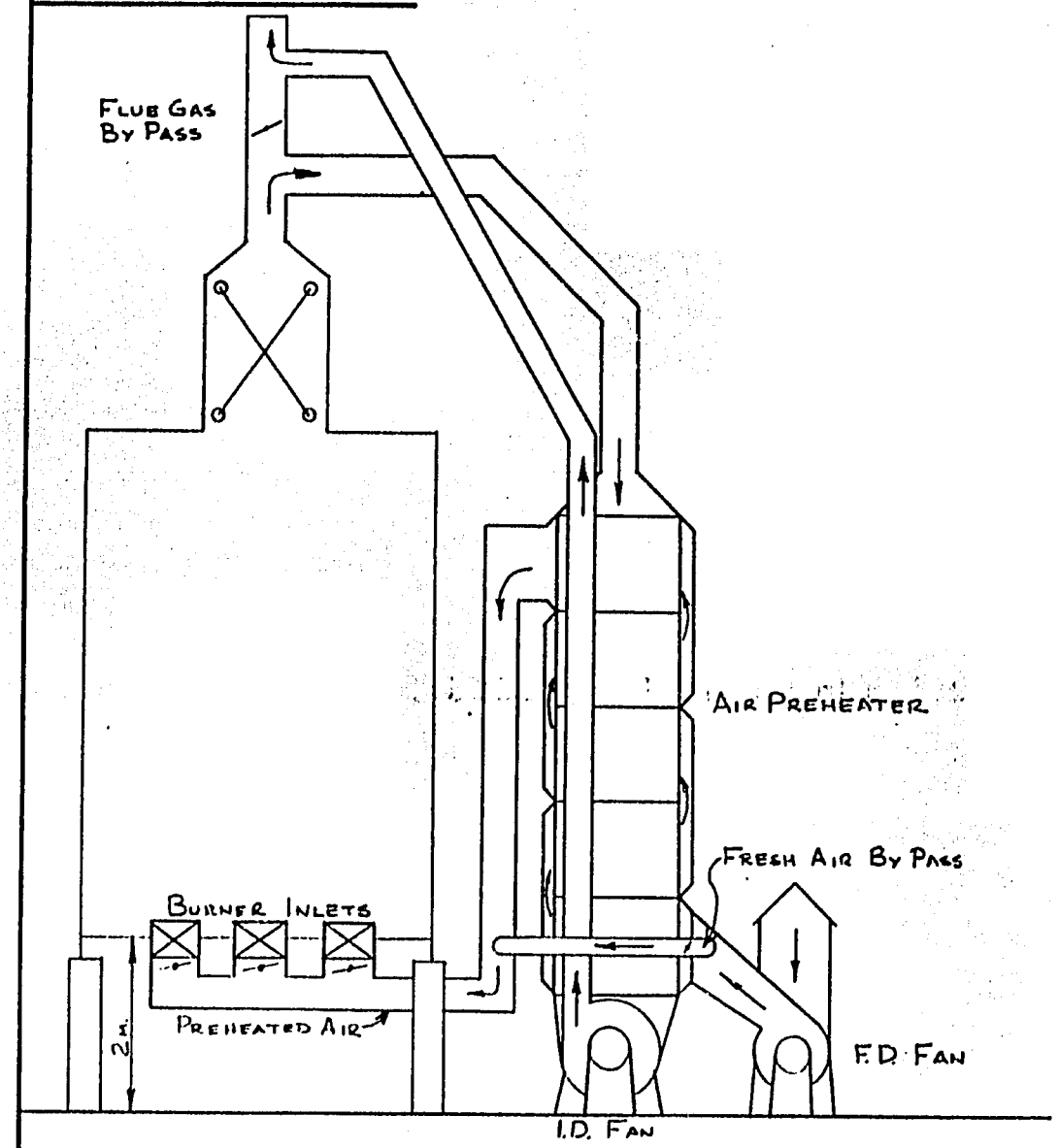
This ECO is not economically attractive. The payout, based on the high investment required, is far in excess of 10 years.

7.0 RECOMMENDATIONS

Implementation of this ECO is not recommended, due to the high investment cost.

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: HPCC

REF. 11-36598
DATE MAY 1988
PAGE
REV.



PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 04

PLANT HPCC

LOCATION HELWAN, EGYPT

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

POWER HOUSE

RECOVERY OF HEAT FROM CONTINUOUS BOILER BLOWDOWN

Annual Savings, TOE	:	211
Annual Savings, $	:	24,319
Investment Cost, $	:	43,360
Payout: Simple, Yrs	:	1.78
DCF , %	:	39

ECO-05

1.0 PURPOSE

The purpose of this ECO is to preheat boiler feed water using hot continuous boiler blowdown. The continuous boiler blowdown rate is 650 Kg/hr. This helps conserve energy by minimizing the amount of fuel needed to heat the BFW in the steam drum.

2.0 PROCESS DESCRIPTION

The present system is to pump cold BFW directly into each steam drum while hot continuous blowdown is sent directly to drainage. The heat recovery system shown on the attached sketch will recover heat from boiler blowdown, thereby reducing the energy consumption of each boiler.

There are two operating boilers and one spare at the Power House. Two identical heat recovery systems are proposed; one for each continuously operating boiler.

3.0 EQUIPMENT LIST/SIZE

Heat Exchanger - two required, locate at grade

22 kg/cm^2 (2160 kPa), 250 ^oC design - tubes

24 kg/cm^2 (2350 kPa), 200 ^oC design - shell

6.5 M^2 surface area. multitube type

carbon steel shell and tubes.

Instrumentation - as shown.

Piping

2" :	15 M
3" :	20 M

It is assumed that the existing BFW pumps or control valve will be able to accommodate a differential pressure increase in the system of approximately 1 kg/cm^2 (98 kPa).

4.0 PREDICTED ENERGY SAVINGS

The anticipated annual energy savings for two boilers after this system is installed is below.

Annual Energy Savings

T.O.E.	Tons Mazout
211	217

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost to purchase and install the necessary equipment and materials described herein, as well as the annual cost savings are below.

Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Energy Cost Savings	
$	LE	$	LE
43,360	97,120	24,319	6,076

6.0 CONCLUSIONS

It is good engineering practice to recover heat from blowdown through heat exchange and/or low-pressure flash drums to produce steam.

7.0 RECOMMENDATION

This ECO should be implemented during a convenient turnaround/shutdown period.

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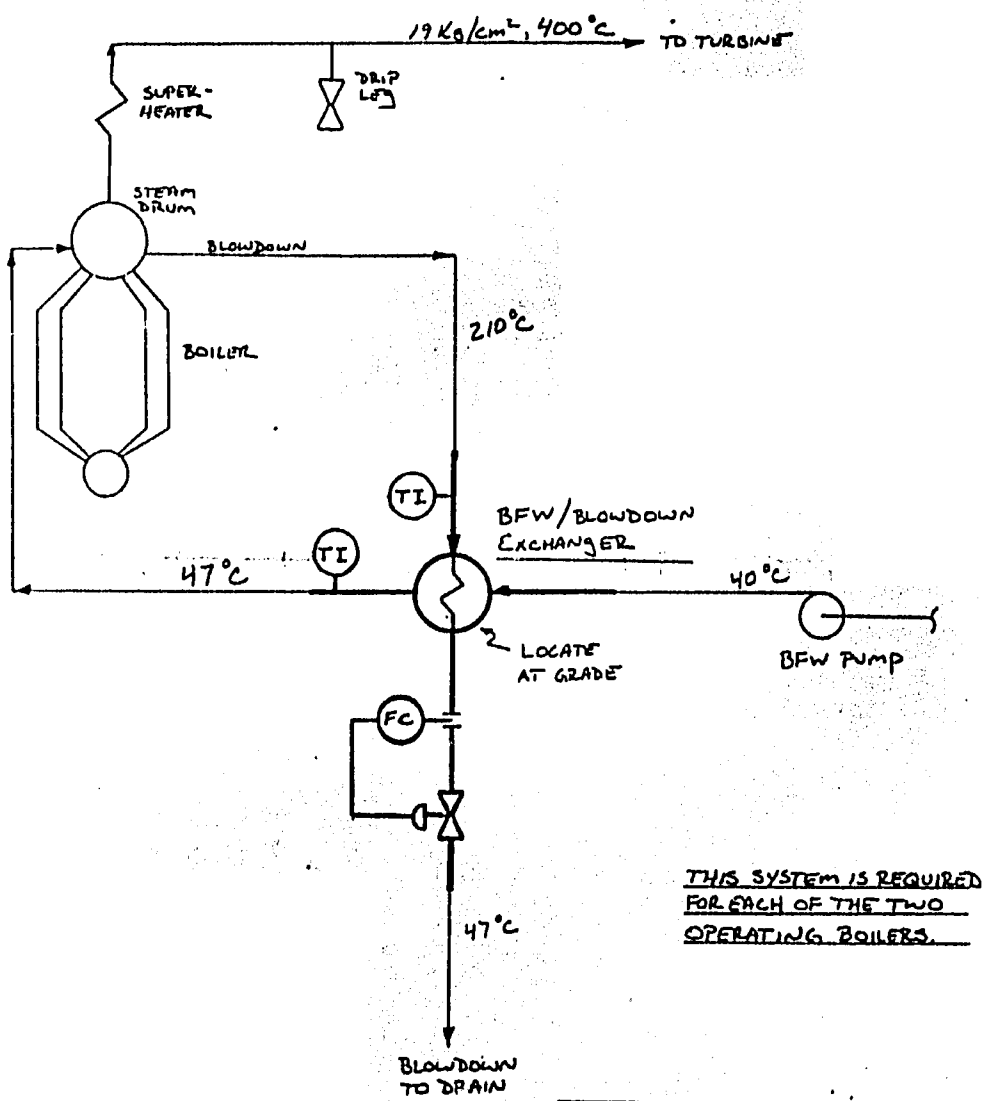
OEP / FWEC
FOR: HELWAN PORTLAND CEMENT

REF. 11-36598
DATE MAY 1988
PAGE
REV.



THIS SYSTEM IS REQUIRED FOR EACH OF THE TWO OPERATING BOILERS.

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 05

PLANT HELWAN PORTLAND CEMENT COMPANY

LOCATION HELWAN, EGYPT

POWER HOUSE

CHECK COMBUSTION EFFICIENCY OF STEAM BOILERS

Annual Savings, TOE	:	1678.
Annual Savings, $	:	193,656.
Investment Cost, $	:	174,600.
Payout: Simple, Yrs	:	0.90
DCF, %	:	--

ECO-06

1.0 PURPOSE

The purpose of this ECO is to improve the overall efficiency of the power house boilers. Combustion efficiency of the power house boilers is highly effected by the oxygen content of the flue gas or excess air. Additionally, combustion efficiency is effected by the degree to which combustion is completed.

2.0 PROCESS DESCRIPTION

The boiler firing rate is manually adjusted in accordance with the required steam demand. Air entering through the burner registers mixes with the misted fuel oil at the burner throat and should be mixed sufficiently to produce complete combustion. Air is forced into the burner registers that are located in a common plenum box by way of a forced draft fan.

When normal load changes of the boiler are made, air should be adjusted with the inlet box dampers located on the forced draft fan. Fine tuning of the air to produce desirable flame patterns and eliminate normal maldistribution that exists in the air paths for the individual burners is accomplished with the burner registers located on each burner. In normal practice the burner registers are not adjusted as boiler loads change. Once air registers are set, the air distribution should remain constant at all boiler loads. Therefore, the only adjustment that should be made is at the forced draft fan.

Monitoring of the flue oxygen provides the operator of the boiler with the information that is needed so that adjustments in the forced draft fan can be made as operating conditions change. It is absolutely imperative that all boilers with a significant load have permanently installed and operating oxygen analyzers.

The condition and design of the burners must be such that complete mixing of the oil and air streams occurs. If a very good degree of mixing is not accomplished in the burners, complete combustion cannot occur. This means that some of the hydrocarbons that are supplied in the oil are not able to complete the oxidation reaction and do not liberate heat. The net result is an effective reduction in the heating value of the fuel oil that is supplied. When smoke is seen in the stack exhaust or in the radiant

section of the boiler this is an indication that combustion is not complete. The existence of carbon monoxide is also an indication of this condition.

Installation of oxygen analyzers in the stack of each boiler and the possible replacement of the burners will make it possible to operate the power house boilers at a stack oxygen level of 3 percent. It is also suggested that the oxygen analyzers have attached combustible analyzers. Design improvements in burners have made it possible to provide excellent combustion efficiency at very low levels of excess air. If the existing burners cannot produce the desired oxygen levels in the flue gas, while also providing complete combustion with well defined flame patterns, burner replacement will be required.

Provided that the burners are replaced it may be necessary to replace the forced draft fans to supply the additional pressure that may be needed for the new burners. This will be determined by the burner manufacturer when the burners are designed.

3.0 EQUIPMENT LIST/SIZE

2 (two) oxygen and combustibles analyzers (as supplied by Thermox Corp. or Teledyne Analytical Instruments Corp.)

10 (ten) oil only burners (as supplied by John Zink corp. or Hamworthy Limited)

2 (two) forced draft fans with variable inlet vanes.

Short runs of duct work to mate up with the new fans.

4.0 PREDICTED ENERGY SAVINGS

A flue gas oxygen reduction from the present 12.5 percent to the proposed 3 percent will improve the overall boiler efficiencies from 73.3 percent to 84.8 percent.

ANNUAL ENERGY SAVINGS	
T.O.E.	TONS MAZOUT
1678	1728

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for purchasing and installing the equipment listed above is listed below for both worldwide and local equipment and utility costs.

INVESTMENT COST		ANNUAL ENERGY COST SAVINGS	
$	LE	$	LE
174,600	391,200	193,656	48,384

- 64

6.0 CONCLUSIONS

This ECO will provided a rapid and considerable payout. Oxygen analyzers should be installed first. If the oxygen levels cannot be reduced with the existing firing equipment then replacement of the burners and possibly the fans should be carried out.

7.0 RECOMMENDATIONS

This ECO should be implemented at the earliest opportunity. It will be absolutely necessary to instruct the operators of the boilers in the proper operation of the above improvements, including equipment maintenance and instrument calibration.

POWER HOUSE

INSTALLATION OF A CONDENSATE RECOVERY SYSTEM FOR EXISTING MAZOUT HEATER AND DRIP LEGS.

Annual Savings, TOE	:	210
Annual Savings, $	:	24,198
Investment Cost, $	:	36,730
Payout: Simple, Yrs	:	1.52
DCF, %	:	--

ECO-07

1.0 PURPOSE

The purpose of this ECO is to install a condensate recovery system for the existing mazout heater and steam header drip legs to recover the condensate presently discharged to the sewer.

2.0 PROCESS DESCRIPTION

At present the condensate from both the mazout heaters and drip legs in the power house is sent hot to the sewer. It is proposed to provide an atmospheric flash drum and pump to pump the unrecovered condensate into an existing BFW tank.

The condensate collection system is shown in the attached sketch.

3.0 EQUIPMENT LIST/SIZE

The equipment required is listed below and shown in the sketch included at the end of this ECO.

Atmospheric flash drum:

18" pipe diameter x 1850 mm T/T

3.5 kg/cm^2g (345 kPa), 150 ^oC design

carbon steel, 75 mm insulation

Vent Condenser:

2.0 M^2 area

3.5 kg/cm^2g (345 kPa) shell design

5.3 kg/cm^2g (520 kPa) tubes design

carbon steel shell and tubes

66

Condensate Pump:

2.0 kg/cm^2 (196 kPa) differential

0.5 M^3/hr condensate

Instruments: as shown

ESTIMATED PIPING LENGTH

1. Condensate piping within the power house:

Line size inches	Estimated length meters
1	50
1.5	10
2	40

4.0 PREDICTED ENERGY SAVINGS

Annual Savings	
T.O.E.	Ton mazout
210	216

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost to purchase and install the equipment and materials above is below.

Figures are based on worldwide and local utility costs.

Investment Cost		Annual Energy Savings	
$	LE	$	LE
36,730	82,280	24,198	6,048

6.0 CONCLUSIONS

This ECO has a very attractive payout.

7.0 RECOMMENDATION

We recommend that the condensate be collected and pumped to the BFW tank in order to minimize the need to make the required BFW makeup water.

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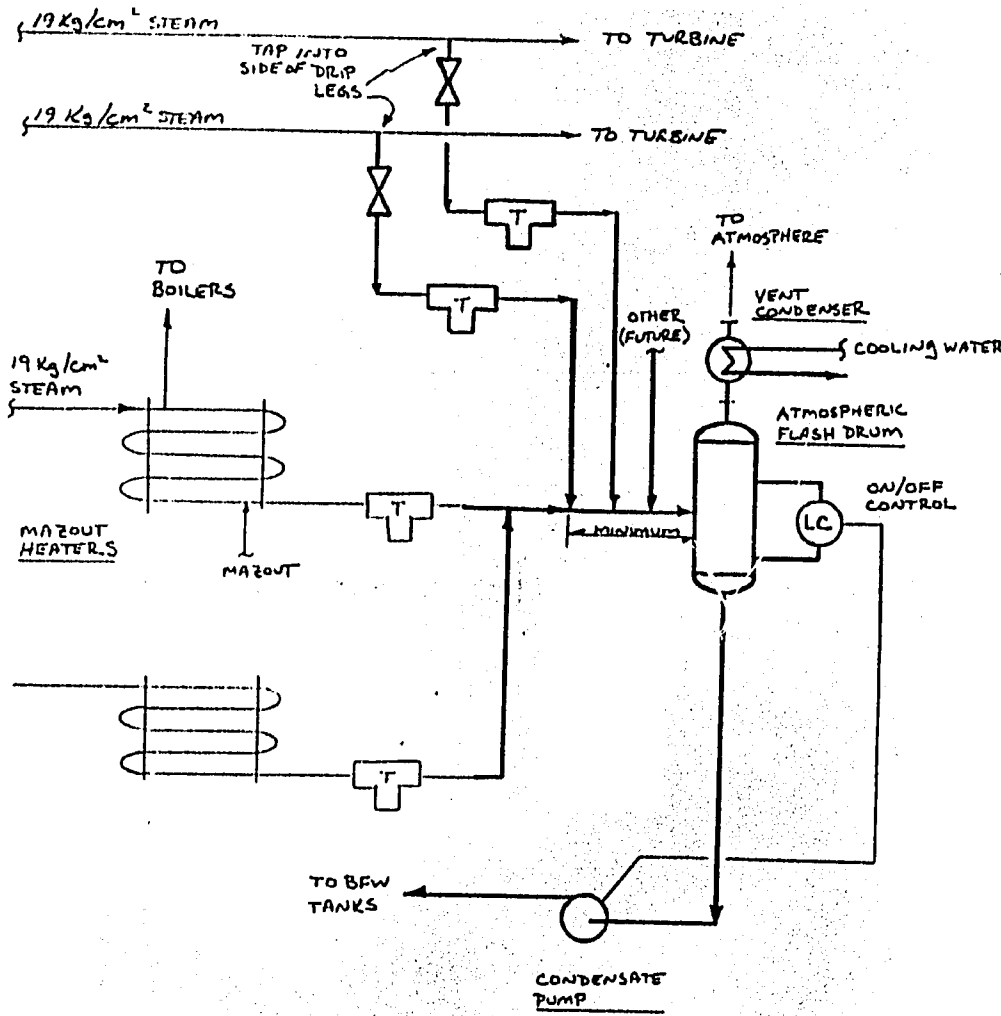
OEP / FWEC
FOR: HELWAN PORTLAND CEMENT

REF. 11-36598
DATE MAY 198
PAGE
REV.



LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUN

ECO 07

PLANT HELWAN PORTLAND CEMENT COMPANY

LOCATION HELWAN, EGYPT

68

POWER HOUSE	Annual Savings, TOE :	198.
	Annual Savings, $:	22,851.
TEST, REPAIR/REPLACE STEAM TRAPS	Investment Cost, $:	2,410.
	Payout: Simple, Yrs :	0.11
	DCF , % :	--

ECO-08

1.0 PURPOSE

The purpose of this ECO is to test, repair and replace defective steam traps.

2.0 PROCESS DESCRIPTION

All of the existing traps in the plant were tested to determine whether they were operating.

The traps were checked by visual and sonic methods. Where steam blow-through was observed, the quantity of steam loss was estimated for the purposes of this ECO.

While a visual check of steam trap operation is the best method, it can only be accomplished, if the discharge is to an open drain or if test valves to atmosphere are installed upstream and downstream of the trap. No test valves were observed in the plant.

The second method of testing used was an ultrasonic listening device. The listening device gives a fairly clear understanding of how the trap is operating.

A normally operating inverted bucket trap can be heard as a definite burst of sound when the bucket sinks and opens the trap valve, thereby discharging condensate until entering steam floats the bucket and closes the valve. In the presence of extremely low loads the bucket can be heard as a continuous clattering sound. This is sometimes referred to as a "dribbling trap". This is still a normally operating steam trap with little, if any, steam loss. This could also be an indication of an oversized trap, therefore requiring a smaller or restrictive orifice. When a trap is failed open, a continuous high frequency sound can be heard due to steam blowing through its orifice.

A definite cycle rate can be heard when a thermodynamic disc (TD) trap is operating normally as the disc is lifted off the inlet orifice allowing condensate to flow through the outlet passage, and then closes the orifice in the presence of steam. A normal operation would consist in cycles at a rate of one to maximum twenty cycles per minute (average is 6 to 10). When the cycle becomes shorter, the disc and seat of the trap start to wear at an accelerated rate and causes the trap to fail in the future. A continuous series of abrupt discharges from a thermodynamic disc trap indicates its failure in the open position.

The normal operation sounds of a float and thermostatic trap are difficult to distinguish as it is a constant flow device with no cycle rate. By shutting off the inlet valve and letting condensate accumulate, and then releasing a large condensate load to the trap, the trap can be heard opening and then modulating down to a steady state flow. The thermostatic air vent in a float and thermostatic trap in many cases opens rather infrequently to release air, making its operational condition quite difficult to determine. A thermostatic trap has a cycle, but is a much more gentle in nature than the inverted bucket or disc trap. A sub-cooling thermostatic steam trap is similar in operation to the float trap. It may have either a bellows or a bimetallic spring as the actuation device, opening and closing the trap according to a set temperature differential.

We did not use a temperature measurement method as it is the least accurate of all test methods. A surface measurement can be made at the inlet and outlet of the trap. This is merely an indication of the corresponding saturation steam pressure upstream of the trap. In the case of a completely failed trap the inlet steam will be blowing through to the trap outlet with little pressure drop. Thus the steam temperature at the inlet and outlet will be much closer to the same reading than for a properly acting trap. In a plant where a condensate recovery system is installed several traps may be tied into a common recovery line. If one trap in this group is blowing steam to its discharge, this steam can cause the discharge temperature of other traps in the group to be higher than normally expected thus leading to an erroneous decision on the condition of the trap. Thus a check of trap performance by temperature must be carefully used.

3.0 EQUIPMENT LIST/SIZE

The following are the results of the trap survey:

Location	Type	Number	Failed	Satisfactory
Mazout Heater (Boiler 2)	T.D.	2	2	0
Mazout Heater (Boiler 1)	T.D.	2	2	0
Superheated Steam Header	Float	2	0	2

As noted, 4 of the 6 traps tested were found to be defective.

The four traps on the Mazout Heaters, both in Boiler 1 and Boiler 2; were blowing through, discharging an extra large quantity of steam. We also noted that the trap bypasses were open prior to our inspection. During the trap test, the operator temporarily shut the bypasses at our request. We have therefore assumed that the total steam leakage quantity for these four traps and the bypasses would be twice the amount through the failed traps. This quantity is estimated to be approximately 300 kg/hr.

The four defective traps at the mazout heaters should be replaced by float and thermostatic type traps as they are best suited for the service.

4.0 PREDICTED ENERGY SAVINGS

Based on the results of the trap survey, 4 out of 6 traps require replacement.

As noted above, the four traps on the mazout heaters were blowing through an excessive amount of steam, estimated to be 300 kg/hr.

Annual Energy Savings

T.O.E.	Tons of mazout
198	203.9

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and cost savings are below. Figures are based on worldwide equipment costs.

Investment Cost		Annual Cost Savings	
$	LE	$	L.E.
2410	5400	22,851	5,709

6.0 CONCLUSIONS

The testing, repair and replacement of steam traps is a very attractive ECO.

7.0 RECOMMENDATION

This ECO should be implemented immediately.

72

MAZOUT STEAM BOILER	Annual Savings,	TOE	:	2.68
WHITE CEMENT	Annual Savings,	$	:	379.6
	Investment Cost,	$	:	1940.
REPAIR OF STEAM, AIR, WATER	Payout: Simple,	Yrs	:	5.11
AND CONDENSATE LEAKS	DCF,	%	:	9.0
FROM PIPING				

ECO-09

1.0 PURPOSE

The purpose of this ECO is to repair steam, air, water and condensate leaks from valves, lines, flanges, etc. to minimize energy losses.

2.0 PROCESS DESCRIPTION

A detailed survey was made of the steam, air, water and condensate leaks in the plant. All leaks were tagged and identified during the preaudit phase. The size of each leak was estimated as either small, medium, large or extra large. Only one steam leak was noticed. No air or condensate leaks were present.

3.0 NUMBER OF STEAM, AIR, CONDENSATE LEAKS

Steam	:	1	(PSV on north boiler)
Air	:	0	
BFW/condensate	:	0	

Total Leakage 5 kg/hr or 37.2 tons/yr (310 days/yr)

4.0 PREDICTED ENERGY SAVINGS

The anticipated energy savings, after repairing the steam leak, is below:

ANNUAL ENERGY SAVINGS	
T.O.E.	TONS DIESEL
2.68	2.52

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for replacing the above-mentioned PSV is below. Figures are based on worldwide and local equipment and utility costs.

INVESTMENT COST		ANNUAL ENERGY COST SAVINGS	
$	LE	$	LE
1940	4340	379.6	151.2

6.0 CONCLUSIONS

The size of the leak does not warrant the replacement of the PSV. This leak should be watched for signs of increasing leak rate.

7.0 RECOMMENDATION

This ECO should be postponed.

-74

MAZOUT STEAM BOILER
WHITE CEMENT

ADD NEW OR REPAIR EXISTING INSULATION ON STEAM AND MAZOUT LINES.

Annual Savings, TOE	:	36.5
Annual Savings, $	:	5,167
Investment Cost, $	:	2,782
Payout: Simple, Yrs	:	0.54
DCF , %	:	--

ECO-10

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on piping in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine locations of hot piping that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to provide new insulation where none is currently installed on the piping and to replace existing insulation in those locations where this insulation is judged to be in bad condition and is visibly not effective for heat conservation.

The pipe sizes and lengths to be insulated were measured. The lengths include flanges and valves that were not presently insulated. The required insulation thicknesses were then determined by use of the "Heatalyzer" Economic Insulation Thickness computer program. The "Optimum Insulation Thickness and Energy Savings" table is included in this report as a separate ECO titled, "Study the Effects of Insulation on Heat Loss From Pipes."

75

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by pipe size, length and service.

Steam Piping - Header Conditions: 686 kPa (7 kg/cm2)
170 °C Saturated

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
0.75	2	19,913,582
1.5	3	50,617,908
2	2	41,697,600
3	23	677,428,145

Condensate Return - Header Conditions: 70 kPa, 120 °C
(0.7 kg/cm2)

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
0.75	24	137,852,265

BFW Line - Header Conditions : 100 °C

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
1.5	3	21,377,466
2	17	147,341,448

Mazout Lines - Header Conditions : 50 °C

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
2	6	15,055,812
4	9	39,605,274

TOTAL ENERGY SAVINGS : 1.151×10^9 kJ
(Based on 7446 Hr/Yr)

Insulation to be mineral wool. Jacketting to be galvanized steel.

76

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer Economic Thickness" computer program determines the heat saved in $/ft. of pipe for various line sizes and at different operating fluid temperatures. It also calculates the economic insulation thickness. These heat savings are summarized as follows based on worldwide costs:

Annual Savings	
T.O.E.	Ton diesel
36.5	34.3

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to all piping is below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
2,782	4,034	5,167	2,058

6.0 CONCLUSIONS

Insulation should be applied to bare lines in plants including those where insulation is in poor condition.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

-77-

MAZOUT STEAM BOILER	Annual Savings, TOE :	9.28
WHITE CEMENT	Annual Savings, $:	1,315
	Investment Cost, $:	1,410
INSULATE BOILER	Payout: Simple, Yrs :	1.07
FEEDWATER TANKS	DCF , % :	--

ECO-11

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on the boiler feed water and make-up tanks in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine the locations of vessels that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to determine the energy savings by providing new insulation where none is currently installed on the vessels.

The vessels to be insulated were measured for size and temperature. The required insulation thicknesses were then determined by use of the "Heatalyzer" Economic Insulation Thickness computer program.

The results of this program are summarized in this ECO.

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by vessel surface.

BFW Tank
Vessel Temperature - 100 °C Design

Location	Estimated Area, M^2	Annual Energy Savings, kJ
Sides/Heads	10	243,500,000

Make-up Tank
Vessel Temperature - 50 °C Design

Location	Estimated Area, M^2	Annual Energy Savings, kJ
Sides/Heads	7	48,735,770

TOTAL ENERGY SAVINGS : 0.292×10^9 kJ
(Based on 7446 Hr/Year)

-78-

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer Economic Thickness" computer progra determines the heat saved in $/sq.ft. of vessel surface a different operating fluid temperatures. It also calculate the economic insulation thickness. These heat savings ar summarized as follows based on worldwide costs:

	Annual Savings	
	T.O.E.	Ton diesel
BFW Tank	7.73	7.27
Make-up Tank	1.55	1.46
	9.28	8.73

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to the vessels is below. Figures are based on worldwide and local equipment and utility costs.

	Investment Cost		Annual Cost Savings	
	$	LE	$	LE
BFW Tank	859	1,246	1,095	436
Make-up Tank	551	799	220	88
	1410	2,045	1,315	524

6.0 CONCLUSIONS

Insulation should be applied to these bare vessels.
Priority should be given to insulating the hotter BFW Tank.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

19

WHITE CEMENT PLANT

CHECK COMBUSTION EFFICIENCY OF STEAM BOILERS

Annual Savings, TOE	:	4.9
Annual Savings, $	:	693.
Investment Cost, $	:	1,060.
Payout: Simple, Yrs	:	1.53
DCF, %	:	--

ECO-12

1.0 PURPOSE

The purpose of this ECO is to improve the overall efficiency of the white cement plant boilers. Combustion efficiency of the white cement plant boilers is affected by the oxygen content of the flue gas or excess air.

2.0 PROCESS DESCRIPTION

The boiler firing rate is manually adjusted in accordance with the required steam demand. Air entering through the burner mixes with the misted fuel oil at the burner throat and should be mixed sufficiently to produce complete combustion. Air is forced into the burner with a self contained forced draft fan.

When normal load changes of the boiler are made, air should be adjusted with a fuel air ratio controller that is an integral part of the burner. At times it is necessary to adjustment the fuel air ratio mechanism of the burner.

Monitoring of the flue oxygen provides the operator of the boiler with the information that is needed so that adjustments can be made.

Portable oxygen analyzers such as the one used to conduct this study should be use a few times each week and adjustments can then be made in the excess air level. As these boilers are very small permanently installed oxygen analyzers can't be justified.

3.0 EQUIPMENT LIST/SIZE

Portable oxygen analyzer (such as M-C Products model 50 or Bacharach Fyrite Gas Analyzers)

4.0 PREDICTED ENERGY SAVINGS

A flue gas oxygen reduction from the present 12.1 percent to the proposed 3 percent will improve the overall boiler efficiencies from 62.0 percent to 69.1 percent.

ANNUAL ENERGY SAVINGS

T.O.E.	TONS DEISEL
4.9	4.6

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The investment cost for purchasing a portable oxygen analyzer is listed below.

The cost savings based on worldwide and local utility costs are below.

Investment Cost		Annual Cost Savings	
$	LE	$	L.E.
1060	2385	693	276

6.0 CONCLUSIONS

This ECO will provide a small savings with a nominal investment cost.

7.0 RECOMMENDATIONS

This ECO should be implemented at the earliest opportunity.

WHITE CEMENT PLANT

STUDY THE FEASIBILITY OF COMBUSTION AIR PREHEAT FOR STEAM BOILERS

Annual Savings, TOE	:	0
Annual Savings, $	:	0
Investment Cost, $	:	0
Payout: Simple, Yrs	:	0
DCF, %	:	----

ECO-13

1.0 PURPOSE

The purpose of this ECO is to study the feasibility of combustion air preheat for the white cement plant boilers. Overall combustion efficiency can be improved on many steam boilers by exchanging stack gas sensible heat with the combustion air and thus decreasing boiler fuel firing.

2.0 PROCESS DESCRIPTION

As fuel is fired into the combustion chamber of the boiler a portion of the heat that is liberated will be absorbed by the combustion air. The combustion air must be brought up to the theoretical flame temperature before combustion can occur. When combustion air is supplied at higher temperatures, less heat must be supplied or used to heat up the combustion air. The result is that less fuel need be fired into the combustion chamber.

Combustion air can be preheated by exchanging heat with hot flue gases that leave the stack of the boiler. Frequently, a cold enough process sink does not exist to cool down the flue gases and thus sensible heat is lost to the atmosphere. Combustion air provides a good cold sink at ambient temperature.

A combustion air preheater is an exchanger that does not allow leakage of flue gas into the combustion air or vice verse. Additionally, a combustion air preheater should not create considerable pressure losses in the air of flue gas paths.

The feasibility of an air preheat system is dependent on the amount of heat that is available for recovery to offset the equipment cost. In general, high stack temperatures and high load boilers are the best candidates for air preheaters. As either the stack temperature or the boiler load becomes smaller it is difficult to justify the investment in such equipment.

3.0 EQUIPMENT LIST/SIZE

No equipment is suggested due to lack of investment incentive.

82

4.0 PREDICTED ENERGY SAVINGS

No energy savings can be realized for these boilers. The stack temperature is 192 °C and therefore nominal heat is available for heat transfer. In addition the total firing of this boiler is so small that even in the event that the stack temperature was higher, it is not likely that combustion air preheat would be feasible.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

No investment is recommended and no energy savings can be realized.

6.0 CONCLUSIONS

This ECO cannot be implemented due to a lack of available heat in the stack gases. As a general rule the minimum stack temperature for an oil fired boiler is between 160 °C and 177 °C. When the stack temperature is lowered below this guideline acid dew point problems can occur. For the white cement steam boilers the actual stack temperature is only 15 °C above the upper limit of this guideline.

7.0 RECOMMENDATIONS

This evaluation finds that this ECO should not be implemented.

MAZOUT STEAM BOILER	Annual Savings, TOE :	34.6
WHITE CEMENT	Annual Savings, $:	4,895.0
	Investment Cost, $:	2,410.0
TEST, REPAIR/REPLACE	Payout: Simple, Yrs :	0.49
STEAM TRAPS	DCF , % :	--

ECO-14

1.0 PURPOSE

The purpose of this ECO is to test, repair and replace defective steam traps.

2.0 PROCESS DESCRIPTION

All of the existing traps in the plant were tested to determine whether they were operating.

The traps were checked by visual and sonic methods. Where steam blow-through was observed, the quantity of steam loss was estimated for the purposes of this ECO.

While a visual check of steam trap operation is the best method, it can only be accomplished, if the discharge is to an open drain or if test valves to atmosphere are installed upstream and downstream of the trap. No test valves were observed in the plant.

The second method of testing used was an ultrasonic listening device. The listening device gives a fairly clear understanding of how the trap is operating.

A normally operating inverted bucket trap can be heard as a definite burst of sound when the bucket sinks and opens the trap valve, thereby discharging condensate until entering steam floats the bucket and closes the valve. In the presence of extremely low loads the bucket can be heard as a continuous clattering sound. This is sometimes referred to as a "dribbling trap". This is still a normally operating steam trap with little, if any, steam loss. This could also be an indication of an oversized trap, therefore requiring a smaller or restrictive orifice. When a trap is failed open, a continuous high frequency sound can be heard due to steam blowing through its orifice.

A definite cycle rate can be heard when a thermodynamic disc (TD) trap is operating normally as the disc is lifted off the inlet orifice allowing condensate to flow through the outlet passage, and then closes the orifice in the presence of steam. A normal operation would consist in cycles at a rate of one to maximum twenty cycles per minute (average is 6 to 10). When the cycle becomes shorter, the disc and seat of the trap start to wear at an accelerated rate and causes the trap to fail in the future. A continuous series of abrupt discharges from a thermodynamic disc trap indicates its failure in the open position.

The normal operation sounds of a float and thermostatic trap are difficult to distinguish as it is a constant flow device with no cycle rate. By shutting off the inlet valve and letting condensate accumulate, and then releasing a large condensate load to the trap, the trap can be heard opening and then modulating down to a steady state flow. The thermostatic air vent in a float and thermostatic trap in many cases opens rather infrequently to release air, making its operational condition quite difficult to determine. A thermostatic trap has a cycle, but is a much more gentle in nature than the inverted bucket or disc trap. A sub-cooling thermostatic steam trap is similar in operation to the float trap. It may have either a bellows or a bimetallic spring as the actuation device, opening and closing the trap according to a set temperature differential.

We did not use a temperature measurement method as it is the least accurate of all test methods. A surface measurement can be made at the inlet and outlet of the trap. This is merely an indication of the corresponding saturation steam pressure upstream of the trap. In the case of a completely failed trap the inlet steam will be blowing through to the trap outlet with little pressure drop. Thus the steam temperature at the inlet and outlet will be much closer to the same reading than for a properly acting trap. In a plant where a condensate recovery system is installed several traps may be tied into a common recovery line. If one trap in this group is blowing steam to its discharge, this steam can cause the discharge temperature of other traps in the group to be higher than normally expected thus leading to an erroneous decision on the condition of the trap. Thus a check of trap performance by temperature must be carefully used.

3.0 EQUIPMENT LIST/SIZE

The following are the results of the trap survey:

Location	Type	Number	Failed	Satisfactory
Mazout Heater (#1)	T.D.	2	2	0
Mazout Heater (#2)	T.D.	2	2	0

As noted all of the 4 traps tested were indicated to be defective since they were blowing an excessive quantity of steam. This quantity is estimated to be approximately 53 kg/hr.

4.0 PREDICTED ENERGY SAVINGS

Based on the results of the trap survey all of the 4 traps required replacement.

As noted above, the four traps on the mazout heaters were blowing through an excessive amount of steam estimated to be 53 kg/hr.

Annual Energy Savings	
T.O.E.	Tons of Diesel
34.6	32.5

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and cost savings are below. Figures are based on worldwide equipment costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
2,410	5400	4895	1950

6.0 CONCLUSIONS

The testing, repair and replacement of steam traps has a very rapid payout.

7.0 RECOMMENDATION

This ECO should be implemented immediately.

MAZOUT STEAM BOILER	Annual Savings, TOE :	224.4
FACTORY 2	Annual Savings, $:	31,785
	Investment Cost, $:	750
REPAIR OF STEAM, AIR, WATER	Payout: Simple, Yrs :	7 days
AND CONDENSATE LEAKS	DCF, % :	--
FROM PIPING.		

ECO-15

1.0 PURPOSE

The purpose of this ECO is to repair steam, air, water and condensate leaks from valves, lines, flanges, etc. to minimize energy losses.

2.0 PROCESS DESCRIPTION

A detailed survey was made of the steam, air, water and condensate leaks in the plant. All leaks were tagged and identified during the preaudit. The size of each leak was estimated as either small, medium, large or extra large. No air leaks were noticed. Four definite steam leaks and one condensate leak were present.

3.0 NUMBER OF STEAM, AIR, CONDENSATE LEAKS

Steam	:	4	(small steam leaks through valves and flanges at main steam header) - 20 kg/hr
Air	:	0	
BFW/condensate	:	1	(under BFW/makeup tank) - 454 kg/hr

Total Leakage 474 kg/hr or 3117 tons/yr (274 days/yr)

4.0 PREDICTED ENERGY SAVINGS

The anticipated energy savings, after repairing all of the leaks, is below:

ANNUAL ENERGY SAVINGS

T.O.E.	Tons diesel
224.4	211.0

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for repairing the above leaks is below. Figures are based on worldwide and local equipment and utility costs.

INVESTMENT COST		ANNUAL ENERGY COST SAVINGS	
$	LE	$	LE
750	1,690	31,785	12,660

87

6.0 CONCLUSIONS

For very little investment this ECO is extremely attractive.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

MAZOUT STEAM BOILER
FACTORY 2

ADD NEW OR REPAIR EXISTING INSULATION ON STEAM AND MAZOUT LINES.

Annual Savings, TOE	:	143.3
Annual Savings, $	:	20,291.0
Investment Cost, $	:	10,949.0
Payout: Simple, Yrs	:	0.54
DCF , %	:	--

ECO-16

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on piping in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine locations of hot piping that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to provide new insulation where none is currently installed on the piping and to replace existing insulation in those locations where this insulation is judged to be in bad condition and is visibly not effective for heat conservation.

The pipe sizes and lengths to be insulated were measured. The lengths include flanges and valves that were not presently insulated. The required insulation thicknesses were then determined by use of the "Heatalyzer" Economic Insulation Thickness computer program. The "Optimum Insulation Thickness and Energy Savings" table is included in this report as a separate ECO titled, "Study the Effects of Insulation on Heat Loss From Pipes."

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by pipe size, length and service.

Steam Piping - Header Conditions: 637 kPa (6.5 kg/cm2)
167 °C

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
2	135	2,403,532,501
4	15	471,126,731

89

Condensate Return - Header Conditions: 70 kPa, 120 °C (0.7 kg/cm2)

Line Size, in	Estimated Length, M	Annual Energy Savings, kJ
1.5	50	428,298,300
2	115	1,211,297,760

TOTAL ENERGY SAVINGS : 4.514×10^9 kJ
(Based on 7920 Hr/Year unless otherwise stated)

Insulation to be mineral wool. Jacketting to be galvanized steel.

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer Economic Thickness" computer program determines the heat saved in $/ft. of pipe for various line sizes and at different operating fluid temperatures. It also calculates the economic insulation thickness. These heat savings are summarized as follows based on worldwide costs:

Annual Savings	
T.O.E.	Ton diesel
143.3	134.7

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to all piping is below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
10,949	15,876	20,291	8,082

6.0 CONCLUSIONS

Insulation should be applied to bare lines in plants including those where insulation is in poor condition.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

MAZOUT STEAM BOILER
FACTORY 2

INSULATE BOILER FEEDWATER TANKS.

Annual Savings, TOE	:	24.3
Annual Savings, $	:	3,435.0
Investment Cost, $	:	4,329.0
Payout: Simple, Yrs	:	1.26
DCF , %	:	--

ECO-17

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on the boiler feed water and make-up tanks in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine the locations of vessels that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to determine the energy savings by providing new insulation where none is currently installed on the vessels.

The vessels to be insulated were measured for size and temperature. The required insulation thicknesses were then determined by use of the "Heatilizer" Economic Insulation Thickness computer program.

The results of this program are summarized in this ECO.

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by vessel surface.

BFW Tank
Condensate Temperature - 100 °C Design

Location	Estimated Area, M^2	Annual Energy Savings, kJ
Sides/Heads	28	615,907,000

Make-up Tank
Vessel Temperature - 50 °C Design

Location	Estimated Area, M^2	Annual Energy Savings, kJ
Sides/Heads	24	145,759,000

TOTAL ENERGY SAVINGS : 0.762×10^9 kJ
(Based on 6570 Hr/Year)

Insulation to be mineral wool. Jacketting to be galvanized steel.

.91

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer Economic Thickness" computer program determines the heat saved in $/sq.ft. of vessel surface at different operating fluid temperatures. It also calculates the economic insulation thickness. These heat savings are summarized as follows based on worldwide costs:

	Annual Savings	
	T.O.E.	Ton diesel
BFW Tank	19.6	18.4
Make-up Tank	4.7	4.4
	24.3	22.8

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to the vessels is below. Figures are based on worldwide and local equipment and utility costs.

	Investment Cost		Annual Cost Savings	
	$	LE	$	LE
BFW Tank	2,462	3,570	2,772	1,104
Make-up Tank	1,867	2,707	663	264
	4,329	6,277	3,435	1,368

6.0 CONCLUSIONS

Insulation should be applied to these bare vessels.
Priority should be given to insulating the hotter BFW Tank.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

.92

MAZOUT STEAM BOILER	Annual Savings, TOE :	60.9
FACTORY 2	Annual Savings, $:	8,632
	Investment Cost, $:	11,150
INSULATE MAZOUT DAY TANK	Payout: Simple, Yrs :	1.29
	DCF , % :	--

ECO-18

1.0 PURPOSE

The purpose of this ECO is to provide new insulation on the mazout day tank in order to conserve energy by minimizing heat losses.

2.0 PROCESS DESCRIPTION

A detailed review was conducted during the preaudit phase to determine the locations of vessels that required new insulation to be installed. It was determined at that time that new insulation was required.

The basis of this ECO is to determine the energy savings by providing new insulation where none is currently installed on the vessels.

The vessels to be insulated were measured for size and temperature. The required insulation thicknesses were then determined by use of the "Heatalyzer" Economic Insulation Thickness computer program.

The results of this program are summarized in this ECO.

3.0 EQUIPMENT LIST/SIZE

The following tabulations list the insulation requirements by vessel surface.

Mazout Tank
Vessel Temperature - 60 °C Design

Location	Estimated Area, M^2	Annual Energy Savings, kJ
Sides	113	1,470,102,700
Top	28	447,727,800

TOTAL ENERGY SAVINGS : 1.918×10^9 kJ
(Based on 6570 Hr/Year)

Insulation to be mineral wool. Jacketting to be galvanized steel.

92

4.0 PREDICTED ENERGY SAVINGS

The "Heatalyzer Economic Thickness" computer program determines the heat saved in $/sq.ft. of vessel surface at different operating fluid temperatures. It also calculates the economic insulation thickness. These heat savings are summarized as follows based on worldwide costs:

Annual Savings	
T.O.E.	Ton diesel
60.9	57.3

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying the economic thickness of insulation to the vessels is below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
11,150	16,167	8,632	3,438

6.0 CONCLUSIONS

Insulation should be applied to this bare vessel.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

DRY CEMENT PLANT	Annual Savings, TOE :	3.6
	Annual Savings, $:	512.
CHECK COMBUSTION EFFICIENCY	Investment Cost, $:	1,060.
OF STEAM BOILERS	Payout: Simple, Yrs :	2.07
	DCF, % :	--

ECO-19

1.0 PURPOSE

The purpose of this ECO is to improve the overall efficiency of the white cement plant boilers. Combustion efficiency of the white cement plant boilers is effected by the oxygen content of the flue gas or excess air.

2.0 PROCESS DESCRIPTION

The boiler firing rate is manually adjusted in accordance with the required steam demand. Air entering through the burner mixes with the misted fuel oil at the burner throat and should be mixed sufficiently to produce complete combustion. Air is forced into the burner with a self contained forced draft fan.

When normal load changes of the boiler are made, air should be adjusted with a fuel air ratio controller that is an integral part of the burner. At times it is necessary to adjustment the fuel air ratio mechanism of the burner.

Monitoring of the flue oxygen provides the operator of the boiler with the information that is needed so that adjustments can be made.

Portable oxygen analyzers such as the one used to conduct this study should be use a few times each week and adjustments can then be made in the excess air level. As these boilers are very small permanently installed oxygen analyzers can't be justified.

3.0 EQUIPMENT LIST/SIZE

Portable oxygen analyzer(such as M-C Products model 50 or Bacharach Fyrite Gas Analyzers)

4.0 PREDICTED ENERGY SAVINGS

A flue gas oxygen reduction from the present 8.5 percent to the proposed 3 percent will improve the overall boiler efficiencies from 85.5 percent to 88.5 percent.

ANNUAL ENERGY SAVINGS

T.O.E.	TONS DFISEL
3.6	3.4

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

No investment required. It is assumed that a portable oxygen analyzer will be available at the cement plant.

The cost savings based on worldwide and local utility costs are below.

