ORGANIZATION for
ENERGY
PLANNING

PN-ABA-279

جهاز تخطيط الطاقة

263-0123.01

ENERGY AUDIT

of the

El-Nasr Company for Coke and Chemicals

Helwan, Egypt

May, 1988

VOLUME 1 of 2

Produced through the joint engineering effort of:

* EL-NASR COMPANY FOR COKE AND CHEMICALS (EL-NASR)
* FOSTER WHEELER USA CORPORATION (FWUSA)
* ORGANIZATION FOR ENERGY PLANNING (OEP)

O.E.P. تلكس دولى ٢٣٤٠٤ ١ شارع عائشة التيمورية ـ جاردن سيتى ـ القاهرة
1, Aisha El-Taymorya — Garden City, Cairo Phone 355-7113 356-4576 Telex. 23404 O.E.P.

TABLE OF CONTENTS

		Page
	Appendices	ii
	List of Tables	iii
	List of Graphs	v
	Acknowledgment	vi
1.0	EXECUTIVE SUMMARY	1
	1.1 Introduction	1
	1.2 Plant Description	1
	1.3 Findings	3
	1.4 Recommendations	8
2.0	DISCUSSION	16
	2.1 Objectives of the Audit	17
	2.1.1 Identify Where Energy is Used	17
	2.1.2 Identify Energy Conservation Opportunities	18
	2.2 Method of Approach	18
	2.3 Goals and Special Considerations	19
	2.4 Analysis of Energy Consumption	20
	2.4.1 Discussion of Tables	58
	2.4.2 Discussion of Graphs	60
	2.5 Economic Evaluation	63
	2.5.1 Value of Energy Saved	63
	2.5.2 Estimating Investment Cost	64
3.0	ENERGY CONSERVATION OPPORTUNITIES (ECO'S)	66
	3.1 Summary List	66
	3.2 Detailed ECO Presentation	69

Appendices
(Report Volume 2 of 2)

Appendix

1 BASIC ENGINEERING DATA

2 PORTABLE INSTRUMENT LIST

3 FERTILIZER PLANT FLOW DIAGRAMS

4 ECO-34 : FORM A COMMITTEE TO PLAN AND IMPLEMENT ECO's (Pg. 269-326)

5 ECO-35 : PUBLICITY TO MAKE EMPLOYEES AWARE OF IMPORTANCE OF ENERGY CONSERVATION (Pg. 327-331)

6 ECO-28,29 : TECHNICAL ARTICLES REFERRING TO POWER FACTOR CORRECTIONS

7 DISCOUNTED CASH FLOW GRAPH

8 ECO-32 : LIST AND LOCATION OF INSTRUMENTS NECESSARY TO PROPERLY MONITOR ENERGY CONSUMPTION

List of Tables

Table No.	Description	Page
1.4A	Housekeeping Items - ECO Summary	11
1.4B	In-Country Investment Items - ECO Summary	13
1.4C	Foreign Investment Items - ECO Summary	15
1A	Monthly Energy Consumption - Coke Plant, Boilers 1 through 6	22
1B	Monthly Energy Consumption - Fertilizer Plant Boilers 1 through 4	23
1C	Monthly Energy Consumption - Calcium Ammonium Nitrate Plant	24
1D	Monthly Energy Consumption - Pure Ammonium Nitrate Plant	25
1E	Monthly Energy Consumption - Dilute Nitric Acid Plant	26
1F	Monthly Energy Consumption - Air Separation Plant	27
2A	Monthly Energy Costs - Coke Plant, Boilers 1 through 6	28
2B	Monthly Energy Costs - Fertilizer Complex, Boilers 1 through 4	29
2C	Monthly Energy Costs - Calcium Ammonium Nitrate Plant	30
2D	Monthly Energy Costs - Pure Ammonium Nitrate Plant	31
2E	Monthly Energy Costs - Dilute Nitric Acid Plant	32
2F	Monthly Energy Costs - Air Separation Plant	33
3A	Monthly Production, Cost & Energy Per Unit Coke Plant Boilers 1 through 6	34

List of Tables (continued)

Table No.	Description	Page
3B	Monthly Production, Cost & Energy Per Unit Fertilizer Complex Boilers 1 through 4	35
3C	Monthly Production, Cost & Energy Per Unit Calcium Ammonium Nitrate Plant	36
3D	Monthly Production, Cost & Energy Per Unit Pure Ammonium Nitrate Plant	37
3E	Monthly Production, Cost & Energy Per Unit Dilute Nitric Acid Plant	38
3F	Monthly Production, Cost & Energy Per Unit Air Separation Plant	39

List of Graphs

Graph No.	Description	Page
1A	Energy Consumed - Coke Plant Boilers	40
1B	Energy Consumed - Fertilizer Boilers	41
1C	Energy Consumed - Calcium Ammonium Nitrate	42
1D	Energy Consumed - Pure Ammonium Nitrate	43
1E	Energy Consumed - Dilute Nitric Acid	44
1F	Energy Consumed - Air Separation Plant	45
2A	Energy Cost/Unit - Coke Plant Boilers	46
2B	Energy Cost/Unit - Fertilizer Boilers	47
2C	Energy Cost/Unit - Calcium Ammonium Nitrate	48
2D	Energy Cost/Unit - Pure Ammonium Nitrate	49
2E	Energy Cost/Unit - Dilute Nitric Acid	50
2F	Energy Cost/Unit - Air Separation Plant	51
3A	Energy/Unit - Coke Plant Boilers	52
3B	Energy/Unit - Fertilizer Boilers	53
3C	Energy/Unit - Calcium Ammonium Nitrate	54
3D	Energy/Unit - Pure Ammonium Nitrate	55
3E	Energy/Unit - Dilute Nitric Acid	56
3F	Energy/Unit - Air Separation Plant	57

Acknowledgment

This project was carried out with the active support of the Organization for Energy Planning, Cairo, Egypt.

We would like to further thank the management and employees of the El-Nasr Company for Coke and Chemicals for their cooperation and assistance during all phases of the energy audit. Everyone was very friendly and extremely helpful in obtaining the necessary data and information that has become a basis for this report.

We also wish to express our appreciation to USAID for their advice and assistance in expediting the smooth flow of this project. This project was funded under USAID Contract Number PDC 5730-I-00-7021-00, Order No. 1.

El-Nasr Company for Coke and Chemicals - Energy Audit

1.0 EXECUTIVE SUMMARY

1.1 Introduction

The Organization for Energy Planning, in conjunction with the plant staff of the El-Nasr Coke and Chemical Company, and with the technical assistance of Foster Wheeler USA Corporation, have executed an energy audit of the El-Nasr Company for Coke and Chemicals, Helwan, Egypt. The field audit began in February, 1988, and continued into April, 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 all the processes in the Fertilizer Plant, excluding the Ammonia Plant, plus the Coke Plant steam system. The focus of the energy audit was in the Fertilizer Plant and Coke Plant steam systems, as they represent the areas of greatest energy expenditure, and therefore the areas where the greatest energy savings can be made. The Ammonia Plant was not included in the review of the Fertilizer Plant as it will be replaced in the near future. 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

The El-Nasr Company for Coke and Chemicals produces nominally 1,000,000 tons per year of coke, 120,000 tons per year of calcium ammonium nitrate fertilizer and 32,000 tons per year of tar as main products. It also produces pure nitric acid, pure ammonium nitrate and many other specialty chemicals.

Although the Coke Plant is an integral part of the manufacture of fertilizer, the Coke Plant and Fertilizer Plant operate as independent units. The Fertilizer Plant, built in 1972, is a two train unit and is fed coke oven gas, produced in the Coke Plant as a raw material. The Fertilizer Plant consists of the following sections:

	Design Capacity, Tons per year
Ammonia Synthesis (Stamicarbon Process)	56,100
Dilute Nitric Acid[1] (as 54% concentrate)	182,160
Calcium Ammonium Nitrate	198,000
Pure Ammonium Nitrate	20,000
Pure Nitric Acid[2]	16,500

The main products sold are Calcium Ammonium Nitrate, as fertilizer, pure ammonium nitrate, and pure nitric acid. The mix of products has differed from year to year due to demand pattern.

The Coke Plant Steam System consists of 6 boilers producing steam at 15 atm (1520 kPa), 350°C. and having the following capacities:

	Design Capacity, Tons per hour
Boiler #1	25
Boiler #2	25
Boiler #3	25
Boiler #4	25
Boiler #5	30
Boiler #6	50

Only three or four boilers are operating at any one time depending on steam demand. Boiler #2 has been shut down for repairs during all of 1987 and is still not operating.