Investment Cost		Annual Energy Cost Savings	
$	LE	$	LE
1,060	2,385	512	204

6.0 CONCLUSIONS

This ECO will provide a small savings with a nominal investment cost.

7.0 RECOMMENDATIONS

This ECO should be implemented at the earliest opportunity.

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MAZOUT STEAM BOILER
FACTORY 2

STUDY THE FEASIBILITY OF COMBUSTION AIR PREHEAT FOR STEAM BOILERS

Annual Savings, TOE	:	Not Required
Annual Savings, $	:	(See Text)
Investment Cost, $	:	"
Payout: Simple, Yrs	:	"
DCF, %	:	--

ECO-20

1.0 PURPOSE

The purpose of this ECO is to study the feasibility of combustion air preheat for the dry cement plant boilers. Overall combustion efficiency can be improved on many steam boilers by exchanging stack gas sensible heat with the combustion air and thus decreasing boiler fuel firing.

2.0 PROCESS DESCRIPTION

As fuel is fired into the combustion chamber of the boiler a portion of the heat that is liberated will be absorbed by the combustion air. The combustion air must be brought up to the theoretical flame temperature before combustion can occur. When combustion air is supplied at higher temperatures, less heat must be supplied or used to heat up the combustion air. The result is that less fuel need be fired into the combustion chamber.

Combustion air can be preheated by exchanging heat with hot flue gases that leave the stack of the boiler. Frequently, a cold enough process sink does not exist to cool down the flue gases and thus sensible heat is lost to the atmosphere. Combustion air provides a good cold sink at ambient temperature.

A combustion air preheater is an exchanger that does not allow leakage of flue gas into the combustion air or vice versa. Additionally, a combustion air preheater should not create considerable pressure losses in the air of flue gas paths.

The feasibility of an air preheat system is dependent on the amount of heat that is available for recovery to offset the equipment cost. In general, high stack temperatures and high load boilers are the best candidates for air preheaters. As either the stack temperature or the boiler load becomes smaller it is difficult to justify the investment in such equipment.

3.0 EQUIPMENT LIST/SIZE

No equipment is suggested due to lack of investment incentive.

-91

4.0 PREDICTED ENERGY SAVINGS

No energy savings can be realized for these boilers. The stack temperature is 165 ^{o}C and therefore no heat is available for heat transfer.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

No investment is recommended and no energy savings can be realized.

6.0 CONCLUSIONS

This ECO cannot be implemented due to a lack of available heat in the stack gases. As a general rule the minimum stack temperature for an oil fired boiler is between 160 ^{o}C and 177 ^{o}C. When the stack temperature is lowered below this guideline acid dew point problems can occur.

7.0 RECOMMENDATIONS

This evaluation finds that this ECO should not be implemented.

98

MAZOUT STEAM BOILER	Annual Savings, TOE :	107.0
FACTORY 2	Annual Savings, $:	15,214.0
	Investment Cost, $:	625.0
TEST, REPAIR/REPLACE, ADD	Payout: Simple, Yrs :	15 days
STEAM TRAPS	DCF , % :	--

ECO-21

1.0 PURPOSE

The purpose of this ECO is to test, repair, or replace defective steam traps and add new traps where needed.

2.0 PROCESS DESCRIPTION

All of the existing traps in the plant were tested to determine whether they were operating.

The traps were checked by visual and sonic methods. Where steam blow-through was observed, the quantity of steam loss was estimated for the purposes of this ECO.

While a visual check of steam trap operation is the best method, it can only be accomplished, if the discharge is to an open drain or if test valves to atmosphere are installed upstream and downstream of the trap. No test valves were observed in the plant.

The second method of testing used was an ultrasonic listening device. The listening device gives a fairly clear understanding of how the trap is operating.

A normally operating inverted bucket trap can be heard as a definite burst of sound when the bucket sinks and opens the trap valve, thereby discharging condensate until entering steam floats the bucket and closes the valve. In the presence of extremely low loads the bucket can be heard as a continuous clattering sound. This is sometimes referred to as a "dribbling trap". This is still a normally operating steam trap with little, if any, steam loss. This could also be an indication of an oversized trap, therefore requiring a smaller or restrictive orifice. When a trap is failed open, a continuous high frequency sound can be heard due to steam blowing through its orifice.

A definite cycle rate can be heard when a thermodynamic disc (TD) trap is operating normally as the disc is lifted off the inlet orifice allowing condensate to flow through the outlet passage, and then closes the orifice in the presence of steam. A normal operation would consist in cycles at a rate of one to maximum twenty cycles per minute (average 6-10). When the cycle becomes shorter, the disc and seat of the trap start to wear at an accelerated rate and causes the trap to fail in the future. A continuous series of abrupt discharges from a thermodynamic disc trap indicates its failure in the open position.

The normal operation sounds of a float and thermostatic trap are difficult to distinguish as it is a constant flow device with no cycle rate. By shutting off the inlet valve and letting condensate accumulate, and then releasing a large condensate load to the trap, the trap can be heard opening and then modulating down to a steady state flow. The thermostatic air vent in a float and thermostatic trap in many cases opens rather infrequently to release air, making its operational condition quite difficult to determine. A thermostatic trap has a cycle, but is a much more gentle in nature than the inverted bucket or disc trap. A sub-cooling thermostatic steam trap is similar in operation to the float trap. It may have either a bellows or a bimetallic spring as the actuation device, opening and closing the trap according to a set temperature differential.

We did not use a temperature measurement method as it is the least accurate of all test methods. A surface measurement can be made at the inlet and outlet of the trap. This is merely an indication of the corresponding saturation steam pressure upstream of the trap. In the case of a completely failed trap the inlet steam will be blowing through to the trap outlet with little pressure drop. Thus the steam temperature at the inlet and outlet will be much closer to the same reading than for a properly acting trap. In a plant where a condensate recovery system is installed several traps may be tied into a common recovery line. If one trap in this group is blowing steam to its discharge, this steam can cause the discharge temperature of other traps in the group to be higher than normally expected thus leading to an erroneous decision on the condition of the trap. Thus a check of trap performance by temperature must be carefully used.

100

3.0 EQUIPMENT LIST/SIZE

The following are the results of the trap survey:

Location	Type	Number	Failed	Satisfactory
Steam Header (Boiler House)	T.S.	1	1	0
Mazout Day Tank	Float	1	0	1

The trap on the steam header in the boiler house was blowing an excessive amount of steam. This defective trap should be replaced by a thermodynamic type trap as it is best suited for this service. The float trap on the Mazout Day tank appeared to be operating satisfactorily. The steam loss through the boiler house trap is estimated to be 31.55 kg/hr.

We did not see any traps for the steam tracing on the Mazout line from the Day Tank to the Boiler. Since this line runs in a trench, it is difficult to install a trap and also it will be necessary to install a long condensate return header to the boilers. The installation of traps will reduce the amount of flash steam coming out of the condensate receiver. However, due to the associated costs, it is not advisable to provide such traps. Since, the mazout is heated in the Day Tank, to save energy, we suggest that a 1/4" (6.35 mm) orifice be installed at the end of the tracer line.

4.0 PREDICTED ENERGY SAVINGS

Based on the results of the trap survey 1 of the 2 traps required replacement.

As noted above, the trap on the Boiler House steam header was blowing through an excessive amount of steam estimated to be 31.5 kg/hr. And 260 kg/hr steam can be saved by shutting off the steam tracing on Mazout line as described in Section 3.0.

Annual Energy Savings	
T.O.E.	Tons of Diesel
107	101

101

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and cost savings are below. Figures are based on worldwide equipment costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
625	1400	15,214	6,060

6.0 CONCLUSIONS

The testing, repair and replacement of steam traps has very attractive payout.

7.0 RECOMMENDATION

This ECO should be implemented immediately.

102

DRY KILNS - FACTORY 2	Annual Savings, TOE :	40,868
	Annual Savings, $:	4,717,475
CHECK EFFICIENCY OF KILNS	Investment Cost, $:	0
	Payout: Simple, Yrs :	Immediate
	DCF , % :	--

ECO-22

1.0 PURPOSE

The purpose of this ECO is to study the consumption of energy in the two dry kilns of Factory 2. The dry kilns of Factory 2 are of modern European design and incorporate a state-of-the-art processing scheme which should, in turn, make this factory extremely energy efficient. In addition to the normal variables that affect the thermal efficiency of the kiln, such as excess air, water content of feed, dust loss, and refractory, a more important variable at HPCC is the quality of the raw materials used to make the clinker.

2.0 PROCESS DESCRIPTION

The dry cement process at Factory 2 utilizes a flash calciner upstream of the kiln. Approximately two-thirds of the total fuel fired in Factory 2 is fired in the flash calciner. The ratio of two-thirds fuel fired in the flash calciner to one-third fired in the kiln agrees well with the general 60:40 ratio now used in modern designs. However, the total amount of fuel fired per ton of clinker is excessive due to the high alkali content of the feed.

The feed to the dry process at Factory 2 is high in alkalis, in particular, and sulfates. These feed impurities are at levels beyond those for which the units were designed to operate. A significant amount of additional heat is required to remove volatilized alkali compounds. These alkali compounds are then carried out with the kiln off-gas through the flash calciner bypass. It has been estimated that 7,200 Btu/short ton (2000 Kcal/metric ton) is lost for each one percent of bypass.[1] The minimum bypass heat loss is possible only when the proper portion of the clinker-cooler air goes directly to the precalciner and not to the kiln for removing alkali compounds.

As the dry kilns at HPCC are of state-of-the-art design, it is concluded that the excessive amount of energy necessary to produce a ton of clinker is primarily due to the impurities in the raw materials. It is expected that the fuel energy consumption levels will drop approximately 18% to typical design fuel energy consumption figures of 3.4 x

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[1]"Energy Conservation Potential in the Cement Industry," U.S. Dept. of Commerce, National Technical Information Conservation Paper No. 26, pg. 161.

103

10^9 J/ton once the quality of feed to the dry kilns is improved.

A new site is already being developed that contains low impurity raw materials for the dry process at Factory 2. HPCC has stated that it will be two years before this new site is fully developed. At that time, fuel energy consumption per ton of clinker should match the value above.

3.0 EQUIPMENT LIST/SIZE

No new equipment is needed to realize the fuel energy savings possible through improvement of the raw materials. Work is already in progress to develop a new source for low impurity raw materials.

4.0 PREDICTED ENERGY SAVINGS

The future energy savings that can be expected one the feed quality to the kilns is improved is below.

Annual Energy Savings	
T.O.E.	Tons Mazout
40,868	42,094

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION.

As the development of a new site is already underway, no further investment is required. The annual cost savings based on worldwide and local utility costs is below.

Investment Cost		Annual Cost Savings	
$	L.E.	$	L.E.
0	0	4,717,475	1,178,632

6.0 CONCLUSIONS

The future fuel energy savings that will be realized when the new raw materials site is developed is tremendous, and pays out immediately.

7.0 RECOMMENDATIONS

Work should progress as rapidly as possible towards development of a better site for low impurity raw materials.

DRY KILNS - FACTORY 2

RECOVERY OF HEAT LOST THROUGH CLINKER COOLER SHELL TO PREHEAT COMBUSTION AIR

Annual Savings, TOE	:	Not
Annual Savings, $	:	Required
Investment Cost, $	:	(See Text)
Payout: Simple, Yrs	:	"
DCF , %	:	"

ECO-23

1.0 PURPOSE

The purpose of this ECO is to preheat primary combustion air to the kilns using the heat lost through the shell of the clinker coolers.

2.0 PROCESS DESCRIPTION

The rotary clinker coolers have a shell temperature of approximately 400°C. It is proposed that this heat be recovered to preheat the primary combustion air to the kilns.

This ECO requires the installation of a heat recovery system for each clinker cooler.

3.0 EQUIPMENT LIST/SIZE

See Section 6.0.

4.0 PREDICTED ENERGY SAVINGS

See Section 6.0.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

See Section 6.0.

6.0 CONCLUSIONS

Although an energy savings can be realized by preheating the primary combustion air, further investigation determined that this ECO was not feasible for implementation from an engineering standpoint. Preheating the primary combustion air would change the operating characteristics of the burner. This change in operating characteristics could result in premature burner failure as a result of burner tile collapse.

7.0 RECOMMENDATION

This ECO should not be implemented.

WET KILNS - (GREY AND WHITE) FACTORY 1	Annual Savings, TOE :	23,670
	Annual Savings, $:	2,202,062
	Investment Cost, $:	64,600
CHECK EFFICIENCY OF KILNS	Payout: Simple, Yrs :	8 days
	DCF , % :	--

ECO-24

1.0 PURPOSE

The purpose of this ECO is to study the consumption of energy in the eight wet kilns of Factory 1 and the White Cement Plant. The overall kiln energy consumption is dependent on the thermal efficiency of the kiln. This, in turn, is affected by excess combustion air, water content of feed, quality of raw materials, dust loss, refractory type and condition, and equipment design.

2.0 PROCESS DESCRIPTION

Fuel firing rates to the wet kilns at HPCC are adjusted manually in accordance with feed flow rates and feed quality. In theory, the amount of fuel required per ton of clinker is mainly affected by the water content of the slurry feed, the quality of the feed, the excess combustion air admitted to the kiln, the condition of the kiln chain and lifter system, and the condition and type of kiln refractory.

There are several common methods used to reduce the amount of energy needed to produce a ton of clinker. Reduction of excess combustion air is easily accomplished by measuring the stack oxygen content and adjusting the combustion air rate accordingly. A reduction from 25 to 15 percent excess air, for example, can reduce energy consumption by approximately 8.3 x 10^7 J/ton of clinker. Feed moisture content also directly affects the amount of energy required to produce a ton of clinker. A 5 wt% reduction in feedwater content can reduce energy consumption by approximately 3.8 x 10^8 J/ton of clinker. Proper refractory condition and type, as well as internal heat transfer systems also directly affect the overall efficiency of the kiln. A reduction of stack temperature of 100 ^oC through improved internal heat transfer can reduce energy consumption by as much as 5.0 x 10^8 J/ton of clinker.

It was noted at HPCC that the average grey cement kiln exhaust temperature was 200 ^oC. An efficient similar system would have a kiln exhaust temperature of 160 ^oC. The energy savings that can be realized by improving the efficiency of the grey cement kilns are given below and are quite substantial. The same comments apply to the white cement kilns. Here, the average stack temperatures were higher than 200 ^oC and therefore the possible energy savings per ton of clinker is even greater than for the grey cement

process. The possible energy saving in the white cement are also given below in Section 4.0.

Measured stack gas oxygen levels in the grey and white cement plants averaged 9.4% and 8.7% respectively. HPCC should obtain design information from F.L. Smidth as to the minimum operating oxygen levels achievable. New oxygen analyzers, as suggested in this ECO, can be used to achieve these minimum stack gas oxygen levels.

As with most wet cement production facilities, including the facilities at HPCC, the efficiency and heat recovery of the system should be realized inside the kiln itself. Heat that leaves the kiln should be considered as unrecoverable. The addition of special alloy chains closer to the burner, in addition to maintaining the condition and integrity of the existing chains, lifters, and refractory, will aid in the operation of the kilns at their best possible efficiency.

3.0 EQUIPMENT LIST/SIZE

It is recommended that eight (8) oxygen analyzers be installed in the kiln exhausts (one for each wet kiln). A Bailey type oxygen analyzer is recommended for this service. Information on this brand of analyzer is contained in Appendix 10.

Temperature indicators are already in place and should be maintained to enable proper operation of the wet kilns. Temperature is an indication of the condition of the refractory and chain system in the kilns and therefore should be monitored frequently.

4.0 PREDICTED ENERGY SAVINGS

The energy that can be saved through proper operation of the wet kilns is below. It has been assumed that the efficiency of the wet kilns can be improved to such an extent that the wet kilns at HPCC operate as efficiently as other wet kilns of similar design.

Annual Energy Savings			
White Cement		Grey Cement	
T.O.E.	Tons Mazout	T.O.E.	M^3 Nat Gas
4,387	4,519	19,283	21,738,685

The total energy savings listed above would reduce the overall energy required to produce a ton of cement by 21% on a joules per ton basis.

-187

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The investment required to purchase 8 oxygen analyzers is below.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
64,600	144,700	2,202,062	783,040

Note: It is not possible to isolate the portion of potential savings due to maintaining proper oxygen levels. Investment may be required to improve the efficiency of the kiln through methods described in Section 2.0.

6.0 CONCLUSIONS

The potential energy and cost savings through proper and improved operation of the wet kilns is tremendous.

7.0 RECOMMENDATIONS

The installation of oxygen analyzers is highly recommended and will prevent energy from being wasted due to high combustion air rates. Further investigation into improvements in kiln design may be required; however, the huge potential energy and cost savings will most likely result in favorable payout periods if design improvement are incorporated.

WET KILNS (GREY)	Annual Savings, TOE :	3,723
	Annual Savings, $:	328,225
INVESTIGATE FEED PREHEAT USING STACK GAS HEAT RECOVERY	Investment Cost, $:	> 4,000,000
	Payout: Simple, Yrs :	> 10 years
	DCF , % :	--

ECO-25

1.0 PURPOSE

The purpose of this ECO is to investigate feed preheat in the wet process grey kilns using heat recovered from the exhaust stacks.

2.0 PROCESS DESCRIPTION

The enthalpies of the wet process, grey cement exhaust stacks were determined through field measurements. Present stack gas temperatures are approximately 200°C. Implementation of this ECO would lower stack temperatures to approximately 160°C.

3.0 EQUIPMENT LIST/SIZE

6 - Feed preheat systems, each to consist of:

- stack gas/feed preheater
- slurry pump
- 30 M of piping (4")

4.0 PREDICTED ENERGY SAVINGS

The predicted annual energy savings is based on the total achievable heat recovery through the installation of 6 feed preheat systems in the wet process, grey cement kilns.

Annual Energy Savings

T.O.E.	Natural Gas, M^3
3,723	4,208,401

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total conceptual investment cost to purchase and install the necessary equipment and materials described below, as well as the annual cost savings are below.

Figures are based on worldwide and local equipment and utility costs.

Investment Cost	Annual Energy Cost Savings	
$	$	LE
>4,000,000	328,255	127,094

6.0 CONCLUSIONS

It was found that even though this ECO has energy saving opportunities, the technical complexity of the system and the poor economics do not warrant further investigation.

7.0 RECOMMENDATIONS

This ECO should not be implemented.

WET KILNS (GREY AND WHITE)
FACTORY 1

INVESTIGATE THE USE OF SLURRY THINNER TO REDUCE WATER CONTENT IN FEED

Annual Savings, TOE	:	5,125
Annual Savings, $	:	295,040
Investment Cost, $	:	388,100
Payout: Simple, Yrs	:	0.76
DCF , %	:	--

ECO-26

1.0 PURPOSE

The purpose of this ECO is to investigate the use of a slurry thinner to reduce the water content in the feed to the wet kilns from 38 weight % to 34 weight %. A lower water content in the feed results in a lower energy consumption per ton of clinker, since less heat is needed to vaporize water in the kiln.

2.0 PROCESS DESCRIPTION

An investigation was undertaken to determine the feasibility of using slurry thinners in the feed to the wet kilns. Slurry thinners allow the use of a lower moisture content in the raw feed, while still maintaining the physical properties needed for proper equipment operation.

Typical slurry thinners are lime, fly ash, sodium carbonate, sodium polyacrylate, and lignosulfonates. Typical addition rates range from 0.3 to 1.5 Kg/ton of clinker. For the purpose of this estimate, lime has been assumed to be a suitable slurry thinner.

3.0 EQUIPMENT LIST/SIZE

The following new equipment and materials must be furnished and installed. Refer to the attached sketch.

1. 1 - 200 M^3 hopper (cone roof, cone bottom)
   1 - 50 M^3 hopper (cone roof, cone bottom)

2. 2 systems, such as a screw conveyor and feeder, for feeding the slurry thinner at a controllable rate to the raw feed (1-540 Kg/hr, 1-64 Kg/hr).

3. A two-stage cyclone system

4. Exhaust fan and 4" transfer line.

4.0 PREDICTED ENERGY SAVINGS

The predicted energy savings would result from the use of less energy to fire the kiln. There would be less water in the raw feed, and subsequently, less water would need to be vaporized in the kiln. These heat savings are summarized as follows based on worldwide costs:

Annual Energy Savings

White Cement		Grey Cement	
T.O.E.	Ton mazout	T.O.E.	M3 natural gas
953	982	4172	4,703,205

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for implementing this ECO is as follows:

Investment Cost		Annual Cost Savings	
$	LE	$	LE
388,100	869,400	295,040	69,633

The cost of slurry thinner is estimated at $181,860/year and has been subtracted from the annual cost savings due to fuel alone.

No investment cost has been added for improvement of the kiln chain system. In general, a lower feed moisture content will result in the generation of excessive dust, leaving the kiln if the kiln chain system is not studied and/or corrected.

The accuracy of this estimate is directly dependent on the type and amount of slurry thinner used. The recommendation below states a company that can help in fine tuning this ECO.

6.0 CONCLUSIONS

The use of slurry thinners should be investigated further, as it shows an excellent energy savings.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

Slurry thinners are used successfully in plants in the U.S. Mr. S.W. Tresouthick of Construction Technology Laboratories, Skokie, Illinois, U.S.A., indicates that slurry thinners are available for many different feeds. A test program to determine possible candidates for use as thinners would cost approximately $2000-3000, according to Mr. Tresouthick. Information is included in the Appendix 7.

- 112 -

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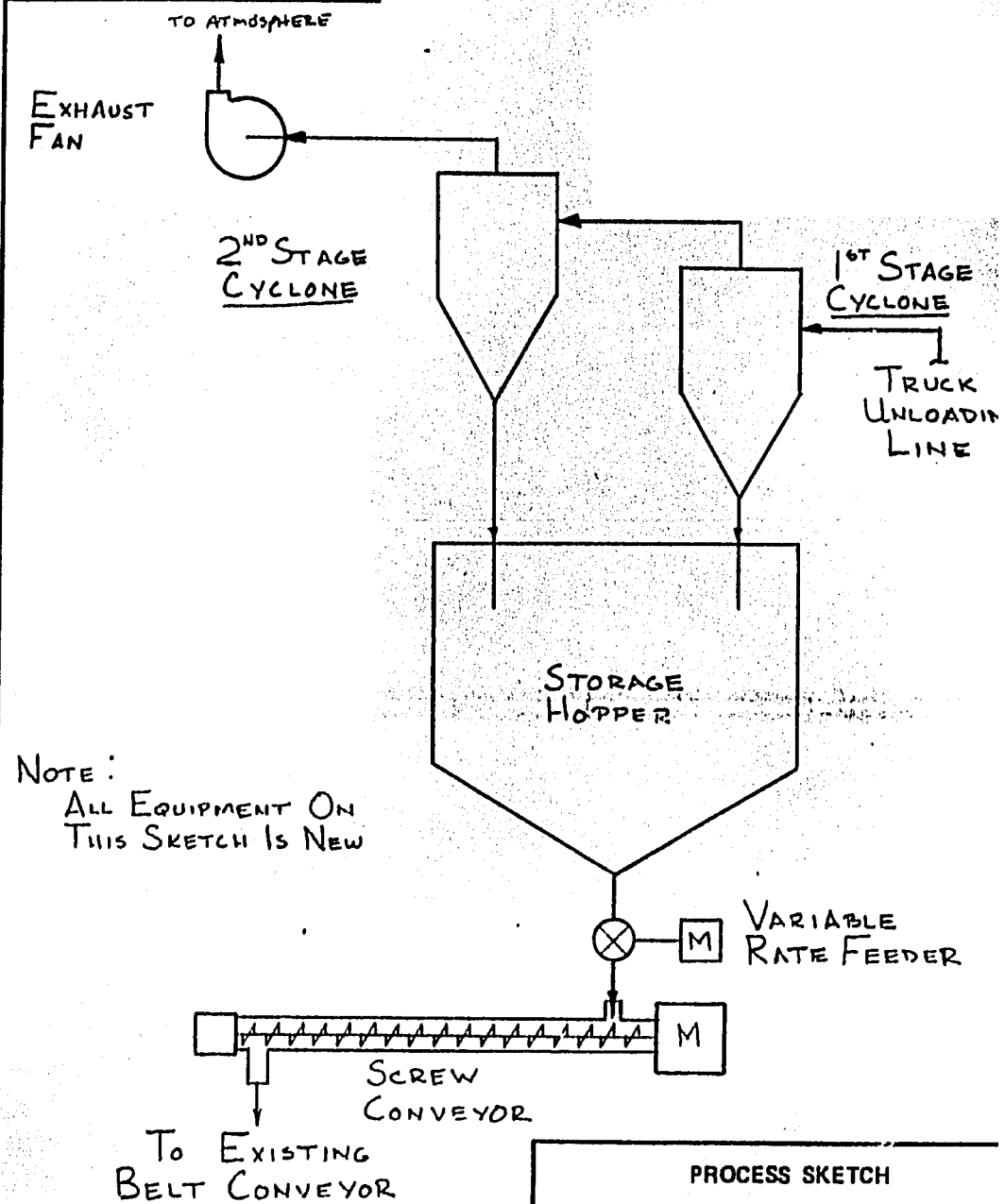

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNIT

ECO 26

PLANT HELWAN PORTLA CEMENT COMPAN

LOCATION HELWAN, EGYPT

117

WET KILNS (GREY AND WHITE) FACTORY 1	Annual Savings, TOE :	4,410
	Annual Savings, $:	755,940
	Investment Cost, $:	6,863,200
INVESTIGATE THE USE OF A ROLLER MILL TO SAVE ENERGY IN PROCESSING CLINKER	Payout: Simple, Yrs :	9.08
	DCF , % :	4.0

ECO-27

1.0 PURPOSE

The purpose of this ECO is to investigate the use a roller mill to save energy in processing clinker.

2.0 PROCESS DESCRIPTION

An investigation was undertaken to determine the feasibility of using a roller mill to process clinker in the wet kiln area. The use of a roller mill might result in significant energy savings in this plant.

3.0 EQUIPMENT LIST/SIZE

The following new equipment and materials must be furnished and installed.

1. 8 roller mills, each with a design capacity of 30 TPH.

2. All necessary ancillary equipment to replace the existing cement mills with new roller mills.

4.0 PREDICTED ENERGY SAVINGS

The predicted energy savings would result from the lower energy requirements of the roller mill, compared to the existing mills.

These savings are summarized as follows based on worldwide costs:

Annual Savings	
T.O.E.[1]	kWh
4,410	17,580,000

[1] Electrical T.O.E. values include a typical 34% efficiency factor and correspond to generating electricity using a condensing steam turbine system.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for implementing this ECO is as follows:

Investment Cost		Annual Cost Savings	
$	LE	$	LE
6,863,200	15,373,600	755,940	298,860

6.0 CONCLUSIONS

The use of a roller mill to process clinker should not be considered since the overall economics of this ECO are not attractive.

7.0 RECOMMENDATION

This ECO should not be implemented.

115

WET KILNS (GREY AND WHITE)
FACTORY 1

INVESTIGATE ENERGY SAVINGS BY CHANGING CEMENT AND RAW MILL DRIVE CONTROLS TO VARIABLE FREQUENCY (SPEED) CONTROLLERS

Annual Savings, TOE	:	3,420
Annual Savings, $	:	583,080
Investment Cost, $	:	2,274,300
Payout: Simple, Yrs	:	3.9(
DCF , %	:	13.0

ECO-28

1.0 PURPOSE

The purpose of this ECO is to incorporate variable frequency speed controllers into the proposed Factory 1 new electrical distribution system.

The variable frequency/voltage controllers (VFC) will match kW consumption to load requirements and thus produce considerable kW/kVAR savings.

This ECO as well as ECO-34 both serve to provide a more economical and efficient electrical system. Only one of these ECO's is necessary to achieve this outcome. Results from these ECO's are not additive.

2.0 PROCESS DESCRIPTION

Based on ammeter readings and power factor (PF) spot checks, the mill drives in Factory 1 appear under utilized at approximately 2/3 of full load.

Installation of variable speed drives (VFD's) will provide:

a) Soft start, i.e. no star-delta or startup resistors and controllers are required.

b) Corrected motor power factor.

c) Energy savings by matching power consumption to load requirements.

d) Savings by eliminating restrictive devices, such as control vanes, throttling valves, recirculation systems, etc.

116

The application of variable frequency controlled AC drives would be similar to the application of variable speed DC drives in Factory 2. The difference being that the AC controllers are generally higher priced but require less maintenance as compared to DC drives.

Both controllers do require reasonably clean ventilated rooms, such as a normal substation area.

The VFC variable frequency controller would replace existing oil-immersed reduced voltage control equipment.

Before implementation, a more detailed study is required for each piece of equipment to determine the status of existing equipment to be deleted and/or retained.

3.0 EQUIPMENT LIST/SIZE

The variable frequency/voltage controllers (VFC) shall be supplied complete with digital controllers, required load sensors, power fuses and disconnect contactors. Isolating transformers may be required depending on supply system. The controllers shall be programmed for expected mill loads.

The equipment required is listed below.

Existing equipment			Required equipment VFC controllers
sec. 1			
CM4	700 kW	6.3 kV	800 kW min.
sec. 5			
WRM	500 kW	6.3 kV	600 kW min.
WCM	700 kW	6.3 kV	800 kW min.
sandmill	260 kW	3.0 kV	300 kW min.
CCM	410 kW	3.0 kV	500 kW min.
CM1	630 kW	500 V	750 kW min.
CM3	560 kW	500 V	750 kW min.
RM2	570 kW	500 V	750 kW min.
RM3	560 kW	500 V	750 kW min.
RM1	635 kW	500 V	750 kW min.
CM2	560 kW	500 V	750 kW min.

4.0 PREDICTED ENERGY SAVINGS

Lacking precise operating data, the energy savings can be only estimated based on similar applications in General Electric computer program for VFC applications.

Annual Energy Savings	
T.O.E.[1]	MWH
3,420	13,560

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The final economic evaluation will be part of the new Factory 1 power distribution system. The below investment evaluation is to serve as a guideline only.

Investment	Annual Cost Savings	
$	$	L.E.
2,274,300	583,080	230,520

6.0 CONCLUSIONS

The incorporation of VFC's into the new Factory 1 distribution system will:

a) reduce power losses in the distribution system and in the processing equipment.

b) replace capacitors used on some motors, including those recommended in ECO-33 for others.

c) eliminate need for reduced voltage starting equipment.

d) improve process equipment control.

7.0 RECOMMENDATION

This ECO should be implemented as part of the new electrical power distribution system. It may also be feasible to install individual controllers selectively.

---

[1] Electrical T.O.E values include a typical 34% efficiency factor and correspond to generating electricity using a condensing steam turbine system.

GENERAL

RUN GENERATORS IN POWER HOUSE AT OR NEAR NAMEPLATE CAPACITY AND SEND THE EXCESS kW TO MAIN POWER SUPPLY GRID

Annual Savings, TOE	:	0
Annual Savings, $	:	372,603
Investment Cost, $	:	1,589,200
Payout: Simple, Yrs	:	4.27
DCF , %	:	12.0

ECO-29

1.0 PURPOSE

The purpose of this ECO is to incorporate the existing steam/diesel power plant into proposed new electrical distribution system for Factory 1. This can be used for essential loads (Kiln drives, etc.) in case of utility failure. In addition there are inherent savings in a plant generating system.

2.0 PROCESS DESCRIPTION

The present power plant is manual with mechanical speed-load governor with no provisions for synchronization into utility sytem.

The switchgear appears rather old and not suitable for plant short circuit levels.

Hence this ECO recommends the replacement of existing switchgear and cabling as required, with new up to date electrically operated switch gear, synchronization and governor control equipment, suitable for isosynchronous and droop control.

The attached one line diagram sketch indicates the system interface equipment.

3.0 EQUIPMENT LIST/SIZE

The following new equipment required for interface with plant distribution system shall be supplied complete with protective and synchronizing relays, metering, potential transformers and current transformers, etc. All switchgear is electrically operated.

S.T. Generator	1	breaker	4000 A	600 V
"	2A	breaker	1200 A	5 kV
"	2B	breaker	1200 A	5 kV
Diesel Generator	1	breaker	1600 A	600 V
"	2	breaker	1600 A	600 V
"	3	breaker	1600 A	600 V
TR1		breaker	1200 A	5 kV
TR2		breaker	4000 A	600 V

1 - synchronizing control panel complete with load and voltage control for steam turbine generators

1 - 3 mVA 6.3 - 0.5 kV transformer (part of new system)

1 - 3 mVA 6.3 - 3 kV transformer (part of new system)

Miscellaneous power buswork and control cables as required.

4.0 PREDICTED ENERGY SAVINGS

Energy savings will result from being able to operate the turbine generators at full capacity. This will result in more electricity being available in the plant during load shedding periods.

The plant will also be able to expand and improve its operations without relying on the purchased unreliable electrical supply in the summer months.

Additional Electricity Generated		Annual Additional Energy Consumed	
MW	MW/YR	T.O.E.[1]	Ton Mazout
3.6	26,806 (7446 hr/yr)	6,758	6,961

[1] Electrical T.O.E. values include a typical 34% efficiency factor and correspond to generating electricity using a condensing steam turbine system.

120

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for applying this ECO is as follows:

Investment	Cost to Produce 1 MW/HR		Savings per MWH	
$	$	L.E.	$	L.E.
1,589,200	29.1	7.27	13.9	9.73

Annual Savings	
$	LE
372,603	260,818

6.0 CONCLUSIONS

Based on the above description the existing power plant can be incorporated into the new distribution system to provide a rather economical in-plant generated power source for essential loads operation.

The kVAR's generated in plant will reduce the kVAR level from the utility's supply.

7.0 RECOMMENDATION

We recommend that this ECO be implemented.

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FOR: HELWAN PORTLAND CEMENT CO.

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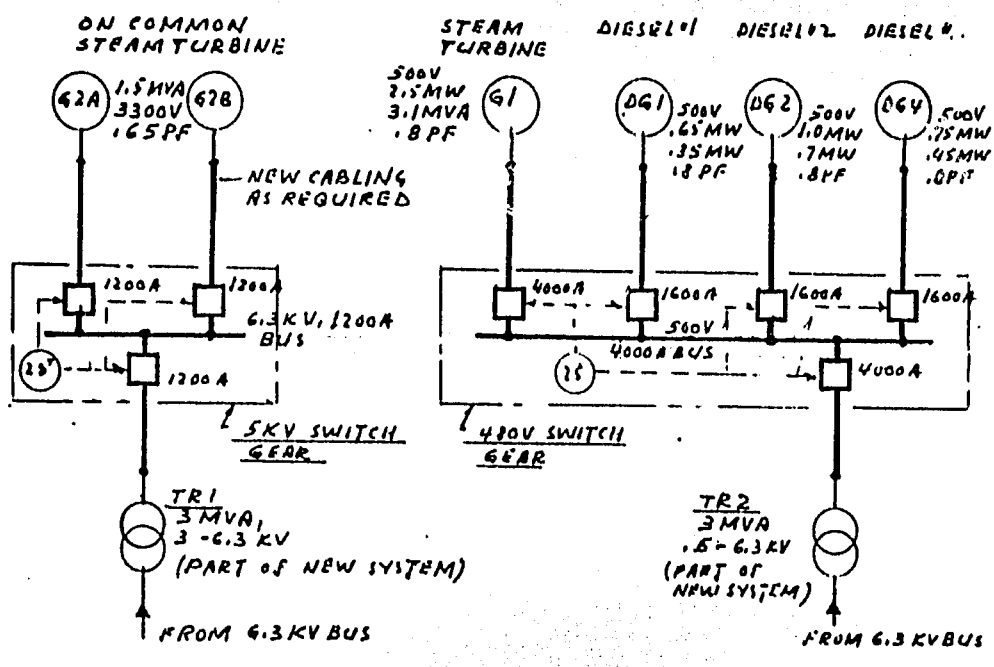

(25) SYNCHRONIZING RELAYS PT-S & ASSOCIATED CONTROLS

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 29

PLANT HELWAN PORTLAND CEMENT

LOCATION HELWAN, EGYPT

GENERAL

INVESTIGATE THE USE OF AN ELECTRICAL GENERATING BOILER PACKAGE TO SUPPLEMENT THE POWER SUPPLY

Annual Savings, TOE	:	--
Annual Savings, $	:	2,116,475
Investment Cost, $	:	22,045,800
Payout: Simple, Yrs	:	10.4
DCF , %	:	3.0

ECO-30A

1.0 PURPOSE

The purpose of this ECO is to investigate the use of an electrical generating boiler package to eliminate the need to shed electricity in the summer months. Currently, in the summer months, the power company requires that the Helwan Portland Cement Company (and Others) "shed load" during peak periods to avoid "brown-out" or a total power failure in the city system. Load shedding, or "turn off" of less critical items of electrical gear results in shut down of the plant from its design rating to a "standby at hot conditions" state, with a power reduction from 68 MW to approximately 40 MW.

Heat losses, however, continue , and the net result is

- lost production,
- heat loss during standby with lower or no product output,
- quality control problems which arise from changing temperature conditions (during shutdown and restart from rated conditions.).

This ECO will also aid in boosting clinker production from 2,600,000 tons/yr in 1987 to the design plant capacity of 3,000,000 tons/yr.

2.0 PROCESS DESCRIPTION

The plant currently must shed its load from approximately 68 MW to approximately 40 MW during the peak time in the summer months. When this occurs, some equipment must be shut off. The plant cannot operate at full capacity during this time, and energy is wasted because of this.

The output of the electrical generator will be connected into the present plant electrical system through a new grid.

122

3.0 EQUIPMENT LIST/SIZE

The following new equipment and materials must be furnished and installed.

1. One 30 MW, 6.3 kV electrical generating boiler package. Equipment to be energy efficient.

2. All the necessary electrical wiring and controls required to tie in to the utility substation. These items are listed below.

   1 - Breaker, 6.3 kV, with potential and current transformers.

   1 - Controllers and synchronizing equipment.

4.0 PREDICTED ENERGY SAVINGS

Energy savings will result from the plant being able to operate at full capacity year-round. The shut down and start-up of equipment for load shedding purposes, will be eliminated.

In addition, the plant will be able to plan future operations without restrictions due to the present electrical supply.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost and associated energy cost savings to purchase and install the equipment and materials described above is below.

Investment Cost $	Annual Energy Cost Savings $
22,045,800	2,116,475

When generating 30 MW of electricity, approximately 93,500,000 M^3/year of natural gas and 22,713 MWH/year of electricity will be consumed. Estimated overall cost per MWH works out to be $34.05 when using worldwide costs.

6.0 CONCLUSIONS

The payout period, based on energy savings alone, is 10.4 years. Considering the disruption of cement production during the summer months and the anticipated decrease in hydro-electric generating capacity in Egypt, the actual payout period will be lower than the payout period due to energy savings alone.

7.0 RECOMMENDATION

We recommend that this ECO be abandoned and the more attractive ECO-30B be implemented in its place.

125

GENERAL

INVESTIGATE THE USE OF A GAS TURBINE ELECTRICAL GENERATOR TO SUPPLEMENT THE POWER SUPPLY

Annual Savings, TOE	:	--
Annual Savings, $	:	4,784,000
Investment Cost, $	:	14,629,100
Payout: Simple, Yrs	:	3.06
DCF , %	:	19.5

ECO-30B

1.0 PURPOSE

The purpose of this ECO is to investigate the use of a gas turbine electrical generator to eliminate the need to shed electricity in the summer months. Currently, in the summer months, the power company requires that the Helwan Portland Cement Company (and Others) "shed load" during peak periods to avoid "brown-out" or a total power failure in the city system. Load shedding, or "turn off" of less critical items of electrical gear results in shut down of the plant from its design rating to a "standby at hot conditions" state, with a power reduction from 68 MW to approximately 40 MW.

Heat losses, however, continue , and the net result is

- lost production,
- heat loss during standby with lower or no product output,
- quality control problems which arise from changing temperature conditions (during shutdown and restart from rated conditions.).

This ECO will also aid in boosting clinker production from 2,600,000 tons/yr in 1987 to the design plant capacity of 3,000,000 tons/yr.

2.0 PROCESS DESCRIPTION

The plant currently must shed its load from approximately 68 MW to approximately 40 MW during the peak time in the summer months. When this occurs, some equipment must be shut off. The plant cannot operate at full capacity during this time, and energy is wasted because of this.

The output of the electrical generator will be connected into the present plant electrical system through a new grid.

3.0 EQUIPMENT LIST/SIZE

The following new equipment and materials must be furnished and installed.

1. One 30 MW, 13.8 kV turbine generator, prepackaged with inlet and exhaust ducting, starter, switchgear, and

126

control room as required. (skid mounted)

2. All the necessary electrical wiring and controls required to tie in to the utility substation. These items are listed below.

   a. Transformer, with disconnect, 13,800 VAC, 3 phase, 50 cycle, to remove to 6,500 VAC, 3 phase, 50 cycle as required in plant. (furnished with package)

   b. Protective switchgear, with automatic and manual synchronization equipment. (furnished with package)

The gas turbine power facility would be completely pre-packaged, and shipped on modules for field erection.

Support services at site will include a foundation for the turbine generator unit, its starter, and local controls. No additional buildings or water supplies are required.

Fuel may be either natural gas or light fuel oil, as convenient to the user.

4.0 PREDICTED ENERGY SAVINGS

Energy savings will result from the plant being able to operate at full capacity year-round. The shut down and start-up of equipment for load shedding purposes, will be eliminated.

In addition, the plant will be able to plan future operations without restrictions due to the present electrical supply.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost and associated energy cost savings to purchase and install the equipment and materials described above is below.

Investment Cost $	Annual Energy Cost Savings $
14,629,100	4,784,000

When generating 30 MW of electricity, approximately 70,983,400 M^3/year of natural gas will be consumed. Estimated overall cost per MWH works out to be $23.07 when using worldwide costs, and 8000 hour per year.

6.0 CONCLUSIONS

The payout period is based on energy savings alone. Considering the disruption of cement production during the summer months and the anticipated decrease in hydro-electric generating capacity in Egypt, the actual payout period will be lower than the payout period due to energy savings alone.

7.0 RECOMMENDATION

We recommend that this ECO be implemented.

GENERAL

INVESTIGATE THE USE OF A GAS TURBINE WITH WASTE HEAT RECOVERY TO SUPPLEMENT THE POWER SUPPLY

Annual Savings, TOE	:	--
Annual Savings, $	:	6,256,000
Investment Cost, $	:	31,610,000
Payout: Simple, Yrs	:	5.0
DCF , %	:	9.0

ECO-30C

1.0 PURPOSE

The purpose of this ECO is to investigate the use of a gas turbine electrical generator with waste heat recovery to eliminate the need to shed electricity in the summer months. Currently, in the summer months, the power company requires that the Helwan Portland Cement Company (and Others) "shed load" during peak periods to avoid "brown-out" or a total power failure in the city system. Load shedding, or "turn off" of less critical items of electrical gear results in shut down of the plant from its design rating to a "standby at hot conditions" state, with a power reduction from 68 MW to approximately 40 MW.

Heat losses, however, continue , and the net result is

- lost production,
- heat loss during standby with lower or no product output,
- quality control problems which arise from changing temperature conditions (during shutdown and restart from rated conditions.).

This ECO will also aid in boosting clinker production from 2,600,000 tons/yr in 1987 to the design plant capacity of 3,000,000 tons/yr.

2.0 PROCESS DESCRIPTION

The plant currently must shed its load from approximately 68 MW to approximately 40 MW during the peak time in the summer months. When this occurs, some equipment must be shut off. The plant cannot operate at full capacity during this time, and energy is wasted because of this.

The output of the electrical generator will be connected into the present plant electrical system through a new grid.

3.0 EQUIPMENT LIST/SIZE

The following new equipment and materials must be furnished and installed.

1. One 30 MW, 13.8 kV turbine generator with waste heat recovery, prepackaged with inlet and exhaust ducting, starter, switchgear, and control room as required. (skid mounted)

2. All the necessary electrical wiring and controls required to tie in to the utility substation. These items are listed below.

   a. Transformer, with disconnect, 13,800 VAC, 3 phase, 50 cycle, to remove to 6,500 VAC, 3 phase, 50 cycle as required in plant. (furnished with package)

   b. Protective switchgear, with automatic and manual synchronization equipment. (furnished with package)

3. All associated waste heat boiler steam facilities.

The gas turbine power facility would be completely pre-packaged, and shipped on modules for field erection.

It is estimated that the steam production from the waste heat boiler package will be 100,000 lb/hr (45,360 kg/hr), and includes the steam necessary for dearation.

Gas turbine section to generate approximately 20 MW. Waste heat boiler section to generate the remaining 10 MW of electricity.

Support services at site will include foundations for the turbine generator unit, its starter, all waste heat boiler facilities, and local controls. No additional buildings are required.

Fuel may be either natural gas or light fuel oil, as convenient to the user.

4.0 PREDICTED ENERGY SAVINGS

Energy savings will result from the plant being able to operate at full capacity year-round. The shut down and start-up of equipment for load shedding purposes, will be eliminated.

In addition, the plant will be able to plan future operations without restrictions due to the present electrical supply.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost and associated energy cost savings to purchase and install the equipment and materials described above is below.

Investment Cost	Annual Energy Cost Savings
$	$
31,610,000	6,256,000

When generating 30 MW of electricity, approximately 47,322,300 M^3/year of natural gas will be consumed. Estimated overall cost per MWH works out to be $16.94 when using worldwide costs, and 8000 hour per year.

6.0 CONCLUSIONS

The payout period is based on energy savings alone. Considering the disruption of cement production during the summer months and the anticipated decrease in hydro-electric generating capacity in Egypt, the actual payout period will be lower than the payout period due to energy savings alone.

7.0 RECOMMENDATION

We recommend that this ECO be pursued. A gas turbine with waste heat recovery should be operated continuously. This type of facility is not meant for short term, intermittent operation.

131

GENERAL

IMPROVE/ADD/FIX INSTRUMENTATION TO BE ABLE TO PROPERLY MONITOR AND CONTROL ENERGY CONSUMPTION

Annual Savings, TOE	:	2,082
Annual Savings, $	:	248,824
Investment Cost, $	:	84,150
Payout: Simple, Yrs	:	0.34
DCF , %	:	--

ECO-31

1.0 PURPOSE

The purpose of this ECO is to improve/add/fix instrumentation, as required, to help conserve energy and to properly monitor its consumption.

2.0 PROCESS DESCRIPTION

A study was made regarding the instrumentation requirements for the plant. This study combined the overall requirements for instrumentation improvements, addition, and fixing. In many cases, the existing instrumentation is inadequate or non-existent and in many cases the existing instruments are not in working order.

3.0 EQUIPMENT LIST/SIZE

The equipment and material required to properly monitor and control energy consumption are described below.

Electrical:

Factory 2 & Powerhouse
2 - MW Recorders (1 each)
2 - kVAr Recorders (1 each)
2 - Ampere Recorders (1 each)

Kiln Combustion & Steam:

Powerhouse

3 - Steam FI's (6")	mounted in Control Room
3 - Mazout FI's (2")	mounted in Control Room
3 - BFW FI's	mounted in Control Room

White Cement

2 - Mazout FI's (2")	mounted in Local Panel

Factory 1

6 - Nat. Gas FI's (6")	mounted in Control Room

132

4.0 PREDICTED ENERGY SAVINGS

Since this ECO covers the plant in its entirety, there is no specific energy savings that can be pinpointed. It is, however, a conservative assumption to infer that proper instrumentation will reduce the yearly energy consumption by at least one half of one percent. The resulting energy savings are listed below.

Electrical Annual Energy Savings		Mazout Annual Energy Savings	
T.O.E.[1]	MWh	T.O.E.	Tons
442.4	1,754	1,060	1,092

Natural Gas Annual Energy Savings		Diesel Annual Energy Savings	
T.O.E.	cu. M.	T.O.E.	Tons
577	650,000	2.47	2.32

5 .0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost to purchase and install the equipment (mainly the instruments and the associated piping) and materials described above is below.

Investment Cost	Annual Energy Cost Savings	
$	$	L.E.
84,150	248,824	80,167

6.0 CONCLUSIONS

This ECO has an attractive payout. We strongly recommend that all the instruments shown on the following tabulations be added/repaired, not only to help conserve energy, but to properly monitor its consumption.

7.0 RECOMMENDATION

This ECO should be implemented without any delay.

---

[1] Electrical T.O.E. values include a typical 34% efficiency factor and correspond to generating electricity using a condensing steam turbine system.

GENERAL		
STUDY THE EFFECT OF INSULATION ON HEAT LOSS FROM PIPES.	Annual Savings, TO% :	Not Applicable
	Annual Savings, $:	
	Investment Cost, $:	"
	Payout: Simple, Yrs :	"
	DCF , % :	"

ECO-32

1.0 PURPOSE

The purpose of this ECO is to study the effects of insulation on heat loss in piping and develop a chart to be used by the plant for all future piping insulation applications.

2.0 PROCESS DESCRIPTION

A chart was developed using the Heatalyzer Economic Thickness Insulation computer program which indicates the optimum insulation requirements for different line sizes at various temperature ranges. The chart covers a range from 50 °C through 450 °C for line sizes 0.75 inch diameter through 16 inch diameter. Mineral wool insulation material with galvanized steel cover is the basis for the chart.

This chart is to be used in the future by plant personnel to specify insulation thickness on new or reinsulated lines.

3.0 EQUIPMENT LIST/SIZE

The chart on the following page was developed.

OPTIMUM INSULATION THICKNESS AND ENERGY SAVINGS PER METER

PIPE SIZE (INCHES)	TEMPERATURE - DEGREES C (F) 50 (122)	100 (212)	150 (302)	200 (392)	250 (482)	300 (572)	350 (662)	400 (752)	450 (842)		
0.75	25	25	25	37.5	37.5	62.5	75	75	75	mm	Thickness
	164	567	1078	1726	2470	3399	4464	5710	7126	kJ	Energy Savings
1	25	25	25	37.5	37.5	62.5	75	75	75	mm	Thickness
	200	692	1317	2109	3024	4167	5480	7000	8775	kJ	Energy Savings
1.5	25	25	37.5	37.5	62.5	75	75	75	75	mm	Thickness
	277	957	1824	2929	4274	5840	7671	9825	12350	kJ	Energy Savings
2	25	25	37.5	50	62.5	75	75	75	75	mm	Thickness
	337	1164	2262	3607	5222	7148	9404	12065	15190	kJ	Energy Savings
3	25	37.5	37.5	62.5	75	75	75	87.5	100	mm	Thickness
	474	1666	3182	5116	7413	10133	13367	17238	21794	kJ	Energy Savings
4	25	37.5	37.5	62.5	75	75	100	100	100	mm	Thickness
	591	2077	3972	6398	9287	12719	16890	21757	27493	kJ	Energy Savings
6	25	37.5	50	62.5	75	75	100	100	100	mm	Thickness
	829	2916	5645	9028	13143	18051	24038	31046	39325	kJ	Energy Savings
8	37.5	37.5	50	62.5	87.5	100	100	100	100	mm	Thickness
	1070	3673	7126	11418	16704	23034	34035	39551	50171	kJ	Energy Savings
10	37.5	37.5	50	75	87.5	100	100	100	100	mm	Thickness
	1298	4452	8657	13952	20358	28203	37371	48406	61473	kJ	Energy Savings
12	37.5	37.5	62.5	75	87.5	100	100	100	100	mm	Thickness
	1509	5180	10134	16244	23730	32809	43655	56599	71934	kJ	Energy Savings
14	37.5	37.5	62.5	75	87.5	100	100	100	100	mm	Thickness
	1638	5622	11007	17653	25806	35699	47525	61642	78371	kJ	Energy Savings
16	37.5	50	62.5	75	100	100	100	100	100	mm	Thickness
	1841	6394	12382	19874	29142	40249	53613	69570	88479	kJ	Energy Savings

4.0 PREDICTED ENERGY SAVINGS

Refer to insulation table. Energy savings between bare and insulated pipe (kJ) is given in the insulation table for each pipe size and temperature. Multiply this value by the length of pipe (M) and then by yearly hours of operation to obtain kJ saved per year.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

Not applicable to this ECO.

6.0 CONCLUSIONS

Based on the results of ECO's - 02, 10, and 16 which cover the addition of insulation to the existing lines in the plants, it is concluded that the use of the Insulation Thickness chart should be followed by the plant when installing new hot piping insulation.

7.0 RECOMMENDATION

This ECO should be implemented by having the plant use the chart included in this ECO for all future piping insulation application.

136

GENERAL

FUEL/AIR RATIO CONTROLLERS
FOR STEAM BOILERS
AND FURNACES

Annual Savings, TOE	:	Not
Annual Savings, $	:	Required
Investment Cost, $	:	(See Text)
Payout: Simple, Yrs	:	"
DCF, %	:	"

ECO-33

1.0 PURPOSE

The purpose of this ECO is to examine the need for fuel air ratio controllers. Fuel air ratio controllers have been used in the boiler and process fired heater industry for many years to maintain combustion air flow as boiler loads are modulated.

2.0 PROCESS DESCRIPTION

Fuel to air ratios can be calculated for various fuels so as to provide a given flue gas oxygen level. As the process load is modulated the quantity of not only the fuel flow rate should be adjusted, but the air flow rate should also be adjusted. Provided that the optimum flue gas oxygen level is maintained it can also be expected that the optimum efficiency is achieved.

In general, fuel air ratio control schemes consist of a controller that receives a signal from a temperature transmitter connected to the process outlet. The setpoint of the transmitter is the desired process outlet temperature. The output of the temperature transmitter supplies the setpoint for a fuel flow transmitter. As the outlet temperature of the process rises above the desired setpoint temperature, the fuel flow is decreased. As the outlet temperature drops below the setpoint temperature, the fuel rate is increased. The ratio controller receives the increased or decreased flow rate of fuel from a flow transmitter that senses a DP cell across a meter in the fuel supply line to the burners. The ratio controller also receives a signal from a flow transmitter that senses a DP cell installed across a meter in the air supply duct. A damper in the duct work or the inlet dampers of the forced draft fan are adjusted with an actuator in accordance with the output of the ratio controller.

A very essential part of the control scheme is the lead/lag system. The lead/lag system prevents the accidental detonation of the boiler or process fired heater. The lead/lag system assures that if the fuel rate is increased, the air flow rate is increased first. If the fuel rate was increased before the air rate, it is likely that combustible material would enter the combustion chamber without sufficient air to complete combustion. If the air rate is then increased an uncontrolled fire or explosion can occur. Where

uncontrolled fire or explosion can occur. Where fuel gas is used an explosion is very likely, if this sequence of events is allowed to occur. Where fuel oil is used a fire in the burner plenum could be expected.

The lead/lag system also assures that if the fuel demand is decreased, the air rate is decreased after the fuel rate. If the air was decreased first the possibility of combustibles entering the combustion chamber without sufficient air to complete combustion is probable. This can also cause damage to the equipment and is extremely dangerous.

In more sophisticated systems, the fuel air ratio is trimmed with a signal from the oxygen analyzer sensing the combustion chamber or the stack flue gas. In the most sophisticated systems, when the fuel composition changes either a fuel specific gravity indication or a fuel heating value indication is used to adjust the ratio.

Ultimately, the intention of these systems is to maintain the flue gas oxygen level at a minimum so that the highest level of efficiency can be maintained. Additionally, the systems are intended to provide a high level of safety while maintaining efficiency.

It must be noted that fuel air ratio control systems are not used on natural draft process fired heaters. Although, attempts have been made in using the air side burner pressure drop as an indication of air flow rate, these attempts have been unsuccessful.

Fuel air ratio systems are most useful when load changes are frequent and erratic. In general, fuel air ratio systems become economical when operator attention is at a minimum, and the instrumentation cost can be offset by reducing manpower.

3.0 EQUIPMENT LIST/SIZE

Assorted controllers,indicators,transmitters, meters, actuators, electricals and pneumatics. Refer to the attached sketch .

4.0 PREDICTED ENERGY SAVINGS

Indeterminate.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

Investment in a fuel/air ratio control system is not recommended. Refer to Sections 6.0 and 7.0.

6.0 CONCLUSIONS

Fuel air ratio control systems can save a considerable amount of fuel and operating cost. However, if boilers or process fired heaters are properly attended by operating staff the same savings can be realized without investment in a fuel air ratio control system. In the cement plant boiler loads do not change from one level of operating load to another at a rate rapid enough to prevent operating staff from being able to maintain excess air. Fuel air ratio control systems require a good amount of attention on the part of instrument technicians. If this attention is not given to the ratio control system it is reasonable to assume that no improvement over a boiler without a fuel air ratio system can be made.

7.0 RECOMMENDATIONS

This ECO is not recommended. Although as stated in other ECO's oxygen analyzers and fuel metering are very strongly recommended. This will provided the operating staff with sufficient information to maintain efficient operation of the boilers or process fired heaters. In addition, proper training and supervision of operators cannot be overemphasized.

139

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: HPCC

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PAGE
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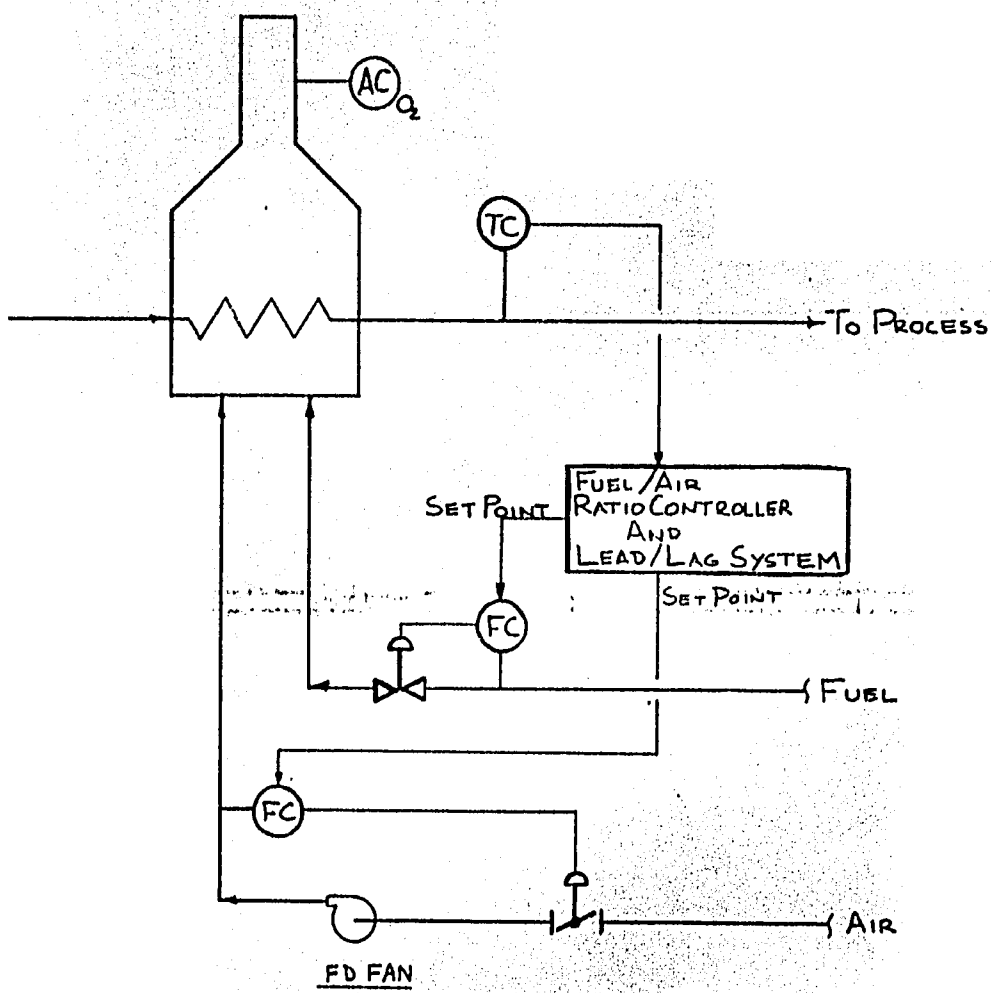

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 33

PLANT HPCC

LOCATION HELWAN, EGYPT

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

110

GENERAL

CAPACITOR INSTALLATION
TO IMPROVE POWER FACTOR
(FACTORY 1)

Annual Savings, TOE	:	787
Annual Savings, $	:	134,261
Investment Cost, $	:	103,620
Payout: Simple, Yrs	:	0.77
DCF , %	:	--

ECO-34

1.0 PURPOSE

The purpose of this ECO is to improve the existing electrical system power factor from the current value of 60-70%, as reported and spot checked, to 90-95%.

The proposed capacitor banks installation (i.e. improved higher power factor) will reduce electrical system voltage drops and associated I^2R losses in system cabling transformers, reactors, etc.

This ECO as well as ECO-28 both serve to provide a more economical and efficient electrical system. Only one of these ECO's is necessary to achieve this outcome. Results from these ECO's are not additive.

Technical articles referring to power factor correction may be found in Appendix 8.

2.0 PROCESS DESCRIPTION

The present Helwan Portland Cement Company, Factory 1, electrical system consists of an existing under utilized steam and diesel generating station feeding isolated equipment and several utility feeders for the remaining installations. In the new system proposed by HPCC, the 6.3 kV distribution system will connect Factory 1 to the Factory 2 power system which presently runs at approximately 90% power factor. At that time, Factory 1's power factor should then be approximately 90%.

3.0 EQUIPMENT LIST/SIZE

The electrical equipment required for this ECO will be capacitor banks of required kVAr and voltage rating, controlled motor controllers (circuit breakers), and supplied with fused switches and cabling as required.

The equipment required is listed below.

Existing equipment			Required equipment	
			kVAr	kV
sec. 1				
CM4	700 kW	6.3 kV	200	7.2
sec. 5				
WRM	500 kW	6.3 kV	150	7.2
WCM	700 kW	6.3 kV	200	7.2
sandmill	260 kW	3.0 kV	75	4.16
CCM	410 kW	3.0 kV	125	4.16
CM1	630 kW	500 V	175	0.575
CM3	560 kW	500 V	150	0.575
RM2	670 kW	500 V	200	0.575
sec. 2				
RM3	560 kW	500 V	150	0.575
RM1	635 kW	500 V	175	0.575
CM2	560 kW	500 V	150	0.575

4.0 PREDICTED ENERGY SAVINGS

Based on Factory 1 estimated 10% energy loss in power system cabling, transformers, etc., a 25-30% improvement in power factor would reduce the losses by 40% of the system loss.

Plant Annual kWH (Table 1A)	Estimated Reduced system losses	Annual Energy savings kWh	T.O.E.[1]
78,059,000	4%	3,122,360	787

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and cost savings are below. Figures are based on worldwide equipment and utility costs.

Investment cost		Annual cost savings	
$	LE	$	L.E.
103,620	232,100	134,261	53,080

---

[1] Electricity T.O.E. values include a typical 34% efficiency factor and correspond to generating electricity using a condensing steam turbine system.

142

6.0 CONCLUSIONS

In addition to above noted energy savings, i.e. improved system I^2R losses, there are additional benefits.

a) Improved electrical system capacity for future expansions.

b) The reduced voltage drop may require lowering transformer taps for proper system voltages.

c) Improved voltage drop during large motor startups.

7.0 RECOMMENDATION

This ECO should be incorporated into the proposed Factory 1 new electrical distribution system design.

GENERAL

INSTITUTE A PERMANENT PROGRAM FOR STEAM TRAP TESTING

Annual Savings, TOE	:	24
Annual Savings, $	:	2,768
Investment Cost, $	:	3,754
Payout: Simple, Yrs	:	1.36
DCF , %	:	--

ECO-35

1.0 PURPOSE

The purpose of this ECO is to institute a permanent program for steam trap testing in order to replace defective traps as soon as practical.

2.0 PROCESS DESCRIPTION

Based on the results of testing steam traps covered in a previous ECO, it is evident that a permanent program should be started to test all steam traps. Much of the efforts to save steam in the plant can be wasted if the steam traps are not working properly.

The program must be a permanent one and should be under the control of the plant energy coordinator and his committee. At a very minimum each trap must be tested once per year; however, a more frequent period of testing is strongly recommended. It is preferable to test traps operating over 1600 kPa (16 Bar) weekly, those operating from 200 to 1600 kPa (2 to 16 Bar) monthly, and lower pressure traps at least once annually. A trap item number and permanent metal tag must be assigned to each trap and records maintained to indicate testing dates, results and trap replacement.

A sample inspection check list is given on the next page.

Items to Inspect

1. Has trap failed in closed position?

   Feel trap. If cold, trap is bad.

2. Check system downstream of trap.

   Close valve to return line and open valve to atmosphere. If a considerable amount of water droplets are issuing from trap together with steam, trap is working.

3. Check system - using an ultrasonic tester or stethoscope.

   Intermittent sounds coming from a bucket trap, a thermostatic trap, and a thermodynamic trap mean that trap is functioning properly.

4. If trap is not functioning properly:

   Use exact replacement parts as manufactured by trap maker.

   Replace all gaskets. Make sure that the metal surfaces are absolutely clean before applying gaskets.

   Connect correct type of trap to steam pressure at which it operates and test it to make sure that it is in proper working order.

Simple devices, like a slide rule similar to Spirax-Sarco "Select a Trap" are available to replace failed traps.

The benefits of a permanent trap testing program can be as follows:

1. Reduction in steam losses.

2. Life expectancy of a trap can be determined from plant records before repair or replacement is required.

3. The best trap for particular services can be determined by analysis of records of performance.

4. Cost figures are available to support how much a particular trap is costing.

5. Only 5 percent of the plant steam traps will require attention at one time, thus less maintenance is required.

3.0 EQUIPMENT LIST/SIZE

- Steam traps as required.
- Identification tags.
- Ultrasonic tester (Sonic, Model 3000 M).

4.0 PREDICTED ENERGY SAVINGS

From the steam trap survey covered by ECO's 8, 14, and 21, it was noted that the estimated steam loss at this time from defective traps for the entire plant is 385 kg/hr. Assuming that the traps are tested once a year and the average life expectancy of a trap is 7 years, the steam loss that can be avoided by instituting a permanent steam trap testing program is estimated to be 27 Kg/hr.

Therefore, energy savings that result from a permanent steam trap testing program is estimated to be as follows:

Annual Energy Savings	
T.O.E.	Tons mazout
24	24.7

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The estimated total investment and annual cost savings for repairing all steam traps is below. Figures are based on worldwide equipment and utility costs.

Number of defective steam traps to replace annually	2
Cost to replace traps, $	1,230
Cost to tag traps and purchase ultrasonic test equipment, $	2,524

Total Investment		Annual Cost Savings	
$	LE	$	LE
3,754	8447	2,768	692

Representatives of steam trap manufacturers will offer a service to survey steam traps in plants. This service costs approximately $8 to $10 per trap. Since we found only 12 steam traps in HPCC, the cost of testing the steam traps either by plant personnel or by the manufacturer's representative, is negligible.

6.0 CONCLUSIONS

The initiation and carrying out of a permanent program to test, repair and replace steam traps has a very attractive payout. This ECO is essential to efficient plant operation and must be carried out year after year.

7.0 RECOMMENDATION

This ECO should be initiated immediately and carried out continuously.

GENERAL

FORM A COMMITTEE TO PLAN AND IMPLEMENT ECO'S

Annual Savings, TOE	:	Not
Annual Savings, $	:	Applicable
Investment Cost, $	:	"
Payout: Simple, Yrs	:	"
DCF , %	:	"

ECO-36

1.0 PURPOSE

The purpose of this ECO is to ensure that the conclusions and recommendations contained within the Audit Report are implemented in a timely manner through the formation of a committee who will be given the responsibility to establish short range and long range plans to implement the in-country housekeeping and investment ECO's as well as the foreign investment ECO's.

2.0 PROCESS DESCRIPTION

Plant management must show its commitment to energy conservation by appointing a committee consisting of representatives from each department of the plant. The chairman of the committee is the energy coordinator for the plant, who should report directly to plant management.

The committee must meet at least once a month (more frequently when it is first getting started) to establish a specific plan for energy conservation implementation. Its first priority is to begin implementation of low cost in-country housekeeping ECO's and to develop a plan and a budget for the implementation of investment ECO's.

The recommendations and priorities established in the audit report must be carefully studied by the committee to help formulate the most reasonable and effective plan possible for implementation.

Once implementation is begun the committee must continuously monitor the results and compare the savings actually achieved with those originally predicted. In this way the effectiveness of the program and the achievement of previously established goals for reduction in energy consumption can be firmly substantiated.

An example of the systems and methods used to implement this ECO is included in Appendix 4.

3.0 EQUIPMENT LIST/SIZE

No new equipment and no new personnel are needed to form the committee.

4.0 PREDICTED ENERGY SAVINGS

This will be a function of the committee's effectiveness in seeing to it that the ECO's recommended in the Audit Report are implemented in a timely manner.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

None, not applicable to this ECO.

6.0 CONCLUSIONS

The formation of the committee and the appointment of an energy conservation coordinator are crucial initial steps in the establishment of an effective program of energy conservation.

7.0 RECOMMENDATION

Formation of the committee and appointment of the energy conservation coordinator should proceed without delay. This should be the first implemented in-country ECO.

GENERAL

PUBLICITY TO MAKE EMPLOYEES AWARE OF THE IMPORTANCE OF ENERGY CONSERVATION

Annual Savings, TOE	:	Not
Annual Savings, $	:	Applicable
Investment Cost, $	:	"
Payout: Simple, Yrs	:	"
DCF , %	:	"

ECO-37

1.0 PURPOSE

The purpose of this ECO is to make all employees of the company aware of the importance of energy conservation through the use publicity, memos, newsletters, etc. Doing this will help insure that each employee will contribute toward making the overall energy conservation program a success.

2.0 PROCESS DESCRIPTION

In any effective energy conservation program, ideas must flow in two directions, from management to the employees and back up to management. Management must take the first step by showing its commitment to energy conservation through publicity such as posters, memos, newsletters, suggestion boxes, and contests/awards for the best energy conservation ideas submitted by employees. Once all employees see that energy conservation is being treated as a serious and important matter by their company, they in turn will act in the same way.

Responsibility for seeing that employees are made aware of the importance of energy conservation must be shared by both plant management and by the committee responsible for energy conservation implementation.

An example of the systems and methods used to implement this ECO is included in Appendix 5.

3.0 EQUIPMENT LIST/SIZE

No new equipment and no new personnel are needed to implement this ECO.

4.0 PREDICTED ENERGY SAVINGS

Not applicable to this ECO.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

A modest annual budget of approximately LE 2,000 should be established to pay for the publicity material (posters, newsletter, etc.) needed to implement this ECO.

6.0 CONCLUSIONS

Although it may not be possible to precisely measure the effectiveness of an employee awareness program, it is nevertheless a most necessary step in establishing the proper mental attitude needed to initiate an effective and comprehensive energy conservation program.

7.0 RECOMMENDATION

Immediately following the formation of the energy conservation committee, a program of employee awareness should be initiated.

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ORGANIZATION for
ENERGY
PLANNING

جهاز تخطيط الطاقة

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ENERGY AUDIT

of the

Helwan Portland Cement Company

Helwan, Egypt

May, 1988

VOLUME 2 of 2 - APPENDICES

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152

APPENDICES

APPENDIX	
1	BASIC ENGINEERING DATA
2	PORTABLE INSTRUMENT LIST
3	ELECTRICAL ONE-LINE DIAGRAMS
4	ECO-36: FORM A COMMITTEE TO PLAN AND IMPLEMENT ECO's (Pg. 269-326)
5	ECO-37: PUBLICITY TO MAKE EMPLOYEES AWARE OF IMPORTANCE OF ENERGY CONSERVATION (Pg. 327-331)
6	TRANSLATION OF REPORT ON EGYPTIAN CEMENT INDUSTRY, EXCERPTS DESCRIBING HPCC (Pg. 1-16)
7	ECO-26: TECHNICAL ARTICLE ON SLURRY THINNERS
8	ECO-34: TECHNICAL ARTICLES REFERRING TO POWER FACTOR CORRECTIONS
9	DISCOUNT CASH FLOW GRAPH
10	ECO-24, 31: OXYGEN ANALYZER BROCHURE

3.7 Basic Engineering Data:

The Basic Engineering Data (B.E.D. Sheets) which will be used during the audit and subsequent design of the various ECO's is given in the pages which follow. The source for the data listed below is as follows:

Utility Cost (Paragraph 3.0)

Fuels - Per Egyptian General Petroleum Corp. and developed by Foster Wheeler from data obtained from Stanford Research Institute.

Electric Power - From Organization for Energy Planning (OEP) and developed by Foster Wheeler from data obtained by Stanford Research Institute.

Steam - Developed by Foster Wheeler from data obtained from Stanford Research Institute.

Water - Developed by Foster Wheeler from data obtained by Stanford Research Institute.

Meteorological Data (Paragraph 4.0)

As developed from data provided by Egyptian Meteorological Authority for a five year period (1978 through 1982).

Minimum Dry Bulb Temp. is average of mean minimum temperatures.

Design Dry Bulb Temperature is average of mean maximum temperatures.

Design Wet Bulb Temperature is determined from Psychrometric Chart using an average relative humidity of 64 percent.

Utility Information (Paragraph 5.0)

Fuel oil specifications - Per Egyptian General Petroleum Corporation.

Sular specifications - Per Egyptian General Petroleum Corporation.

Rule from Electric Billing

Specified by contract between the plants and the Electric Authority.

ENERGY CONSERVATION PROJECT

BASIC ENGINEERING DATA

1.0 General:

This form defines the basic engineering data which will provide the technical and economic basis for the evaluation of energy conservation opportunities (ECO's) for the audit.

2.0 Economic Guidelines:

2.1 Operating Time:

2.1.1 Number of operating days per year 310 (wet)
274 (dry)

2.1.2 Number of shifts per day 3, 7 days/week (both)

2.1.3 Normalized number of operating hours per year

7446 (wet)
6570 (dry)

2.2 Economic Evaluation Basis:

2.2.1 Payback priority list, simple basis yes

2.2.2 Discounted cash flow yes

Taxes 32%

Inflation 30%

Interest 14%

Required R.O.I 6-8% (if known)

Project Life 10 yr.

Depreciation straight

Salvage Value 2.5% (initial investment)

3.0 Utility Cost :

Utility	Units	Public Sector Domestic Price (L.E.)/Unit	World Price $/Unit(1)
Fuels			
Mazout (#6)	Metric Ton	28	112.07
Sular	Metric Ton	60	150.64
Electric Power	KWH	0.017	0.043
Natural Gas	M^3	0.0302	0.078
Propane (liquid)	M^3	12.24	65.33
Butane (liquid)	M^3	-	102.28
Steam (2)			
(3) High Press.	Metric Ton	3.26	11.66
(3) Med. Press.	Metric Ton	3.11	11.09
(3) Low Press.	Metric Ton	2.94	10.49
Water			
Raw	Metric Ton	0.070	0.18
Cooling	Metric Ton	0.006	0.015

Notes:

(1) Based on "Mid 1987 Prices" provided by the Stanford Research Institute (latest figures to date)

(2) Steam Pressures

HP - 40 ATM or more
MP - 10 ATM to 40 ATM
LP - 3 ATM to 10 ATM

Boiler efficiency assumed to be 75%

(3) The price of condensate or boiler feed water is 10 % of steam price.

156

4.0 Meterological Data :

4.1 Meteorological Data: (Cairo Area)

Temperatures:

Minimum Dry Bulb	6 °C
Design Dry Bulb	34 °C
Design Wet Bulb	28 °C

Note: For insulation calculations use dry bulb temperature at 20 °C.

Wind Velocity and Direction: 0 - 15 km/hr Random direction

Winterization Area Classification: None.

Allowance for Earthquake Forces: None.

Rainfall: Less than 10 cm/yr.

Design Humidity (relative): 64% (34 °C/28 °C)

5.0 Utility Information :

5.1 Fuel Oil #6 (mazout):

Temperature (pour point) ,	°F	100.0
	°C	37.8
Specific Gravity @ 15/4 °C		0.990
Viscosity, R I @ 100 °F		2000.0
Sulfur, % by wt.		2.5
Heating Value, J/M Ton		4.077×10^{10}

5.2 Diesel (sular):

Specific Gravity @ 15/4 °C		0.840
Viscosity, R I @ 100 °F		60.0 max
Sulfur, % by wt.		2.0
Heating Value, J/M Ton		4.467×10^{10}
Flash Point P.M. Closed,	°C	65.0

5.3 Natural Gas:

Specific Gravity @ 15/4 °C		0.56 (air = 1.0)
Heating Value, J/M^3		37,256,270

157

5.4 Propane:

Specific Gravity @ 15/4 °C	0.51
Heating Value, kcal/kg	11943
J/M Ton	5.00×10^{10}

5.5 Butane:

Specific Gravity @ 15/4 °C	0.58
Heating Value, kcal/kg	11722
J/M Ton	4.908×10^{10}

6.0 Rules for Electric Billing

The following rules for electric billing (or application of rates) will apply to economic analysis of ECO's which relate in depth to the cost of power. These rules assume a consumption at more than 625 KVA (500 kw), at a voltage level of 380 volts, for industrial uses other than limited lighting.

6.1 Demand Factor

The demand factor envisions a base load for this complex, which is _____ kw, and allows excursions beyond the base period not to exceed zero minutes per excursion. If this excursion limit is exceeded, the electric bill is calculated on the basis of this maximum load condition for the billing year (5% grace is allowed).

6.2 Power Factor

The target power factor for all users is 1.0. Two price variations exist, however, based on an acceptable power factor of 0.8. These are respectively, an incentive, and a penalty, as well as a shutdown clause.

6.2.1 Power Factor Incentive:

An incentive of a discount on the electric bill is offered, at a rate of 0.5% discount (factor 0.005) on each percent of power factor greater than 0.8 (i.e. a maximum of 20 steps at 1% to achieve a P.F. = 1.0).

6.2.2 Power Factor Penalty:

A penalty of an increase on the electric bill is mandated, at a rate of 0.5% increase (factor 0.005) on each percent of power factor less that 0.8 (i.e. a penalty of 10 x 0.5% or 5% for a PF equal to 0.7).

Additionally, if the power factor is 0.6 or less, a second 0.5% increase per 1% of P.F. is additive, for a total penalty of 1% of P.F. below 0.6.

6.2.3 Shutdown for Power Factor:

The billing system provides a clause to shutdown any user who has a power factor of less than 0.6, who does not correct this adverse power factor within 3 months.

6.3 Billing Rates:

The following rates are based upon a yearly billing basis, and normally apply to a fiscal year from July to June.

The bill is based upon the sum of several elements, which consist of three major categories, thereafter ratioed up or down by the power factor rate adjustment.

The three major elements are:

a) constant annual charge, based on the maximum stated demand, and priced at 7.756 LE/year for each kw.

b) a cost per KWH consumed, on a sliding scale, in accord with table #1.

c) taxes, which are the sum of:

- o broadcast tax, @ 0.001 LE per KWH for lighting[1].
- o consumption tax, @ 0.005 LE per KWH for lighting[1].
- o power tax, @ 0.0001 LE per KWH for 90% of KWH.

See Table #1 on next page.

[1] assumed to be 10% of total.

KWH Rate Table #1

Range	1 Time	2 Maximum Rate	3 Total Power (measured)	4 Total Power (calculated)	5 Power Remaining	6 Rate	7 Cost
	(hours)	(KW)	(KWH)/year	(KWH)	(KWH)	(LE)	(LE)
1	1000					0.0312	
2	500					0.0294	
3	1000					0.0256	
4	1000					0.0220	
5	1500					0.0167	
6	note 7					0.0143	

Notes :

1. column 1 represents hours at the stated demand rate, i.e. first 1000 hours, next 500 horus, etc. Range 6 does not have an entry, since the power at range 6 is found by difference.

2. column 2 is the maximum rate, as determines from short term maximum during the year (not applicable to range 6)

3. column 3 is measured power at the meter, in KWH, for the billing year (enter at range 1 position only).

4. column 4 is total power calculated, as the product of columns 1 & 2.

5. column 5 is remaining power, as column 3 - column 4 for range 1, and thereafter the entry for the previous range minus the entry for the previous range minus the entry in column 4 for the current range, i.e. power in KWH not yet accounted for.

6. column 7 is the product of columns 4 & 6, until such time as the power remaining is less that the power calculated. When this occurs, colunm 7 is the product of the power remaining (column 5) and column 6. Note that this occurs always at range 6, if not before.

7. Maximum hours which could exist in column 1 is: 365 x 24 - 5,000 = 3,760 hours.

PORTABLE INSTRUMENT LIST

Item	Qty	Instrument Type and Manufacturer	Model No.	Serial No.	Brief Description
1.	1ea	Digital Thermometer * Thermoelectric	Micromite 3115300000	48614-1-1	T/C Thermometer w/ Accessories
2.	1ea	Dial Thermometer (0/220 F)	None	None	Temperature Indicator
3.	1ea	Dial Thermometer (-40/160 F)	None	None	Ditto
4.	1ea	Mercury Thermometer (0/330 F)	None	None	Ditto
5.	1ea	Infared Thermometer M-C Product (-20/2000 F)	LT-100	011924	Hand Held Digital Thermometer
6.	1ea	Flue Gas Test Kit**** Bacharach	10-8001	None	Analyze Stack Gases
7.	1ea	Sample Test Cooler Bacharach	11-7046	None	Accessory To Test Kit
8.	1ea	Digital Stack Gas Analyzer-Enerac	50	12122	Same as no. 6
9.	1ea	Anemometer Davis	None	55609B	Propeller driven Air Flow Indicato
10.	1ea	Air Velocity Meter *** Dwyer	400-10	5806	Pitot Tube Manometer
11.	1ea	Sling Psychometer Taylor	1330	None	Measure Relative Humidity
12.	1ea	Ultrasonic Leak Detector-Sonic	3000	801621	Check for Steam Trap Leaks
13.	1ea	Stopwatch Cole-Palmer	R-8672-20	None	Measure Fractions of Seconds
14.	1ea	Tachometer Yokogawa	363200	77GF00288	Measure Shaft Speed (RPM)
15.	1ea	Lightmeter General Electric	214	154	Measure Lighting Levels
16.	1ea	Power Factor Meter Epic Inc.	COS0512	78267	Meter to Indicate Power Factor

Portable Instrument List

Item	Qty	Instrument Type and Manufacturer	Model No.	Serial No.	Brief Description
17.	1ea	KW/KVA Meter Epic Inc.	KW4802	78267	Measures Power in Kilowatts
18.	1ea	Ammeter TIF	1000	5707	Measure electric current in Amperes
19.	1ea	Volt-Ohm Meter Fluke	8021B	4330356	Meter Various Electric Measurements
20.	4ea	Volt/Ammeter Recorder** Rustrack	230	80022AH 80023AH 80024AH 80026AH	Recording Meter to Measure Current/Voltage

* Includes loose thermocouples and accessories

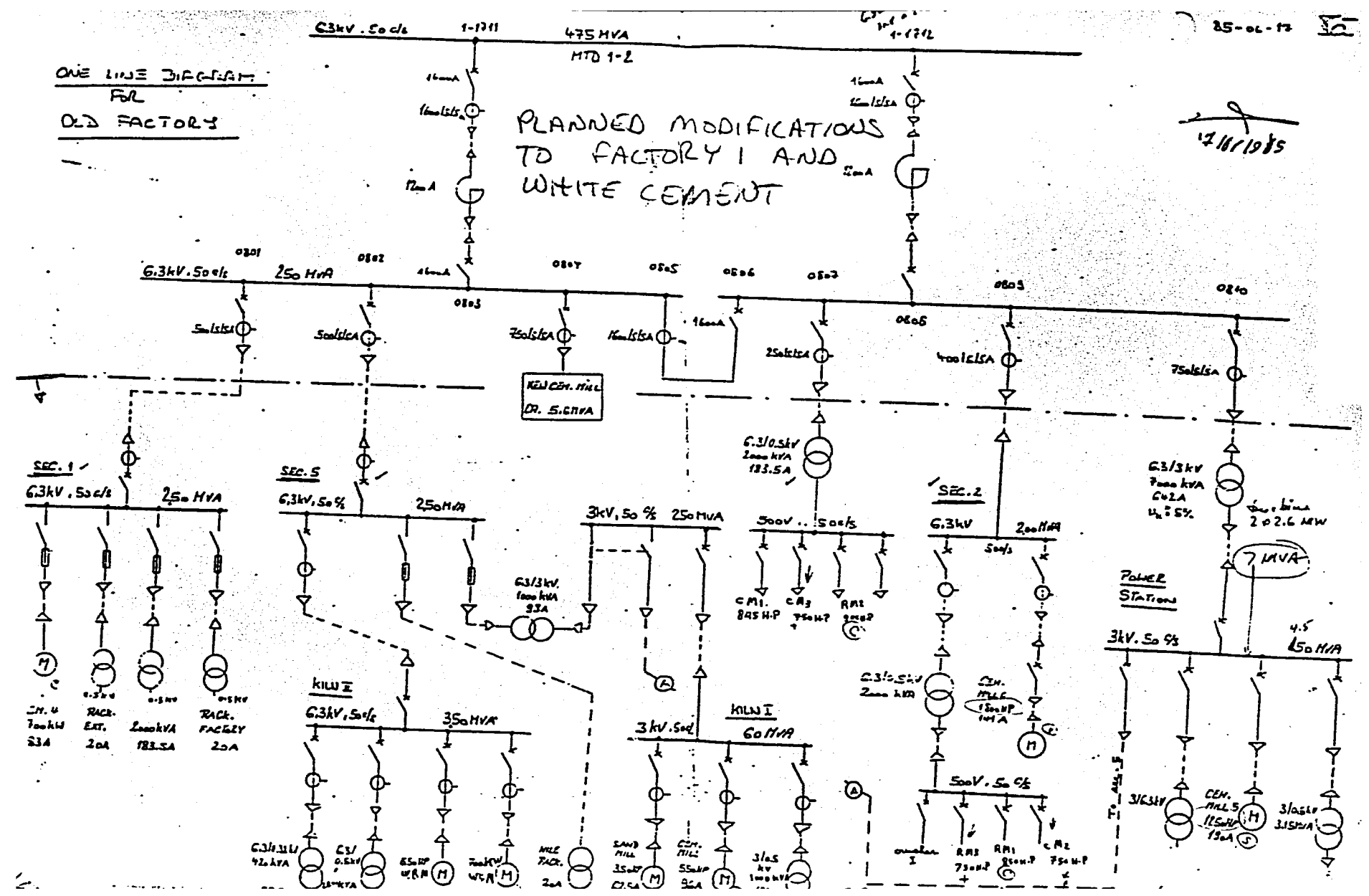
2ea type J, 36" long thermocouples
1ea type K, 4" long thermocouple
1ea type K surface contact thermocouple
1ea armored extension handle
1ea charger, 220vac
2ea extra rechargeable batteries

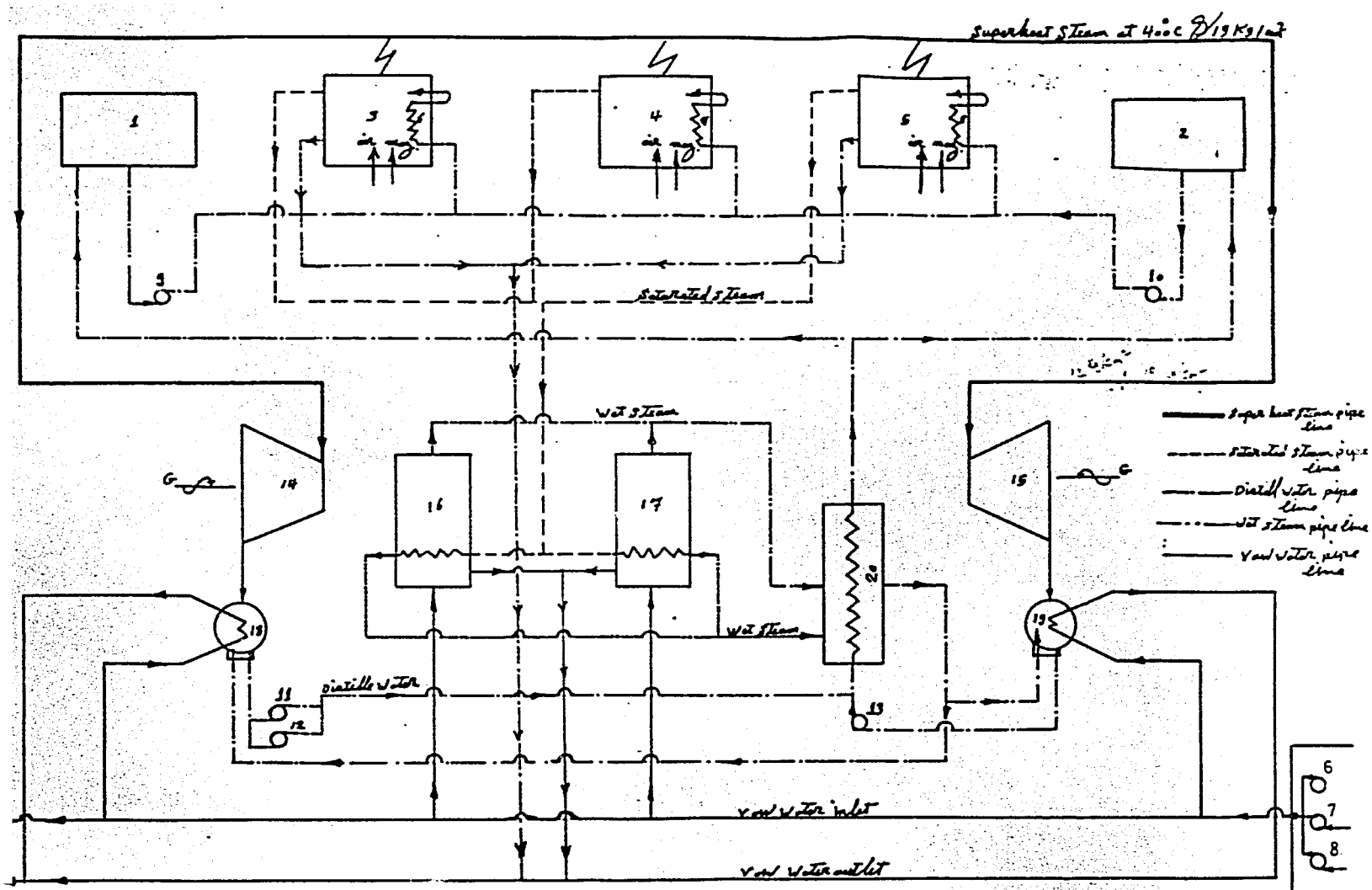
** Includes extra chart paper(10 rolls amp/10 rolls volt)

*** Includes additional red gauge oil (1 quart bottle and 5ea 3/4oz. bottle)

**** Includes following consummables:

36ea tubes of CO detector
3ea bottles Fyrite CO2 indicator refill (11-0058)
3ea bottles Fyrite CO2 indicator refill (11-0057)
2ea bottles Fyrite O2 indicator refill (11-0059)
3ea bottles Fyrite O2 indicator refill (11-0169)


ONE LINE DIAGRAM FOR OLD FACTORY
PLANNED MODIFICATIONS TO FACTORY I AND WHITE CEMENT
17/8/1985
25-01-17
6.3kV. 50 c/s
475 MVA
MTD 1-2
1-1711
1-1712
6.3kV. 50 c/s
250 MVA
0801
0802
0803
0807
0805
0806
0803
0806
0840
KILN CEM. MILL DR. 5.6MVA
6.3/0.5kV 2000 kVA 183.5A
6.3/3kV 7000 kVA C42A
7 MVA
POWER STATION
SEC. 1
6.3kV. 50 c/s
250 MVA
SEC. 5
6.3kV, 50 c/s
250 MVA
3kV, 50 c/s 250 MVA
500V .. 50 c/s
SEC. 2
6.3kV
200 MVA
50 c/s
6.3/3kV 1000 kVA 93A
CM1. 845 H.P
CM3 750 H.P
RM2 2000 HP
CEM. MILL 1500 HP 144A
KILN II
6.3kV, 50 c/s
350 MVA
KILN I
3kV. 50 c/s
60 MVA
3kV. 50 c/s
450 MVA
500V. 50 c/s
CM. 4 7000 kW 83A
RACK. EXT. 20A
2000 kVA 183.5A
RACK. FACTORY 20A
RM3 750 HP
RM1 2000 HP
CM2 750 HP
CEM. MILL 5 1250 HP 130A
To 45.5



Power station layout

16

1 Distille Water Tank № 1

2 " " " № 2

3 Boiler № 1

4 " № 2

5 " № 3 Stand by

6 Nyle pump № 1

7 " " № 2

8 " " № 3 Stand by

9 principle Feed pump

10 Stand by " "

11 principle Injector pump (Condensate pump) For Turb. № 1

12 Stand by " " " " " № 1

13 Condensate pump For Turb. № 2

14 Turbine № 1

15 " № 2

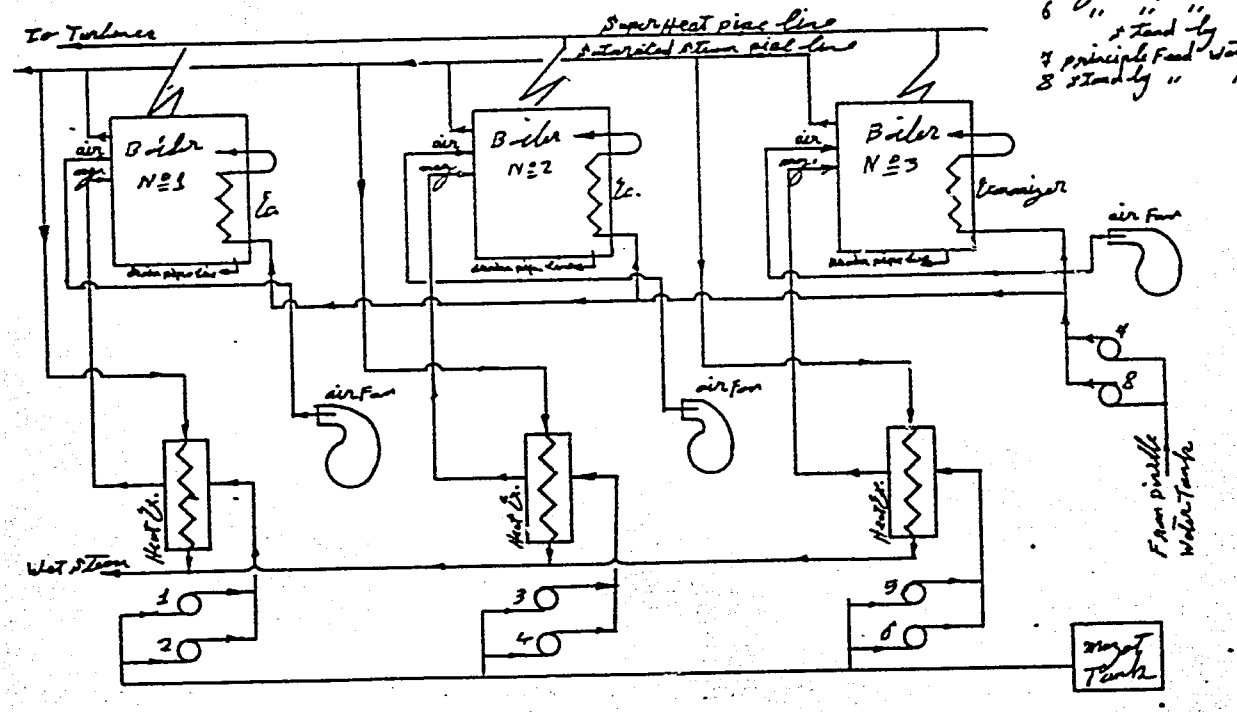
16 evaporator № 1

17 " № 2

18 Condenser For Turb. № 1

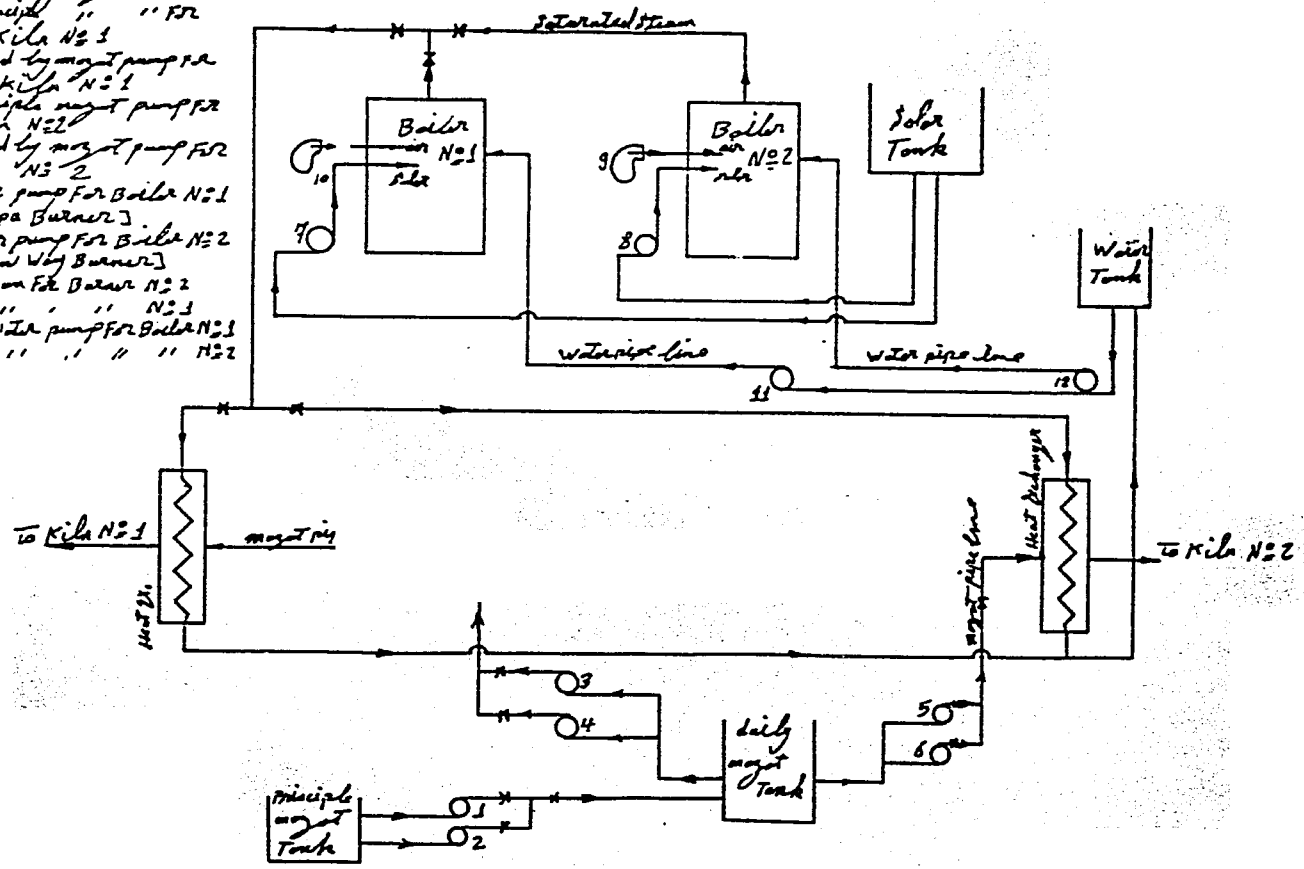
19 " " " № 2

For Each Boiler
- 16 Ton/hr super heat steam
- 19 Kg/cm² at 400°C
1 magnet pump for Boiler No. 1
2 " " " " No. 1
stand by
3 Magnet pump for Boiler No. 2
4 " " " " No. 2
stand by
5 Magnet pump for Boiler No. 3
6 " " " " No. 3
stand by
7 principle Feed water pump
8 stand by " " "