---

[1] Dilute Nitric Acid as 54% is 552 tons per day and as 100% is 282 tons per day.

[2] The pure Nitric Acid Plant is in the process of being commissioned and has not been handed over to El-Nasr at the time of this audit.

1.3 Findings

The qualitative and quantitative findings at the El-Nasr Company for Coke and Chemicals are given 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, EL-NASR) 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 fertilizer plant and the coke plant boiler houses use mazout, coke oven gas and tar oil to fire water tube boilers. Electricity is used for various compressors, fans, pumps and other motors.

The total energy consumption for the Coke Plant and Fertilizer Plant boilers for calendar year 1987 was 2.62 x 10^{15} joules. Approximately 68% of this energy was used in the Coke Plant Boilers where 70% of the steam is produced. The overall energy cost to produce one ton of steam was US $3.78.

In the Fertilizer Plant boiler/steam system, mazout accounts for 61.3% of the annual energy consumption, in joules, coke oven gas for 37.7%, and electricity for 1.0%.

The process units in the Fertilizer Plant, excluding the Ammonia Plant, consume 3743.6 MWH per month.

In the Coke Plant boiler/steam system, mazout accounts for 34.6% of annual consumption, coke oven gas for 59.3%, tar oil for 5.7% and electricity for 0.4%.

The average energy required to produce one ton of 3334 kPa, 400 °C steam in the Fertilizer Plant is 3.20×10^9 joules. The average energy required to produce one ton of 1373 kPa, 350 °C steam in the Coke Plant is 2.92×10^9 joules. Both of these energy-to-steam values are above values that can be expected in similar installations.

The amount of energy needed to make a ton of steam does not reflect the fact that more steam is being produced than is actually required by the processes. Large quantities of energy are lost due to non-recovery of condensate, leaking steam valves and flanges, damaged and/or missing insulation, and non-operational steam traps. As a result, there is substantial room for energy savings.

With the exception of the new future ammonia plant, the largest potential for future energy savings lies within the steam systems of the Coke and Fertilizer Plants. The largest cost savings will result from maximizing the use of coke oven gas and tar oil in the boilers.

Instrumentation

The instrumentation in the Coke and Fertilizer Plants is in a state of disrepair. Most of the instruments need new parts or total replacement to make the service operational. Non-availability of parts due to lack of foreign currency, technical expertise, and commitment to repair the instruments has left the plant in an ongoing state of disrepair, which must be improved. Of those instruments found to be working, only those required for production are calibrated and kept in working order. Instrumentation required for energy monitoring either does not exist, is not calibrated regularly, or is broken.

Pollution and Pollution Control

The primary sources of pollution at El-Nasr are coal and coke dust from the coke oven batteries and ammonia from the ammonia synthesis plant. Coal and coke dust have spread all over the Coke Plant and Fertilizer Plant, and has detrimentally affected almost all pieces of equipment to one extent or another. A significant amount of dust has worked its way into instruments, equipment, buildings, machinery and the general surroundings. In the Fertilizer Plant, leaking flanges, valves and pump and compressor glands are discharging

waves of ammonia into the atmosphere. In addition, cooling pump failures in the dilute nitric acid plant result in considerable atmospheric discharges of nitrous oxide and nitrous dioxide fumes.

The ammonia plant is old and obsolete and is to be replaced shortly. Good engineering practice and maintenance should eliminate similar leaks in the new plant.

Electrical

The El-Nasr chemical plant electrical system consists of two 66 kV incoming feeders to the utility's 66 - 6.3 kV transformer sub-station which feeds the plant via four 1000 A, 10% reactors.

The metering, though perhaps adequate for operation, is not suitable for power profile monitoring and needs calibration and updating.

The Fertilizer Plant operations utilize several synchronous motors and capacitors on two substations to supply plant and kVAr demand. The meters indicated a 0.98 power factor, though by calculation it appears to be approximately 0.95.

The Coke Plant in general appears to have a low power factor of approximately 0.7. This is apparently due to under-utilized motors, such as large motor running at half load or variable load.

The best remedy would be to include variable speed AC controllers in the existing Coke Plant power system revamp.
The next best solution would be to include power factor correction capacitors for large motors with proper relaying and switching equipment.