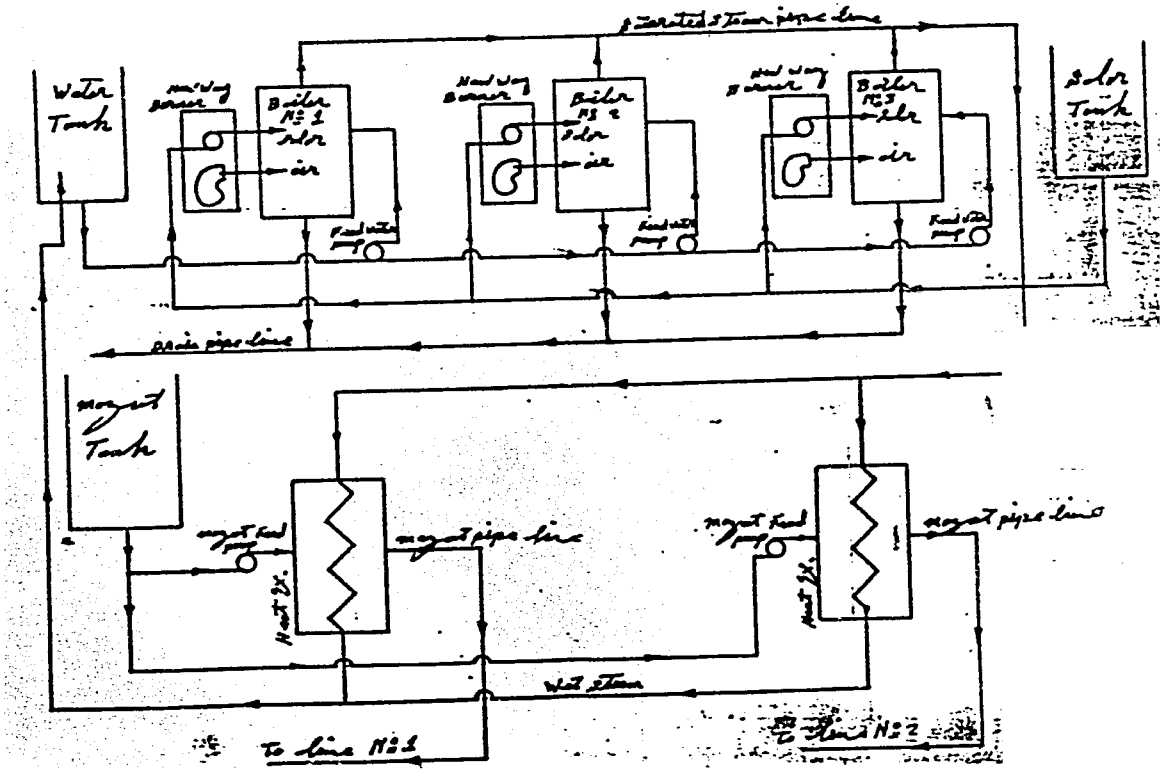


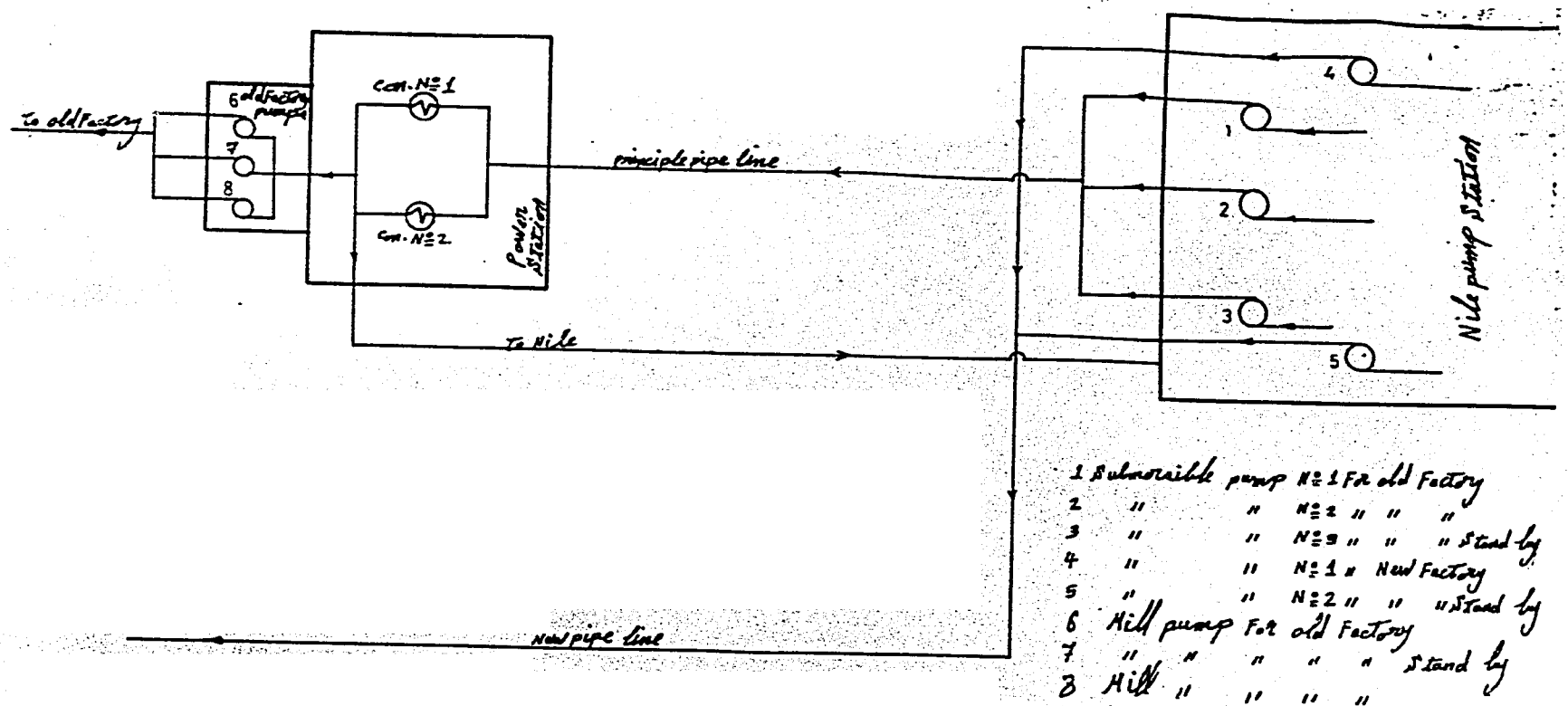
White Cement Boilers

Each Boiler:
½ Ton/hr saturated steam
8 Kg/cm² working pressure
To heat magnet at 110°C
1 principle magnet pump
2 stand by magnet "
3 principle " " for Kiln No 1
4 stand by magnet pump for Kiln No 1
5 principle magnet pump for Kiln No 2
6 stand by magnet pump for Kiln No 2
7 solar pump for Boiler No 1 [Vompa Burner]
8 solar pump for Boiler No 2 [New Way Burner]
9 Air fan for Burner No 2
10 " " " " No 1
11 Feed water pump for Boiler No 1
12 " " " " " No 2



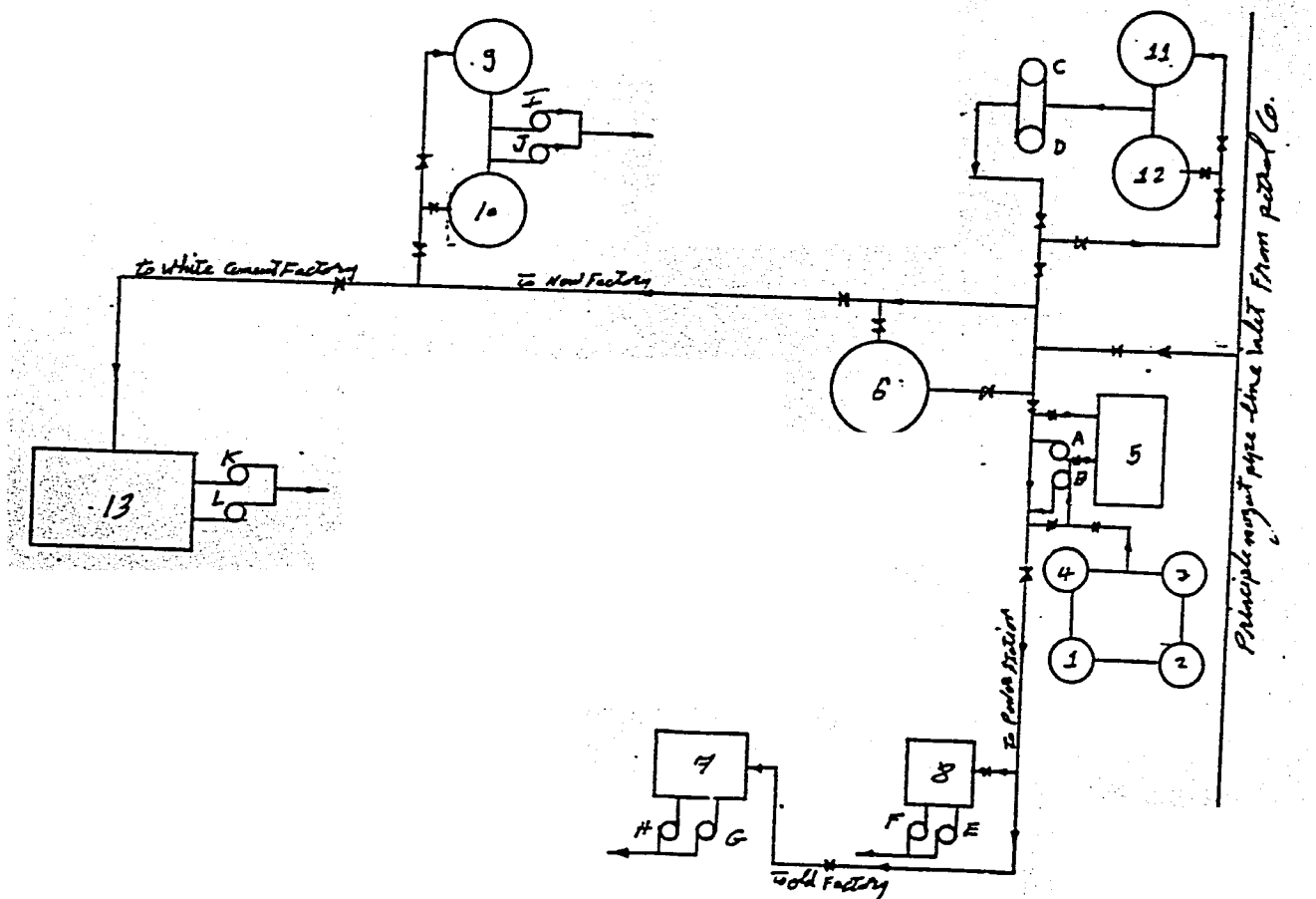
Each Boiler 4 Ton superheated steam
2 Boilers for each line and third Boiler
stand by





Cooling water layout for factory n° 1
and the main pumps only for factory n° 2

Mag^st Gyle in Helvetia Portland Cement Co.



No. of Tank		Capacity	
1		500	Ton
2		500	"
3		600	"
4		600	"
5		4500	"
6		8000	"
7	old Factory Tank	300	"
8	power Station "	80	"
9	New Factory Tank	3000	
10		3000	"
11		4500	"
12		4500	"
13	W. Cement Factory Tank	300	"

A principle mazot pump 60 m³/hr 6 bar
B Stand by " " (small) 30 m³/hr 6 bar
C Stand by mazot pump 136 m³/hr 6 bar
D principle mazot pump 80 m³/hr 6 bar
E principle mazot pump For power Station Boiler
F Stand by mazot pump For power Station Boiler
G principle mazot pump For old Factory
H Stand by " " " " "
I principle " " " New Factory
J Stand by " " " " "
K principle " " " white cement factory
L Stand by " " " " " "

171

Section 2

ENERGY CONSERVATION PROGRAM IMPLEMENTATION

TABLE OF CONTENTS

2.0 Introduction 2-1
2.1 Program outline 2-1
2.2 Format and contents 2-4
2.3 Plant Manager Takes First Action
2.3.1 Letter to department heads from plant manager organizing an energy conservation committee and defining its responsibilities 2-5
2.3.2 Bulletin from plant manager to all employees announcing energy conservation program 2-7
2.4 First meeting of energy conservation committee 2-8
2.4.1 Coordinator's letter presented to committee members at first meeting proposing assignments 2-9
2.5 Second meeting of energy conservation committee 2-11
2.5.1 Agenda for second committee meeting 2-12
2.5.2 Letter discussing plans for first energy saving-survey and attached survey report form 2-13
2.5.3 Letter proposing future surveys 2-15
2.5.4 Report on energy equivalents and costs for plant utilities 2-18
2.5.5 Report on present and projected cost of fuel and electric power 2-20
2.5.6 Report on quantities of purchased fuel and electric power used each month in 1973 and 1974 2-21
2.5.7 Letter proposing a system for developing the energy unit ratio, Btu per unit of production, and a tracking chart form 2-23
2.6 First energy saving survey 2-34
2.6.1 Plant manager's letter to department heads endorsing the first energy-saving survey of wastes 2-35
2.6.2 Energy-saving survey team's letter to department heads submitting the timetable for the first survey 2-36
2.6.3 Survey team's report of findings in first survey 2-37
2.6.4 Survey team's letter suggesting supervisor training in energy conservation 2-39
2.7 Third meeting of the energy conservation committee 2-40
2.7.1 Agenda for third committee meeting 2-41
2.7.2 Manager's letter regarding capital project reviews for efficient utilization of energy 2-42
2.7.3 Coordinator's letter submitting forms for list of energy-saving projects and a project evaluation summary form 2-43
2.7.4 Letter about communication of ways to save energy 2-48
2.7.5 Coordinator's letter about a continuing program with attachments showing planned activities for each month for the rest of the year. 2-50
2.8 Conclusion 2-53
2.8.1 Manager's letter demonstrating his continuing concern about energy conservation and requesting a contingency plan 2-54
2.8.2 Report on contingency plan status 2-56

2. ENERGY CONSERVATION PROGRAM IMPLEMENTATION

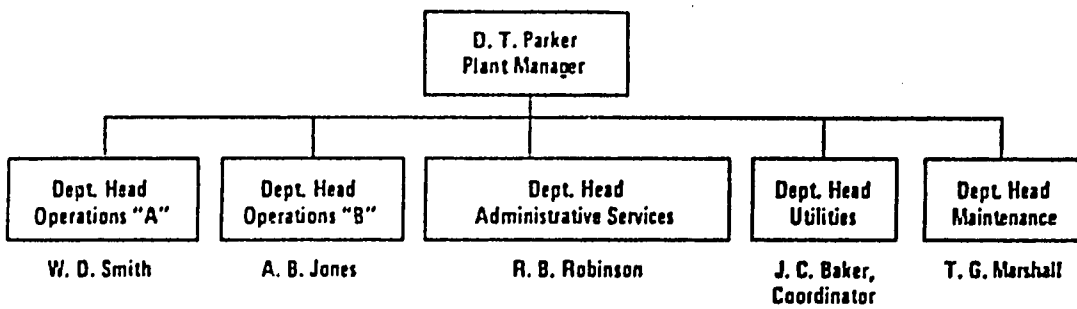
2.0 INTRODUCTION

This section of the kit describes the initiation and implementation of an energy conservation program. Section 2.1 is an outline of the elements of a program. It may be used as a guide to design your own program, tailored to your company's requirements and capabilities.

For those interested in more detail, the remainder of Section 2, starting with 2.2, illustrates the important steps in the program by a series of memoranda based on the internal correspondence generated in several actual energy conservation programs. Many of these communications could be accomplished verbally at staff meetings and committee meetings and then be documented in minutes. All of your needs may not be anticipated and some of the actions illustrated may not be necessary or appropriate for your management structure but you will find illustrated in this section most of the necessary communications. Suggested methods and forms for recording and reporting plant survey data and for tracking the progress of the program are included.

The memoranda are based on a hypothetical company, the ECONERGY Company, which has two production departments, a utilities department, a maintenance department, and an administrative services department responsible for the purchasing, accounting, shipping, and receiving functions.

The formal organization chart for the ECONERGY Company is shown below for reference. The names shown beneath the department blocks are the names of members of the Energy Conservation Committee.



2.1 PROGRAM OUTLINE

	Reference Section
I. TOP MANAGEMENT COMMITMENT	
A. Inform line supervisors of:	2.3.1
1. The economic reasons for the need to conserve energy	
2. Their responsibility for implementing energy saving actions in the areas of their accountability	
B. Establish a committee having the responsibility for formulating and conducting an energy conservation program and consisting of:	2.3.1
1. Representatives from each department in the plant	
2. A coordinator appointed by and reporting to management	
Note: In smaller organizations, the manager and his staff may conduct energy conservation activities as part of their management duties.	
C. Provide the committee with guidelines as to what is expected of them:	2.3.1
1. Plan and participate in energy saving surveys	
2. Develop uniform record keeping, reporting, and energy accounting	

173

	Reference Section
3. Research and develop ideas on ways to save energy	
4. Communicate these ideas and suggestions	
5. Suggest tough, but achievable, goals for energy saving	
6. Develop ideas and plans for enlisting employee support and participation	
7. Plan and conduct a continuing program of activities to stimulate interest in energy conservation efforts	
D. Set goals in energy saving:	
1. A preliminary goal at the start of the program	
2. Later, a revised goal based on savings potential estimated from results of surveys	
E. Employ external assistance in surveying the plant and making recommendations, if necessary	6.2
F. Communicate periodically to employees regarding management's emphasis on energy conservation action and report on progress	2.8.1, 2.3.2
II. SURVEY ENERGY USES AND LOSSES	
A. Conduct first survey aimed at identifying energy wastes that can be corrected by maintenance or operations actions, for example:	2.5.2, 2.6.1, 2.6.2, 2.6.3
1. Leaks of steam and other utilities	
2. Furnace burners out of adjustment	
3. Repair or addition of insulation required	
4 Equipment running when not needed	
B. Survey to determine where additional instruments for measurement of energy flow are needed and whether there is economic justification for the cost of their installation	2.5.3
C. Develop an energy balance on each process to define in detail:	2.5.3
1. Energy input as raw materials and utilities	
2. Energy consumed in waste disposal	
3. Energy credit for by-products	
4. Net energy charged to the main product	
5. Energy dissipated or wasted	
Note: Energy equivalents will need to be developed for all raw materials, fuels, and utilities, such as electric power, steam, etc., in order that all energy can be expressed on the common basis of Btu units.	2.5.4
D. Analyze all process energy balances in depth:	2.5.3
1. Can waste heat be recovered to generate steam or to heat water or a raw material?	
2. Can a process step be eliminated or modified in some way to reduce energy use?	
3. Can an alternate raw material with lower energy content be used?	
4. Is there a way to improve yield?	
5. Is there justification for:	
a. Replacing old equipment with new equipment requiring less energy?	
b. Replacing an obsolete, inefficient process plant with a whole new and different process using less energy?	
E. Conduct weekend and night surveys periodically	2.7.5 2.5.2
F. Plan surveys on specific systems and equipment, such as:	2.5.3
1. Steam system	
2. Compressed air system	
3. Electric motors	
4. Natural gas lines	
5. Heating and air conditioning system	
III. IMPLEMENT ENERGY CONSERVATION ACTIONS	
A. Correct energy wastes identified in the first survey by taking the necessary maintenance or operation actions	2.6.2
B. List all energy conservation projects evolving from energy balance analyses, surveys, etc. Evaluate and select projects for implementation:	

	Reference Section
1. Calculate annual energy savings for each project	
2. Project future energy costs and calculate annual dollar savings	
3. Estimate project capital or expense cost	
4. Evaluate investment merit of projects using measures, such as return on investment, etc.	
5. Assign priorities to projects based on investment merit	
6. Select conservation projects for implementation and request capital authorization	
7. Implement authorized projects	
C. Review design of all capital projects, such as new plants, expansions, buildings, etc., to assure that efficient utilization of energy is incorporated in the design.	2.7.2
Note: Include consideration of energy availability in new equipment and plant decisions.	
IV. DEVELOP CONTINUING ENERGY CONSERVATION EFFORTS	
A. Measure results:	2.5.7
1. Chart energy use per unit of production by department	2.5.6
2. Chart energy use per unit of production for the whole plant	
Note: The procedure for calculating energy consumption per unit of product is presented in "How to Profit by Conserving Energy"	2.5.7
3. 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 rate, product mix, etc.	
a. Compare Btu/product unit with past performance and theoretical Btu/ product unit	
b. Observe the impact of energy saving actions and project implementation on decreasing the Btu/unit of product	
c. Investigate, identify, and correct the cause for increases that may occur in Btu unit of product, if feasible	
B. Continue energy conservation committee activities	2.7.5
1. Hold periodic meetings	
2. Each committee member is the communication link between the committee and the department supervisors represented	
3. Periodically update energy saving project lists	
4. Plan and participate in energy saving surveys	
5. Communicate energy conservation techniques	
6. Plan and conduct a continuing program of activities and communication to keep up interest in energy conservation	
7. Develop cooperation with community organizations in promoting energy conservation	
C. Involve employees	2.7.5
1. Service on energy conservation committee	2.7.4 2.6.4
2. Energy conservation training course	
3. Handbook on energy conservation	
4. Suggestion awards plan	
5. Recognition for energy saving achievements	
6. Technical talks on lighting, insulation, steam traps, and other subjects	
7. "SavEnergy" posters, decals, stickers	
8. Publicity in plant news, bulletins	
9. Publicity in public news media	
10. Letters on conservation to homes	
11. Talks to local organizations	
D. Evaluate program	
1. Review progress in energy saving	
2. Evaluate original goals	
3. Consider program modifications	
4. Revise goals, as necessary	

12

2.2 FORMAT AND CONTENTS

Throughout this section, the letters, reports, forms, and meeting agendas are in time sequence. Where appropriate, there are comments or explanations which relate to the following memoranda.

Energy costs and cost projections, quantities of energy, and equivalent energy factors for utilities have been left as blanks, rather than stated numerically, in order to avoid any implication that the figures are typical. Such numbers will vary from industry to industry, plant to plant, and region to region. Each plant must make its own determination of these figures.

Names of individuals and of the company are, of course, fictitious.

Please note the definitions of the following symbols used in this section:

k = thousand or kilo
M = million or mega

2.3 PLANT MANAGER TAKES FIRST ACTION

The plant manager has decided that energy conservation must become a specific part of the company management program. He takes action by appointing an energy conservation coordinator and requesting the head of each department to select someone to work with the coordinator. His actions are expressed in the following memoranda.

176

2.3.1

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 7, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: Formation of Energy Conservation Committee

The rising costs of energy and the allocations brought about by shortages have become a problem of increasing concern. The need for energy conservation has been discussed in previous staff meetings, but frankly we are not getting the results we want.

Many companies achieved 5 to 10% savings in energy usage last year by implementing formal energy conservation programs. Our plant uses _____ million Btu of energy yearly and our annual bill for purchased fuel and electric power is about $_____ at current energy prices. If we could achieve, for example, a 10% cut in our annual consumption, that would be a saving of $_____-- an appreciable amount of money. Consider also that energy costs are rising at a rate of about _____% per year.

We must initiate an aggressive energy conservation program at once. We need to establish a committee with the responsibility for formulating and conducting the program. I am appointing J. C. Baker to the fulltime responsibility as committee coordinator, reporting directly to me, and I am asking that by one week from today each of you assign someone to represent your department on the committee. That person should be knowledgeable and influential. He will be the communication link between the committee and the key supervisors in your areas. Appointment to this committee will be considered a major assignment requiring a significant amount of time, particularly during the early stages of the energy conservation program.

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2-5

We expect the committee to research and come up with ideas, to establish an energy conservation goal, to communicate suggestions on ways of achieving that goal, to develop a common economic base to work from, and to do some record keeping. The committee will need to compile lists of energy conservation projects, their costs and benefits so that we can plan our expenditures. It will be the line supervisors, however, who must see to it that actions are taken to accomplish energy conservation.

I suggest that a good way to kick off the program would be to conduct surveys throughout our plant - tracing out the energy streams to identify where our energy is used so that wasted energy can be reduced or eliminated. Fixing leaks of steam and other utilities, adjusting furnace burners, repairing steam traps, and repairing or adding insulation are some of the maintenance and operating actions we can take immediately to start realizing energy savings. The Energy Conservation Program Guide for Industry and Commerce (EPIC) published by the U. S. Department of Commerce will provide the guidance for developing our program.

I am thoroughly convinced that the continuing success of our company requires that we use our energy supplies as effectively as possible. The success of our program will depend upon the support and interest that we, as management, demonstrate.

I think we should set a tough, achievable goal for ourselves. Let's set an initial target of 10% savings in energy this year. This goal can be revised after we conduct our surveys and estimate the actual potential savings.

ECONERGY COMPANY

EMPLOYEE BULLETIN

Date: January 15, 1974

To: All Employees

From: D. T. Parker, Plant Manager

Subject: Initiation of Energy Conservation Program

Television, radio and newspapers are filled with reports on the energy shortages. This problem has implications far beyond the inconvenience we experience at our local gasoline service stations. This energy problem has a potentially serious impact on American industry, including the ECONERGY Company.

Not only are the costs of purchasing electricity and fuels soaring but the availability of our vital raw materials is declining as a result of the energy shortages. To avoid production disruptions which may result from these shortages, the ECONERGY Company is initiating a far-reaching Energy Conservation Program (ECP) to identify and eliminate inefficient, unnecessary, or wasteful uses of energy throughout the plant.

To accomplish this task I have appointed Mr. J. C. Baker, Utilities Department, to head the Energy Conservation Committee. This Committee will formulate a program which will enable us to reduce our energy consumption without disruption to our production flow. The support and active participation of every employee is essential if we are to achieve our goal of 10% savings in energy use this year.

You will soon be seeing signs that say "savEnergy." This is more than a catchy slogan: it is a reminder that energy will always be available at home and at work if we are careful in the ways we use it.

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171

2.4 FIRST MEETING OF ENERGY CONSERVATION COMMITTEE

As soon as the committee coordinator learns of his new assignment, he starts planning how the committee can go about accomplishing the tasks set forth in the plant manager's letter (2.3.1). When he has the names of all members of the committee and a plan in mind, he calls a meeting of the committee and submits to them the proposed plan in the following letter.

For simplification, we are assuming that the plan and assignments were accepted by the committee and no additional topics were discussed. However, if the committee agreed on some changes to the plan and/or talked about other matters, minutes of the meeting would be written and copies given to committee members.

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 18, 1974

To: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker
Energy Conservation Coordinator

Subject: Committee Assignments

D. T. Parker's letter dated January 7, 1974 outlines the formation of the Energy Conservation Committee, to which we have been appointed, and indicates some of the actions we are to undertake. As he suggests, each of us should become thoroughly familiar with the program suggestions and energy conservation opportunities described in EPIC.

We must get started on several of the tasks immediately, so I have developed a plan for dividing these duties among us. The first priority is to conduct a survey of present energy usage and to begin reducing or eliminating waste. Because of their familiarity with these problems, our operations representatives, W. D. Smith and A. B. Jones, should be responsible for developing a plant-wide plan for energy saving surveys.

Another area that requires early attention is the establishment of a common economic base from which to work. There will be energy saving projects that will involve dollar expenditures which require financial justification. We need a uniform method of calculating the value of savings for our various forms of energy - electric power, fuel, steam, and compressed air. As Utilities representative, I will undertake this task.

I would appreciate it if R. B. Robinson of Administrative Services could obtain from Accounting data on the quantities of purchased fuel and electric power used monthly last year and this year. A continuing plot of energy consumption per unit of production is necessary to help us monitor the progress in our plant-wide energy conservation effort.

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In addition, we need to consider projected energy costs. So, would R. B. Robinson also please ask the Purchasing Section if they can develop fuel and electric power cost projections for this year, three years and five years into the future.

We are going to need to communicate ideas and suggestions on energy conservation techniques applicable to our plant. Since T. G. Marshall of Maintenance has had broad experience throughout the plant, I am asking that he assume responsibility for coordinating this function. To start with, we have several literature references and the Energy Conservation Opportunities (ECO's) in EPIC. As time goes along, we surely will have generated additional ideas deserving of broad communications through our committee.

If all of you are in agreement with this plan, I suggest that each of us meet with the key supervisors in our areas this week to inform them of our program plans and to ask them to come up with energy saving projects.

Let us meet again in my office one week from today, at the same time, to report our progress. If you are unable to attend that meeting or any future meeting, please ask an alternate to attend in your place.

cc: D. T. Parker
Plant Manager

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-182

2.5 SECOND MEETING OF ENERGY CONSERVATION COMMITTEE

The week passes and the committee holds its second meeting. The coordinator gives each member a copy of the agenda shown on the next page. Then, in the sequence of the agenda, each member presents his report, giving a copy of his letter and attachments to all present. The following six letters document the reports and proposals submitted at the meeting. It is assumed that all these matters were accepted or approved by the committee.

Note that in Section 2.5.4, and elsewhere in EPIC, a ratio of 10,000 Btu/kWh is used for illustrative purposes for the energy used by a utility to generate electricity. According to the Federal Power Commission, the national average for 1972 was approximately 12,000 Btu/kWh. This figure will vary from region to region, however.

2.5.1

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: Energy Conservation Committee

From: J. C. Baker, Coordinator

Subject: Agenda for Second Meeting of the Energy Conservation Committee

1. Report of plans for energy saving surveys
2. Energy equivalents for plant utilities
3. Present and projected future costs of energy
4. Monthly energy use for 1973 and 1974
5. Proposed forms:
   a. Calculation of Btu per unit of production
   b. Tracking chart

cc: D. T. Parker
Plant Manager

:.5.2

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: Energy Saving Survey Team
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Plans for First Energy Saving Survey

The first survey will be aimed at identifying energy wastes that can be corrected by maintenance or operations actions. The attached survey form indicates the types of wastes we will be looking for. In addition, we will refer to the Energy Conservation Checklist in EPIC. All process areas and buildings will be included in the survey. The main part of the survey will be conducted during normal daytime work hours, but one or more night visits will be required to search for excess nighttime lighting and HVAC (heating, ventilating, and air conditioning), as well as equipment running when not needed. Areas or buildings that are in a full or partial shutdown condition on weekends will warrant weekend visits to look for energy use that is not necessary.

The survey team proposes to conduct the survey of each area in cooperation with and accompanied by a foreman, supervisor, or engineer designated by the department head. Findings of the survey of each area will be recorded on the attached form and copies will be made available to the department head, the maintenance department, and the Energy Conservation Committee.

Work orders for correction of energy wastes will be prepared by department supervisors, as is the case for any other maintenance work.

This week, the survey team will prepare a timetable for visits to the various areas and communicate the schedule to department heads.

By copy of this letter to Mr. Parker we are requesting management endorsement of our plans for this first energy survey.

cc: D. T. Parker, Plant Manager

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2-13

ENERGY SAVING SURVEY

Surveyed by: _____

Department: _____

Date: _____

Fuel Gas or Oil Leaks	Steam Leaks	Compressed Air Leaks	Condensate Leaks	Water Leaks	Damaged or Lacking Insulation	Excess Lighting	Excess Utility Usage	Equipment Running & Not Needed	Burners Out of Adjustment	Leaks of or Excess of HVAC	Location	Date Corrected

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

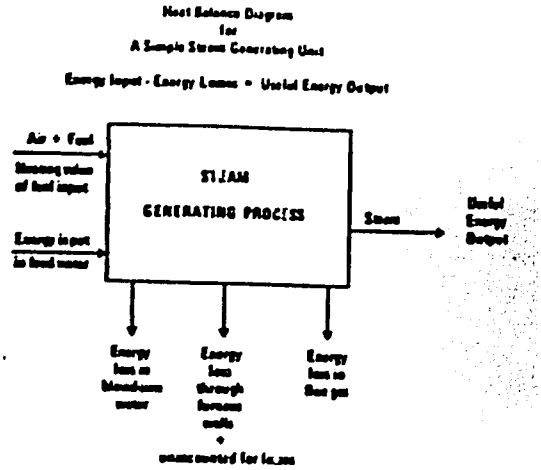
From: Energy Saving Survey Team
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Future Energy Savings Surveys

After our first energy saving survey, which is aimed at correction of the more obvious energy losses, there are other surveys which we feel certain will reveal additional ways to reduce energy consumption but which probably will require capital investment.

1. The Energy Balance

The basic data needed for energy conservation efforts is an energy balance on each process and department. This study can be done by an engineer in the department concerned, who is thoroughly familiar with the process flow sheet or the building energy uses. The object is to define in detail the energy input, energy utilized, and energy dissipated or wasted. In some areas this will require improving measuring capability. The cost of this additional measuring capability must be weighed against the potential savings. An example is shown on the following energy flow diagram for a steam generating unit. Having identified the individual energy wastes, the engineer can then determine methods for reducing or using these energy wastes. (The ECO Checklist in EPIC can be helpful.) The engineer's next task is to evaluate the alternate methods and recommend the best one.



2. Energy Surplus Survey

After the energy balances have been completed, some coordination by the survey team is indicated. The survey team can contact the engineers who have prepared the energy balances to determine if there are energy wastes that could be recovered economically but have no use within their process area. Let's say that there is potential for recovering waste heat from furnace flue gases by using it to (a) preheat combustion air or (b) generate low pressure steam. Suppose that air preheat is impractical because of furnace construction and there is no use for low pressure steam within that department. The survey team can communicate through the energy conservation committee to other departments and perhaps find a use for the low pressure steam.

3. Survey of Pressure Reducing Stations

Determine location of all steam and high pressure gas, pressure-reducing valves, upstream and downstream pressures, and flow rates. Evaluate feasibility of letting pressure down by flowing through an expander driving some equipment, such as a pump or compressor.

4. Survey of Compressed Air Pressure Requirements

Survey all users of plant air to find minimum pressure levels required. Lowering compressor discharge pressure saves energy. If all but one or two users can be satisfied with a lower pressure, an evaluation of the feasibility of installing a separate compressor or a booster to supply these higher pressure users should be made.

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5. Steam System Survey

a. Traps

Review all steam trap installations. Are there too many traps on a line? Or too few? Of an efficient type? Or inefficient? Are traps sized properly? Installed properly? Are they functioning as they should? Should traps receive special maintenance attention?

b. Increase Condensate Return to Boilers

Loss of condensate is a waste of heat and of valuable high purity water. Identify all sources of condensate and evaluate economic feasibility of installing pump and insulated piping to return condensate to boiler feedwater tank. If condensate is contaminated, evaluate possible clean-up.

c. Use of Lower Pressure Steam

Search for situations where use of high pressure steam can be switched over feasibly to lower pressure steam. It is advantageous to use the lower pressure steam where the higher pressure is not needed. This is particularly true when the lower pressure steam is being supplied from extraction or back-pressure turbines or a low pressure boiler separate from the high pressure boiler. Of course, lowering pressure by a pressure reducing valve offers no savings in energy.

6. Survey for Oversized Electric Motors and Equipment

Electric motors and equipment, such as centrifugal pumps, operate with best efficiency at rated load. If they are operating at reduced load, efficiency suffers. Take ampere readings on motors and compare to rating. Evaluate replacement of oversized motors and equipment with proper sizes.

7. Insulation

Inspect insulation and furnace walls with infrared scanners to detect excessive heat losses. Repair insulation and walls where needed.

8. Combustion Survey

Determine combustion efficiency in all furnaces. Evaluate economic feasibility of replacing burners with more efficient type and installing oxygen and combustibles analyzers on flue gas along with improved combustion control system to maintain optimum excess air.

cc: D. T. Parker
Plant Manager

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ECONERGY COMPANY

INTER-OFFICE CORRESPONDENC

Date: January 25, 1974

To: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker, Energy Conservation Coordinator

Subject: Energy Equivalents and Costs for Plant Utilities

We need a uniform method for calculating the value of our energy savings for our various utilities and I recommend we institute an accounting system based on Btu usage. For our purchased electric power, dollar accounting is simply a matter of using the $/kWh rate(s) we pay the utility company. The matter is more involved, however, for our Btu accounting of electric power. One kWh is capable of producing 3412 Btu of heat. But due to power plant inefficiency, approximately 10,000 Btu of fuel are burned by the utility company to generate one kWh. Therefore, the "energy equivalent" for electric power is:

10,000 Btu/kWh

Following this example then, an "energy equivalent" may be defined as the number of Btu of fuel that are consumed in generating a unit of utility, such as a kWh of electricity or 1000 lb of steam. Defined this way, the "energy equivalent" is the factor we can use across the board to put all projects on a common base in our energy conservation program.

Next let us consider the fuels that we purchase. The energy equivalent is the heat of combustion. The unit cost comes from accounting.

Fuel	Cost	Energy Equivalent	Cost/MBtu
Natural Gas	$_____/1000 cu ft	_____Btu/cu ft	$_____/MBtu
Fuel Oil	$_____/gal	_____Btu/gal	$_____/MBtu
Coal	$_____/ton	_____Btu/lb	$_____/MBtu

The costs of our generated steam, compressed air, water and treated boiler make-up water published by our accounting department include depreciation, maintenance and operating costs, etc., and therefore cannot be used in figuring dollar value of energy saving. When we save these utilities we save only the fuel or electric power that was used to generate, compress or pump the utilities. In our boilers generating 400 psig and 150 psig steam, the energy equivalents of steam are the fuel Btu used in generating steam based on the boiler efficiencies. The steam costs to be used in energy saving accounting are, therefore, the costs of the energy equivalents.

Steam	Cost	Energy Equivalent
400 psig	$_____/1000 lb	_____Btu/1000 lb
150 psig	$_____/1000 lb	_____Btu/1000 lb

With regard to compressed air, water and treated boiler make-up water, the costs are for electric power used for compressing or pumping. The energy equivalents take into account 10,000 Btu/kWh.

Utility	Cost	Energy Equivalent
Compressed Air	$_____/1000 cu ft	_____Btu/1000 cu ft
Water	$_____/1000 lb	_____Btu/1000 lb
Boiler Make-Up Water	$_____/1000 lb	_____Btu/1000 lb

When we save condensate and return it to the boilers, we reduce the boiler make-up water requirement and save the Btu difference between the heat content of the condensate at _____F and of fresh water at its temperature. Thus, our energy equivalent for condensate is _____Btu/1000 lb and its cost is $_____/1000 lb.

cc: D. T. Parker
Plant Manager

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2.5.5

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance

From: R. B. Robinson, Administrative Services

Subject: Fuel and Power Cost Projections

The Purchasing Section has provided the following information:

	Cost at Present	Estimated Cost 3 Years	Estimated Cost 5 Years
Electric Power	$____/kWh	$____/kWh	$____kWh
Natural Gas	$____/1000 cu ft	$____/1000 cu ft	$____1000 cu ft
Fuel Oil	$____/gal	$____/gal	$____/gal
Coal	$____/ton	$____/ton	$____/ton

Purchasing has agreed to advise our committee whenever these costs are revised.

cc: D. T. Parker, Plant Manager

192

2.5.6

ECONERGY COMPANY

NTER-OFFICE CORRESPOND

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance

From: R. B. Robinson, Administrative Services

Subject: Monthly Use of Fuels and Power - 1973 and 1974

The attached form was developed and submitted to Accounting. They hope to have the information compiled within a few days.

cc: D. T. Parker, Plant Manager

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MONTHLY PLANT ENERGY USE

1973	ELECTRIC POWER			NATURAL GAS			FUEL OIL			COAL			TOTAL Btu	Number of Units Produced	Btu Per Unit of Production
	kWh	Btu/kWh	Btu	k cu ft	Btu/k cu ft	Btu	gal	Btu/gal	Btu	TONS	Btu/lb	Btu			
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															
1974															
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: W. D. Smith Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker, Energy Conservation Coordinator

Subject: Department Energy Unit Ratio and Tracking Chart

Attachment A is a copy of the do-it-yourself kit "How to Profit by Conserving Energy" by the Sub-Council on Technology of the National Industrial Energy Conservation Council. The form in the kit details a suggested procedure for calculating the energy content (Btu) of a product.

In our particular operations, we have no by-products, and our energy use for waste disposal is negligible. Therefore, our prime concern is raw material energy and conversion energy. Conversion energy is the energy equivalent of utilities used in manufacturing the product. Raw material energy content can be somewhat more involved. The raw material suppliers may be able to provide this number, or an approximation is available for most materials from the U. S. Department of Commerce. If unavailable from these sources, it can be estimated as the heat of combustion of the material. This estimate is always low. Any energy spent on the raw material in getting it to the point of use should be considered - for example, mining, crushing and sizing, and transportation. Bear in mind that less energy intensive raw materials should escalate less in price as energy costs increase. Having determined the energy content of raw materials, and given a choice, a better raw material selection should be possible.

Attachment B is a three page form for tabulating monthly department use of raw materials and utilities, for calculating Btu content of these quantities, and for determining the total Btu and the energy/production unit ratio in Btu per unit of production. As this information is developed we will probably find that there is a need to install additional metering and to rehabilitate some existing meters, if economically justified.

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Attachment C is a graph for plotting the monthly Btu per unit of production for 1973 and 1974. This graph can be used for charting the energy used by individual production departments and also by the total plant.

If you have any questions, see me. These records are important to our on-going program.

cc: D. T. Parker, Plant Manager

ATTACHMENT A

HOW TO PROFIT BY CONSERVING ENERGY

A Do-It-Yourself Kit

SUB-COUNCIL ON TECHNOLOGY OF THE NATIONAL INDUSTRIAL ENERGY CONSERVATION COUNCIL

OBJECTIVE Encourage industrial firms to set measurable goals for reducing energy consumption per unit of product produced.

GOAL. X-percent reduction in energy content* expressed in BTU'S per unit of product.

PROCEDURE Use the energy calculator on page two to determine the current energy content in BTU'S per unit for any kind of manufactured or processed product.

With this yardstick, measure progress to determine if energy reduction goals are being met, exceeded or missed.

*Energy content per unit of product includes energy content of the raw material plus energy spent in converting or upgrading and in waste disposal.

"DO IT YOURSELF KIT" For Calculating The Energy Content of A Product

GUIDELINES OF THE NATIONAL INDUSTRIAL ENERGY CONSERVATION COUNCIL
SUGGESTED PROCEDURE FOR CALCULATING ENERGY CONTENT (BTU'S) OF A PRODUCT

FOR THE PERIOD BEGINNING January 1, 1974 PERIOD ENDING February 1, 1974

COMPANY: The Dow Chemical Co.
RESPONSIBLE MANAGER: I. G. Snyder, Jr.
1 PRODUCT
2 PRODUCT I.D. NO.

RAW MATERIAL ENERGY (LIST MAJOR RAW MATERIALS)

4 RAW MATERIAL	5 TOTAL UNITS	X 6 BTU'S UNIT	= 7 TOTAL BTU'S
A:			
B:			
C:			
D:			
E:			
		TOTAL BTU'S 8	

3 TOTAL UNITS PRODUCED

UNITS OF PRODUCTION (LB., GAL., PIECE, ETC.)

CONVERSION ENERGY (LIST ALL MAJOR UTILITIES)

9 UTILITY	10 TOTAL UNITS	X 11 BTU'S UNIT	= 12 TOTAL BTU'S
A:			
B:			
C:			
D:			
E:			
		TOTAL BTU'S 13	

WASTE DISPOSAL ENERGY

14 WASTE	15 TOTAL DISPOSAL BTU'S	17 TOTAL WASTED UNITS
A:		
B:		
C:		
D:		
E:		
TOTAL BTU'S 16		

GROSS ENERGY CONTENT OF PRODUCT (SUM OF ITEMS 8, 13 AND 16) BTU'S 18

BY-PRODUCT ENERGY CREDIT (LIST ALL MAJOR BY-PRODUCTS)

19 BY-PRODUCT	20 TOTAL UNITS	X 21 BTU'S UNIT	= 22 TOTAL BTU'S
A:			
B:			
C:			
D:			
E:			
		TOTAL BTU'S 23	

NET ENERGY CONTENT OF PRODUCT (ITEM 18 LESS ITEM 23) 24 BTU'S

ENERGY CONTENT PER UNIT OF PRODUCTION (ITEM 24 DIVIDED BY ITEM 3) 25 BTU'S UNIT

GOAL (TARGETED ENERGY CONTENT FOR THIS PERIOD) BTU'S UNIT 26

IF ITEM 26 IS EQUAL TO ITEM 25, GOAL WAS MADE (CHECK ITEM 27) 27 ☐ MADE GOAL

IF ITEM 26 IS NOT EQUAL TO ITEM 25, COMPUTE DEVIATION FROM GOAL:

ITEM 26 LESS ITEM 25 28

ITEM 28 DIVIDED BY ITEM 26 29

MULTIPLY ITEM 29 BY 100 30

IF ITEM 26 IS GREATER THAN ITEM 25, COPY ITEM 30 HERE 31+ % BEAT GOAL

IF ITEM 26 IS LESS THAN ITEM 25, COPY ITEM 30 HERE 32− % MISSED GOAL

GUIDE FOR FILLING OUT FORM ON OPPOSITE PAGE

1 Finished product ready for shipment.

2 Product I.D. No. is the numerical identification of the product.

3 Units of the product (item 1) made during this time period.

4 The material that goes into producing and packaging the product (includes fuels used as raw material).

5 Units of the raw material (item 4) that were used during this time period.

6 Every material has a specific energy content. Energy content is measured in terms of BTU'S. Raw material supplier may provide this number or an approximation is available for most materials from the U. S. Department of Commerce. If unavailable from these sources, it can be estimated as the heat of combustion of the material. This estimate is always low.