Compared to the Fertilizer Plant, the Coke Plant meterings need upgrading for any reliable readings.

Housekeeping

The majority of the electrical and mechanical equipment maintenance calls are a result of the high concentration of coal and coke 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 need for immediate repair. No

effort is being made to clean the surroundings of dust, consequently, no improvement in useful equipment life can be expected.

There are an enormous number of steam, condensate, and boiler feedwater leaks. The plant, as a whole, suffers greatly in this area of energy loss.

Insulation in the Fertilizer and Coke Plant is not good. There are many items of equipment and piping that require the addition or repair of insulation. Insulation at the steam boiler houses is sporadic and in other cases, totally ineffective due to damage, deterioration, or improper installation.

There are a modest number of steam traps at El-Nasr. Of these, only 30 percent were found to be functioning properly. Items such as these, though physically small, can lead to significant energy loss over the course of a year. Considering the number of steam traps, the time involved in checking, cleaning, and repairing steam traps, new procedures must be established whereby at least 90% of the steam traps are functioning properly all of the time at El-Nasr.

Maintenance

The ability of El-Nasr to execute maintenance on items in need of repair must be improved. Lack of spare parts for various items of equipment has made many machines and other devices redundant, as it is easier to purchase new items than repair existing ones.

Maintenance is performed on-the-run as opposed to during scheduled shutdown and turnarounds. The commitment of management towards production has resulted in equipment being run until it breaks due to lack of proper scheduled maintenance.

Management and Personnel

The priority of management is 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 El-Nasr.

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 unit of production 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, presented at the end of this section, 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.

The implementation of all housekeeping items identified would result in a minimum of 5,320 T.O.E. saved annually, and represents 8.4% of the total energy used in the production of steam in the Fertilizer and Coke Plants. In terms of potential savings in mazout alone, it represents 20% of all the mazout fired in the Fertilizer Plant and Coke Plant boiler houses. This savings does not take into account the energy savings possible through the implementation of ECO's 26,33,34 and 35. While it is impossible to quantify the energy savings realized from these latter four ECO's, it is expected that they will result in significant continuing energy saving.

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. 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 in-country investment items identified refer to the steam system and process insulation. The implementation of all these items would save a total of 18,188 T.O.E. per year, or 29% of the fuel fired in the Fertilizer Plant and Coke Plant boiler houses. In terms of potential savings in the firing of mazout, it represents a savings of essentially all of the mazout fired in these two boiler houses. Thus, if the majority of the ECO's in Tables 1.4A and 1.4B were to be implemented, it may be possible to lower the use of mazout in the two boiler houses by 80 to 85 percent.

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.

The energy savings that can be expected if all ECO's were implemented is 14,522 T.O.E. per year.

Repairing turbogenerator and generating electricity when letting down steam pressure would result in an energy saving of 2995 T.O.E. per year. This investment would pay out immediately.

Improving, adding and repairing instrumentation alone would result in an indirect energy saving of 1,489 T.O.E. per year. This investment would pay out in 4.05 years.

Improving the efficiency of the Coke Plant and Fertilizer Plant steam boilers will save 8,640 T.O.E. per year, with 7,881 T.O.E. per year being saved in the Coke Plant alone.

These ECO's should be implemented as soon as possible to realize full advantage of the investment.

Other Items For Consideration

Considering the age, disruption of the steam supply, and the frequent failure of Boilers #1, #2, #3, and #4 in the Coke Plant, the installation of a 75 ton/hour boiler to replace the above four boilers should be studied further. This new package boiler should make the steam system more efficient and reliable. This ECO is discussed further in Section 3.2, ECO-11. The simple payout is 6.5 years based on energy savings alone. Loss of production due to boiler downtime, and the high cost of maintaining these boilers will make the actual simple payout of this ECO less than 6.5 years.

Although not covered by an ECO in this report, The El-Nasr Company for Coke and Chemicals may wish to study the installation of a catalytic combustion unit in the Dilute Nitric Acid Plant. Such a system will heat the tail gas to approximately 670 ^{o}C before expansion. This will enable all the power required for compression to be recovered, and the need for a make-up driver can be eliminated.

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 implementation of all ECO's listed in tables 1.4 A, B, and C is 38,030 T.O.E. This annual energy savings has a corresponding value of U.S. $4,645,772. The investment cost to implement all ECO's is U.S. $3,007,768 and results in an overall simple payout of 0.65 years.

Table 1.4A HOUSEKEEPING ITEMS - ECO Summary

Plant: El-Nasr Company for Coke and Chemicals

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
Fertilizer Plant Steam System								
02	Eliminate the use of high pressure steam and use desuperheated 16 atm steam for total steam requirements in Calcium Ammonium Nitrate plant.	573.0 tons mazout	556.0	13,952	64,216	IMMEDIATE	31,253	1.95
08	Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.	1908.0 tons mazout	1852.0	5,333	213,800	IMMEDIATE	11,945	IMMEDIATE
Coke Plant Steam System								
17	Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.	1138.0 tons mazout	1105.0	5,278	127,536	IMMEDIATE	11,822	0.37
24	Repair heat exchanger leaks and install necessary non-return valves to avoid steam and condensate contamination.	1504.0 tons mazout	1460.0	9,111	168,553	IMMEDIATE	20,408	0.48
General								
25	Institute a permanent program for steam trap testing.	357.0 tons mazout	347.0	14,610	40,009	0.37	32,873	3.29
26	Show the effect of insulation on heat loss from pipes.	—	--	--	--	IMMEDIATE	--	IMMEDIATE

Table 1.4A HOUSEKEEPING ITEMS - ECO Summary (continued)

Plant: El-Nasr Company for Coke and Chemicals

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
33	Develop and implement a formal equipment maintenance program.	--	--	--	--	IMMEDIATE	--	IMMEDIATE
34	Form a committee to plan and implement an energy conservation program in plant.	--	--	--	--	IMMEDIATE	--	IMMEDIATE
35	Use of publicity, memos, newsletter, etc. to implement an energy program and make personnel aware of the importance of energy conservation.	--	--	--	--	IMMEDIATE	--	IMMEDIATE
TOTAL		--	5,320	48,284	614,114	0.08	108,301	0.71

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: El-Nasr Company for Coke and Chemicals

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
Fertilizer Plant Steam System								
01	Recover heat and produce steam from continuous boiler blowdown in Dilute Nitric Acid Plant.	222.5 tons mazout	216.0	28,240	24,935	1.13	--	--
03	Installation of a condensate recovery system for the Ammonia, Nitric Acid, Calcium Ammonium Nitrate and Pure Ammonium Nitrate Plants.	2723.0 tons mazout	2644.0	233,480	305,166	0.77	--	--
							--	--
06	Test, repair, and replace steam traps.	1,609 tons mazout	1,562	22,500	180,321	IMMEDIATE	--	--
07	Add new or repair existing insulation on steam and condensate lines.	1,539 tons mazout	1,494	42,341	172,475	IMMEDIATE	--	--
Coke Plant Steam System								
15	Installation of a condensate recovery system for the Coke Plant.	3,216 tons mazout	3,122	464,820	360,417	1.29	--	--
16	Add new or repair existing insulation on steam and condensate lines.	1,558 tons mazout	1,513	44,603	174,605	0.26	--	--

Table 1.4B IN-COUNTRY INVESTMENT ITEMS - ECO Summary (Continued)

Plant: El-Nasr Company for Coke and Chemicals

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
18	Test, repair, and replace steam traps.	3151.0 tons mazout	3059.0	48,120	353,107	IMMEDIATE	--	--
19	Complete commissioning of new demineralized water plant and put into service.	2277.0 tons mazout	2211.0	0	255,183	IMMEDIATE	--	--
21	Improve insulation and add drip legs to main low and high presure steam headers in order to reduce pressure drop and heat loss.	2055.0 tons mazout	1995.0	410,877	230,303	1.78	--	--
23	Recover heat and produce steam from continuous boiler blowdown.	383 tons mazout	372	98,570	42,945	2.30	--	--
TOTAL		--	18,188	1,393,551	2,099,457	0.66	--	--

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 1.4C FOREIGN INVESTMENT ITEMS - ECO Summary