7 (Item 5) multiplied by (item 6).

9 Utilities include primarily electricity, fuel oil and natural gas.

10 Units of utility (item 9) used during this time period.

11 For fuel, this is the heat of combustion of the fuel. This number is available from supplier. For other utilities, this is the energy necessary to generate one unit of the utility (e.g., 1 KWH). Use 10,000 BTU'S per KWH unless your supplier has a better number.

12 (Item 10) multiplied by (item 11).

14 Waste is that material which has no economic value and which requires additional BTU'S to dispose of.

15 Estimated energy to dispose of the waste (item 14). This may be the energy to truck away and bury a solid, the energy to burn some scrap or the energy to run a waste disposal plant.

17 Units of waste produced during this time period. Units of waste is not needed for the calculation, but may be recorded for later reference.

19 By-products are those saleable materials which are made incidental to the production of the desired product or products.

20 Units of by-product (item 19) made during this time period.

21 The usable energy in the by-product. As an approximation, use the ratio of the value of the by-product to the value of the product multiplied by the gross energy content of the product (item 18).

22 (Item 20) multiplied by (item 21).

"DO IT YOURSELF KIT" For Calculating The Energy Content of A Product

GUIDELINES OF THE NATIONAL INDUSTRIAL ENERGY CONSERVATION COUNCIL
SUGGESTED PROCEDURE FOR CALCULATING ENERGY CONTENT (BTU'S) OF A PRODUCT

FOR THE PERIOD BEGINNING January 1, 1974 . PERIOD ENDING February 1, 1974

COMPANY: The Dow Chemical Co. — RESPONSIBLE OFFICER: T. G. Snyder, Jr.

1 PRODUCT: Ethylene — 2 PRODUCT I.D. NO.: 007-23-1

RAW MATERIAL ENERGY (LIST MAJOR RAW MATERIALS)

4 Raw Material	5 Total Units	6 BTU'S/Unit	7 Total BTU'S
A: Ethane	52.29×10^6	22,304/lb	1166.3×10^6
B: Caustic Soda	252×10^6	12,500/lb	3.2×10^6
C: Hydrogenation Cat.	6.048×10^3	75,000/lb	5×10^6
D: Desiccant	1.117×10^3	80,000/lb	1×10^6
E:			

TOTAL BTU'S 8 1170.9×10^6

3 TOTAL UNITS PRODUCED: 42,000,000

UNITS OF PRODUCTION (LB, GAL, PIECE, ETC.): Pounds

CONVERSION ENERGY (LIST ALL MAJOR UTILITIES)

9 Utility	10 Total Units	11 BTU'S/Unit	12 Total BTU'S
A: Steam, 150 psig	181.31×10^6	1077/lb	195.3×10^6
B: Electricity, KWH	6.71×10^6	10,000/KWH	7.1×10^6
C: Natural Gas, ft³	263.4×10^6	1030/ft³	277.5×10^6
D: Cooling Water, gal	1764×10^6	10/gal	17.6×10^6
E: Process Water, gal	1.974×10^6	15/gal	[illegible]

TOTAL BTU'S 13 497.5×10^6

WASTE DISPOSAL ENERGY

14 Waste	15 Total Disposal BTU'S	17 Total Wasted Units
A: Oily, Caustic Water	Disposal Plant 1.8×10^6	Water: 5.97×10^6 gal.
B:	Muriatic Acid 4.3×10^6	Oil in water: 11,200 lbs.
C:		Muriatic Acid to neutralize
D:		Caustic: 699,120 lbs.
E:		

TOTAL BTU'S 16 6.1×10^6

GROSS ENERGY CONTENT OF PRODUCT (SUM OF ITEMS 8, 13 AND 16) BTU'S 18 1673.5×10^6

BY-PRODUCT ENERGY CREDIT (LIST ALL MAJOR BY-PRODUCTS)

19 By-Product	20 Total Units	21 BTU'S/Unit	22 Total BTU'S
A: Residue Gas	6.048×10^3	20,000	121.0×10^6
B: Pyrolysis Gas	1.722×10^3	17,946	31.0×10^6
C: C_3-C_4 Fraction	2.436×10^3	20,833	50.7×10^6
D:			
E:			

TOTAL BTU'S 23 202.7×10^6 BTU'S

NET ENERGY CONTENT OF PRODUCT (ITEM 18 LESS ITEM 23) 24 1470.8×10^6 BTU'S

ENERGY CONTENT PER UNIT OF PRODUCTION (ITEM 24 DIVIDED BY ITEM 3) 25 35,019 BTU'S/UNIT

COAL (TARGETED ENERGY CONTENT FOR THIS PERIOD) BTU'S/UNIT 26 35,000

IF ITEM 26 IS EQUAL TO ITEM 25, GOAL WAS MADE (CHECK ITEM 27) ..... 27 ____ MADE COAL

IF ITEM 26 IS NOT EQUAL TO ITEM 25, COMPUTE DEVIATION FROM GOAL:

ITEM 26 LESS ITEM 25 ..... 28 481

ITEM 28 DIVIDED BY ITEM 26 ..... 29 0.135

MULTIPLY ITEM 29 BY 100 ..... 30 1.35

IF ITEM 26 IS GREATER THAN ITEM 25, COPY ITEM 30 HERE ..... 31 +1.35 % BEAT GOAL

IF ITEM 26 IS LESS THAN ITEM 25, COPY ITEM 30 HERE ..... 32 — % MISSED GOAL

2

4 All significant input materials are listed even though they may not appear in the final product.

5 These quantities of materials were used during January, 1974. The desiccant may be purchased only once every six months, but a proportional amount is allocated to this month.

6 The energy content of ethane is the heat of combustion which is available from several reference books.

The energy content of caustic was estimated from literature sources.

The heat content of the hydrogenation catalyst and the desiccant are educated guesses. The quantities of these materials used are so small that the error introduced by an incorrect guess is insignificant.

11 The BTU'S per unit of steam are available from steam tables. In this case credit was taken for the hot water returned to the steam plant. 10,000 BTU'S/KWH was used since this is close to the energy that an average utility uses to generate a KWH of electricity.

1030 BTU'S/ft³ of gas was provided by the gas supplier. The energy in the cooling and the process water is the power necessary to pump the water. The power in KWH'S/gallon was multiplied by 10,000 BTU'S/KWH to arrive at the BTU'S per gallon.

15 The oily, caustic water was neutralized and then treated in a bio-oxidation plant. The total disposal BTU'S include the energy to run the bio-oxidation plant plus the energy in the neutralizing agent, muriatic acid.

21 All of the energy contents here were assumed to be equal to the heat of combustion since these materials may be readily burned as fuel. Residue gas was assumed to be the same as light fuel oil, pyrolysis gas was assumed to be the same as toluene and the C_3-C_4 fraction was assumed to be butane.

The basic information in this example was taken from the Stanford Research Institute report on "Ethylene" dated August, 1967, page 219.

WHY MEASURE ENERGY

As energy is used more effectively, product costs can be reduced and profits improved. This can be accomplished even in the face of sharply increasing energy costs. Since industrial energy consumption accounts for approximately 40% of total energy used in the United States, significant contributions can be made to the national effort.

The first step to meaningful energy conservation is measurement of all the energy that enters and leaves a plant during a given period. This measurement will probably be an approximation at first but should improve with experience.

To calculate the energy content of your products, use the attached form, and then set goals for improvement. The filled in example is for ethylene; but the procedure applies equally well to any manufacturing operation, be it a grain mill pulp mill, steel mill, furniture factory, or assembly line.

Though time consuming and challenging to make the initial calculations, it will be worth the effort. Raw materials which contain, and manufacturing processes which use large amounts of energy will be pinpointed.

What To Expect – Once BTU content is determined, products can be ranked by BTU'S per unit, BTU'S per dollar of sales, and BTU'S per dollar profit. Then, as energy availability becomes more limited, it will be possible to quickly focus on the most profitable products.

Equipment associated with the large energy consuming steps will be identified. Once the energy-hogging equipment is isolated, efforts can be focused on replacing old machinery and equipment, using more energy-conscious designs, and improving maintenance programs.

Less energy-intensive raw materials should escalate less in price as energy costs increase. Having determined the energy content of raw materials, and given a choice, a better raw material selection should be possible.

Stressing the importance of BTU'S per-unit-of-production to plant operating people should provide the incentive for them to chase down where all of the input BTU'S actually end up. Often, the first attempt will account for less than 50% of the input BTU'S. Simply the act of identifying the other 50% will reveal many opportunities for improvement. For example:

1. A reduction in scrap or an improvement in yield will often be the most significant energy reduction that can be accomplished.
2. Leaking water, steam, inert gas or raw material may seem quite small as it escapes into the air, but over time this can represent a sizeable quantity of energy.
3. Heat loss from equipment can sometimes be reduced with more insulation once the losses are identified.
4. Sometimes energy lost to the environment, either through cooling water or through air, can be used advantageously to heat inlet raw materials or process equipment.
5. The energy content of waste may be recovered in part or in total by treating and recycling the waste back through the manufacturing process. In some instances, it may be possible to burn the waste and use the recovered heat in the process.
6. Temperature control equipment may be alternately heating and cooling. This problem is often corrected by a simple adjustment of the controls.
7. Recognizing that it takes 10,000 BTU'S to generate one KWH may suggest using less electricity for heating since this same KWH is capable of producing only 3,413 BTU'S of heat.
8. It may be possible to combine some manufacturing steps so that the product does not cool down between steps and subsequently have to be reheated before it is processed further.

The energy shortage is a national concern. It can also be viewed as an exciting challenge. Those companies that move quickly to meet the challenge will contribute substantially to the solution of a national problem – and make money at it.

The first step is measurement.

MONTHLY DEPARTMENT ENERGY USE

1973	ELECTRIC POWER			NATURAL GAS			FUEL OIL			COAL			COMPRESSED AIR		
	kWh	Btu/kWh	Btu	k cu ft	Btu/k cu ft	Btu	gal	Btu/gal	Btu	TONS	Btu/lb	Btu	k cu ft	Btu/k cu ft	Btu
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															
1974															
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															

DEPARTMENT _____

MONTHLY DEPARTMENT ENERGY USE

1973	psig STEAM			psig STEAM			CONDENSATE USED OR LOST			WATER			TOTAL CONVERSION Btu	NUMBER OF UNITS PRODUCED	CONVERSION Btu PER UNIT OF PRODUCTION
	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu			
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															
1974															
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															

DEPARTMENT _____

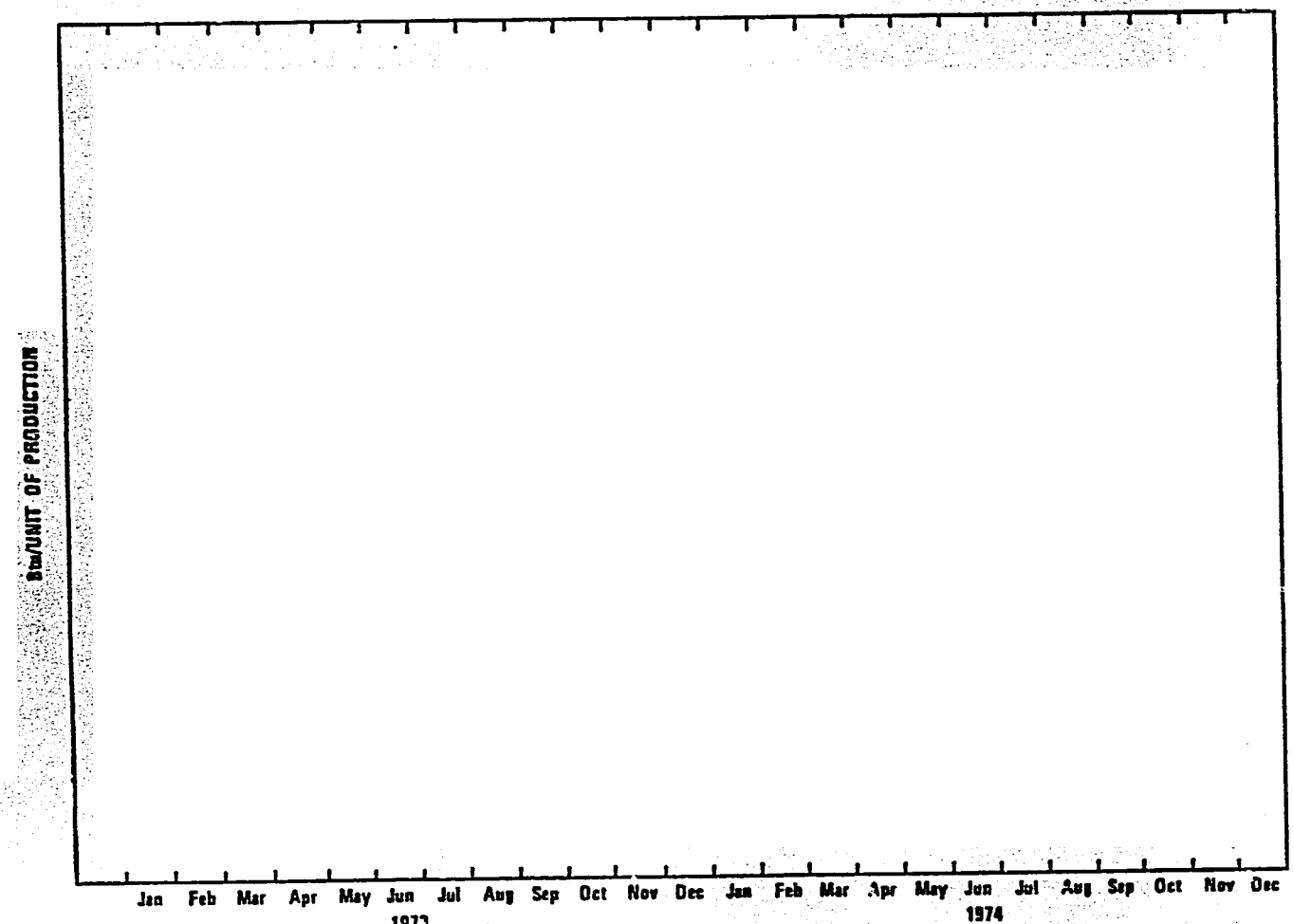
MONTHLY DEPARTMENT ENERGY USE

1973	RAW MATERIAL "A"			RAW MATERIAL "B"			RAW MATERIAL "C"			Total Raw Material Btu	Raw Material Btu Per Unit of Production	Total Conversion & Raw Material Btu Per Unit of Production
	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu			
Jan.												
Feb.												
Mar.												
Apr.												
May												
June												
July												
Aug.												
Sep.												
Oct.												
Nov.												
Dec.												
1974												
Jan.												
Feb.												
Mar.												
Apr.												
May												
June												
July												
Aug.												
Sep.												
Oct.												
Nov.												
Dec.												

Tracking Chart

Energy Use Per Unit of Production

Attachment C



2.6 First Energy Saving Survey

The survey team's plan for the first survey was approved by the Energy Conservation Committee, you recall. Now we have a sequence of four letters regarding the survey. The manager endorses the survey plan. The team submits their timetable to department heads. Findings of the survey are reported. Finally, the team suggests the need for foreman training in energy conservation. Note the application of:

- Survey
- Employee involvement
- Top management commitment

2.6.1

ECONERGY COMPANY

INTER-OFFICE CORRESPONDEN

Date: January 29, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: First Energy Saving Survey

You each have a copy of the January 25, 1974, letter from W. D. Smith and A. B. Jones detailing their plans for the survey aimed at energy wastes that can be corrected by maintenance or operations actions. These are the types of energy losses that can be stopped or reduced right away, or fairly soon, and at little or no expense.

Smith and Jones will contact you in the near future regarding a timetable for the survey. Each of you should inform them of the name of the person you designate to accompany them and participate with them in the survey of areas under your responsibility.

Everyone's cooperation in this program is important. I urge that you put some real priority on this survey and on taking corrective actions as soon as practical.

cc: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

2.6.2

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 1, 1974

To: Department Head

From: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: First Energy Saving Survey

The timetable for this survey is given below. If any of these dates are not convenient, please contact us so that other times can be arranged.

Area	Date
Furnaces	February 11
Shop	February 12
Heat Treating	February 13
Shipping	February 14
Receiving	February 15
Laboratory	February 19
Utilities	February 20
Chemicals	February 21
Administrative Building	February 22

cc: D. T. Parker, Plant Manager

savEnergy

2.6.3

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 28, 1974

To: Department Heads

From: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Results of First Energy Saving Survey

Attached are the findings of the survey. Some of the operating items have already been corrected by operations personnel. Department supervisors have already written work orders for a number of the maintenance repairs. Those operating or maintenance items that require process shutdown for correction have been added to the lists of jobs to be done at the first shutdown opportunity by department supervisors.

It is important that we monitor the progress of work on correcting these energy wastes by keeping up-to-date records; therefore, it is essential that we are advised when each job is completed.

If there are any questions concerning the survey, please contact us.

As a result of the survey and some energy conservation projects being proposed, we have developed an estimate of potential savings and we suggest that our goal be increased to 12% savings in energy this year.

cc: D. T. Parker, Plant Manager
Energy Conservation Committee

ENERGY SAVING SURVEY

Department: _____

Date: _____

Surveyed by: W.D. Still
A.B. JONES

Fuel or Gas Leaks	Steam Leaks	Compressed Air Leaks	Condensate Leaks	Water Leaks	Damaged or Lacking Insulation	Excess Lighting	Excess Utility Usage	Equipment Running & Not Needed	Burners Out of Adjustment	Leaks of or Excess of HVAC	Location	Date Corrected
		near #1 furnace									Furnaces	
					#7 furnace lines						Furnaces	
						Parts Storage					Shop	
										Broken Window	Shop	
#3 furnace									#1 furnace		Heat Treating	
											Heat Treating	
								#3 furnace			Heat Treating	
	Bldg. Heater Tran							#1 conveyor			Assembly	
						Storage Area					Assembly	
											Shipping	
										Doors need weatherstrip	Shipping	
								Elev cooler fan			Receiving	
						Above Shelves					Receiving	
								Fume hood fan			Laboratory	
				safety shower							Laboratory	
	boiler					Chemical Storage					Laboratory	
					#2 steam line						Utilities	
		#2 compressor									Utilities	
	#1 reheater										Utilities	
			#2 reheater								Chemicals	
							steam jets				Chemicals	
						Hallways					Chemicals	
											Administration Building	
				Men's rm. faucet						exhaust air condition	Administration Building	
											Administration Building	

2.6.4

E CONE. C. COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 28, 1974

To: J. C. Baker, Energy Conservation Coordinator
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Need for Supervisor Training Program

During our first energy savings survey we had opportunities to discuss energy conservation with the foremen accompanying us. We learned that these foremen should be made more aware of the costs of utilities, the potential of savings through conservation, and the methods for saving energy.

Therefore, we recommend that the Energy Conservation Committee design a course on energy conservation to be included in the Supervisor Training Program.

cc: D. T. Parker
Plant Manager

21

2.7 THIRD MEETING OF THE ENERGY CONSERVATION COMMITTEE

This meeting is the last to be recorded in this section. On the following pages are four memoranda dealing with the topics shown on the agenda. The last memorandum presents plans for special activities each month for the rest of the year. At this point an active, effective program should be well into the process of implementation.

2.7.1

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Energy Conservation Committee

From: J. C. Baker, Coordinator

Subject: Agenda for Third Meeting of the Energy Conservation Committee

1. Capital project reviews
2. Energy saving project lists and project evaluation summar
3. Communication of ways to save energy
4. Continuing program

cc: D. T. Parker
Plant Manager

2.7.2

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: Capital Project Reviews

As you know, in our authorization procedure every capital project must be reviewed and approved with regard to safety, fire protection, pollution abatement, and additional utility requirements. As of this date, we are adding energy conservation to this checklist.

Every capital job will be reviewed by the Coordinator of the Energy Conservation Committee. On large jobs the interested committee member will also participate with the coordinator and project team. The purpose of these reviews is to assure that there is efficient utilization of energy in the design. If the project has to do with production, the design Btu per unit of production will be calculated and compared with the historical Btu unit ratio. More efficient use of energy is expected.

cc: Energy Conservation Committee

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker, Energy Conservation Coordinator

Subject: Energy Saving Project Lists and Project Evaluation Summary

Some of our energy conservation projects will require capital; others can be done on expense. Therefore, we should have two separate lists of projects. In order to have the lists in a uniform format, the two attached forms for capital and expense projects are provided for use by all departments.

The ratio of energy savings/year per dollar invested is an indicator of how good a project is, compared to other projects. The higher the number, the better the project. In the forms, a column for percent return on investment is also included as an aid in assigning priorities on projects.

Also attached is an evaluation summary form to be used for each project.

Please submit copies of these forms to the key supervisors in your area and request that they enter their project information and return completed copies (lists and evaluations) before our next meeting one month from today.

Our manager, Mr. Parker, has requested that we continue working on the lists, revising and updating them monthly, adding new projects that evolve and additional maintenance jobs that become necessary.

cc: D. T. Parker, Plant Manager

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ENERGY CONSERVATION
CAPITAL PROJECTS

Department: _____

Date: _____

Project Number	Project Description	Energy Savings Btu/Year	Capital Cost $	Ratio Btu/Year Saving / $ Capital	Percent ROI	Priority	Status

ENERGY CONSERVATION
EXPENSE PROJECTS

Department: _____

Date: _____

Project Number	Project Description	Energy Savings Btu/Year	Expense Cost $	Ratio Btu/Year Saving / $ Expense	Percent ROI	Priority	Status

ENERGY CONSERVATION PROJECT
EVALUATION SUMMARY

Capital _____ or Expense _____

Department _____

Date _____

Project No. _____ Person Responsible _____

Project Title: _____

Description of Project: _____

_____

_____

_____

_____

Location: _____

Financial Evaluation

Estimated

Energy saving (electric power kWh/yr steam lb/yr etc.)

Utility or Raw Material	Saving
_____	_____ /yr
_____	_____ /yr
_____	_____ /yr
Total energy saving	_____ MBtu/yr
Total energy cost saving	_____ $/yr
Other cost saving due to:	
_____	_____ $/yr
Additional cost due to:	
_____	_____ $/yr
Net cost saving	_____ $/yr
Cost of project	_____ $

ENERGY CONSERVATION PROJECT
EVALUATION SUMMARY

Calculated

Return on investment _____ %

Pay back period _____ months

Other _____ _____

Cost/unit of production: Now _____ After project implemented _____

Benefits/Problems

Product quality _____

Product yield _____

Production rate _____

Safety _____

Pollution _____

Maintenance-manpower/materials _____

Utilities _____

Working conditions _____

Employee attitude _____

Community _____

Other benefits/problems connected with implementation:

_____

_____

_____

Comments: _____

_____

Project ranking: _____

_____

_____

Planned authorization request date: _____

249

ECOENERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Energy Conservation Committee

From: T. G. Marshall, Maintenance

Subject: Communication of Ways to Save Energy

I have assembled a group of ECO's from EPIC, which are particularly applicable in our operation, along with a few good articles from the literature. I propose that we publish this as a booklet for plant wide use by supervisors. A copy of the list of ECO's chosen is attached hereto. After each of you has looked over the copy and indicated your approval, I will proceed with publication and distribution.

May I suggest that this booklet could be a useful tool in a training course as suggested in the recent letter from W. D. Smith and A. B. Jones.

cc: D. T. Parker
Plant Manager

220

LIST OF SUGGESTED ENERGY CONSERVING OPPORTUNITIES

	ECO
Building and Grounds	
Reduce Warehouse Ventilation Air	3.2.1
Reduce Outside Lighting	3.13.1
Reduce Air Conditioning During Non-Working Hours	3.2.5
Electric Power	
Schedule to Minimize Electrical Demand Charge	3.3.1
Steam	
Insulate Bare Steam Lines	3.4.1
Return Steam Condensate to Boiler Plant	3.4.3
Stop Steam Leaks	3.4.5
Inspect and Repair Steam Traps	3.4.6
Other Utilities	
Eliminate Leaks in Combustible Gas Lines	3.5.1
Lower Pressure of Compressed Air to Minimum Necessary Level	3.5.2
Eliminate Leaks in Compressed Air Lines	3.5.3
Use Fan for Personnel Cooling – Not Compressed Air	3.5.5
Combustion	
Replace Worn and Obsolete Controls	3.8.2
Daily Monitoring of Boiler Efficiency	3.8.4
Flue Gas Analysis as a Maintenance Tool	3.8.5
Scheduling	
Standby at Reduced Temperature	3.9.1
Shut Down Idle Heating Equipment	3.9.2
Process Specifications as a Source of Energy Savings	3.9.3
Schedule Equipment for Maximum Utilization	3.9.4

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Energy Conservation Committee

From: J. C. Baker, Energy Committee Coordinator

Subject: Continuing Program

At this point we have our program well underway, but I believe you will agree that we need a continuing program to maintain our momentum. Periodic energy saving surveys are one important activity. Communication and education also need emphasis to develop awareness. I thought it would be well to list the elements in this area, some of which we already have in the mill and others we may wish to include in plans for the future.

1. Monthly meetings of Energy Conservation Committee.
2. Monthly meetings of each committee member with key supervisors in the area he represents.
3. Booklet on ways to save energy.
4. Energy conservation course to be included in Supervisor Training program.
5. Periodic bulletins or features in the Plant News publicizing energy saving achievements and recognizing individuals responsible.
6. Posters on energy saving to be used in much the same way as safety posters.
7. "savEnergy" decals for placing at light switches, typewriters, and on hard hats.
8. Technical talks on energy saving aspects of steam traps, lighting, insulation, etc.
9. Letters to employees and their families giving energy saving tips for the home.
10. In public relations, company ads stressing energy conservation on radio and in newspaper; talks on energy saving before civic groups.

Attached to this letter is the outline of a proposed program of activities for each month for the rest of the year.

cc: D. T. Parker, Plant Manager

savEnergy

Planned Activities in Energy Conservation for Remainder of 1974

The following activities will take place each month and will not be repeated in the plans for individual months:

1. Meeting of Energy Conservation Committee
2. Meeting of each Committee Member with the key supervisors in his area
3. Updating of energy saving project lists
4. Communicate progress with updated plot of Btu/unit of production
5. Department supervision will conduct weekend audit

Month	
April	1. Distribute booklet of selected ECO's 2. Review status of corrective actions regarding first energy saving survey 3. Publish bulletin on energy saving tips for driving 4. Technical talk on steam traps
May	1. Energy conservation course in Supervisor Training 2. Departments develop energy balances 3. Distribute "savEnergy" decals 4. Technical talk on economics of insulation 5. Letter to employees at home with energy saving tips for the home
June	1. Trained foremen start holding monthly meetings with their people on energy conservation 2. Publish bulletin on air conditioning tune-up 3. As a result of energy balances, committee will conduct energy surplus survey 4. Coordinator gives talk at high school
July	1. Poster contest 2. Bulletin on energy saving during vacations 3. Survey of steam pressure reducing stations 4. Technical talk on lighting
August	1. Publicize poster contest winner in plant and community newspaper 2. Distribute posters 3. Survey compressed air requirements 4. Bulletin - "Don't use compressed air for cooling"
Sept.	1. Bulletin - "Tune up space heating systems" 2. Survey steam condensate system 3. Coordinator prepares talk with slides for local technical society meeting 4. Committee rides through plant at night and suggests corrective action on lighting
October	1. Demonstration of infrared survey to detect excessive heat losses 2. Steam trap survey 3. Bulletin on steam tracing systems 4. Technical talk on combustion

November 1. Survey oversized electric motors and equipment
2. Bulletin - Recognize someone's energy saving achievement
3. Second course in Supervisor Training
4. Technical talk on electric motors and power factor

December 1. Bulletin - "Use reflectors and reduce Christmas lighting"
2. Report achievements in reductions of energy use and announce goal for next year
3. Survey use of low pressure steam
4. Plan program activities for next year

2.8 CONCLUSION

This section on program implementation began with a discussion of the importance of management interest and support. It seems appropriate to include in the conclusion a letter from the manager to his staff demonstrating his *continuing concern* about energy conservation. His request for a contingency plan is then answered by his department heads with a report on the status of the contingency planning in each deparment.

.8.1

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 2', 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: Request for Energy Curtailment Contingency Plan

You should all be aware that energy supply is a very real and serious problem to our operations. Briefly, our anticipated allocations of fuel oil, natural gas, electric power, and gasoline are insufficient to support our operation as they have in the past. Our ability to eliminate unnecessary use of these commodities and to allocate fuel to vital functions will ultimately determine how severely our operations are curtailed.

Even more serious is our inability to secure adequate quantities of coal to meet anticipated needs. Efforts during the past two months have failed to increase deliveries, and inventories are currently at a low level. Current fuel suppliers are operating at their ultimate capacity and they face problems associated with weather, fuel shortages for their mining equipment and ever increasing strip mine regulations. To date, we have been unable to secure additional suppliers as those who are mining coal are sold out beyond their production capabilities.

At this time it appears that some production curtailments may be necessary. Each supervisor should review his operations: those pieces of equipment which are operating at less than desired efficiency with respect to energy consumption should be identified and plans made to restrict or curtail their operation. The basic factors which influence fuel efficiency and/or energy utilization in all processes should be identified and immediate steps taken to minimize our energy requirements.

savEnergy

2-54

226

In anticipation of possible short term reductions in energy supply, for instance electric power, we need a contingency plan. This should include a list of the equipment that would be shut down and the sequence of shut down in your department in case of 25%, 50%, 75% and 100% energy curtailments.

Your plan for reducing energy requirements in your area should be formalized and available for review by me one week from today. Remember - NO SAVING IS TOO SMALL TO BE CONSIDERED.

cc: Energy Conservation Committee

savEnergy

232

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 27, 1974

To: D. T. Parker, Plant Manager

From: Department Heads

Subject: Reduction of Energy Requirements and Contingency Plan Status

Significant reductions in energy use have been achieved in our operating units as follows:

Utilities

It has been our operating practice to fire all three boilers even though steam requirements could be provided by two boilers fully loaded. In this way, a forced outage of one boiler could be handled without decreasing steam output and causing interruption of operations of steam users.

We have shut down #1 boiler, the oldest and least efficient boiler, and the result is a fuel saving of ____M Btu/hr. In case of a forced outage of one of the two operating boilers, we have set up a communication procedure to curtail steam to certain units that can be shut down safely and quickly with the least impact on other operations in the plant and re-started with a minimum loss of productivity.

Conditions "A" and "B"

Similarly, in both departments, we have been able to shut down one of three furnaces by rescheduling throughput. The schedule is extremely tight at our present production rate, and on occasion we may need to fire up the third furnace in order to meet commitments. Fuel saving at present is ____M Btu/hr.

savEnergy

Contingency Plan Status

1. Electric Power

In general, during any curtailment of power, air conditioning thermostats in all buildings will be reset to ____F. System interlocks have been provided to avoid inadvertant operation of the heating system, except in those situations where the controlled lower humidity is required.

If a "brown out" occurs (voltage reduction in excess of 10%), certain motors trip off automatically and others must be tripped manually to avoid damage. We are surveying all motors to identify the ones that require manual tripping. Utilities will set up a communication procedure to inform the appropriate people when a "brown out" occurs.

Following is a tabulation of shutdown sequence for curtailments of electric power:

Curtailment	Shutdown Section
25%	1
50%	1,2
75%	1,2,3
100%	1,2,3,4

We have designated a number of units that will be included in each of the four sections but the plan is not complete yet.

2. Fuels

For each fuel, we will have a tabulation like the one for electric power. We are holding meetings this week to complete the designation of units in each section for each tabulation. We hope to submit the detailed plan to you next week.

In general, when fuel curtailment causes a cut-back in steam generation, all steam heated buildings will have thermostats reset to ____F. Again, system interlocks will prevent inadvertant operation of the cooling system, except where the controlled lower humidity is required.

savEnergy

224

EMPLOYEE MOTIVATION AND COMMUNICATION METHODS

David M. Heller
Air Products and Chemicals, Inc.
Paulsboro, New Jersey

ABSTRACT

This paper discusses the compelling reasons for involving all employees in the plant energy conservation effort, offers suggestions on how to implement and maintain a plant-wide, people oriented conservation program and provides examples to illustrate the methods involved and benefits possible. Three areas will be stressed: publicity, or communicating down the ladder, through newsletters and the use of distinctive logos; communicating up the ladder, by means of employee suggestion programs and discussion forums; and training, necessary to free employees from a pre-Embargo approach to manufacturing.

Current technical literature is full of information on how to reduce energy use. Consider energy management systems, waste heat recovery or heat pumps - all the facets of the design, construction, and operation of such equipment and many other new devices takes up an ever-increasing amount of our time. No one can deny the benefits achievable through capital investment and new technologies, but there are other, oft-neglected aspects of energy conservation to be considered. The development and use of an effective energy management organization and the involvement of the entire plant in the conservation effort can and should go hand-in-hand with the physical improvement of the operation.

I'd like to share with you my experiences as a member of one very successful energy management organization - explaining how we are set up to implement energy conservation and detailing a number of programs we have found effective.

ORGANIZATION FOR ENERGY CONSERVATION

I am employed as Technical Supervisor at Air Products and Chemicals' Paulsboro, New Jersey plant. The Paulsboro Plant is part of the Chemicals Group of Air Products. We are located in Southern New Jersey, in the Greater Philadelphia area. Of our 2[illegible] employees, 2[illegible] are exempt and the balance hourly bargaining. We produce various types of industrial catalysts, with our major product being DASCO, a nickel foam catalyst.

The Paulsboro Plant has seen sharply spiraling energy costs over the last few years, as we all have. From 1979 to 1981, our average cost for energy rose more than 50 percent. The impact of these costs

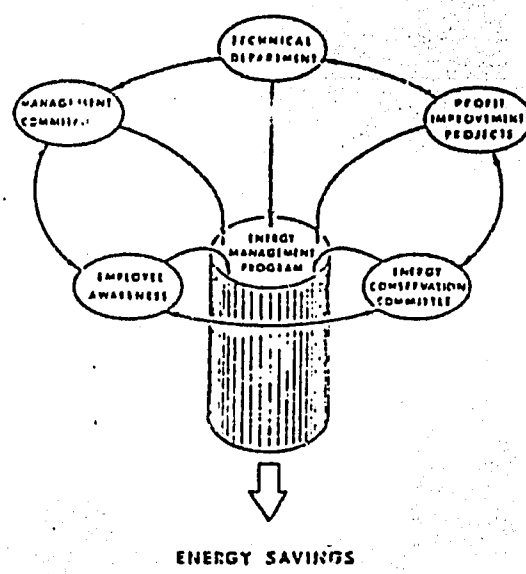


FIGURE 1

forced us to re-evaluate our conservation efforts and two conclusions came to light. First, conservation projects once glossed over because of a low rate of return now looked more attractive. It became necessary to refocus our technical efforts towards auditing our process flows and examing heat and material balances with the proverbial 'fine tooth comb.' Secondly, we came to realize that in order to be successful in reducing energy costs it made sense to involve the entire plant in the effort, not just a handful of engineers and technicians. The Paulsboro Plant conservation effort was thus or-

230

PAULSBORO ENERGY REPORT

NUMBER 10
JULY 1981

ENERGY USAGE REMAINS DOWN

lant energy usage was 4.0% less than the same period
a ner to keep your eyes open for energy waste.

THIRD QUARTER SUGGESTION DRAWING

icke as this quarter's winner of a $25 gift certi-
suggestions. Thanks to everyone who submitted
the last three months.

STEAM TRAP CAPS

ered of steam trap inspections, Dave DiPietro will
all steam traps. The caps insulate the traps by
of dea air around the trap and protecting it from
ve about ,500 a year on our steam bill. Plant steam
every three months.

OXIDIZER SAVINGS

is on the Thermal Oxidizer saved $20,000 in natural
or $80,000 over the entire year. A few bugs cropped
woul have been even greater.

SEE THE LIGHT

lamps produce up to five times as much light for the
s incandescent lamps and last 10 to 15 times longer.

not measure the amount of light - it measures the
ed to light the bulb. The amount of light is measured
example - you need six 25-watt bulbs to equal the
e 150-watt bulb.

wive's tale that there is a surge of power when you
ht . If you leave a room, even for a minute, turn
t.

* * * * * * * * * * * * * * * * * * * *

HAVE ANY SUGGESTIONS FOR IMPROVING THIS
DROP ON IN THE SUGGESTION BOX.
ENTER YOUR IDEAS. THANKS.

FIGURE 2

ganized along the lines shown in Figure 1.

The Technical Department and Technical Supervisor have major responsibility for the program. The Technical Supervisor serves as Plant Energy Conservation Coordinator; a part-time function at Paulsboro, but a position that requires full-time attention at larger facilities. The Conservation Coordinator's responsibilities include: developing and communicating conservation techniques and ideas to the employees, monitoring and reporting plant energy consumption, developing plant programs, goals and budgets and maintaining a plant environment conducive to energy conservation.

The Profit Improvement Program is a suggestion program for our technical people. This program encourages new ideas and recognizes the contributors.

The Energy Conservation Committee is composed of representatives from Production, Maintenance, Technical and Project Groups. The Committee meets monthly to discuss and evaluate the status of the plant conservation program. The Committee feeds information to the employees and communicates employee's concerns to management. The most important function of the Committee is to serve as a place where inter-departmental problems involving conservation projects or programs can be resolved.

Management commitment is a major component of our overall effort. Management communicates standards and goals and measures performance. Group and Corporate management provide support through people and capital, and acts as a clearing house for ideas. On the plant level, management communicates directly with the employees through our newsletter and letters sent to the homes.

The position of Energy Coordinator, the PIP program, and the Conservation Committee have all been active for a number of years. I believe the fact that we have organized specifically for the conservation of energy has helped us keep the effort alive and has resulted in a number of outstanding innovations. Now, I'd like to focus on the last box in our organization diagram - employee awareness.

INVOLVE THE ENTIRE PLANT

Proper motivation of operating, maintenance, laboratory and clerical personnel can be one of the most cost-effective energy conservation techniques. Hourly employees have the closest contact with the operating equipment and are often the most knowledgeable about production problems and unit idiosyncracies. They will see things that you as an engineer or manager might overlook and they will extend your eyes and ears to round-the-clock coverage.

These people are just as concerned as you are about the continued escalation of energy costs and the implications of dependence on foreign oil. Our responsibility is to direct them to utilize on the job the same resourcefulness they demonstrate in dealing with home energy problems.

What kind of results can be expected? The effects of improved operations and maintenance are often difficult to quantify - a steam leak reported a few days before a supervisor notices it, a spare pump turned off, a steam tracing line insulated rather than ignored. Then again, an operator might suggest a process modification that could yield large savings. There are also a number of intangibles - an improved morale, an esprit de corps, a spirit of cooperation. The point is that the benefits will far outweigh the costs of organizing the program and maintaining the effort.

There are many methods that can be used to motivate and communicate with your employees. The approach should be one of common-sense, stressing facts, with just enough pizzazz so they are noticed, without being laughed at. I'd like to stress three areas - publicity, or communicating down the ladder, communicating up the ladder, and training.

PUBLICITY

The "Paulsboro Energy Newsletter, (Figure 2) was developed to publicize the plant program. The Newsletter has been published monthly since October, 1980 and is posted on plant bulletin boards. A variety of items are presented - updates on plant conservation projects, recognition of outstanding contributions, progress toward conservation goals, and home energy tips.

The Newsletter has been very well received by our employees. One comment I often hear is that they feel better about their jobs and relations with the plant when they're told what's going on. Now that we've established an energy conservation presence at the plant, I find employees asking me if I have any information on air conditioner sizing, solar heating, and other items discussed in Newsletters.

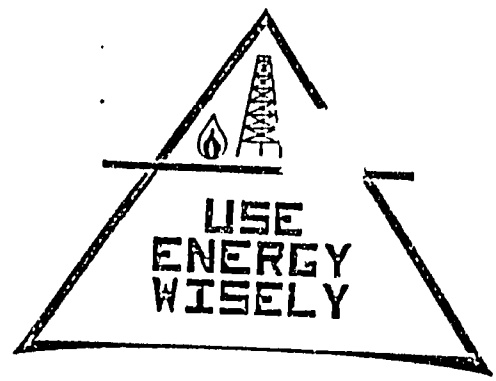


FIGURE 3

Please notice the emblem in the top left corner of the Newsletter (Figure 3). One of the first steps in publicizing Paulsboro's program was the development of an energy logo. This is a recognition tool used on all our conservation literature. We based ours on our corporate logo, adding the simple phrase "USE ENERGY WISELY" and adding a gas flame, an oil derrick, and electrical transmission

232

lines to illustrate our plant energy sources. One excellent way to kick off a conservation program is to hold a logo design contest among employees, or their children.

The types of publicity vehicles you employ will depend on your imagination, and your ability to judge what will be effective at your location. Handouts and pay envelope stuffers can present useful news, especially home conservation tips. These items can be obtained at a nominal price from public and private energy conservation organizations. Your local utility companies should also be a good source of information. This material is usually presented on a seasonal basis - heating tips in January, air conditioning ideas in July.

LISTENING TO EMPLOYEES

While communication down the ladder has been stressed to this point, input from the hourly employees should not be ignored. The programs already mentioned will help promote a spirit of cooperation at your location and employees will feel better about sharing their supervisors with their thoughts and ideas. And the number and quality of these ideas could probably surprise many of you.

To help tap this source of information, an Energy Conservation Suggestion Program was begun at Paulstown. Our capital expenditure consisted of a short form and a suggestion box. Each suggestor receives a personal reply thanking him and explaining what the follow-up action will involve. The reply is most important, unfeasible and even absurd suggestions are acknowledged in order to show we appreciate the interest and respect the input. Responsibility for acting on worthy suggestions is assigned at Conservation Committee meetings. (Figure 4).

During the first full year of operation twenty-five percent of our hourly personnel submitted suggestions and total suggestions numbered sixty. Quarterly a randomly drawn suggestion wins a $25 gift certificate at a local department store and a $50 certificate is given each year for the best suggestion. After completion of all projects and work orders resulting from last year's suggestions total savings are expected to be $25,000. The suggestions have included items such as: installation of light switches in under-utilized rooms, installation of skylights to reduce the need for light fixtures during the day, and lists of areas requiring insulation that were overlooked during energy audits. We have received only a few worthy process improvement suggestions to date. Process improvements could of course save many times over the $25,000 figure.

There are pros and cons on the question of prizes. One of the most-voiced complaints - when prizes are discontinued the signal is given that the program is ended. This is a valid point, and the answer must be decided at each location, based on

ENERGY CONSERVATION SUGGESTION

E1-31

TO SAVE ENERGY IN THE PLANT, I SUGGEST:

SHUT OFF GLYCOL CIRCULATING PUMP FOR DABCO II STILL WHEN NOT IN USE.

PUMP RAN 22 HRS DURING JANUARY WHILE STILL WAS DOWN.

SUGGESTOR [illegible] DEPT. OPERATIONS DATE [illegible]

SEND SUGGESTION TO: DAVE HELLER

(Figure 4)

past experiences. Any publicity or motivational program is going to slack off after the first flush of enthusiasm. This can be discouraging and help put a damper on everyone's conservation spirit. Let me suggest that this slackening off is a signal to transfuse some new ideas into your program.

I have always had an aversion to the use of competition between shifts as a means of promoting energy conservation. The key point in any awareness program should be cooperation, and competition, as friendly as you might try to make it, will often ruin any cooperative spirit. As an example, at a plant where I was formerly employed, we were interested in seeing which shift could produce the highest percentage of on-spec product. It was discovered that the operators on one shift would come in and rearrange the settings on a number of critical instruments to settings they knew worked well. Just before the shift ended, they would return the settings to those in use before they came on. Of course, after running lined-out for seven and one-half hours at one set of conditions the unit would go to pieces and the next shift would require several hours to get lined-out again. We decided after that to stick to softball for inter-shift competition.

ENERGY CONSERVATION TRAINING

Back in the good old, pre-Embargo days, it was not uncommon for operators in the chemical industry to use a little extra energy to maintain a safety margin on product quality. Increasing the reflux rate on a distillation column is one example. More often than not, supervisors shared the blame for wasting energy since they took the lumps if the product was off-spec. Unfortunately, old habits die hard. Employees must be re-trained to respect energy costs.

As I mentioned earlier, an "energy-awareness" is a necessary first step, but specific training will also be required.

One of the first things our supervisors did at Fairbanks was to re-read and where necessary, revise operating procedures to focus on conservation. There is no point in purifying a product way beyond its specification. We also expanded our preventive maintenance program in the hopes that it would help us eliminate energy-intensive startups and shutdowns.

This year, we plan to introduce energy training sessions for all employees, similar to a program we now use for safety training. A typical session could include an explanation of the operation of a new piece of equipment, information on how much a steam leak can cost and how to report one, and a question-and-answer period on energy issues.

Currently, we are developing an energy conservation slide show for presentation to all employees at upcoming training sessions. The program will use photographs shot at our plant to explain our energy usage, showing plant utility trends, the operation of energy users, examples of energy wasters - such as steam leaks, and uninsulated lines, methods for reducing energy use and a review of plant utility costs. The slides will be accompanied by a tape recorded narration. Employees relate well to this type of program since it is specific to their activities. At a cost of twenty to thirty dollars per show, "homemade" training aids are less expensive and more effective than commercially available programs.

A number of equipment vendors present short training seminars for operating personnel. Recently, we had a steam trap manufacturer present information on trap inspection and repair techniques to our maintenance men.

Instruction in conservation techniques should be included in the training of new employees, but if experienced men are used to train the newcomers, as is often the case, be sure the experienced ones are not going to hand down a pre-Embargo approach to manufacturing.

In summary, I've tried to present a "punch-list" of techniques and tools to increase the effectiveness of your energy conservation programs. Consider organizing for energy conservation. And try to find one person in your organization who shows an interest in conservation and formalize that interest into the position of conservation coordinator. Many methods are available that will pull your entire organization into the effort - newsletters, handouts, posters. Remember to listen to your employees too, through suggestion programs and forums. And retrain your people to appreciate the impact that energy is having on the cost of doing business.

The mix of methods you use will of course, vary with the type and size of the audience and the resources available, but I hope you have discovered one or two techniques that might be worth a try.

H.I. Helwan Cement Factory:

a.) Wet Process for normal cement production; production capacity 750,000 ton/year.

1. Incase of using 24hr/day Cement furnace: clinker will be produced by 2400 ton.
- raw material required: 2400 X 1.75 = 4200 ton/day
- If we know that mills used for raw have capacity of 165 ton/hr, then min. hours required for working these mills are 25.5 hrs/day i.e. these mills must not stopped at all to gurantee the continuity of production (but the actual daily working schudle is 18 hr./day).

2. Raw Crushers:

according to gathered data from the factory hours required for making the crushers are 12 hrs/day to produce 4200 ton/day.

1/16

3. Cement Mills:

clinker quantity required for cement mills is 2400 X 1.05 = 2520 ton/day.

If you know that nominal capacity for these mills is 125 ton/hr, in case of finding area for storage of clinker will capacity of 50,000 ton, then min. hours required for mills working per day to mill furnace products (working 24 hr/day) is 21 hrs.