Plant: El-Nasr Company for Coke and Chemicals

ECO #	TITLE	WORLDWIDE ANNUAL ENERGY SAVINGS FUEL	T.O.E.	INVESTMENT COST, $	ANNUAL COST SAVINGS, $	SIMPLE PAYOUT, YRS	LOCAL INVESTMENT COST, LE	LOCAL SIMPLE PAYOUT, YRS
Fertilizer Plant Steam System								
04	Improve combustion efficiency of steam boilers	782.0 tons mazout	759	27,000	87,648	0.31	--	--
05	Repair turbogenerator and generate electricity when letting down steam pressure.	11,880 MWH	2,995	16,780	510,840	IMMEDIATE	--	--
Coke Plant Steam System								
13	Operate the turbogenerator at design capacity.	5544.0 MWH	1398.0	717,183	238,392	3.01	--	--
14	Improve combustion efficiency of steam boilers.	8,118 tons mazout	7,881	54,000	909,784	IMMEDIATE	--	--
General								
32	Improve, add, or fix instrumentation to be able to properly monitor and control energy consumption. (Note 5)	984 MWH 556 tons mazout 64 tar oil 1,487,680 M3 coke gas 10,500 M3 blast gas	1,489 (5)	750,970	185,537	4.05	--	--
TOTAL		--	14,522	1,565,933	1,932,201	0.81	--	--
GRAND TOTAL	(Tables 1.4 A, B, and C)	--	38,030	3,007,768	4,645,772	0.65	--	--

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 El-Nasr Company for Coke and Chemicals and Foster Wheeler USA Corporation have conducted an energy audit of the El-Nasr 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 El-Nasr plant was performed in three steps, namely,

- Screening
- Preaudit
- Audit

The initial phase, screening, resulted in the selection of the El-Nasr 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 Objective 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 audit work was developed. The time frame for the audit work was set at sixteen weeks, including reports and presentation.

OEP, El-Nasr plant personnel, 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 their location, 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, and 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. Almost all of the necessary plant data was collected in the first four weeks, with the next two needs used for verification of plant data where required.

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.

At the end of the seventh week, estimated sizing of equipment was well under way.

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.

Equipment sizing, system design, energy savings, and estimated investment for the various ECO's were continued through the tenth week.

During the latter part of the eighth week report preparation began and continued through the thirteenth 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 60 percent reduction in yearly

consumption of mazout at the end of two years, following partial implementation of housekeeping and in-country investment items. Since coke oven gas and blast furnace gas are each considered to have no cost, they must always be used preferentially instead of mazout. That is why this goal is expressed in terms of mazout rather than all fired fuels. A second goal would be a 30 percent reduction in the yearly consumption of electricity 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. 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 following tables 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 this calculation technique permits direct plots to be made on the computer, to exhibit a graphic display of the tabulated data, and to aid in analysis.

The choice of curves to be presented is generally made after a careful review of the tables, to detect trends which would be meaningful as curves, when plotted.

Such trends may include those which indicate costs not directly dependent upon production, such as discontinuities in production or energy consumption, and the like.

Generally, the plots of greatest interest will be energy consumption, production costs per production unit and energy consumption per production unit, plotted against calendar time.

Tables 1A through 1F detail the energy consumption for each of the six sections of the complex that were audited. Tables 2A through 2F detail the cost of the energy in both worldwide and local price structure. Tables 3A through 3F detail the production of each section, and the energy and energy cost required per unit of production.

Eighteen graphs have been plotted by the computer for the El-Nasr Company. Energy consumption has been plotted in joules in order to compare the energy consumption figures to worldwide energy consumption figures. The conclusions drawn from the eighteen energy consumption tables and the eighteen graphs follow the presentation of the tables and graphs.

TABLE 1A - MONTHLY ENERGY CONSUMPTION

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : COKE PLANT BOILERS 1 THROUGH 6