The following table shows a summary for different production steps, min. hours required for daily working for each step; step load

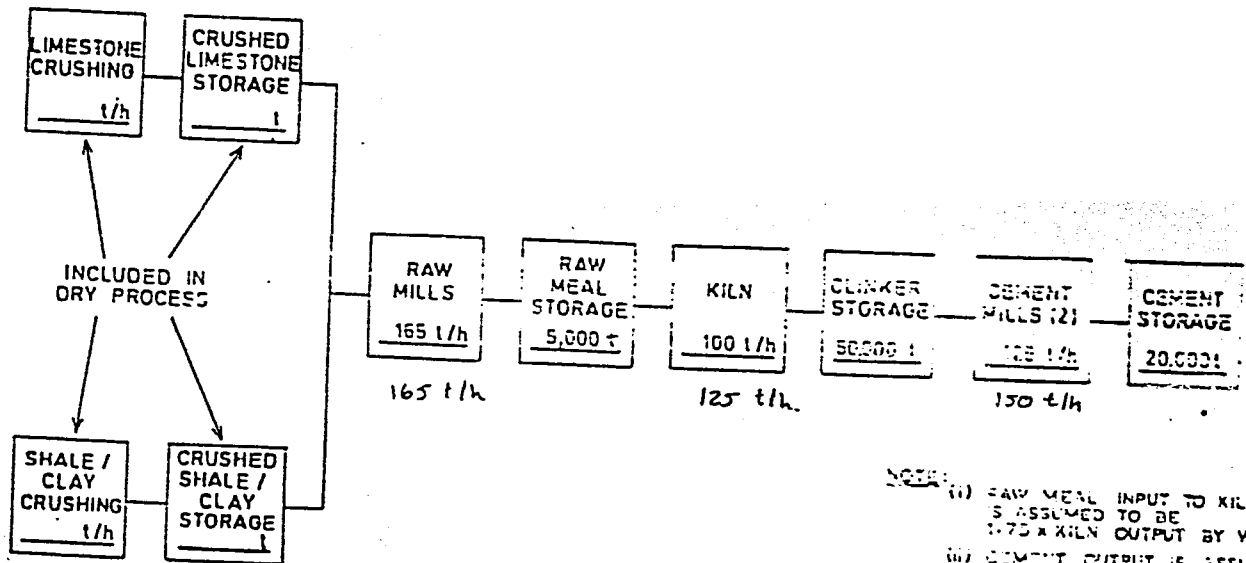
production steps	min. daily working hrs.	step load
- Furnace	24 hrs	1.45
- raw crushers	12 "	0.075
- raw mills	18 "	1.8
- Cement mills	18 "	6.0
helpers	18 "	

b) Wet process used for white cement production:

production capacity for this line is 100,000 ton/year which is low compared to that of normal cement production

1.000.000

NOMINAL PRODUCTION CAPACITY: 750,000 t/year
WET PROCESS LINES



NOTE: (i) RAW MEAL INPUT TO KILN IS ASSUMED TO BE 1.75 x KILN OUTPUT BY WEIGHT
(ii) CEMENT OUTPUT IS ASSUMED TO BE 1.05 x KILN OUTPUT BY WEIGHT

PRODUCTION / STORAGE DATA
PLANT: HELWAN

3/164

1. Raw mills:

for the continuous kiln 24 hr/day production is 300 ton clinker.
raw materials required is:

$$300 \times 1.75 = 525 \text{ ton/day.}$$

mills capacity is 12 ton/hr, min. hours required is $525/12 > 24$

i.e working hours required is greater than 24 hr/day. and it is working 18 hours only/day to keep it working ~~all the time~~ in good conditions

2. Raw crushers:

Raw crushers capacity 110 ton/hr, 6 hr/day to crush 525 ton/day.

3. Cement Mills:

for 24 hr kiln, clinker quantity for the mills is $300 \times 1.05 = 315$ ton/day

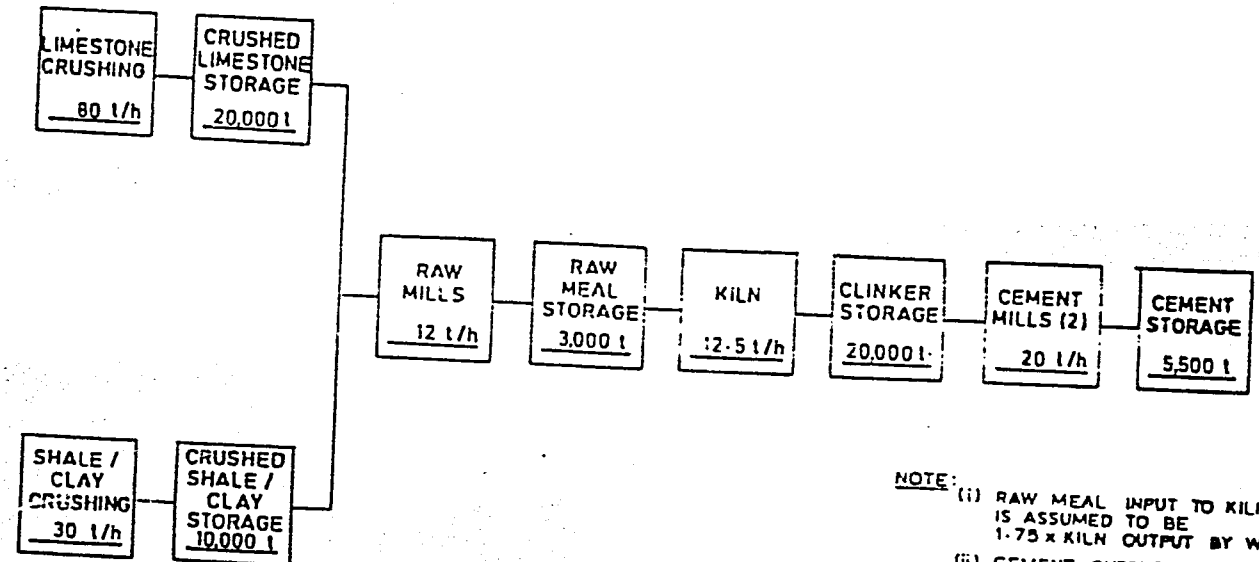
if the nominal capacity for these mills is 20 t/hr, in case of existance of clinker storage area with a capacity of 20,000 ton, min. hours required for mills working is 16 hrs to mill kiln production cement of 24 hr/day

following table shows different steps, min. hours required /day for each step.

production step	min. work hours/day	step load M.W
- kiln	24	0.59
- raw crushers	6	0.13
- " mills	18	0.8
- Cement mills	16	1.2
- helpers	18	0.06

calculated ~~capacity~~ power = 12.105 Megawatt
required power = 16.0 -"-

NOMINAL PRODUCTION CAPACITY: 100,000 t/year
WET PROCESS LINE WHITE CEMENT PLANT



NOTE:
(i) RAW MEAL INPUT TO KILN IS ASSUMED TO BE 1·75 x KILN OUTPUT BY WEIGHT
(ii) CEMENT OUTPUT IS ASSUMED TO BE 1·05 x KILN OUTPUT BY WEIGHT

PRODUCTION / STORAGE DATA
PLANT: HELWAN

6/16

line ① <u>Dry Process</u>

production capacity for this line is 1,500,000 ton/year

1. <u>Raw Mills</u>:

for kiln working 24hr/day clinker is produced by 4500 ton

- Raw material required :
  4500 x 1.75 = 7875 ton/day

- Mills capacity 360 ton/hr, min. hours required is 22 hr/day.

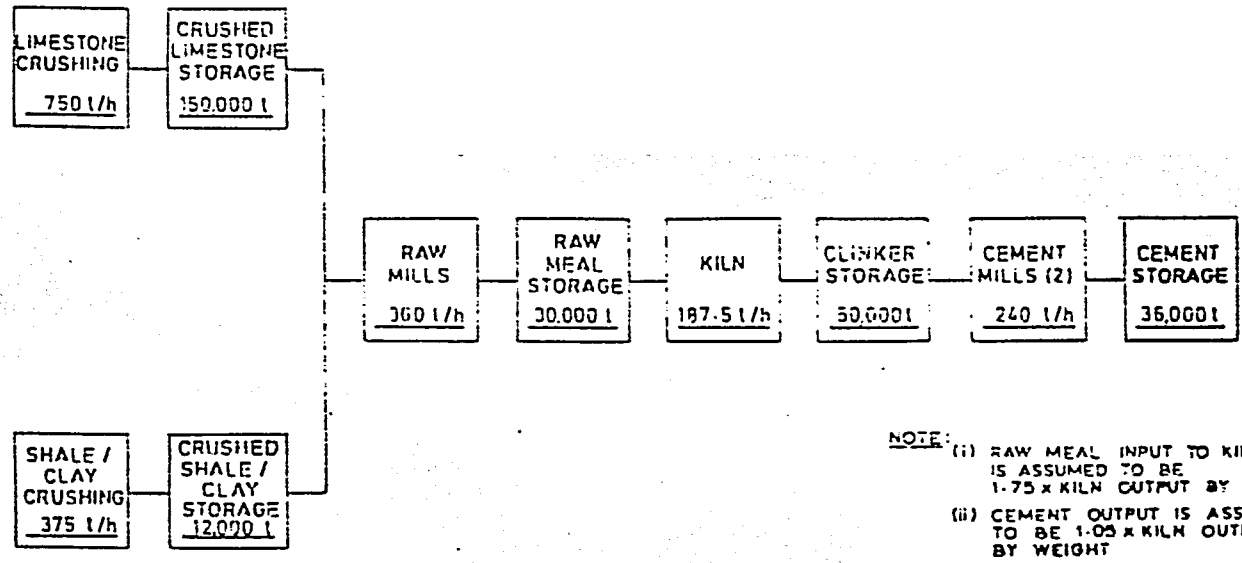
2. <u>Raw crushers</u> :
   crushers capacity 1125 ton/hr, hours required for working is 9hr/day.

3. <u>Cement Mills</u>:

clinker quantity : 4500 X 1.05 = 4725 ton/day

If you know that nominal mill capacity is 240 t/hr, existance & storage area wit capacity of 50,000 ton, min. hours /day is 20 hr for kiln working 24hr/day.

NOMINAL PRODUCTION CAPACITY: 1,500,000t/year
DRY PROCESS LINE 1



NOTE: (i) RAW MEAL INPUT TO KILN IS ASSUMED TO BE 1·75 x KILN OUTPUT BY WEIGHT

(ii) CEMENT OUTPUT IS ASSUMED TO BE 1·05 x KILN OUTPUT BY WEIGHT

PRODUCTION / STORAGE DATA

PLANT: HELWAN

8/12

following table shows production steps, min. hours required for working/day for each step:

production steps	min. working hour/day	stoppood
kiln	24	9.0
raw crushers	9	3.8
raw mills	22	8.0
Cement "	20	11.6
helpers	16	1.4

d). line no (2) dry process (after studies)

Production capacity 1,500,000 t/year

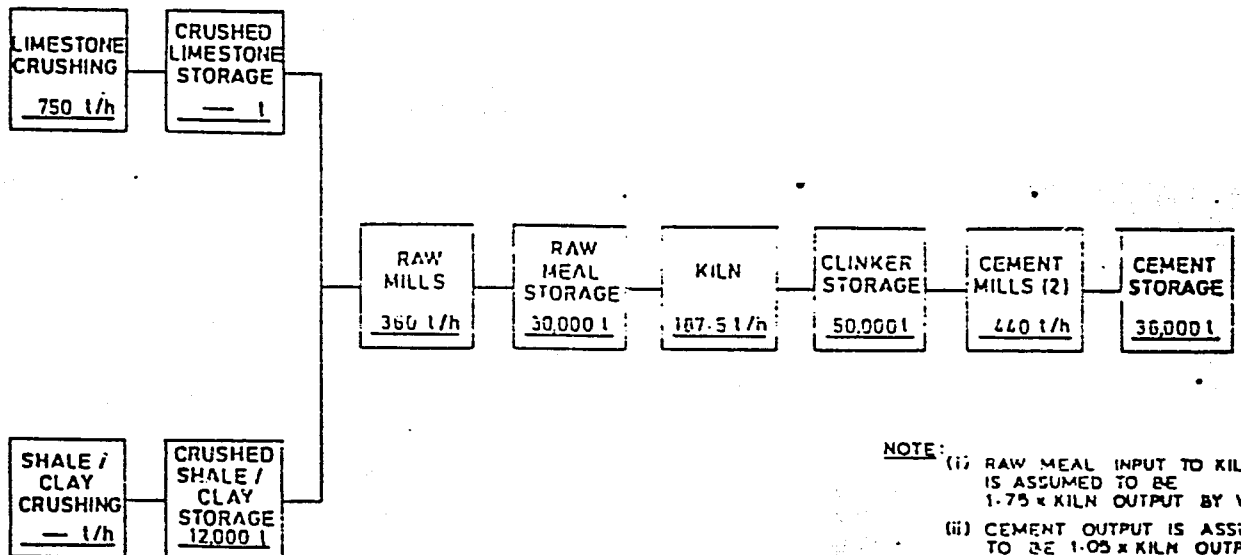
1. Raw Mills:

- kiln working 24 hr/day, produces 4500 ton clinker
- raw materials required: 4500 × 1.75 = 7875 t/day
- raw mills capacity 360 t/hr, min hours reqd 22 hr/day

2. Raw Crushers capacity 750 t/hr
working hours required 9 hr/day to produce 7875 t/day.

3. Cement mills: for kiln working 24 hr/day:

NOMINAL PRODUCTION CAPACITY: 1,500,000t/year
DRY PROCESS LINE 2



NOTE:
(i) RAW MEAL INPUT TO KILN IS ASSUMED TO BE 1.75 x KILN OUTPUT BY WEIGHT
(ii) CEMENT OUTPUT IS ASSUMED TO BE 1.05 x KILN OUTPUT BY WEIGHT

PRODUCTION / STORAGE DATA
PLANT: HELWAN

10/12

clinker 4500 X 1.05 = 4725 t/day

nominal capacity for mill 240 t/hr,
storage for clinker 50,000 t,
min. working hours for these mills 20 hr

following table shows production steps, min. working hours for each step

production step	min. work/hr/day	step load MW
- kiln	24	9
- raw crushers	9	1.0
- raw mills	22	8.0
- Cement "	11	14.6
- helper 5 "	16	0.7

4/2 Toura Cement Factory:

a. Wet process (line 1 → 6):
Production capacity for these lines 1,000,000 t/year

1. Raw mills:
24 hr kiln/day produces 3900 ton

raw quantity : 3900 X 1.75 = 6825 t/day

mills capacity 365 t/hr, min. working hours required 19 hr/day
18,000 ton raw is stored to work the kiln more than 24 hr/day

Weekly Report
Cement Company Helwan
Period from : 24.3.85 to : 26.5.85

Week Starting date	Total El. Energy Consumption KWH	Max load		Load factor	Power factor	% of Peak load to total energy
		Peak	off Peak			
24.3.1985	2337	25,6	25,9	0,536	0.955	25
31.3.1985	3927	29,4	29,1	0.795	0.953	26,2
7.4.1985	3828	26,9	27,1	0.84	0.946	25.1
14.4.1985	3213	24,8	26,3	0.726	0.939	25.7
21.4.1985	4106	30,4	30,2	0.805	0.957	25.2
28.4.1985	3899	28,9	29,9	0.777	0.95	25.5
5.5.1985	2164	30,9	31,1	0.415	0.935	25.3
12.5.1985	3816	31,6	31,6	0.718	0.955	25.3
19.5.1985	3919	31,1	32,0	0.729	0.945	24.4
26.5.1985	2205	24,4	31,6	0.415	0.963	23.2

Weekly Report
Cement Company
Period From : 2.6.85 to : 4.8.85

Week Starting date	Total Elc. Energy Consumption KWH	Max load Peak	Max load off Peak	Load factor	Power factor	% of Peak load to total energy
2.6.85	3058	26,2	31,6	0.576	0.93	23,7
9.6.85	3981	30,5	30,5	0,776	0.884	24,7
16.6.85	3338	28,9	29,5	0.672	0.863	25,2
23.6.85	3126	27,3	29,1	0.639	0.853	22,4
30.6.85	2243	24,7	26,5	0.503	0.861	23,6
7.7.85	946	8,5	13,4	0.421	0.847	23,7
14.7.85	2867	27,1	26,8	0.628	0.853	27,6
21.7.85	324	30	29,5	0.641	0.856	25,6
28.7.85	2858	28,9	29,2	0.582	0.866	26,6
4.8.85	2798	26,2	25,7	0.636	0.873	26,1

Weekly Report
Cement Company
Period From : 11.8.85 to : 13.10.85

Week Starting date	Total Elc. Energy Consumption KWH.	Max load Peak	Max load off Peak	Load factor	Power factor	% of Peak load to total energy
11.8	2813	25,9	24,5	0.647	0.864	26,2
18.8	3043	23,5	23,7	0.763	0.846	24,4
25.8	3943	30,8	31	0.757	0.815	26,2
1.9	2835	27,9	28,1	0.601	0.804	24,2
8.9	1417	18,4	19,3	0.746	0.861	24,9
15.9	3908	30,2	33,2	0.701	0.822	25,8
22.9	3639	33,2	30,4	0.653	0.817	26,2
29.9	4001	32,2	33,6	0.709	0.814	25,3
6.10	3320	32	32,4	0.610	0.802	25,3
13.10	2556	23,8	25,4	0.6	0.825	25

Weekly Report
Cement Company Helwan
Period from : 20.10.85 to : 22.12.85

Week Starting date	Total Elc. Energy Consumption KWH	Max load Peak	Max load off Peak	Load factor	Power factor	% of Peak load to total energy
20.10	4264	34,4	34,6	0.738	0.825	26.5
27.10	3838	35,1	32,8	0.65	0.816	25.3
3.11	3382	33,4	32,3	0.603	0.812	27
10.11	4752	34,3	34,3	0.824	0.81	25,8
17.11	4149	33,1	34,1	0.725	0.808	25,8
24.11	3067	25,1	25,1	0.726	0.824	25
1.12	2892	24,2	27,5	0.626	0.776	25
8.12	2584	22	21,3	0.7	0.766	27,5
15.12	3160	27,3	28,8	0.654	0.788	26,2
22.12	1528	24,3	29,9	0.304	0,381	

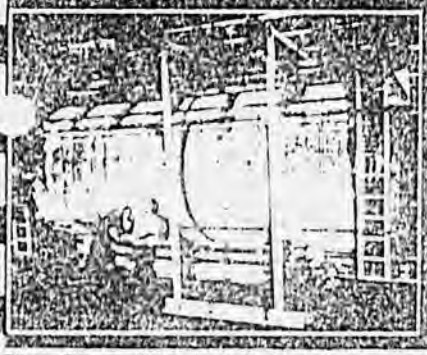
Weekly Report
Cement Company Torah
Period from = 24/3/85 to = 26/5/85

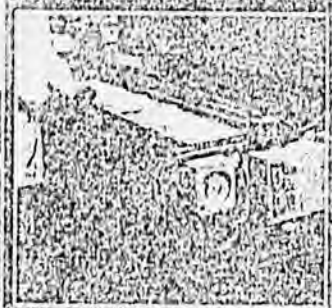
Week Starting date	Total Elc. Energy Consumption KWH	Max load Peak MW	Max load off Peak MW	Load factor	Power factor	% of Peak load to total energy
24.3.1985	3907	27,372	27,372	0,85	0,841	26,3
31.3.1985	3552	27,98	27,676	0,756	0,834	26,3
7.4.1985	2837	25,851	25,851	0,653	0,829	26,7
14.4.1985	3600	26,763	26,763	0,801	0,839	26,7
21.4.1985	3052	23,722	24,330	0,747	0,844	25,3
28.4.1985	3006	26,459	26,155	0,676	0,832	26,9
5.5.1985	3799	28,284	28,284	0,799	0,847	25,1
12.5.1985	3703	27,676	27,676	0,796	0,853	26,1
19.5.1985	3800	25,851	27,067	0,836	0,855	24,9
26.5.1985	3471	25,851	27,067	0,763	0,851	25,2

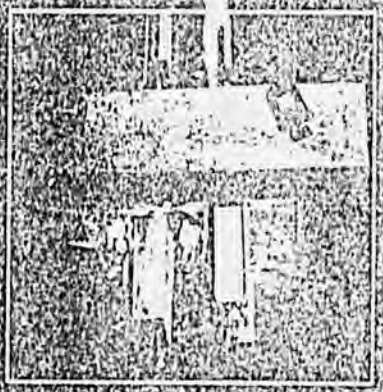
CTL

construction technology laboratories, inc.

CATALOG OF PROFESSIONAL SERVICES







Contents

Structural
- Testing 3
- Analytical Design 4
- Evaluation/Nondestructive Testing 6
- Repair, Restoration 6

Expert Witness Testimony 6, 12
Thermal Behavior 8
- Fire Testing 8

Package and Contents Testing 10
Transportation Engineering
- Highways/Railroads 10

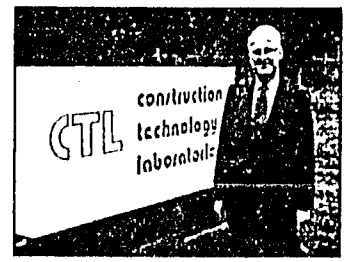
Materials Analysis
- Design, Testing 12

Materials Evaluation 14
Process Development 14

Why You Should Consider CTL

When you need solutions to problems concerning structures, construction processes, or materials, consider the specialized consulting and engineering resources of Construction Technology Laboratories, Inc.

As one of the largest technological centers in the world devoted to the scientific study of construction materials and applications, CTL is fully qualified to solve your construction, engineering, or manufacturing problems.



Walter E. Kunze, president

Our laboratories are equipped with state-of-the-art facilities for structural testing, fire testing, and materials analysis. We even provide highly specialized testing services for products as diverse as railcar bolsters and soft drink containers. Many of these are shown in the following pages, where you will be introduced to the broad spectrum of services available to you.

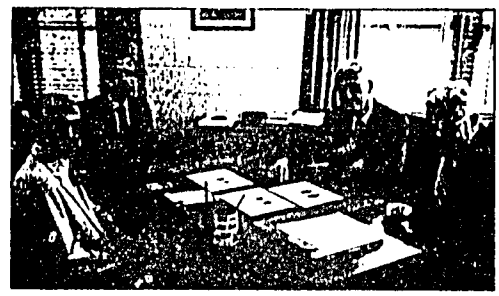
As a CTL client you receive the benefit of our more than 70 years of expertise, technology, and data in research and engineering. Investigations are handled in our Skokie laboratories or in the field at your jobsite. Our professional staff includes structural, civil, mechanical, and chemical engineers, geologists, chemists, and quality-assurance specialists. Our specialized consulting services also include expert witness testimony.

Many of our growing number of clients can be found in the Fortune 500 list of companies. They include engineering and construction firms, manufacturers, energy-related and chemical companies, electric utilities, railroads, building owners, loss prevention insurers, government agencies, and others.

We urge you to read this catalog and discover for yourself the many ways in which you too can have your technical problems solved by CTL. Join the increasing number of business firms, government agencies, and others who are supplementing their engineering and product development capabilities with the contract services of CTL.

For a firsthand look at our facilities and staff, we invite you to visit us the next time you are in the Chicago area. We are only a short distance from O'Hare Airport.

Walter E. Kunze, President
Construction Technology Laboratories, Inc.
(312) 965-7500



CTL officers (left to right): Anthony E. Fiorato, vice president, Materials Technology; W. Gene Corley, vice president, Engineering and Planning; W. E. Kunze, president; J. Worth Slade, vice president, Administrative Services.

©1986 Construction Technology Laboratories, Inc.

Structural Testing and Analysis

Structural engineers, architects, builders, owners, and contractors—you can prove to yourself what others in your field already know. When you need help finding answers to questions concerning small and large structural members or components, Construction Technology Laboratories is your most reliable source.

Most experimental investigations are conducted in the structural laboratory. A 56x121-ft test area permits both large- and small-scale specimens to be tested in a temperature- and humidity-controlled environment. Specimens may be loaded in many ways to simulate the effects of gravity, wind, earthquake, or other forces. Static and dynamic tests are conducted on both small and large structural members or components. Loading may be controlled manually or with programed closed-loop test systems.

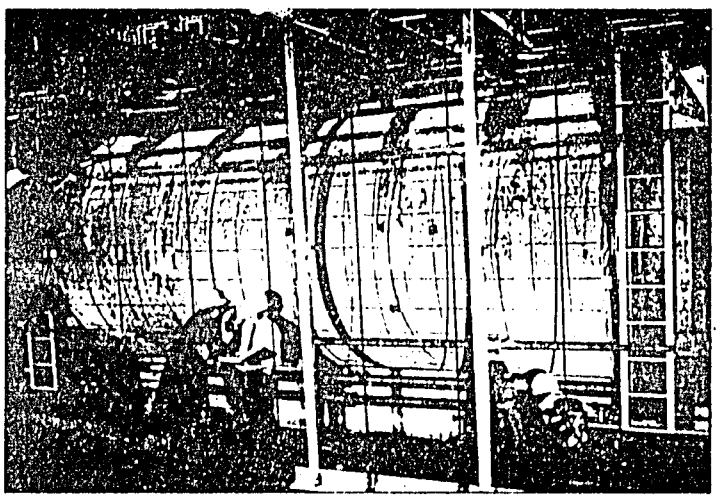
State-of-the-art electronic equipment measures and records strains, deformations, and loads. On-line computers provide instant data reduction.

The structural laboratory houses MAX—the world's largest Multi-AXial test facility. MAX has the capability of resisting loads up to 50 million lbs and can accommodate structural elements or components formerly considered too large to test at full scale.

Henry G. Russell, executive director, Structural Engineering Department (left to right), Ralph G. Cesterle, manager, Structural Analytical Section, and Donald M. Schultz, manager Structural Development Section.

The laboratory also includes a facility to test large-diameter concrete pressure pipes at hydrostatic pressures up to 700 psi.

Structural testing may also be performed in any of the laboratory's conventional testing machines. Capacities range from a few hundred pounds to a million pounds. In addition to full-scale structural members, these machines can be used to test prestressing tendons,



CTL's pipe-testing facility can test a 96-in.-diameter pipe at pressures up to 700 psi.

Herm Hanson, principal engineer, uses computer programs to analyze complex structures.

Structural Testing and Analysis (continued)

steel reinforcing bars, mechanical bar slices and anchorages, and any other large mechanical part that requires tensile or compressive loading. Small testing machines are also available for testing fiber-reinforced products or other building components.

You can now have Construction Technology Laboratories' expertise in structural testing and instrumentation on your job in the field. Electronic systems using automated data acquisition systems can measure strains, deformations, and temperatures in steel and concrete structures over long periods of time. These unique systems are utilized to verify design assumptions, construction stresses, and overall structural performance.

Specialized structural analytical design services are also available. These services can be used to

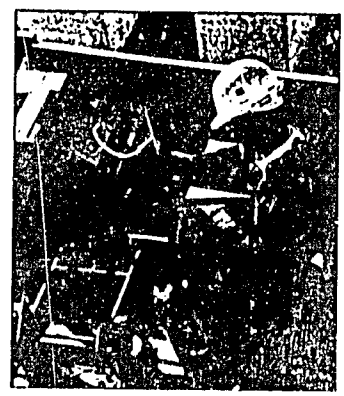
- develop analytical models of reinforced or prestressed concrete
- predict elastic and inelastic response of structures to seismic or other dynamic loads
- predict response to thermal loads
- analyze behavior of unusual structures using finite element programs
- perform third-party review of design requirements or field and laboratory testing programs
- review new designs for cost effectiveness

Construction Technology Laboratories' structural engineers combine field- and laboratory-testing experience with analytical ability to solve your engineering problems. Their expertise in instrumentation, computers, structural modeling, and testing techniques offers unparalleled qualifications in the areas of structural testing.

For more information, contact Dr. Henry G. Russell, executive director, Structural Engineering Department.

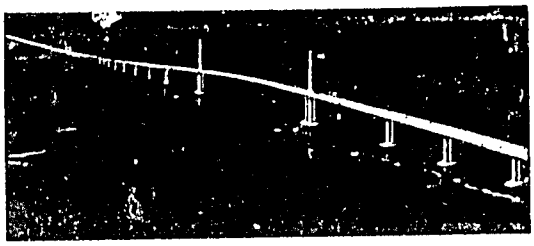
Bill Hummerich, Jr., chief instrumentation technician, installs strain gages on bridge pier reinforcement to monitor structural behavior.

Analysis of deformations in deep-space antenna structure was conducted by CTL engineers.

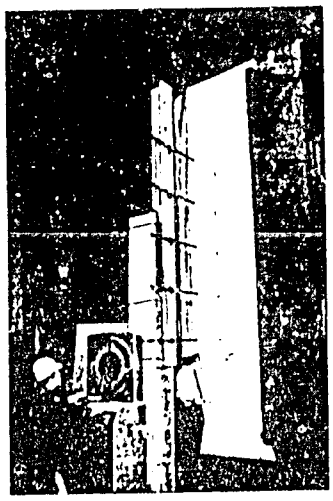


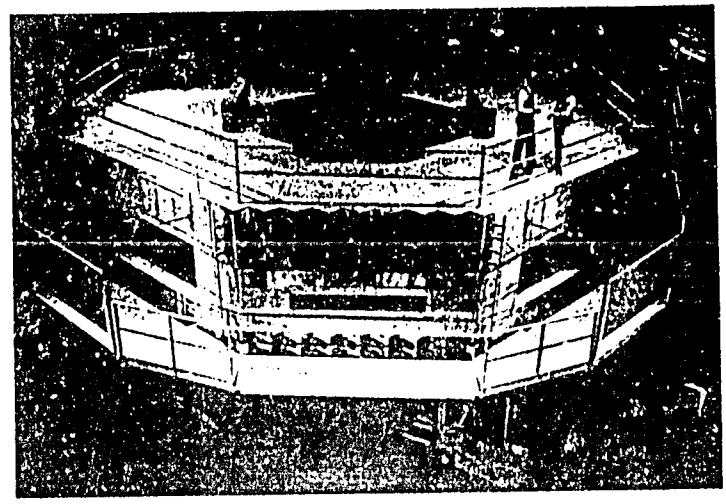
Bruce Morgan, principal engineer, uses a dynamic analyzer to determine behavior of structures.

CTL field instrumentation contributes to design and construction of long-span bridges

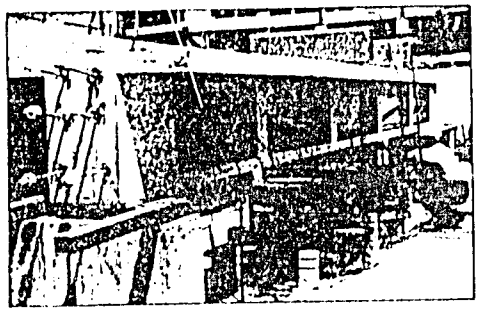


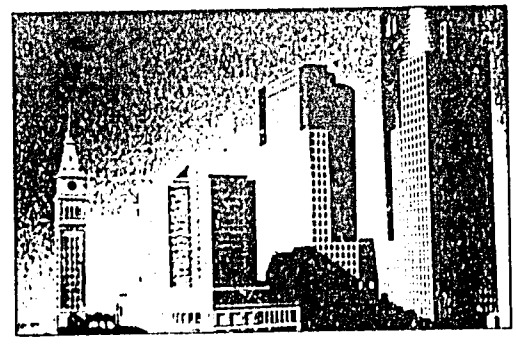
Testing of wall panel under vertical and horizontal loads

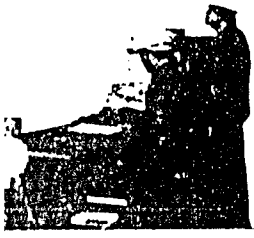




Testing the strength of large scale precast concrete girders







Testing of large scale structural members in CTL's 1 million lb-capacity machine

Structural Evaluation, Repair, Rehabilitation

Registered structural and professional engineers specialize in solving problems in structures caused by defects, deterioration, and accidents. You deal directly with project engineers experienced in design, construction, evaluation, and rehabilitation.

Often responding on short notice, specialized engineering staff take advantage of CTL's unique spectrum of integrated services:

- visual inspection and condition surveys
- nondestructive flaw detection and materials quality evaluation
- corrosion surveys
- detailed review of documents and building codes
- advanced structural analysis
- full-scale load tests
- laboratory tests of construction materials

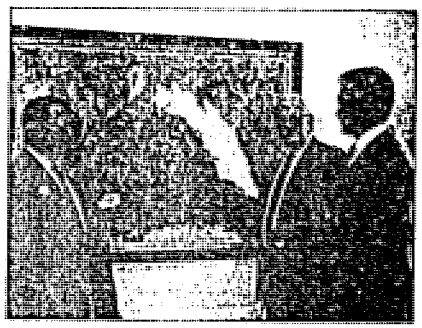
Data is analyzed in-house by project engineers in consultation with other staff experts in relevant disciplines. Results are reviewed by senior staff, and products of the evaluation may include

- concise engineering reports that can withstand the highest degree of scrutiny
- rational repair procedures for restoration of structural integrity and durability
- experience-tempered repair strategies supported by cost estimates
- repair bid documents including technical specifications and drawings
- expert witness testimony

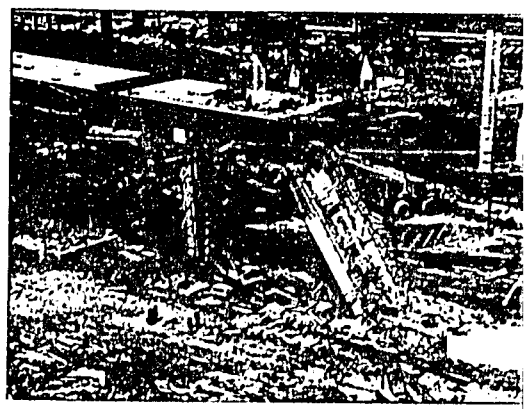
When you seek engineering solutions for structures impaired by defects, deterioration, and accidents, call on Construction Technology Laboratories' specialized engineering expertise. For further information, contact Hans C. Kosel, manager, or Adrian T. Ciolko, assistant manager, Structural Evaluation Section.

Since 1982, structural area staff have bee ding long-term, consulting se during rehabilitatio major petrochemical in the Middle

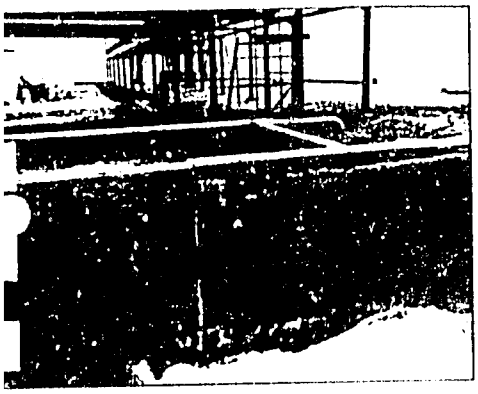
CTL has evaluated engineered structures on eight major mass transit systems throughout the country. Successful projects include nearly 50 combined miles of tunnel, elevated, and surface mass transit line structures and 15 passenger stations.

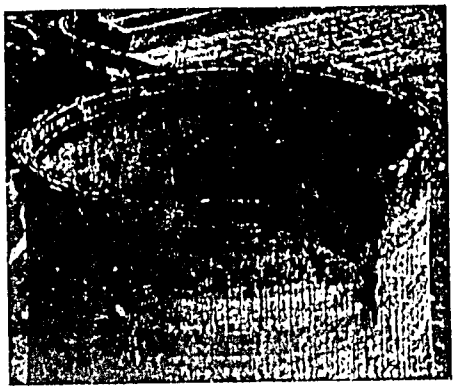


Hans Kosel, manager, (left to right), Eivind Hegnestad, principal consultant, and Adrian T. Ciolko, assistant manager, Structural Evaluation Section



The Indiana Department of Highways asked CTL structural engineers to evaluate the cause of the Cline Avenue elevated highway ramp collapse near Gary.



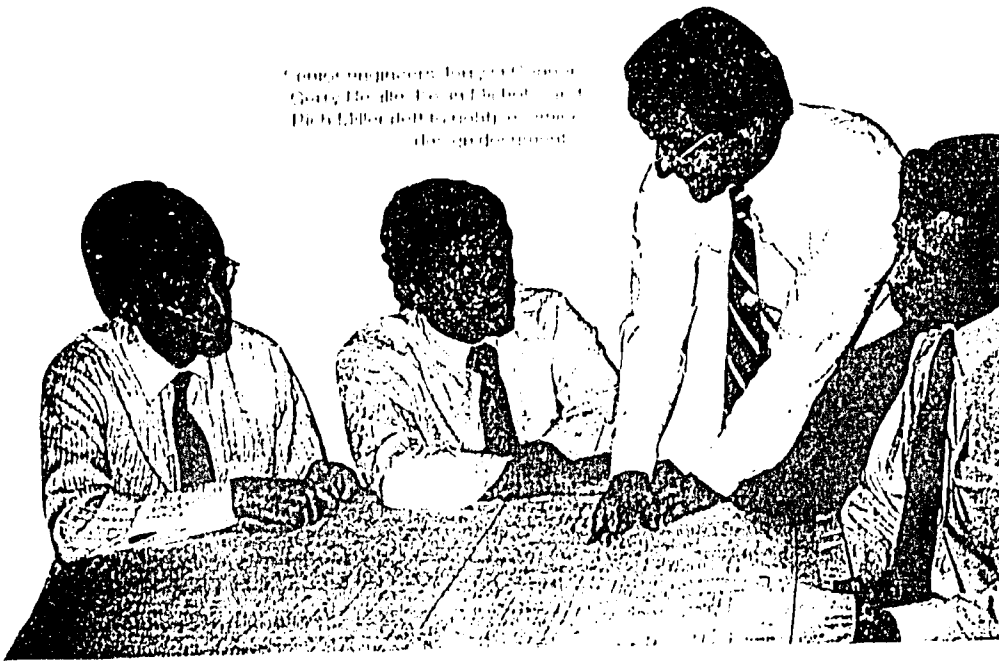


[illegible] and cooling [illegible] high winds [illegible] was left wa[illegible] by a [illegible] to the tower [illegible] evaluation, [illegible] structive [illegible] resulted in CT[illegible] consultant [illegible] repair of the 52 [illegible]

Advanced [illegible] techniques [illegible] Hong Kong's Wah [illegible] technician [illegible] and Ian Taylor [illegible] engineer [illegible] equipment to calculate [illegible] and location of tendering [illegible] on a concrete wall.

CTL's [illegible] elevation capa[illegible] are utilized in rehabilitation [illegible] and appurten[illegible] structur[illegible]

Group engineers [illegible] Gary [illegible] and [illegible] discuss design [illegible]



Fire Resistance and Thermal Technology

When you need to know how materials, building products, or structures react to very cold or hot temperatures, CTL's Fire/Thermal Technology Section can provide the answers. Our experienced engineers and technical support staff can evaluate fire-damaged structures, build and fire-test specimens, analyze heat transfer in materials and building components, and design special test programs to aid in product development. Our sophisticated computer modeling programs provide state-of-the-art solutions to complex thermal problems.

The Fire/Thermal Technology laboratory testing facilities include

- three test furnaces for testing nearly any full-sized specimen
- a calibrated hot box for measuring heat flow through wall specimens up to 8½ feet square
- a guarded hot plate for determining thermal resistance for temperatures ranging from -255°F to 1150°F
- various environmental chambers for conditioning specimens at temperatures as low as -300°F and as high as 2500°F

CTL laboratory facilities are recognized by the Council of American Building Officials (CABO). This assures that your test results will be accepted by all major building codes. Insurance agencies, fire departments, and the Nuclear Regulatory Commission also accept CTL test results.

Ron Burg, manager, Fire/Thermal Technology Section, gathers field data at a hazardous waste storage building

The Fire/Thermal Technology Section has provided testing, specialized consulting, and engineering analysis services to utilities, manufacturers, building owners, insurance companies, architects, engineers, contractors, and many government agencies.

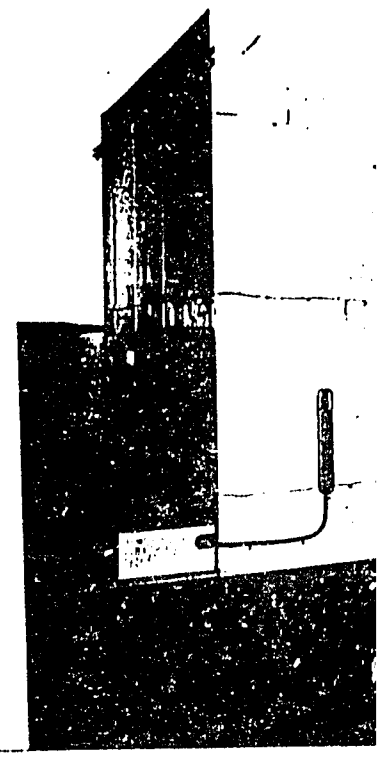
All clients benefit from CTL's service-oriented policies that include

- prompt scheduling of work
- same-day formatted test-data printout for many tests
- excellent turnaround time for final reports

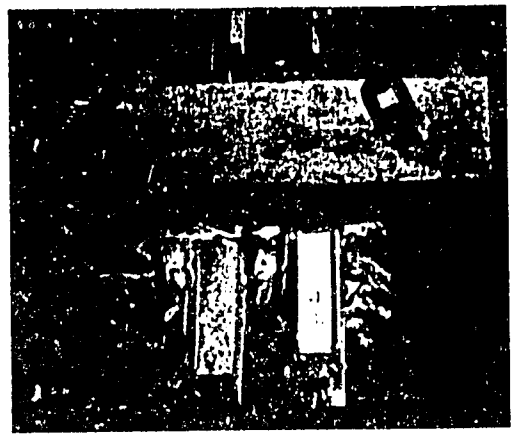
The following detailed information sheets that describe CTL's Fire/Thermal Technology Section qualifications are available:

- *Fire Testing and Evaluation of Building Components*
- *Fire Testing and Rating of Penetration Seal Systems*
- *Fire Technology Laboratory Furnace Information*
- *Evaluation of Structures Exposed to High Temperatures*
- *Evaluation Services in Heat Transfer and Thermal Technology*

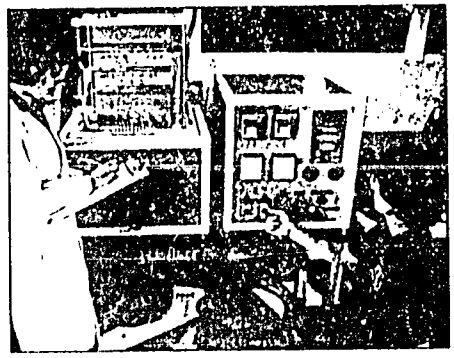
For further information, contact Ronald G. Burg, manager, Fire/Thermal Technology Section.



huck Schmidt, laboratory foreman, alls a concrete test cylinder inside trical resistance heaters in a draulic load apparatus. High-mperature creep properties of cement other cementitious materials are fied in this manner.

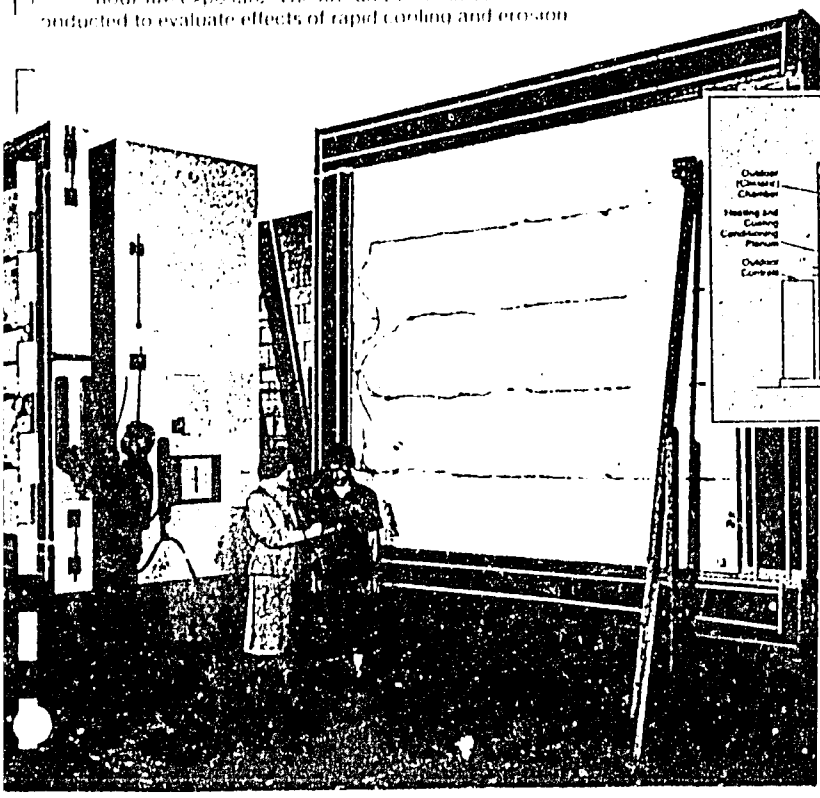


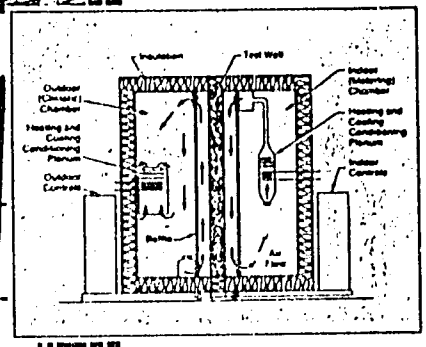
Flaming electrical penetration assembly is removed from the furnace during fire tes Construction Technology Laboratories serves as the primary testir facility for nuclear powerplant electrical assemblies.



Martha Van Geem, s ior research enginec (left), and laboratory technician use the guarded hot plate to termine thermal resi ance (R-value) of tw normal-weight conc specimens. The gua ed-hot plate test me (ASTM C177) is the most widely accepte primary test method measuring thermal r sistance of material

A hose stream is applied to a specimen following a three-hour fire exposure. The fire and hose stream test is conducted to evaluate effects of rapid cooling and erosion





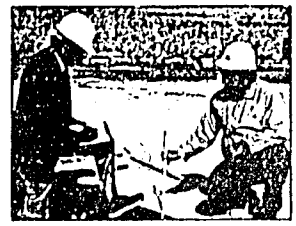
Wall (at left) has been tested in the calibrated hot box. The calibrated hot box measures thermal performance of wall as conditions under steady-state and dynamic temperature conditions. Steady-state test are used to determine R-values. Heat storage and passive solar effects can be determined only by facilities with dynamic capabilities. CTL is the only laboratory in the United States that does dynamic testi on a contract basis

Comprehensive Services in Transportation Development

If you are involved in the design, construction, or maintenance of concrete pavements, industrial floors, railway track systems, rolling stock, automotive components, or product packaging, CTL's Transportation Development Section can offer you a wide variety of engineering services.

Transportation Development services include

- laboratory and field tests to evaluate the effect of design factors on highway and airfield pavements
- roadway and airfield pavement design, specification preparation and review and construction quality control
- troubleshooting of problems, design, and construction supervision of concrete floors (slab on grade) systems
- design, testing, and evaluation of railroad track, crossties, slab-track systems, rails, and ballast
- Association of American Railroads approved bolster- and side-frame tests
- dynamic testing of railcar, truck, and automotive components
- fatigue evaluation of new materials and products
- vibration, shock, and compression testing of products and packaging systems



Shiraz D. Tayabji, manager, Transportation Development Section (left), troubleshooting at an airfield construction site

In the area of pavements and floor slabs, our transportation engineers specialize in pavement testing and evaluation, pavement management systems, evaluation of pavement materials, foundation analysis and design, and soil stabilization studies.

In railway and automotive work, we offer structural analysis and testing of track systems, track components, and rolling stock components; testing and evaluation of truck, semi-tractor-trailer, and automotive components.

We can also test and evaluate products and packaging for their ability to withstand the rigors of shipping and handling. We can perform preshipment testing of packaged products and assist in developing efficient packaging to meet specific needs.

Laboratory and field testing facilities are equipped to handle static loads, dynamic and repetitive loads, and soil investigations. Dynamic testing can also determine performance of components such as crossties, pavement joints, and pavement slabs. Equipment used in these tests is also used to test truck bolsters and railcar bulkheads, shipping containers, and semi-tractor trailer components.

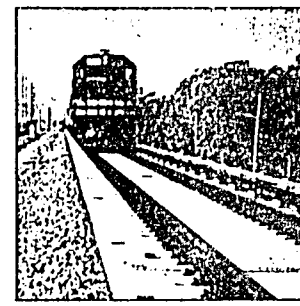
Our dynamic-load facility can accommodate almost any type of test. It includes a large 17x42-ft testing bed and a 500,000-lb-capacity load frame. Ten dynamic-load rams, ranging in capacity from 15,000 to 220,000 lb, can be used independently or grouped together as needed. Almost any type, frequency, and magnitude of load can be applied.

Specimen behavior is monitored by sensors during laboratory and field tests. Measurements are primarily recorded on a specially designed, 64-channel computer-based, high-speed data-acquisition system. Data are immediately reduced, analyzed, and presented in tabular or graphic form.

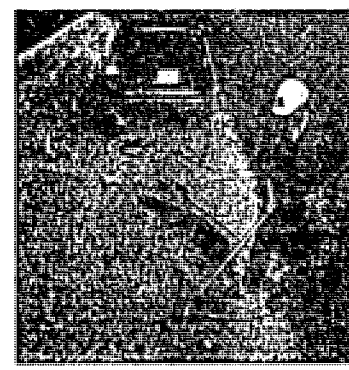
During field testing, the data acquisition system and other necessary support equipment are housed in a self-contained instrumentation van that also serves as a mobile test laboratory and electronics shop.

CTL investigations have contributed to solving a wide range of transportation-related problems for government and industry clients. For further information, contact Shiraz D. Tayabji, manager, Transportation Development Section.

Peter Hussbaum, principal transportation engineer, discusses cracking in [illegible]

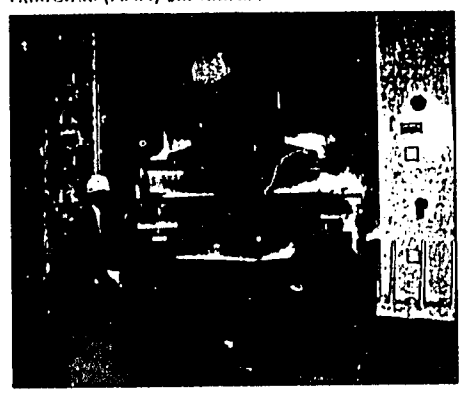


CTL developed and implemente[illegible] a field test program for the Lo[illegible] Island Railroad to evaluate perfo[illegible] mance of its concrete slab track



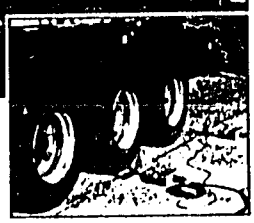
Transportation engineers [illegible] Olaniyan (rear) and Mark [illegible] [illegible] to evaluate [illegible] on concrete beds [illegible]

Static load test of railroad car bolster is conducted in CTL's 1 million lb capacity machine that can accommodate specimens up to 10 ft wide. Tests are performed according to Association of American Railroads (AAR) standards.



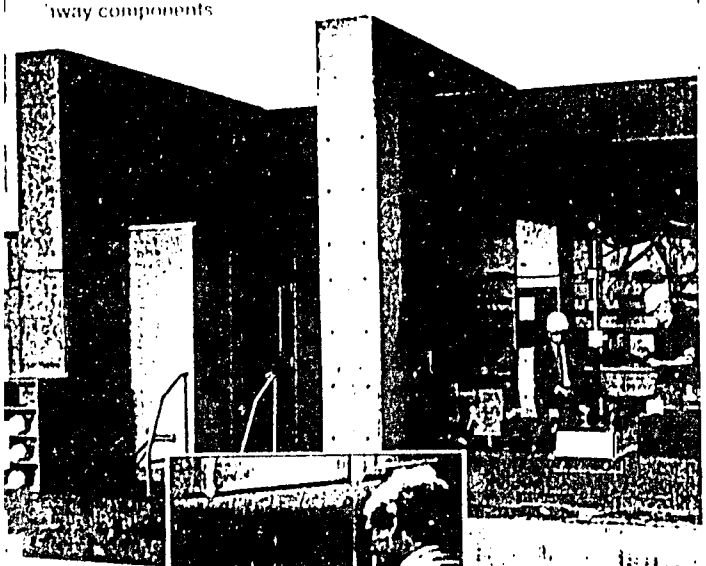
Claire Ball, principal engineer, operates vibration test system that uses vertical shock test to simulate vibration frequencies encountered in semitrailer shipping.

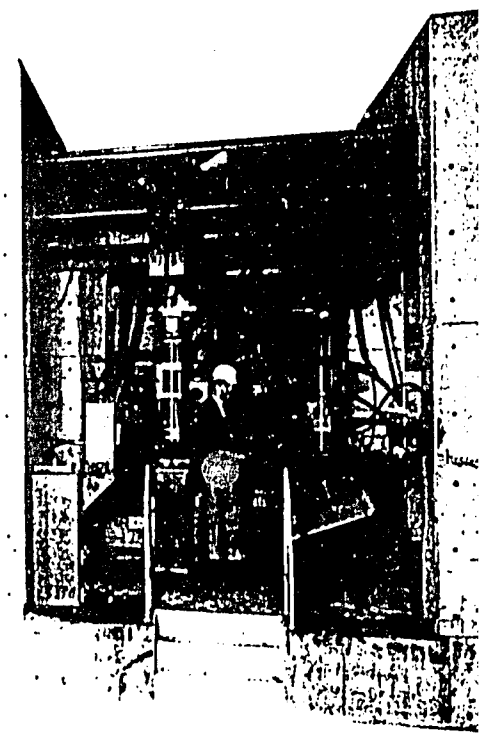
ı field tests CTL's mobile ıentation van with its rtable, high-speed, computer-sed data-acquisition system is thering data.



Tridem axle loading of instrumented test section to determine pavement performance

MTS test facility used for static and dynamic testing of railroad and ıway components





Claire Ball monitors pavement strains, deflections, temperature, and soil pressures with high-speed data acquisition equipment.

261

Construction Materials— Design, Testing, Evaluation

CTL's Concrete Materials/Technical Services Department has the expertise and facilities to solve your problems with concrete and concrete-related construction materials.

Our professional staff of engineers, chemists, petrographers, geologists, and technicians is available to conduct field investigations, evaluate concrete materials and admixtures, perform petrographic examinations, prepare concrete mix designs, and provide chemical analysis of cement, concrete, and other related materials.

We can test any material that is used in concrete mixes, including cement, aggregates, and chemical and mineral admixtures. We can recommend concrete mix designs with special properties, such as very high strength and resistance to freezing and thawing.

In addition to its testing services, the Concrete Materials/Technical Services Department can

- develop products with special properties
- evaluate concrete in existing structures
- evaluate protective coatings
- recommend remedial measures to improve performance
- provide inspection services

We can perform detailed analyses of concrete by chemical and microscopical techniques to determine cement, air, aggregate, and admixture contents and water-cement ratio.

CTL's research in brick, concrete masonry, plaster, stucco, and tile grouts provides practical benefits to industrial, commercial, and residential clients. We deal with questions related to bond strength, resistance to water penetration, durability, and the effects of different mortars, admixtures,and construction practices.

Staff engineers conduct field inspections and evaluations of masonry-related problems. They also perform materials studies and onsite evaluation of historic buildings and recommend procedures for restoration.

Test facilities include freeze-thaw, cement, mortar, concrete, and physical testing laboratories and compression-testing machinery capable of one-million-pound loads. Petrographers work with state-of-the-art equipment such as a scanning electronic microscope and X-ray diffraction units. They resolve problems in concrete such as scaling, cracking, alkali-aggregate reactivity, and sulfate and chemical attack.

Other client services provided by staff professionals include evaluating architectural concrete problems, creating special architectural finishes, and consulting on such problems as cracking, blistering, fire damage, and chemical attack. They can also provide expert witness testimony.

For further information, contact David C. Stark, manager, Concrete Materials Section, or Agostino Alonzo, manager, Technical Services Section.

Agostino Alonzo, manager, Technical Services Section (left), and David Stark, manager, Concrete Materials Section, review a CTL report.

Senior Materials Technologist Fletch Klouthis inspects concrete undergoi rapid freeze-thaw test.

Research chemists JoAnne Delles and Abu Aboyade Cole identify by infrared spectrophotometry organic admixtures extracted from concrete specimen.

Jake Ribar, principal masonry research engineer, measures strength of block prisms. Testing of concrete masonry prisms is conducted according to ASTM E447 specifications. CTL has machine capacity for testing 3-unit-high prisms

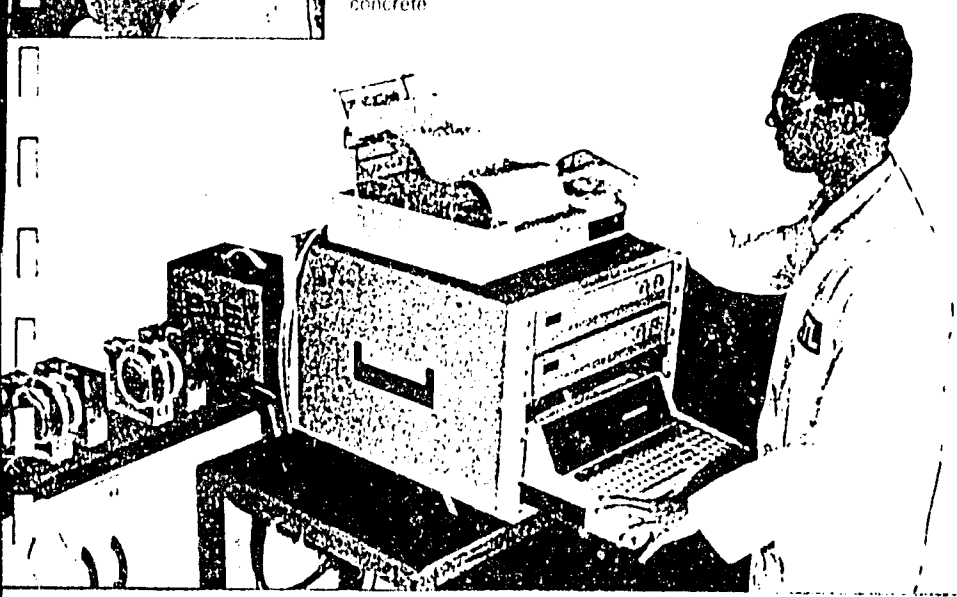
Expert Technician Mick McCann operates computerized linear traverse equipment to measure the air-void system in hardened concrete

Principal Research Engineer Steve Gebler (right), assisted by Expert Technician Mike Morrison, uses air meter to measure air content of fresh concrete in CTL's concrete laboratory

Albert Litvin, consultant, considers exposed aggregate for architectural design project.

Dave Stark (left) and Expert Technician Mike Morrison taking samples from a 45-year-old dam to check the relative humidity of the concrete

Photomicrograph of concrete from cracked pavement showing reaction rim, microcracks, and gel reaction products due to alkali-silica reactivity



Principal Research Engineer David Whiting uses the rapid chloride permeability cell to assess chloride permeability of concrete. This test defines to what extent different concretes can effectively protect reinforcing steel from deicer-salt penetration, which can accelerate corrosion

Creative Expertise Provides New Processes, Developments, Services

Developing new products and processes and providing effective support to marketing product improvements and innovations are major thrusts of the work conducted by Construction Technology Laboratories.

CTL's widely recognized staff of engineers, chemists, and scientists employs state-of-the-art apparatus and a pilot plant facility for comprehensive studies to provide a worldwide clientele with innovative approaches.

Process-development work has given a wide variety of companies

- increased capacity and improved products
- increased efficiency and energy savings
- improved process control and simulation using computer modeling
- innovative approaches to methodology

New developments explore the uses of cement, concrete, and other materials in the construction and process industries. Work also involves potential uses of industrial waste, new applications for existing materials, and hazardous materials solidification programs.

Analysis and testing is performed to determine

- physical performance of materials
- chemical properties of cements and nonmetallics
- particle size distribution in powders
- rheological properties of liquids, slurries, and pastes

Scanning electron and light microscopy of cements, clinkers, concrete, and other nonmetallic materials and X-ray diffraction, fluorescence, and chromatography are utilized in the analysis process.

Problem solving services cover cements, cement products, concrete products, production difficulties, and manufacturing in nonmetallics fields.

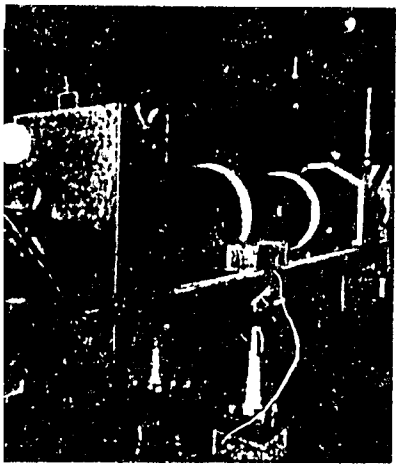
In addition, CTL provides forensic expertise, standard reference materials and pure compounds, consultation, and expert testimony.

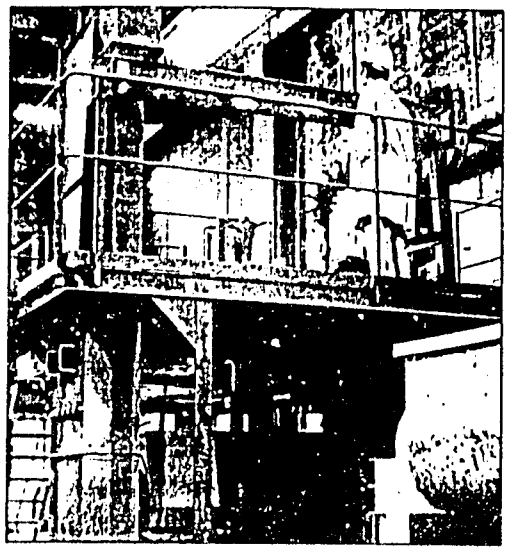
For more information on these services, contact Stewart W. Tresouthick, director, Chemical/Physical Research Department.

Stewart Tresouthick (left) and Richard Helmuth, principal research consultant, observe test conducted on deformation and flow properties of cement paste.

Automated X-ray diffraction spectrometer results are discussed by Howard Kanare, laboratory supervisor (left), Senior Research Chemist Fulvio Tang (rear), and Pressbury West, senior research scientist.

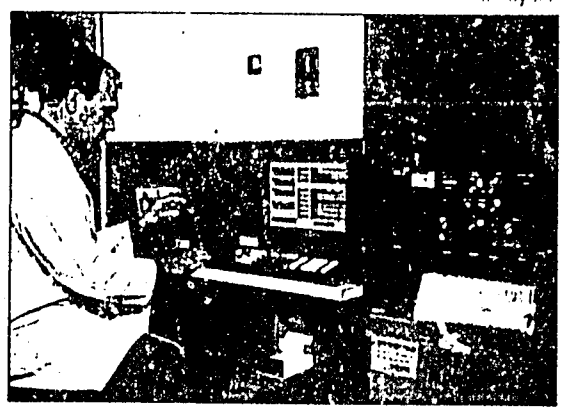
Pilot rotary kilns for production of special products.

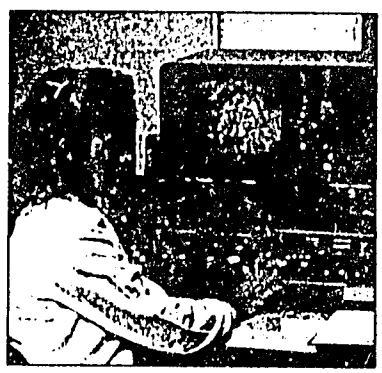




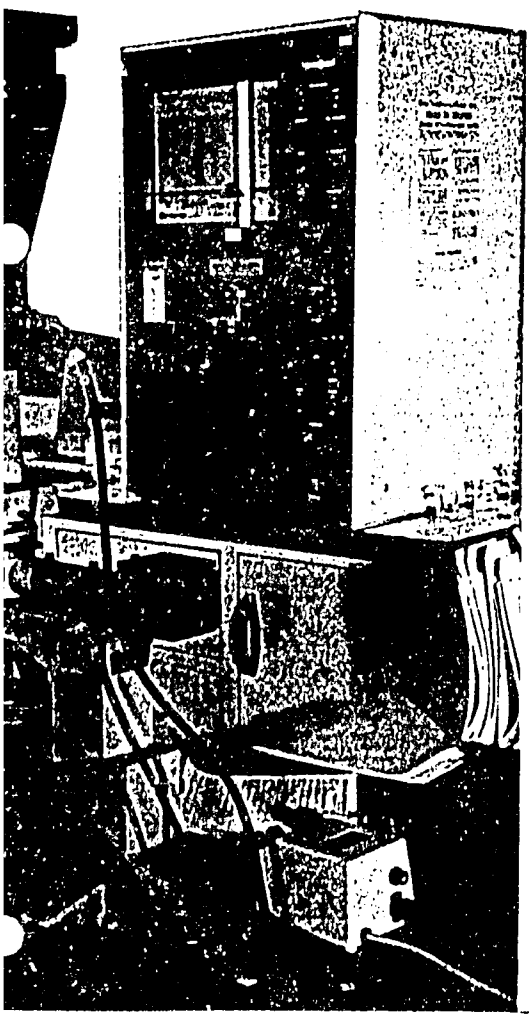
Closed circuit ball mill is used for research, development, and custom grinding

Computer-enhanced X-ray spectrometer, operated by Joseph Heinz, laboratory technician, provides rapid, accurate chemical analysis





Laboratory Technician Linda Hills operates scanning electron microscope. The SEM is used for materials science research and development.

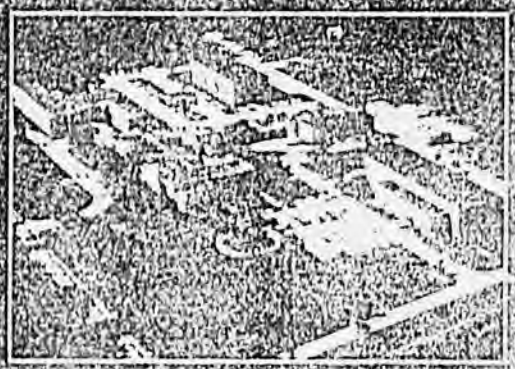


Fine particles laboratory determines particle sizes and shapes and distribution of powders. Hugh Love, materials technologist, uses fine-particles analyzer.

Information Services

The CTL library offers one of the most comprehensive collections of technical literature on cement and concrete technology in the world. More than 8500 books, 13,000 periodicals, 22,000 government and university reports and 6500 PCA/CTL publications are contained in the collection. An abstract file with more than 100,000 entries is available to the engineering and construction industries.

The library maintains international literature exchange agreements with cement and concrete associations, universities, institutes and testing laboratories throughout the world. CTL's contract research projects are supported by relevant materials provided through literature searches, bibliographies, and interlibrary loans. For information contact Cynthia Spogeman, librarian.



Construction Technology Laboratories, Inc. (CTL) is located in Skokie, Illinois, a suburb of Chicago, located approximately 20 miles from downtown Chicago and a short distance from O'Hare Airport. The map at right shows a recommended route from O'Hare to CTL.

CTL

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Fig. 1. Data collection provides information on the need for capacitors. After capacitors are installed, data should be taken to see if they are operating correctly (as shown at left), providing the necessary kVAR, and not contributing to serious harmonic problems. Photo courtesy of Capacitor Products Dept., General Electric Co.

Applying Capacitors To Improve Operations

Importance of evaluating, planning and economics is discussed

Low power factor can be a plague to any industrial or commercial business in the form of excessive utility charges. Some power companies adopt rate structures penalizing a customer for low power factor while providing a bonus for high power factor. Low power factor results in higher peak kW requirements, thus affecting equipment utilization. A greater percentage of equipment kVA ratings is needed to supply magnetizing currents. The material that follows lays the groundwork for remedial action in the form of power capacitors.

Data Collection

Plant pf can be measured with portable metering instruments (see Fig. 1). Chart recorders tracing the load cycles over a 24 hour period for one week are recommended. The two wattmeter method may be applied to loads with stable demand. Utility metered kW and kVAR data will suffice for the service entrance. Rate schedules are available from the utility and should be studied for choosing an economical solution. Figure 2 is a typical utility rate structure showing how an electrical system's pf may affect a client's utility bill. Data collection should include harmonic voltage levels, which can be measured with frequency spectrum analyzers.

Causes Of Low Power Factor

Partially loaded induction motors create the largest reactive power demand on the system sources. A conservative motor size is usually selected in anticipation of the maximum accelerating and torque characteristics of the mechanical load. The variation of motor power factor (pf) with changes in shaft load is represented graphically in Fig. 3.

The phasor diagram in Fig. 4 illustrates the effect of adding capacitive kVARs to a load having a lagging pf. The two main reasons for installing capacitors are power capacity release and reduction of utility charges. An analytical tool for calculating the kVA, kVAR and pf variables is the power triangle, shown in Fig. 5. Trigonometric formulas will complete the triangle with knowledge of any two parameters.

Capacitors On Motor Feeders

The optimum location for power-factor correction capacitors is at the terminals of an induction motor. This arrangement, illustrated in the single-line diagram of Fig. 6 (capacitors C4 and C6), insure proper matching in time and magnitude of capacitive kVARs to the inductive kVARs of the motor for the desired power factor. Common circuit protection and switching can be utilized to serve the combination of motor and capacitor. In some instances, the feeder cable size can be reduced as a result of the decreased line current.

Motor Starting Effects

When switched into a power system, the capacitor bank will draw a high-frequency inrush current, charging in one cycle or less. For an isolated capacitor, the inrush current and frequency can be calculated from the equations:

$$I_s = (\sqrt{2})\left[\frac{\text{CkVAR}}{(\sqrt{3})(V_L)}\right] \text{amps}$$

$$I_{PK} = (I_s)\left[1 + \frac{\text{Short Ckt. kVA}}{\text{CkVAR}}\right] \text{amps}$$

$$f_r = f_s\left[\frac{\text{Short Ckt. kVA}}{\text{CkVAR}}\right] \text{Hz}$$

Where:

I_s = steady state peak current (crest value)
I_{PK} = peak inrush current
f_r = transient frequency
f_s = steady state frequency
CkVAR = capacitor kVAR
V_L = line voltage in kV

To prevent nuisance tripping of the circuit breaker because of the short-time, high-peak inrush, harmonic restraint devices may be applied to the protective relay for

By Joseph W. Fay, P.E.,
Syska & Hennessy, Consulting Engineers

the circuit breaker to ride through the inrush period. For example, assume the short circuit capability at the location of C4 in Fig. 6 is 75 MVA. Then the calculated peak inrush current is 898 A with a transient frequency of 1039 Hz. The derivation follows:

$$I_s = (\sqrt{2})\left[\frac{CkVAR}{(\sqrt{3})(V_L)}\right] = (1.41)\left[\frac{250}{(1.73)(4.16)}\right] = 49\ A$$

$$I_{PK} = (I_s)\left[1 + \sqrt{\frac{Short\ Ckt.\ kVA}{CkVAR}}\right] = (49)\left[1 + \sqrt{\frac{75{,}000}{250}}\right] = 898\ A$$

$$f_r = (f_s)\left[\sqrt{\frac{Short\ Ckt.\ kVA}{CkVAR}}\right] = (60)\left[\sqrt{\frac{75{,}000}{250}}\right] = 1039\ Hz$$

Motor starting effects with capacitors applied usually do not improve the voltage more than 5%. The nameplate kVAR rating of the capacitor bank can be used for calculating the voltage drop during starting conditions. Applying the percent voltage drop method (not described in this article because of space limitations) to the 1000 hp load of Fig. 6, the percent voltage drop is 6.5% without capacitor C4, and 6.2% with the capacitor added. For the 480 V, 200 hp motor, the drop is 6.1%, improved to 5.9% with capacitor C6. Therefore, with shunt capacitors on the circuit, the voltage improvement is a small 3% to 5%.

Steady-State Voltage Operation

One of the myths in power capacitor applications is the belief that system voltage problems will disappear with a dramatic voltage rise. In reality, capacitors are not purchased to remedy low voltage. With the exception of overhead distribution systems and associated high reactance, the voltage improvement will usually be small, producing a rise of between 2% and 5%.

When the system resistance/reactance (R/X) ratio is less than 1, an approximate formula for the voltage rise can be applied:

$$\%V\ rise = \frac{(CkVAR)(X)}{10 \times (kV)^2}$$

Where:

CkVAR = capacitor nameplate rating in kilovars,

and X = system reactance in ohms from the source to the capacitor location and incorporates the reactance of all electrical system components, e.g., transformers, buses and other conductors. The system reactance must be calculated on the basis of one standard voltage level for the entire electrical system.

For example, the voltage rise at the 480 V bus in Fig. 6 can be calculated for a pf correction from .75 to .92 using

Demand Charge: Per kilowatt of maximum demand, $5.00
Energy Charge: All kilowatt-hours, per kWh, $0.07
Power Factor Adjustment (power factor to be computed at the time of peak kilowatt demand.)

Penalty: A penalty, based on the number of percentage points *below* 85% of an installation's power factor, will be charged, based upon: (.85 minus actual pf)(peak kW)(demand charge)

Bonus: A bonus (rebate) based on the number of percentage points an installation's power factor is *above* 85%, will be deducted from the utility bill and will be based upon: (actual pf minus .85) (peak kW)(demand charge)

Fig. 2. A typical utility rate structure. Not only do different utilities have different rates, a number of utilities have different rates for different areas they serve. A rate structure must be evaluated carefully to carry out an economic analysis.

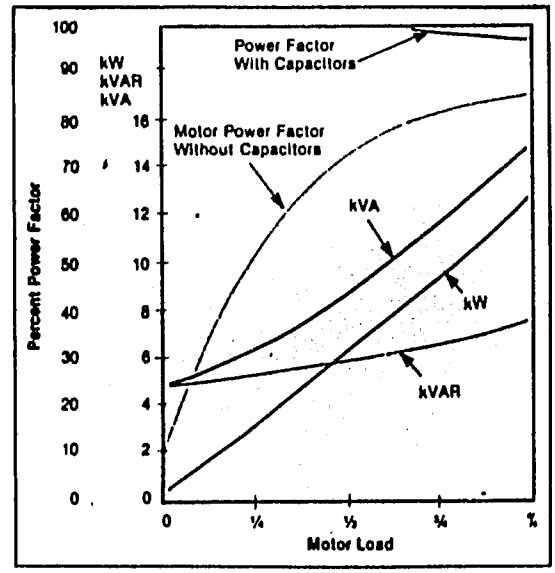


Fig. 3. Typical characteristics of a 15 hp induction motor. Changes in load affect all the parameters.

340 CkVAR of capacitors. In the one-line diagram shown in Fig. 6, the system reactance is based upon the 480 V level and has been calculated to be 0.0145 ohms.

$$\%V\ rise = \frac{(340)(.0145)}{10 \times (480 \times 10^{-3})^2} = 2.14\%$$

Alternatively, the percent method of voltage drop calculation can be used as another method (based on the difference of voltage drops) for finding the percent voltage rise because of capacitors being added to the system. This method can be used as a check to the above formula.

$$\%V\ drop = 100\left(1 - \frac{Z_L}{Z_s}\right)$$

where Z_L = impedance of the load, including capacitors,
and Z_s = total system impedance, including Z_L

%V drop (w/o cap) = 4.11% drop
%V drop (w/ cap) = 1.97% drop
2.14% voltage rise

The actual kilovars generated by a capacitor installation will vary with the applied voltage as follows:

$$actual\ CkVAR = rated\ CkVAR \times \left(\frac{operating\ voltage}{rated\ voltage}\right)^2$$

NEMA standards require capacitors to carry 135% of rated kilovars including the fundamental and harmonic components.

Sizing Capacitor For Connection At Motor

The CkVAR rating of capacitor banks should be carefully selected so as to produce maximum power factor correction, while minimizing the possibility of transient overvoltages. This is accomplished by choosing a nameplate CkVAR value that is slightly below the motor no-load magnetizing requirements, available from the manufacturer or by test. The tabulated data in Fig. 4, from the article on motors, page 22, can be used as a guide line for this selection.

Transient overvoltages may result if excessive corrective kilovars are connected to the motor terminals. Upon opening the circuit breaker the load inertia will maintain rotation while the stored energy in the capacitor discharges

to provide field magnetization. This results in induction generator action. With the conservative values of Fig. 4, (pg 22) selected for capacitor sizing, and normal deceleration of the load, this problem is eliminated. Article 460-7a of the NEC governs the maximum size allowable for the shunt capacitor.

Circuit Protection

Common circuit protective devices can be utilized if some adjustments are made. The overload relay will be desensitized because of the reduced line current with the capacitors connected. Therefore, a new setting is required, responsive to that component of the line current which is due to motor loading. Article 460-9 of the NEC references overcurrent protection.

When steady-state harmonic currents exist, the extent to which they add to the circuit loadings depends on the magnitude and frequency of the system harmonic voltages. If a third harmonic current flows, the resulting total rms current is:

$$\sqrt{(I_1)^2\text{rms} + (I_3)^2\text{rms}}$$

where $(I_1)^2$ rms is for 60 Hz and $(I_3)^2$rms is for 180 Hz. Adjustment of the long time trip element may be necessary to prevent the new full load current from exceeding equipment thermal ratings.

Transient Torque

This condition results from the closing of a circuit breaker into a capacitor-corrected motor circuit having a residual voltage. It is similar to the paralleling of synchronous generators with out-of-phase voltages. Therefore, reclosing and motor jogging applications are not recommended. Reduced-voltage starting equipment may produce transient torques when transfer is made to the full voltage tap. Sufficient time should be allowed for the stored energy of the capacitor to discharge prior to reconnecting to the system. Selection of capacitor sizes from the table in Fig. 4, (pg 22), will decrease the chance of having transient torques resulting from overcorrection and excessive capacitive kilovars.

Circuit Losses

Electrical equipment losses are reduced with capacitors by the change in the square of the line current. By itself, this loss savings is seldom sufficient to justify the purchase of capacitors. However, the savings in losses serves as an added benefit. The kW loss component of total power will remain virtually unchanged, but the kVA is reduced and the associated I^2R loss will also be reduced. This results in the shaving of peak kW demand and lower kWh energy costs.

The kW losses in a typical plant vary from 2% to 5% of the load kWh, depending on the load factor and operating efficiency. As a measure of the reactive line losses, the percent of total losses because of reactive power flow equals

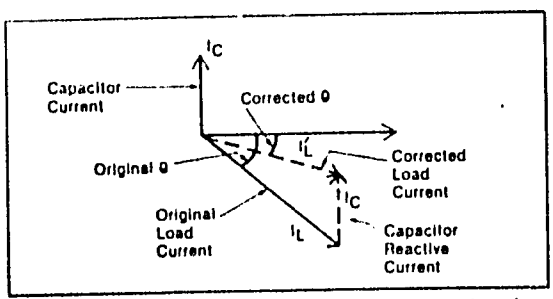


Fig. 4. A phasor diagram. The power factor, which equals cosine θ, is improved when the reactive load is decreased.

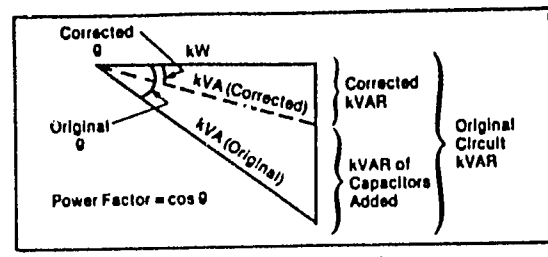


Fig. 5. A power triangle. Using some of the known parameters, trigonometric calculations will reveal missing data.

$\sin^2\theta$ where θ is the power factor angle. For example, if the power factor is .75, θ = 41.4 degrees, $\sin^2\theta$ = .44 and 44% of the total losses are reactive.

The kW percent loss reduction from an improved power factor can be calculated:

$$\%\text{kW loss reduction} = (100)\left[1 - \left(\frac{\text{pf original}}{\text{pf corrected}}\right)^2\right]$$

The monthly kWh saving is computed by the following equation:

kWh saving = [(peak kW loss)(% loss reduction)-capacitor loss](720)(load factor)($/kWh)

Where:

$$\text{Load factor} = \frac{\text{kWh per month}}{(\text{peak kW})(720 \text{ hr per month})}$$

Sometimes overlooked in loss studies are the capacitor losses which typically are equal to 0.15 W/kVAR for all film and 0.5 W/kVAR for paper film capacitors. This should be considered in all energy/economic studies.

Using the one-line diagram shown in Fig. 6 and the typical rate structure in Fig. 2, an example of circuit losses, energy savings after pf improvement and resulting cost benefits follows:

Given:

1000 ft 1-3/C No. 2/0 cable, where R = 0.107 ohms per phase
1000 kVA load @ .75 power factor
340 CkVAR capacitors
corrected power factor = .92
monthly load factor = .5

Computation:

capacitor losses = (340 kVAR)(0.5 W/kVAR)
= 170 W = 0.17 kW

$$I^2R \text{ losses} = \left[\frac{1000 \text{ kVA}}{(\sqrt{3})(4.16 \text{ kV})}\right]^2 (3 \text{ phases})(.107 \text{ ohms/phase})$$

$$= (139)^2(0.321) = 6202 \text{ W} = 6.202 \text{ kW}$$

$$\%\text{ kW loss reduction} = (100)\left[1 - \left(\frac{.75}{.92}\right)^2\right] = (100)(1 - .665)$$

$$= (100)(.335) = 33.5\%$$

Savings per month:

kW demand = [(I^2R loss in kW)(% kW loss reduction) -capacitor loss] (demand charge)
= [(6.202)(.335)-.17]($5/kW) = $9.54

Energy Savings = [(peak kW loss)(% loss reduction) -capacitor loss] (720 hr/mo)(load factor)($/kWh)
= [(6.202)(.335)-.17](720)(0.5)(0.07) = $48.07

Total savings per month = $9.54 + $48.07 = $57.61

Load Center Capacitors

The purpose of locating capacitors at the service entrance and power distribution centers is for the addition of kilovars that are necessary to correct the system to the desired pf, recognizing that, at times, not all pf improvement is carried out by capacitors at motor circuits. This type of installation can be justified when a large number of motors are supplied, inhibiting the purchase of individual capacitors on each feeder. Or, simply, when the economic study reveals this arrangement as a preferred alternative. Outdoor rack mounted, indoor metal clad, or vault located capacitors are available for this application.

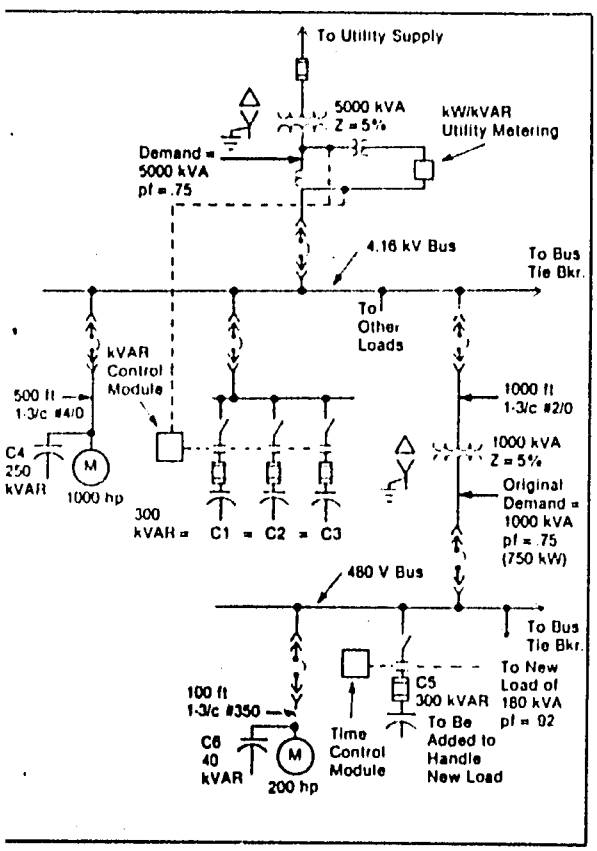
Capacitor Release

The kVA loading of electrical apparatus is represented in Fig. 5 as the vector sum of the kW and kVAR power requirements. By reducing the reactive power demand on the source, the length of the kVA vector becomes smaller. Therefore, additional kW of load can be added without exceeding the original kVA demand. In other words, new loads can be installed utilizing the existing equipment capacity. Shunt-connected capacitors reduce the reactive power demand and can be used to relieve overloaded transformers, cables or other equipment.

The capacitor kVAR required to accommodate a new load and increasing the pf to .92 without exceeding the circuit capability can be computed as follows:

$$CkVAR = \sqrt{(kVA_2)^2-(kW_2)^2} - \sqrt{(kVA_1)^2-(kW_2)^2}$$

Where subscript 2 indicates the total new circuit kW and kVA, and subscript 1 indicates the circuit capability.



For example, if 180 kVA of new load is expected at the 480 V bus in Fig. 6, prevention of overload equipment requires:

$$CkVAR = \sqrt{(1153)^2-(915)^2} - \sqrt{(1000)^2-(915)^2} = 298$$

Where 1153 equals the existing kVA of 973 plus the new load of 180 kVA. The 1000 kVA equals the circuit capability and the 915 kW equals 750 kW plus the new load of 180 kVA at .92 pf which equals 750 kW + (180)(.92) kW = 750 + 165 = 915 kW.

Since 298 kVAR does not correspond to a standard capacitor rating, choose one 300 kVAR bank. As there already is one 40 kVAR capacitor on this circuit, the total amount of capacitor rating equals 340 kVAR.

For another way to determine the capacitor kVAR rating for improvement of the circuit power factor, refer to Fig. 7. The circuit kW is multiplied by the appropriate factor read from the table. For example, to correct from 75% to 92% with 750 kW of load, find .453, then (750)(.453) = 340 kVAR.

Automatic Switching

Capacitors are available in single and multi-step banks. Consideration should be given for connecting them to automatic controllers governed by parameters of time, voltage, or kilovars (see Fig. 8). The choice of control depends on the cyclical nature of the load. In Fig. 6, capacitors C1, C2, C3 and C5 are connected to control modules. Time-switched capacitors may be fitted to the base load kVAR. When this is done, the kVAR control module automatically matches capacitor loading to the varying inductive loads. The capacitor banks can be purchased complete with the controller, fuses, load break switch, potential and current transformers.

The design tool used for selection of automatic switching is the load kVAR profile, an example of which is shown in Fig. 9. The profile is developed from the time-charted data of kVAR flow and adjusted for motor capacitors added.

A greater degree of flexibility is achieved using steps of kVAR switched into the system. The point of diminishing return is reached when the cost of an additional step to the capacitor bank outweighs the advantage of correcting to the desired power factor for a given load.

For plant load cycles that result in a fairly constant profile of kVAR versus time, fewer increments of kVAR switched would be sufficient to correct the power factor at peak load and some value at partial peak. The size and number of steps are tailored to the kVAR profile so that each plateau corrects the power factor to a value no greater than the desired level while attempting to minimize the number of steps and the difference between desired and actual power factor.

Economic Study

An expenditure for power factor improvement will produce future income from the savings in energy, peak kW, and power factor penalty charges. An economic study will provide the payback period for a given investment, or determine the permissible purchase cost for a given payback period. In the example below, a dollar value for the installed cost of capacitors is calculated assuming a three-year payback period, annual utility rate increases of 12% and a stipulated rate of return of 15%. Taxation benefits are not considered making this study a conservative one. For this example, please refer to the single-line diagram of Fig. 6,

Fig. 6. A one-line diagram of a hypothetical electrical system. The data given is used in a number of examples presented in the article.

the utility rate structure of Fig. 2, and the cash flow diagram in Fig. 10.

Given:

peak kW = 3750
power factor = .75
load factor = .5
kW circuit losses = 27

Proposed:

power factor = .92
capacitor kVAR = 1715
capacitor losses = (1715 kVAR)(0.5 W/kVAR)
= 857.5 W
= .858 kW

Monthly Savings with Capacitors:

■ Determination of percent loss reduction (%LR)

$$\%LR = (100)\left[1-\left(\frac{\text{old pf}}{\text{new pf}}\right)^2\right] = (100)\left[1-\left(\frac{.75}{.92}\right)^2\right] = 33.5\%$$

■ Reduction In Demand Charge (RDC)

RDC = [(kW loss)(%LR)-capacitor loss](demand charge)
RDC = [(27)(.335)-.858]($5/kW) = $41

■ Reduction In Energy Charge

REC = [(kW loss)(%LR)-capacitor loss](720 hr/mo)(load factor)(rate)
REC = [(27)(.335)-.858](720)(.5)($.07/kWh) = $206

■ Power Factor Penalty Elimination (PFPE). This represents the elimination of low pf penalty charges by increasing the pf from the original low value to a value up to or exceeding the utility break-even value of .85 pf and is based on a 1% decrease in demand charge for each pf percentage improvement up to .85 pf.

PFPE = (.85-original pf value)(peak kW)(demand charge)
PFPE = (.85-.75)(3750)($5/kW) = $1875

■ Power Factor Improvement Bonuses (PFIB). This is the utility's incentive for a customer to further enhance his pf improvement beyond the .85 pf break-even point and is based upon a bonus of 1% of the demand charge for each pf percentage improvement beyond the utility .85 pf break-even point. Because the peak kW will decrease with pf improvement, this change must be taken into account. The reduction in peak kW demand equals (kW losses)(% loss reduction) less capacitor loss = (27)(.335)-.858 = 8 kW

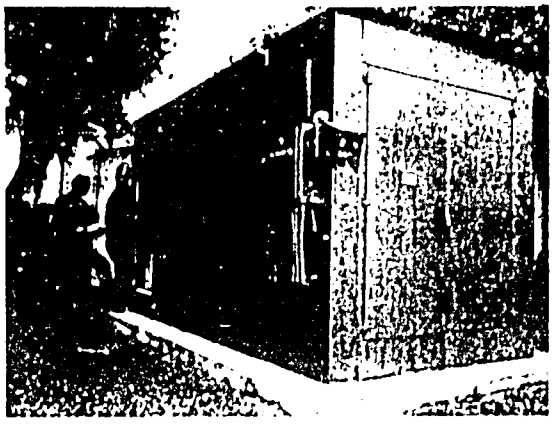
PFIB = [(improved pf value-.85)(original peak kW -reduction in kW demand)](demand charge)
PFIB = (.92-.85)(3750-8)($5/kW) = $1309

1st year monthly savings = $41 + $206 + $1875 + $1309 = $3431
2nd year monthly savings = $3431 × 12% rate increase = $3843
3rd year monthly savings = $3843 × 12% rate increase = $4304

DESIRED POWER FACTOR IN PERCENT

ORIGINAL POWER FACTOR IN PERCENT	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.442	1.481	1.529	1.590	1.732
51	.937	.962	.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
52	.893	.919	.945	.971	.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
53	.850	.876	.902	.928	.954	.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
54	.809	.835	.861	.887	.913	.939	.966	.992	1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.559
55	.769	.795	.821	.847	.873	.899	.926	.952	.979	1.007	1.035	1.063	1.090	1.124	1.156	1.190	1.228	1.268	1.316	1.377	1.519
56	.730	.756	.782	.808	.834	.860	.887	.913	.940	.968	.996	1.024	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.480
57	.692	.718	.744	.770	.796	.822	.849	.875	.902	.930	.958	.986	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.442
58	.655	.681	.707	.733	.759	.785	.812	.838	.865	.893	.921	.949	.976	1.010	1.042	1.076	1.114	1.154	1.202	1.263	1.405
59	.618	.644	.670	.696	.722	.748	.775	.801	.828	.856	.884	.912	.939	.973	1.005	1.039	1.077	1.117	1.165	1.226	1.368
60	.584	.610	.636	.662	.688	.714	.741	.767	.794	.822	.850	.878	.905	.939	.971	1.005	1.043	1.083	1.131	1.192	1.334
61	.549	.575	.601	.627	.653	.679	.706	.732	.759	.787	.815	.843	.870	.904	.936	.970	1.008	1.048	1.096	1.157	1.299
62	.515	.541	.567	.593	.619	.645	.672	.698	.725	.753	.781	.809	.836	.870	.902	.936	.974	1.014	1.062	1.123	1.265
63	.483	.509	.535	.561	.587	.613	.640	.666	.693	.721	.749	.777	.804	.838	.870	.904	.942	.982	1.030	1.091	1.233
64	.450	.476	.502	.528	.554	.580	.607	.633	.660	.688	.716	.744	.771	.805	.837	.871	.909	.949	.997	1.058	1.200
65	.419	.445	.471	.497	.523	.549	.576	.602	.629	.657	.685	.713	.740	.774	.806	.840	.878	.918	.966	1.027	1.169
66	.388	.414	.440	.466	.492	.518	.545	.571	.598	.626	.654	.682	.709	.743	.775	.809	.847	.887	.935	.996	1.138
67	.358	.384	.410	.436	.462	.488	.515	.541	.568	.596	.624	.652	.679	.713	.745	.779	.817	.857	.905	.966	1.108
68	.329	.355	.381	.407	.433	.459	.486	.512	.539	.567	.595	.623	.650	.684	.716	.750	.788	.828	.876	.937	1.079
69	.299	.325	.351	.377	.403	.429	.456	.482	.509	.537	.565	.593	.620	.654	.686	.720	.758	.798	.840	.907	1.049
70	.270	.296	.322	.348	.374	.400	.427	.453	.480	.508	.536	.564	.591	.625	.657	.691	.729	.769	.811	.878	1.020
71	.242	.268	.294	.320	.346	.372	.399	.425	.452	.480	.508	.536	.563	.597	.629	.663	.701	.741	.783	.850	.992
72	.213	.239	.265	.291	.317	.343	.370	.396	.423	.451	.479	.507	.534	.568	.600	.634	.672	.712	.754	.821	.963
73	.186	.212	.238	.264	.290	.316	.343	.369	.396	.424	.452	.480	.507	.541	.573	.607	.645	.685	.727	.794	.936
74	.159	.185	.211	.237	.263	.289	.316	.342	.369	.397	.425	.453	.480	.514	.546	.580	.618	.658	.700	.767	.909
75	.132	.158	.164	.210	.236	.262	.289	.315	.342	.370	.398	.426	.453	.487	.519	.553	.591	.631	.673	.740	.882
76	.105	.131	.157	.183	.209	.235	.262	.288	.315	.343	.371	.399	.426	.460	.492	.526	.564	.604	.652	.713	.855
77	.079	.105	.131	.157	.183	.209	.236	.262	.289	.317	.345	.373	.400	.434	.466	.500	.538	.578	.620	.687	.829
78	.053	.079	.105	.131	.157	.183	.210	.236	.263	.291	.319	.347	.374	.408	.440	.474	.512	.552	.594	.661	.803
79	.026	.052	.078	.104	.130	.156	.183	.209	.236	.264	.292	.320	.347	.381	.413	.447	.485	.525	.567	.634	.776
80	.000	.026	.052	.078	.104	.130	.157	.183	.210	.238	.266	.294	.321	.355	.387	.421	.459	.499	.541	.608	.750
81	...	.000	.026	.052	.078	.104	.131	.157	.184	.212	.240	.268	.295	.329	.361	.395	.433	.473	.515	.582	.724
82	...	...	.000	.026	.052	.078	.105	.131	.158	.186	.214	.242	.269	.303	.335	.369	.407	.447	.489	.556	.698
83	...	...	...	.000	.026	.052	.079	.105	.132	.160	.188	.216	.243	.277	.309	.343	.381	.421	.463	.530	.672
84	...	...	...	...	.000	.026	.053	.079	.106	.134	.162	.190	.217	.251	.283	.317	.355	.395	.437	.504	.645
85	...	...	...	...	...	.000	.027	.053	.080	.108	.136	.164	.191	.225	.257	.291	.329	.369	.417	.478	.620
86	...	...	...	...	...	...	...	.026	.053	.081	.109	.137	.167	.198	.230	.265	.301	.343	.390	.451	.593
87	...	...	...	...	...	...	...	...	.027	.055	.082	.111	.141	.172	.204	.238	.275	.317	.364	.425	.567
88	...	...	...	...	...	...	...	...	...	.028	.056	.084	.114	.145	.177	.211	.248	.290	.337	.398	.540
89	...	...	...	...	...	...	...	...	...	...	.028	.056	.086	.117	.149	.183	.220	.262	.309	.370	.512
90	...	...	...	...	...	...	...	...	...	...	...	.028	.058	.089	.121	.155	.192	.234	.281	.342	.484
91	...	...	...	...	...	...	...	...	...	...	...	...	.030	.061	.093	.127	.164	.206	.253	.314	.456
92	...	...	...	...	...	...	...	...	...	...	...	...	...	.031	.063	.097	.134	.176	.223	.284	.426
93	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.032	.066	.103	.145	.192	.253	.395
94	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.034	.071	.113	.160	.221	.363
95	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.037	.079	.126	.187	.328
96	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.042	.089	.150	.292
97	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.047	.108	.251
98	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.061	.203
99	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.142

Fig. 7. Power-factor multiplier to determine the kVARs needed to correct a low pf. The multiplier is found at the intersection of the original pf and desired pf. This number multiplied by the kW equals the amount of kVARs required to increase the existing pf to the desired pf.