		ELECTRICITY			# 6 FUEL OIL			COKE OVEN GAS			TAR OIL			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	135.2	486.6	34.1	1018.0	41505.4	988.2	5980000	110155.4	2622.7	175.0	5494.8	130.8	157642.2	3775.9
2	FEB	133.7	481.2	33.7	797.0	32494.9	773.7	4960000	91366.3	2175.4	0.0	0.0	0.0	124342.4	2982.8
3	MAR	114.9	413.8	29.0	1108.0	45174.9	1075.6	3384000	62335.4	1484.2	200.0	6279.8	149.5	114203.9	2738.3
4	APR	69.8	251.4	17.6	2048.0	83500.1	1988.1	4720000	86945.4	2070.1	352.0	11052.4	263.2	181749.3	4339.0
5	MAY	59.1	212.9	14.9	1639.0	66824.5	1591.1	5780000	106471.3	2535.0	546.0	17143.9	408.2	190652.5	4549.2
6	JUN	158.3	569.7	39.9	1485.0	60545.7	1441.6	4840000	89155.9	2122.8	674.0	21162.9	503.9	171434.2	4108.1
7	JUL	291.2	1048.5	73.4	1680.0	68496.2	1630.9	3560000	65577.5	1561.4	404.0	12685.2	302.0	147807.3	3567.7
8	AUG	181.1	651.9	45.7	1855.0	75631.2	1800.7	3120000	57472.4	1368.4	225.0	7064.8	168.2	140820.3	3383.0
9	SEP	174.1	626.8	43.9	1407.0	57365.5	1365.8	4655000	85748.1	2041.6	300.0	9419.7	224.3	153160.1	3675.6
10	OCT	226.5	815.3	57.1	1000.0	40771.5	970.8	4520000	83261.3	1982.4	125.0	3924.9	93.4	128772.9	3103.7
11	NOV	174.2	627.1	43.9	657.0	26786.9	637.8	6220000	114576.3	2728.0	120.0	3767.9	89.7	145758.2	3499.4
12	DEC	188.7	679.3	47.6	342.0	13943.9	332.0	5360000	98734.6	2350.8	80.0	2511.9	59.8	115869.7	2790.2
ANNUAL TOTALS		1906.8	6864.3	480.7	15036.0	613040.7	14596.2	57099000	1051799.8	25043	3201.0	100508.2	2393.1	1772213.1	42512.8
MONTHLY AVERAGE		158.9	572.0	40.1	1253.0	51086.7	1216.4	4758250	87650.0	2086.9	266.8	8375.7	199.4	147684.4	3542.7
NOTES		3.6 x 10E9 J/MWH			40.7715 x 10E9 J/TON			18420635 J/CU. M.			31.3990 x 10E9 J/TON			42.00 x 10E9 J/T.O.E.	

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

TABLE 1B - MONTHLY ENERGY CONSUMPTION

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : FERTILIZER PLANT - BOILERS 1 THROUGH 4

		ELECTRICITY			# 6 FUEL OIL			COKE OVEN GAS			TAR OIL			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	196.6	707.8	49.6	392.0	15982.4	380.5	2589380.0	47698.0	1135.7	0.0	0.0	0.0	64388.3	1565.8
2	FEB	197.1	709.5	49.7	1510.0	61565.0	1465.8	174120.0	3207.4	76.4	0.0	0.0	0.0	65481.9	1591.9
3	MAR	192.4	692.7	48.5	1381.0	56305.5	1340.6	1041085.0	19177.4	456.6	0.0	0.0	0.0	76175.6	1845.7
4	APR	201.2	724.2	50.7	761.0	31027.1	738.7	2016500.0	37145.2	884.4	0.0	0.0	0.0	68896.6	1673.9
5	MAY	197.0	709.1	49.7	343.0	13984.6	333.0	3143900.0	57912.6	1378.9	0.0	0.0	0.0	72606.4	1761.5
6	JUN	197.0	709.1	49.7	334.0	13617.7	324.2	2360990.0	43490.9	1035.5	0.0	0.0	0.0	57817.7	1409.4
7	JUL	198.1	713.0	49.9	1589.0	64786.0	1542.5	520230.0	9583.0	228.2	0.0	0.0	0.0	75081.9	1820.6
8	AUG	197.7	711.7	49.8	1313.0	53533.0	1274.6	997360.0	18372.0	437.4	0.0	0.0	0.0	72616.7	1761.9
9	SEP	197.2	710.0	49.7	1763.0	71880.2	1711.4	0.0	0.0	0.0	0.0	0.0	0.0	72590.2	1761.2
10	OCT	200.7	722.5	50.6	1829.0	74571.1	1775.5	0.0	0.0	0.0	0.0	0.0	0.0	75293.6	1826.1
11	NOV	196.0	705.6	49.4	891.0	36327.4	864.9	1890590.0	34825.9	829.2	0.0	0.0	0.0	71858.9	1743.5
12	DEC	198.4	714.3	50.0	618.0	25196.8	599.9	2550950.0	46990.1	1118.8	0.0	0.0	0.0	72901.2	1768.6
ANNUAL TOTALS		2369.3	8529.4	597.3	12724.0	518776.9	12351.8	17285105	318402.6	7581.0	0.0	0.0	0.0	845709.0	20530.1
MONTHLY AVERAGE		197.4	710.8	49.8	1060.3	43231.4	1029.3	1440425	26533.6	631.8	0.0	0.0	0.0	70475.7	1710.8
NOTES		3.6 X 10E9 J/MWH			40.7715 x 10E9 J/TON			18420635 J/CU. M.			31.3990 x 10E9 J/TON			42.00 x 10E9 J/T.O.E.	