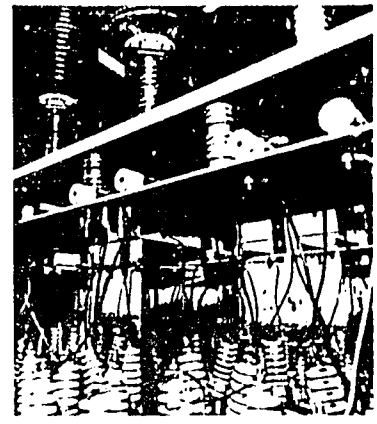


Fig. 8 An automatic power factor control unit. The far left photo shows the cabinet and the adjacent photo looks into the interior where the capacitors, oil switches and current limiting reactors are shown. Photos courtesy of H.K. Porter Co., Inc. Electrical Div.

Economic Study

A cash flow diagram, prepared for the calculation of the present value of future savings, or for the amount which can be invested in capacitors, is shown in Fig. 10. The present worth factors for the series of positive cash flow are 11.08, 20.62 and 28.85, for the first, second and third series.

The present value of this future savings equals (11.08)($3431) + (20.62−11.08)($3843) + (28.85−20.62)($4304) = $110,100

A lesser expenditure will produce a smaller payback period, or a greater rate of return for the same period. A lower stipulated rate of return will allow for a greater initial investment for the same payback period. For a longer payback, a greater investment can be tolerated, with a constant rate of return.

Harmonics And Resonance

A system study of harmonic effects and resonance will protect against misapplication of capacitors. Some sources of harmonic voltages include transformers, static switching power supplies (UPS systems, variable speed drives) and generators. A measurement of harmonic voltages can be obtained with a frequency spectrum analyzer.

Capacitors do not generate harmonics; however, they act as a reactance which varies with frequency by $X = [1/(2\pi fC)](j)$ where j is a phasor operator. Higher order harmonics produce proportionally greater currents in the capacitor because of the lower impedance.

Capacitors are rated to carry 135% of the nameplate kVAR to include the effect of harmonics and operating voltage. The percentage of nameplate kVARs actually drawn by the capacitor bank can be calculated as follows:

$$kVARs = (V_1)^2 + 3(V_3)^2 + 5(V_5)^2 + \ldots$$

where V_1, V_3, and V_5 are the fundamental, third and fifth harmonic voltages expressed as a fraction of the rated voltage.

The total rms current is equal to the square root of the sum of the squares of the harmonic currents:

$$I_{rms}\text{total} = \sqrt{(I_{1rms})^2 + (I_{3rms})^2 + (I_{5rms})^2 + \ldots}$$

Higher harmonics do occur and can be analyzed. The following example will be limited to the fifth harmonic. Suppose the system voltage data at C5 in Fig. 6 indicates a fundamental of 103%, a third harmonic of 25% and a fifth harmonic of 5% of rated voltage. Then the kVAR loading is $(1.03)^2 + 3 \times (.25)^2 + 5 \times (.05)^2 = 1.26$ or 126% of the rated kilovars. In calculating the total rms current using:

$$I = \frac{E}{Z},$$

E is the harmonic voltage and Z is the impedance of the capacitor at the harmonic frequency. The impedance decreases proportionally with increasing harmonic frequency. Thus, for the third harmonic, we have a harmonic voltage of .25 per unit (pu) divided by the impedance, which is one-third that of the first harmonic, hence the current becomes:

$$\frac{.25}{1/3} = .75 \text{ pu.}$$

On this basis the total rms current is:

$$\sqrt{(1.03)^2 + (.75)^2 + (.25)^2} = 1.30$$

or 130% of rated current.

The above example illustrates the necessity of sizing switches, cables and fusing of the capacitor installation for

(continued on page 54)

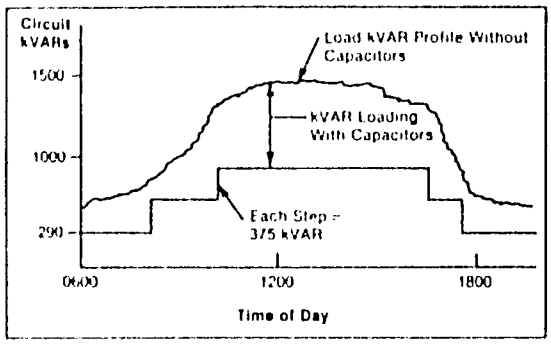


Fig. 9 Load kVAR profile with power factor correction using a multi step capacitor bank. In the above plot, a peak demand of 2500 kW is corrected to .92 from .75 pf.

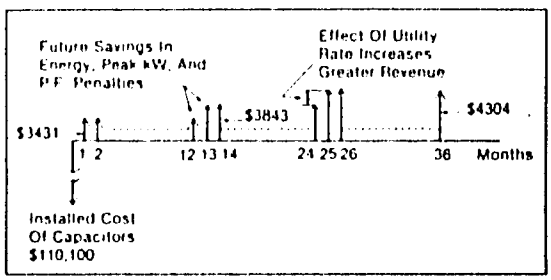


Fig. 10 Cash flow diagram showing the present value of future savings that can be invested in capacitors to improve the power factor to .92 in the circuit shown in Fig. 6.

Applying Capacitors
(continued from page 18)

125% of rated current as required by the NEC. Ratings of equipment between the source and the capacitor bank should be checked for adequate capability to carry the total current *including* harmonics, if present. Also, it is important that the relay settings for the circuit breakers be checked so that the breakers can ride through the calculated inrush current at the high frequency. If this matter is not addressed, nuisance tripping may occur.

Any combination of inductance and capacitance has a characteristic frequency at which there exists an oscillation of energy, called resonance, reactive in nature, that shuttles between the electrical equipment. For a known inductance L, and capacitance C, the frequency that may trigger this phenomenon is equal to:

$$\frac{1}{2\pi\sqrt{LC}}$$

This oscillatory condition, if not alleviated, results in large current values and overvoltages in the power system. When the characteristic harmonic voltage exists, and in sufficient magnitude, the oscillating current will depend on the circuit time constant. These currents can fatally damage capacitors, overload equipment or, at best, open circuit fuses.

Resonant shunts, consisting of a reactor and capacitor in series, with the combination in parallel with the circuit, can be effective in trapping the harmonic currents, thereby eliminating oscillation within the power system. Usually the exchange of energy is between the customer's capacitors and the low pf devices.

Conclusion

Power capacitors can frequently offer benefits for an industrial/commercial facility. They are available in various ratings and can be connected to control systems to closely follow the power factor performance of an electrical system. Before installing capacitors, an economic analysis should be carried out to justify their installation. Planning for a capacitor installation requires a check on equipment ratings, protective device settings, harmonics and resonance effects. ■

The Author

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...LIMITED SYSTEM CAPACITY
...VOLTAGE FLUCTUATIONS

INSTALL...
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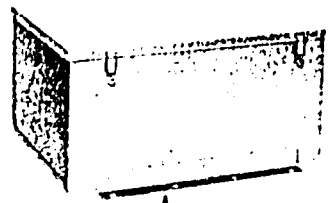

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Inquiry 24

Forensic Engineering
(continued from page 46)

not protecting the electrician from such a shock. It was noted that if there had been the proper green bonding wire with the temporary wiring, the accident would most likely not have happened.

An executive of the ballast company who attended certain of the courtroom hearings realized that the paper and foil condenser was from a vendor whose products were purchased by the ballast manufacturer. Interestingly, the attorneys who defended the ballast manufacturer then hired a member of our company to carry the case on to the manufacturer of the paper and foil condenser that was used within the ballast. The case was a second job for our company, and the second case did go to court, and a settlement was made in the courtroom.

Conclusion

Attorneys are important people. They synthesize the knowledge and information given to them, and frequently seek this knowledge from outside consultants. Attorneys will respect you for soliciting the help of other experts when necessary. They do not expect you to know all of the answers all of the time. There will be times when you think the case is unfair — and you can back out. Many of the attorneys in such cases have called us back on other cases. You won't need to be either young or old to participate in forensic electrical engineering. Our experience in this area runs over 30 years and we have found the work interesting and profitable. ■

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Scott Beamer heads his own consulting engineering firm in Oakland, CA. He received a BSEE degree from the University of California in Berkeley, and is a Registered Professional Engineer in several states. Beamer is a member of IEEE, IES, the American Arbitration Assoc. and has served as chairman of the Council of East Bay (San Francisco) Electrical Engineers. He has taught various engineering courses and has 32 years of experience.

The Best Of Capacitor Installations Can Have Side Effects

Avoiding troubles from surges and resonance

When capacitors are used to improve power factor on ac circuits, there can be side effects. In some cases, the capacitors are the victims; in others, they are part of the cause. In either case, the electrical consultant should be aware of the possibilities and take necessary steps to prevent damage from surges and from continuous harmonics. Both these effects are of growing importance because of increased application of chopped-wave equipment—especially silicon-controlled rectifier (SCR) drives.

By Myron Zucker, P.E.,
President, and
Lewis M. Clark, Production Manager,
Myron Zucker, Inc

Although it rarely happens, major damage can be caused by transients produced by false triggering of devices such as controls and computers, fuse blowing, breakdown of insulation and other malfunctioning in transformers, switchgear, motors and capacitors.

These events can be made worse by resonance, matching the circuit inductance and capacitance to the frequency of the pulses so that they are amplified over certain parts of the system. Resonance can not only make things worse by creating unusually high voltages and currents, compounding the problems of transients, but can also add overheating of lines and equipment by the addition of resonant current to a 60 Hz system.

Glimmers of electrical problems appeared as far back as the 1930s, when medical x-ray machines caused disturbances in power lines from which they were fed. In the 1940s additional line disturbances from large spot welders and flash welders brought the flicker problems to the attention of electrical engineers. Lighting, television sets and the welding apparatus itself were afflicted by the surges.

In those days, problems were few and large enough so that each one could be solved by individual engineering attention. Arc furnaces, large rectifiers and high horsepower induction motors created surges, and this equipment was sometimes involved in resonant combinations.

Rectifiers Alter Conditions

The surge/harmonic syndrome became more common in the 1960s with the spreading of chopped-wave equipment (that allows only a portion of each half-cycle of voltage to get through to the load). Ignitrons and saturable reactors also caused problems and, nowadays, rectifier systems such as SCRs are used with increasing frequency and are a major cause of creating surge and resonance difficulties. Power line noise troubles were encountered even without power capacitors. False operation of equipment, cross-currents, voltage distortions both high and low, and overcurrents were experienced.

Now in the '80s, power-distorting equipment is becoming even more common. More efficient and cheaper solid-state phase-controlled switches, such as SCRs, are widely used for controlling and/or providing power to dc motors, ac motors (both constant and variable speed), furnaces (both inductive and resistive), and uninterruptible power supply (UPS) systems. And, rec-

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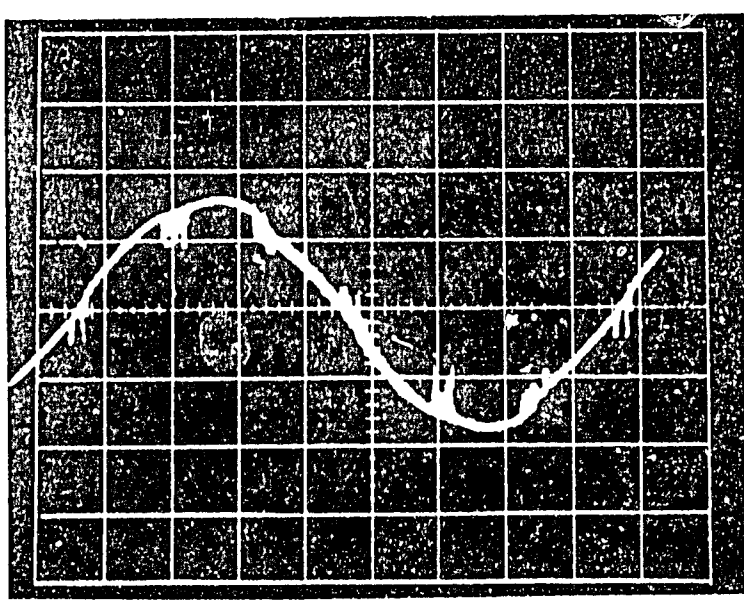

Photo courtesy of Myron Zucker, Inc

Fig. 1. Line voltage transients (spikes) caused by commutation of an SCR unit powering a 400 hp dc motor. The system is fed from a 2000 kVA substation.

Capacitor Installations
(continued from page 24)

tifier firing circuits create problems of surges and harmonics.

It should be recognized that rectifier equipment not only distorts wave shapes; this equipment also frequently lowers pf, sometimes substantially, thus creating the need for pf correction, which is done by the installation of capacitors. However, capacitors may cause resonant problems. It is important to switch capacitors off a line during periods of light loading.

Recognizing that the above electrical problems are increasing, emphasis should be placed on analyzing a project's circuit characteristics, looking for possible resonances that can increase overvoltages and overcurrents. It does not mean that every installation is full of problems; it simply means that there are possible causes for concern that the electrical consultant should watch out for.

Circuit Analysis

There are three distinct phenomena that should be evaluated in a circuit analysis. First, there are transients caused by one form or another of switching. Rectifiers and inverters are in effect a complex series of switching circuits that primarily use solid state devices. They take current first from one line of an ac power circuit and then from the next and so on—feeding each in turn to the same output wires, with the output being dc. Each time that the primary current is transferred from one wire to the next, the two wires are essentially short circuited. The short circuit lasts only a fraction of a second, but this is what creates spikes and notches in the supply line voltage (see Fig. 1). These surges are the basis of all the ills listed at the start of this article.

A second phenomenon is that the rectifier itself is affected while providing a reasonably unvarying dc. This requires that the ac lines provide not only 60 Hz current to the load, but also continuous harmonics which, when put through the rectifier circuitry, come out as a nearly flat dc. This, in turn, affects the ac primary power source.

The third phenomenon is a combination of inductance (L) and capacitance (C), of which each circuit has definite amounts (regardless of discrete capacitor equipment), which can create resonance and enlarge voltage and current by many times (see Fig. 2). The electrical consultant's job is to locate and correct the conditions that can create excessive currents and voltages.

Of the above aspects, resonance and harmonics lend themselves to measurement by computation.

Trouble Spots

In the typical factory or office building, a moderate amount of SCRs will cause little trouble. However, conditions that may cause problems and should be investigated are:

- A few SCR drives that are large in relation to the power system. For instance, if there are one or two drives whose loads amount to about 40% of the transformer kVA feeding them, the commutating spikes may readily blow capacitor fuses and possibly puncture capacitor insulation.
- Rectifiers usually operating at great (more than 50%) retardation. Watch frequently switched capacitors, especially those in large banks, whether switched all at once, or in small steps.
- SCR drives that draw more load than the other equipment on the same low-voltage line.
- Capacitors that bring power factor above 90% at full load, especially if remaining on the line at light load.
- Capacitor kVAR greater than 25% of the transformer kVA feeding it.

Spikes

Spikes seem to cause fuse blowing more often than do harmonics. To explain this, consider the capacitor "device" fuse connected to each capacitor. This is a fast-acting, current-limiting fuse (as distinguished from a slow-blowing circuit fuse), and it acts as an isolator to take a capacitor off the line the instant it develops a short circuit. Speed is important to prevent case rupture, and device fuses have an excellent record in providing such protection.

But the fuse is nervous. Fuses of relatively small I^2t (a few thousand amperes^2 seconds) capability, as used with the now prevalent unit cell construction, will be blown by spikes.

So fuse amperage has to be chosen carefully. In the days of good sine waves, conventional rules were satisfactory. A fuse rating of 1.67 times steady-state current allowed margin for the normal variations in capacitor current: up to 1.35 times rated kVAR, computed by the factors of 1.15 times rated microfarads, 1.1 times rated

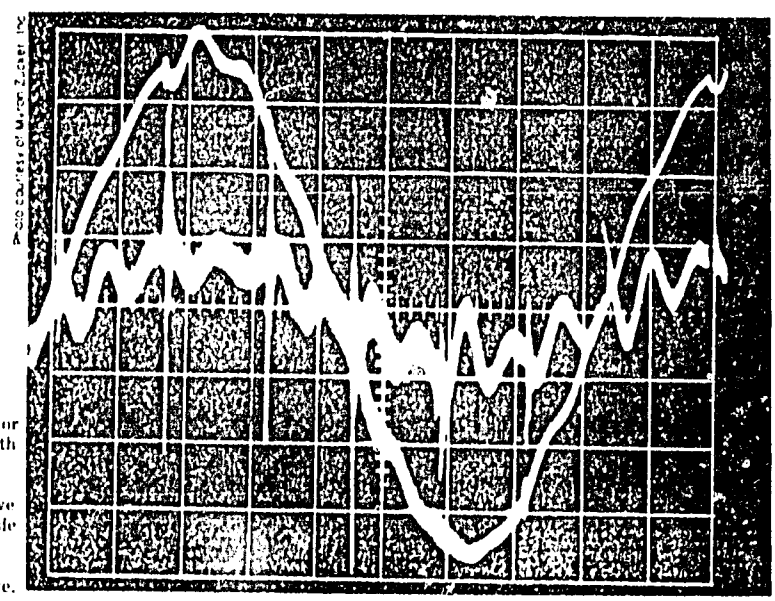

Fig. 2. Photo of a CRT monitoring the line voltage and current at a 130 kVAR capacitor installation. The equipment is in a plant with a 300 hp, SCR powered motor on a 200 ft bus, fed from a 1000 kVA substation. This picture shows the spikes in the current wave (the low amplitude wave—the high amplitude wave is the voltage) that are providing the excitation to a resonant circuit. The 11th harmonic is clearly seen in the current wave.

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voltage and 1.06 additional harmonics, which are always present to some degree.

Ragged waves, however, will blow such fuses. In line with recent fuse manufacturers' thoughts, many electrical consultants now consider 2.2 to 2.5 to be the normal multiplier. Some installations go considerably higher. Our firm, which manufactures capacitors, has no reports of cell rupture when such ratings are used.

Spikes may also damage contactors. The nominal limit for spikes, set by makers of the lighting or resistance load contactors, that should be used for power-factor control capacitors by themselves, is six times rated current.

Spike Reduction

The electrical consultant's job is to specify fuses that will operate under normal conditions without jeopardizing the capacitor, the contactor or, even more important, people—or else to call for means to suppress the transients at the capacitor. Spikes can be reduced by the correct amount of inductance or by shunt suppressors (choppers) near the sensitive equipment. Should a line not have sufficient inductance in itself, the line inductance can be supplemented by solenoidal chokes. To obtain optimum results, filters should be applied.

Harmonics

Harmonics lend themselves to a more analytical treatment than spikes in the usual electrical system where potential resonant circuits can usually be well identified.

Remember, that for harmonic currents or voltages to build up, there must be both a *resonant circuit* and *excitation*. If both exist they will create oscillations that can cause trouble from overcurrent or overvoltage. Let's look at the two requirements.

In determining the first criterion for having a resonant circuit, it is important to see if the resonant frequency matches excitation frequency. Resonant frequency depends on the inductance (L) and capacitance (C) of the electric circuit:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where f is in cycles per second, L is in henries and C in farads.

On new projects, L and C may be found from:

- Transformer impedance (Z) on the nameplate, thus ascertaining the major inductive element in an electrical system.
- Ohms impedance (or the reactance) from textbook values for the electric lines between the transformer and the capacitor.
- Equivalent impedance of the utility system before the transformer, a value usually available either as Z or as short-circuit kVA from the local utility.
- The kVAR rating of capacitors in the circuit being considered. If they are spread over the distribution circuit, a first approximation may be made by considering them all located at a load center.

Power Factor Improvement

When improving the power factor of an existing plant, it is helpful to make field tests to determine the reactance of the system by projecting back from known capacitance and by observing the frequency of oscillation as some excitation is applied to the circuit. An oscilloscope, preferably with a retentive screen, will be useful to read the frequency. The resulting oscillogram will provide a recording of line conditions. There is noticeable variation in waves in most plants which makes the use of harmonic analyzer scopes, while convenient, somewhat questionable because the amplitude of one harmonic (e.g., the 11th) relative to the 5th, may have changed by the time it is scanned.

An interesting phenomenon is that, in actual practice, the resonance is usually between 300 and 750 Hz, the range in which the possibility of oscillation related to solid-state rectification devices is greatest and gives the worst consequences.

More specifically, for a circuit having a 5.7% Z transformer (a common value) and a capacitor kVAR rating of about 25% of transformer kVA rating, f (resonant frequency) = 450 to 500 Hz. Using other capacitor kVAR/transformer kVA ratios, the following frequencies are obtained:

30% ratio, f = 400 to 450 Hz
40% ratio, f = 350 to 400 Hz

The resonant frequency of electrical systems is likely to decrease as solid-state rectification devices become more economical and proliferate on smaller, weaker systems. It is important for the electrical consultant to be alert against harmonics when small 240/480 V and 240/208 V transformers feed SCR loads.

The second criterion needed for a harmonic problem to exist is having an excitation frequency matching the circuit's natural frequency. And, not only is the rate of excitation important, but also the amplitude, which must be large enough to exceed circuit losses. To determine an electrical system's high frequency excitation, an investigation should be made of the loads, especially rectification devices.

When evaluating a rectifier's har-

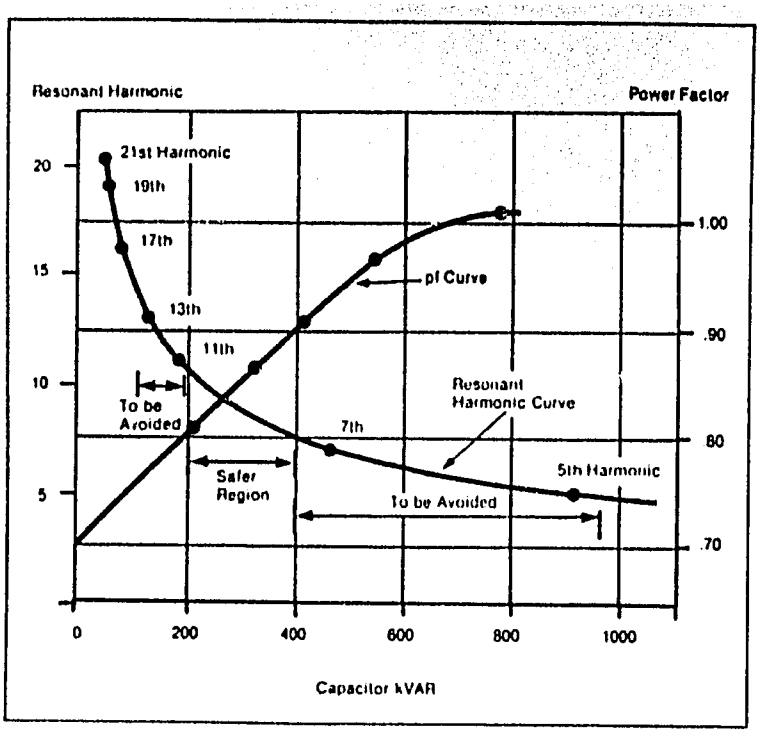

Fig. 3. Chart showing resonant frequency vs. amount of capacitance (blue curve) in a circuit fed from a 1500 kVA substation with a 1000 A, 200 ft bus with reactors. Also shown are the resonant harmonic frequencies that should be avoided. The red curve shows how pf is improved as capacitance is increased. At times a compromise must be made between pf improvement and exposure to harmonics.

monic excitation, it will be noted that usually the 5th, 7th, 11th and 13th harmonics are affected. These harmonics have frequencies of 300, 420, 660 and 720 Hz respectively and are the primary problem frequencies. The 9th harmonic is absorbed by delta connected equipment. In our experience, there is little chance of harmonic problems if the system resonates at 660 Hz (11th harmonic) or higher.

With oversimplification, the rectifier will create square waves of current on the 60 Hz system. The amplitude of each harmonic is related to the inverse of the frequency (i.e., the 5th is greatest, 7th less, and so on up through even higher values than those mentioned, but those values are in such small degree that they are usually negligible).

If the generated harmonics coincide with any resonances in the supply circuit, there will be oscillations, and possible trouble. The higher the frequency, the less the excitation energy comes from the rectifying device (unbelievable as it may seem, these units should be considered as a current generator for the harmonics!).

Capacitor Level

The electrical consultant has some options if he finds conditions are favorable for oscillations. One—the most direct—is to limit capacitors to safe levels. This is done by having the capacitor kVAR rating less than 25% of the transformer kVA rating. Another is to start with a minimum amount of capacitors to avoid circuit resonance (see Fig. 3) and then gradually increase the amount until the desired power factor is attained or until there are signs of trouble. This requires careful monitoring.

Another approach to avoiding the critical resonant point is by applying either a little more or a little less than the target amount of capacitance. This may be practical if a system is static—but in a changing system, today's solution may not be tomorrow's.

An effective but expensive option is to use rectifiers in which the ac power is divided into 12 or more circuits before being rectified. This raises the level of harmonic frequency excitation to a range where it can be handled better. This option is economical only for large installations.

Filter Application

A more practical approach is to use filters, or traps, either in large (substation) capacitor banks or in smaller units. A filter can consist simply of a reactor in series with each capacitor, tuned near the lowest expected oscillating frequency. Most commonly this is the 5th harmonic.

These series-resonant filters invite the harmonic currents to stay in the capacitor-rectifier part of the circuit, relieving the electrical power system of the undesired excess resonance while providing a smooth dc to the load.

To trap the 5th harmonic, a reactor of about 4% impedance at 60 Hz is used. This increases the voltage on the capacitor by 5%, which, in view of the increased harmonic current that the capacitor must carry, leads to the recommendation that 600 V capacitors be used on 480 V circuits. Because of the derated capacitors and the addition of reactors, the cost increase must be evaluated.

We have found the trapping method to be effective even on small systems, especially when the capacitor-at-the-load philosophy is used with modular trapped capacitors near individual rectifier loads and switched on and off the line with them.

Conclusion

Resonance and spikes may become more common as rectification loads increase in use. The effects of spikes can be mitigated as discussed. Resonance problems can be overcome by judicious selection of ratings for capacitors and traps. Costs must be weighed against benefits. ■

The Authors

Myron Zucker is the proprietor of Myron Zucker Engineering Co., and is president of Myron Zucker, Inc. He obtained an EE degree from Cornell University and an MSEE degree from Union College. Zucker has spent 29 years working on power factor correction while with G.E., Detroit Edison Co., and his own firm. He is a Registered Professional Engineer and is active in IEEE.

Lewis M. Clark is production manager at Myron Zucker Engineering Co. He has been employed by the firm for the past year, working in the areas of marketing and product development. Clark has a background in economics from Cornell University.

Power factor and conservation

You may look on PF improvement as a load easer in transformers, generators, and feeders, along with trimming the rate structure and monthly billing. Now consider the sheer practical aspect of energy conservation

Every plant-systems engineer should have a clear picture in his mind of just what power factor means. This is a must, since pf, plant operation and energy economics go hand in hand. "That's fine," you'll say, "but my plant has been running for years and the electrical system appears OK. Why should I start worrying about pf?" Well, pf is important because good power factor means less load on your feeders, better plant voltage, a good-sized dip in your monthly power bill and, if you buy power, probably lower electricity rates from the utility company.

Interested? Of course you're always interested in and on the lookout fo. ways to cut costs. Your first step is to get a clear picture as to what pf really is. We're not going to cover pf calculations now. For the time being, let's settle for a clear picture of what pf is, in simple terms, and what you can do to improve it in your plant. The saving in power losses—transformers, feeders and generators—can constitute a sizable energy saving.

What pf is. Think of your electric system as one carrying two types of power: useful power (kilowatts) that goes to work pulling your load, and reactive power (kvar) that generates magnetism within induction motors. The only one of the two that drives load on the end of the shaft is the useful power or kilowatts. Nevertheless the generator, transformers and feeders carry both.

You can get a clear picture of this by studying the sketches on the facing page. The mug of beer represents your electrical system. It, too, is made up of two parts; the useful (liquid) beer and the suds.

Beer and pf. Compare the liquid beer with useful power, kilowatts or watts, used to drive the load in your plant. Then compare the froth or suds to the reactive kva flowing through your plant feeders and transformers. Now what is pf? Well, we could say the pf of the mug of beer is the ratio of the useful beer (liquid) to the total volume of the mug.

Let's apply the same definition to your electrical system. Looking at it in the same light, you will find that pf is nothing more than the ratio of the useful power (kilowatts) to the plant's total kva. Translating that, we may say that kva is voltage multiplied by amperes (flowing in a single-phase circuit), divided by 1000.

Coming back to our homely beer-mub analogy, we can readily see that we're much better off with less suds in the beer mug and less reactive power in our electrical system. You can understand this at a glance by just looking at the sketches once again.

Reactive power. For the moment, let's look at electric power flowing between generator and motor as through it were beer. It doesn't take a genius to realize the size of the generator and transformer, as well as the feeder, must be large enough to handle both liquid beer and froth. We're saying that an induction motor needs both froth and liquid beer; this certainly holds true in comparing beer to electricity, since your induction motors need both real power, kilowatts, and reactive power.

Now the froth flowing through the pipe causes loss in the generator, transformers and feeders similar to that caused by the liquid beer. Such is also the case in your electrical system, where the reactive power causes power loss all along the line just as real power does. Pf in your plant is low when there's a lot of froth (kvar) flowing.

What to do. Now the thought might occur to you that it would be wise if we could place a machine next to our motor just to supply the froth. And that is often the way pf is improved in the industrial plant. By supplying the froth from a source other than the original generator, the load on the system is reduced.

Realize that you're not going to improve pf and then buy a smaller generator, transformer and feeder for your plant. What you have already installed will probably remain there. The point is, by improving pf you reduce the reactive power flowing in your system, and wind up with ample electrical room to add additional load without going to bigger feeders and transformers. This is in addition to reduced losses within the generator, transformers and feeders.

We mentioned before that reactive power supplies the magnetism in your induction motors; this also holds for other inductive equipment. Remember that this reactive power is roughly constant between low and full load of an induction motor. Naturally the useful power, kilowatts, drawn by the motor will be much less at low load than at full load. On the other hand, since the reactive power to the motor is practically constant, you can see that pf of the unloaded or lightly loaded motor will be low. In other words, the portion of useful power will be low when compared to total kva drawn.

Over-motoring. This all leads to the first rule for establishing good pf in your plant. And that is, don't "over-motor" when using induction motors.

Of course, the best time to analyze over-motoring is when you select motors. The next thing to remember is a possible rearrangement of induction motors in your plant. Along these same lines, think of the synchronous motor when selecting motors for slow-speed application.

Capacitors. Now for a word about shunt capacitors. They are stationary devices whose main function is to deliver froth or reactive kva to the induction motors and other induction equipment in the plant. These do the job nicely and require little attention in the way of maintenance or operation. Don't overlook the fact that they can be installed practically anywhere without disturbing production.

Synchronous motors. Take another look at the sketches. Remember, there is a big difference between a synchronous motor and a capacitor. The synchronous motor will supply mechanical power output as well as reactive power to induction motors in the plant. In other words: The solution to your problem might be to install a synchronous motor along with smaller induction motors to make up the total shaft horsepower required.

On the other hand, the capacitor is strictly a froth machine. It is tied onto your line to supply this reactive kva to induction motors in the plant. You will have to make a detailed cost study to determine whether the synchronous motor, shunt capacitor or a combination of the two is the best bet in your particular case. ■

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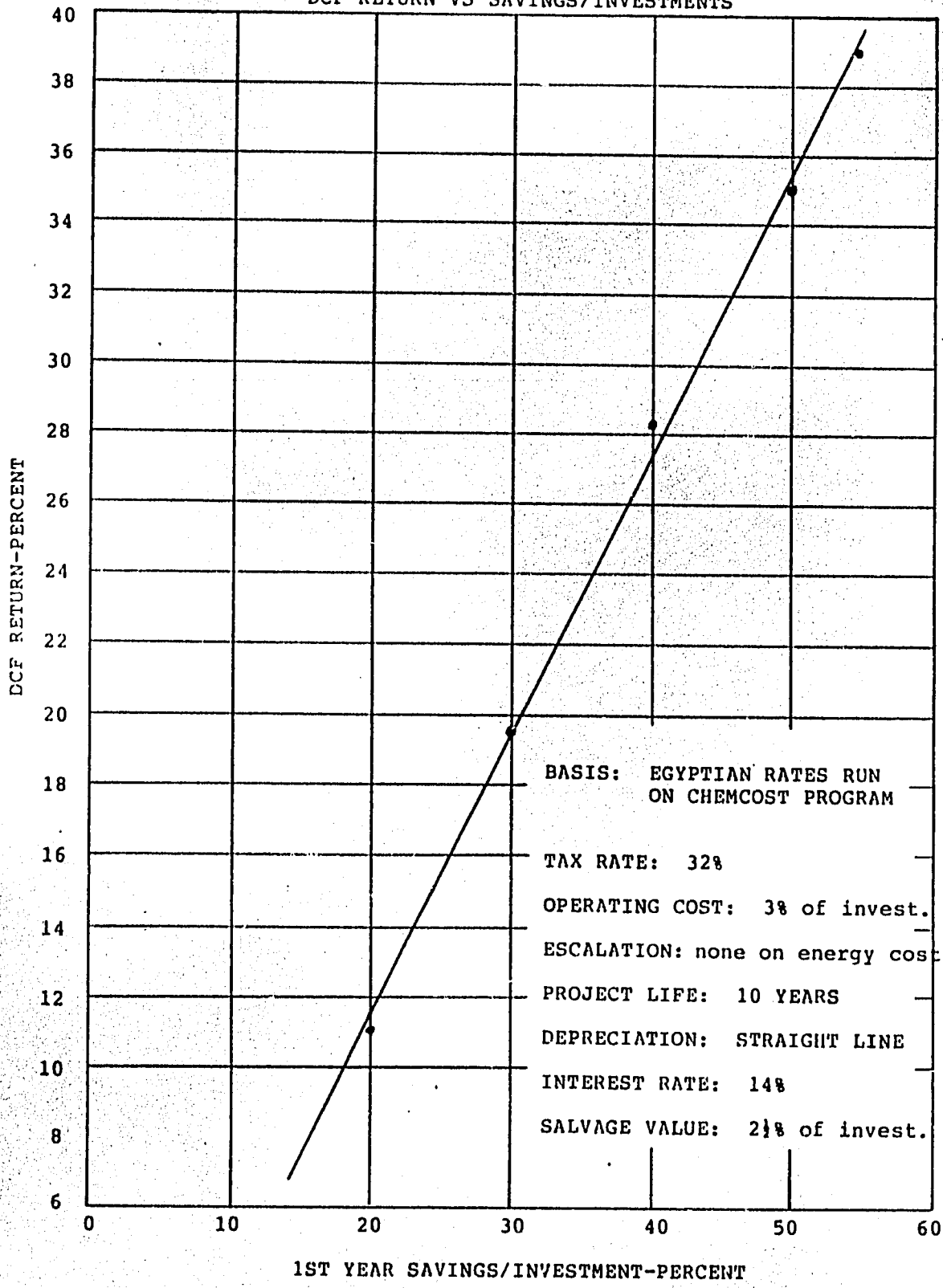

revised 17 Apr 88

Type OL110 Oxygen Analyzer

w/75' cable $3,800 for up to 1500°F 2/9/88
$4,160 for up to 2000°F

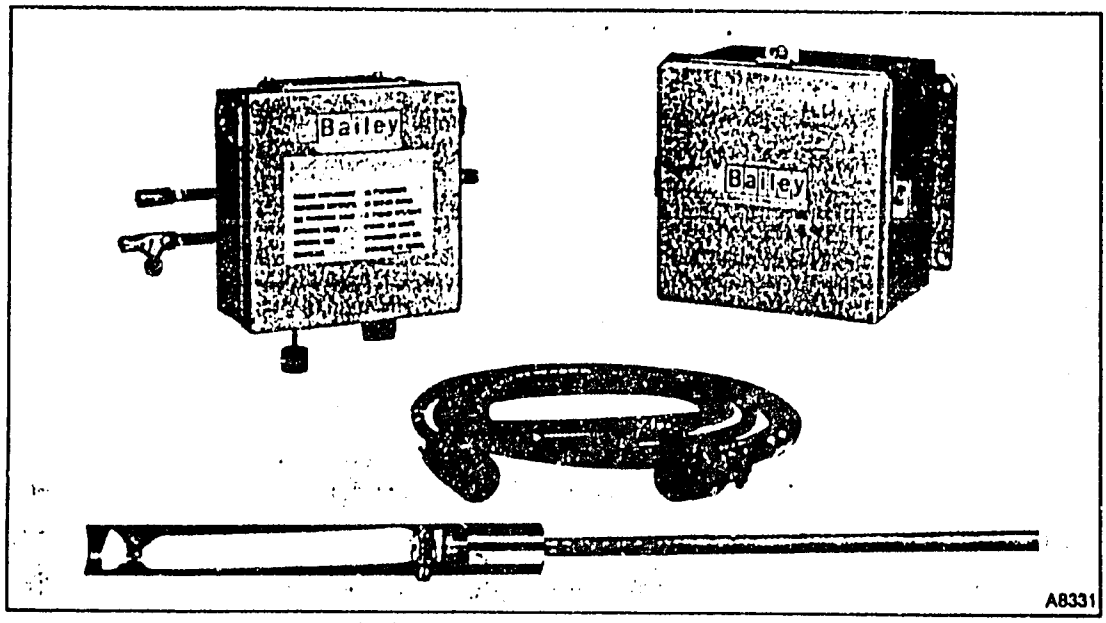

FIGURE 1 — Type OL110 Oxygen Analyzer.

The Bailey OL110 Oxygen Analyzer is designed for duct mounting with a choice of single point or average sampling systems. An air-powered aspirator draws a sample of gas from the boiler flue or process stream through the sampling system and past the O_2 sensor. This sensor provides independent and continuous percent-by-volume measurement after analysis. The sample is never transported more than a few inches from the duct.

FEATURES

- **In-house maintenance.** Present instrumentation technician can easily maintain the OL Analyzer.
- **Troubleshooting display.** Status lights in the electronic enclosure monitor sensor and temperature status.
- **Range change by switches with no recalibration required.** O_2 range switches are on the electronics boards.
- **Reduced analyzer maintenance.** The patented floppy filter keeps itself from becoming plugged while keeping large particles out of the highly reliable sample transport system previously proven in our Type OJ Analyzer.
- **Averaging sample system.** A three-point sampling system is available for obtaining an average sample from multiple burner combustion processes.

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- **Gas temperatures.** Handles flue gas temperature to 1500°F/816°C. Special probes are available for gas temperatures up to 3000°F/1649°C.

- **Duct mounting.** Mounting on duct or process eliminates long, troublesome sample lines.

- Accuracy of O_2 measurement is not affected by flue gas temperature, particulates or variations in water vapor or CO_2. The absolute accuracy of the OL is dependent upon the accuracy of the test gas used to calibrate it.

FUNCTIONS/APPLICATIONS

The Type OL110 Oxygen Analyzer uses a zirconium oxide sensor for continous sampling and measuring of excess O_2 in flue gases. It consists of: (1) a sensor assembly (see Figure 2) that flange-mounts to a duct or process wall so that the probe protrudes into the flue gas stream; and (2) an electronics assembly with attached flexible conduit that permits the electronic enclosure to be located away from the hot environment around the sensor assembly.

PRINCIPLES OF OPERATION

The OL110 Oxygen Analyzer measures on a wet basis. This means that sampling system heaters prevent water vapor from condensing on the sampling surfaces. Analyzers which measure on a dry basis cool the sample gas so that most water vapor is condensed and removed. The sensor assembly of the Oxygen Analyzer connects to a duct or process wall via an insulated/heated mounting nipple which encloses the probe and exhaust stream. The probe extends into the flue gas flow. An air-powered aspirator draws a sample gas through heated passages within the manifold block. The sample is diverted to a zirconium oxide O_2 sensor where it is analyzed for oxygen content. After analysis, all sample gases and aspiration air are returned to the duct. Electrical (analog) output from the sensor is converted into a linear (4-20 mA dc) output signal that represents the amount of O_2 measured.

In most cases, a gas sample is drawn through a single point probe and a patented floppy filter which is suitable for process gases up to 1500 °F/816°C. The floppy filter oscillates to remove particles filtered from the sample gas stream for trouble-free operation. For applications involving large ducts fed by exhausts from several burners, the analyzer may be fitted with a multisample probe which will be available in late 1984.

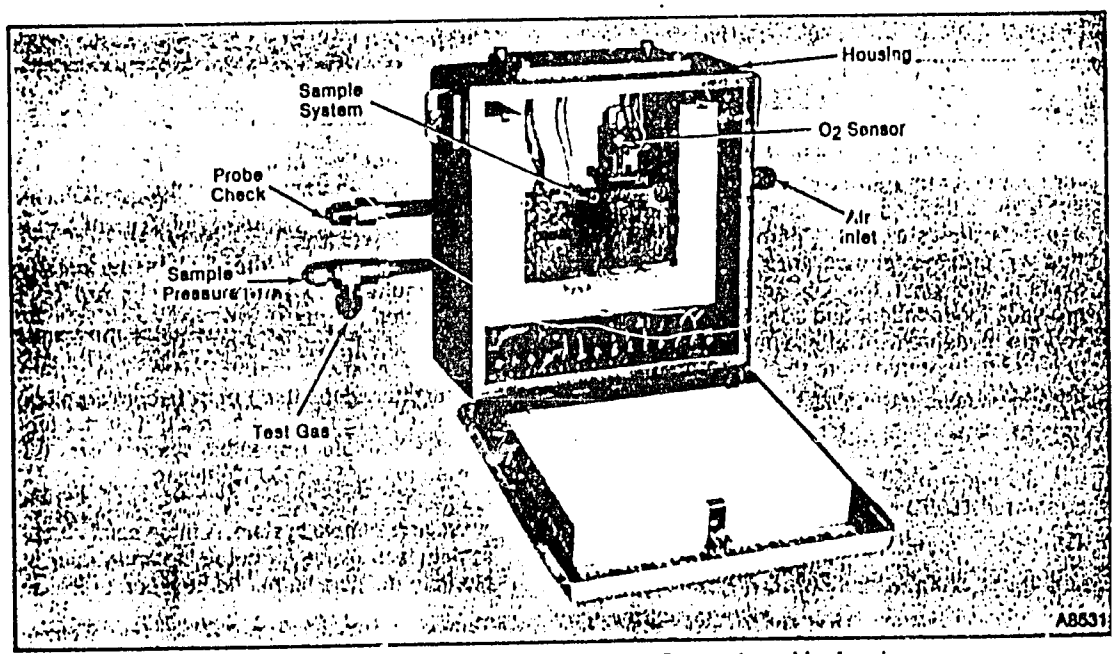

FIGURE 2 — Type OL110 Oxygen Analyzer Sensor Assembly, Interior.

SPECIFICATIONS

Switch Ranges Selectable	Linear O_2 Output: 0.1-1%, 0.1-10%, 0.1-25%*, 0.1-50%
Accuracy	Linearity: ± 2% of span Repeatability: Less than 0.1% of span
Measurement Errors Due to Flue Gas Variables	CO_2, none; water vapor, none; particulates, none; temperature, none.
63% (undamped) Response Time	Less than three seconds
Deviation from Calibrated Value	O_2 combined zero and range: ± 1% of span. There is no permanent deviation.
Probe Temperature	Single point probe with floppy filter: 1500°F/816°C for single burners. Special high temperature probe available for 1500° to 3000°F (consult factory).
Ambient Temperature Limits	Sensor Assembly: – 15 to 200°F/ – 26 to 93°C. Electronics Assembly: – 15 to 160°F/ –26 to 71°C.
Temperature Effect	Linear O_2 reading: ± 2.5% of span per 100°F/56°C.
Approvals/ Certification	Factory Mutual (FM) approved against flashback into duct. Canadian Standards Association (CSA) certified for use in ordinary non-hazardous locations.

*Factory calibrated range

Supply Pressure	Aspirator: 15 psig @ 0.22 scfm/103 kPa @ 6.2 L/min.
Supply Voltage:	120 ± 12 V ac, 50-60 Hz, 525 W start-up, 270 W operating
Supply Voltage Effect	Linear O_2 unit: ± .18% of span per volt
Output Load Capability	1 to 600 ohms
Output Signal	4-20 mA dc with adjustable damping 1 to 7 seconds
Radio Frequency Interference	Less than 1.0% output shift when subjected to MIL-STD 462 test RS01, RS02, RS03 and CS01.
OL110 Housings	NEMA 4 (watertight and dusttight for outdoors)
Wiring	12 ft. (3.66 m) lg. flexible cable with military-type connectors, standard. Optional 75 ft. (22.9 m) cable is available.
Humidity	95% R.H. at 158°F/70°C (non-condensing)
Weight	Sensor Assembly: approx. 15 lbs (6.8 kg) Electronics Assembly: approx. 10 lbs. (4.5 kg)

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

QUOTATION/ORDERING INFORMATION

List each item called for in the appropriate application column.

IDENTIFYING PART NUMBER OR NOMENCLATURE	DESCRIPTION	ANALYZER PACKAGE SELECTION: BOILERS PROCESS HEATERS GAS/OIL & COAL	LIME KILN ANY FUEL	TUNNEL KILN/ REHEAT FURNACES GAS/OIL
		'X' = REQUIRED EQUIPMENT		
OL110	ANALYZER	X	X	X
6634528-12'	12 FT. CABLE (STANDARD)	X	X	X
6634528-75	75 FT. CABLE	OPTIONAL	OPTIONAL	OPTIONAL
	FOR SINGLE POINT SAMPLE	Select single point sample and a probe length or a 3 point average sample and a duct width.		
6635398-1	SINGLE FILTER WHEN USING THESE PROBES			
1951469-4	4' PROBE			
1951469-5	7' PROBE 1500°F max.			
1951469-6	10' PROBE			
	FOR A 3 POINT AVERAGE SAMPLE			
6635526_4	Manifold Assy 1000°F max 5' to 10' Duct			
6635664_1	Probes Filters included			
6635526_5	Manifold Assy 1000°F max 10' to 15' Duct			
6635664_2	Probes Filters included			
6635526_6	Manifold Assy 1000°F max. 15' to 20' Duct			
6635664_3	Probes Filters included			
6635611-1	HI-TEMP PROBE 3000°F max.			X
6635733-1/6635398-1	DUAL FILTER 1500°F max.		X	
258239-1	ADAPTER FLANGE KIT REQUIRED FOR 3" or 4" FLANGE MOUNTING	OPTIONAL but required for 3 point sample	X	X
258274-1	TEST GAS KIT (NOT FOR AUTO CAL) 3 GAS CYLINDERS REG. VALVE, HOSE & CARRYING CASE	OPTIONAL	OPTIONAL	OPTIONAL

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