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

TABLE 1 C - MONTHLY ENERGY CONSUMPTION

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : CALCIUM AMMONIUM NITRATE

		ELECTRICITY			34 KG/CM2 STEAM			16 KG/CM2 STEAM			BLAST FURNACE GAS			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.	TONS	J x 10E9	T.O.E.	CU. M.	J x 10E9	T.O.E.	J x 10E9	T.O.E.**
1	JAN	298.8	1075.7	75.3	1490.0	2616.4	62.3	2153.0	4146.7	98.7	93000.0	366.0	8.71	8204.8	245.1
2	FEB	284.7	1024.9	71.8	1394.0	2447.9	58.3	2051.0	3950.2	94.1	79000.0	310.9	7.40	7733.9	231.5
3	MAR	295.4	1063.5	74.5	1521.0	2670.9	63.6	1561.0	3006.5	71.6	90000.0	354.2	8.43	7095.0	213.1
4	APR	255.8	921.0	64.5	1248.0	2191.5	52.2	1932.0	3721.0	88.6	54000.0	212.5	5.06	7046.1	210.3
5	MAY	251.8	906.5	63.5	1260.0	2212.6	52.7	1677.0	3229.9	76.9	31000.0	122.0	2.90	6471.0	196.0
6	JUN	268.0	964.8	67.6	1474.0	2588.3	61.6	2408.0	4637.8	110.4	45000.0	177.1	4.22	8368.0	243.8
7	JUL	242.6	873.4	61.2	1332.0	2339.0	55.7	1799.0	3464.9	82.5	29500.0	116.1	2.76	6793.4	202.1
8	AUG	271.5	977.3	68.4	1430.0	2511.1	59.8	1981.0	3815.4	90.8	31000.0	122.0	2.90	7425.8	222.0
9	SEP	274.9	989.8	69.3	1402.0	2461.9	58.6	2005.0	3861.6	91.9	23500.0	92.5	2.20	7405.8	222.1
10	OCT	296.7	1068.2	74.8	1433.0	2516.3	59.9	2044.0	3936.7	93.7	15500.0	61.0	1.45	7582.3	229.9
11	NOV	360.4	1297.5	90.9	1565.0	2748.1	65.4	2058.0	3963.7	94.4	20500.0	80.7	1.92	8090.0	252.6
12	DEC	272.8	982.1	68.8	1445.0	2537.4	60.4	1614.0	3108.6	74.0	13000.0	51.2	1.22	6679.3	204.4
ANNUAL TOTALS		3373.5	12144.8	850.5	16994.0	29841.5	710.5	23283.0	44843.1	1067.7	525000.0	2066.0	49.19	88895.3	2677.9
MONTHLY AVERAGE		281.1	1012.1	70.9	1416.2	2486.8	59.2	1940.3	3736.9	89.0	43750.0	172.2	4.10	7407.9	223.2
NOTES		3.6 X 10E9 J/MWH			1.7560 x 10E9 J/TON DELTA H			1.9260 x 10E9 J/TON DELTA H			0.00394 x 10E9 J / CU.M.			42.00 x 10E9 J/T.O.E.	

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

TABLE 1 D - MONTHLY ENERGY CONSUMPTION

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : PURE AMMONIUM NITRATE

		ELECTRICITY			34 KG/CM2 STEAM			16 KG/CM2 STEAM			BLAST FURNACE GAS			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.	TONS	J x 10E9	T.O.E.	CU. M.	J x 10E9	T.O.E.	J x 10E9	T.O.E.**
1	JAN	13.4	48.1	3.4	0.0	0.0	0.0	236.0	454.5	10.8	0.0	0.0	0.0	502.6	14.19
2	FEB	43.3	155.8	10.9	0.0	0.0	0.0	822.0	1583.2	37.7	0.0	0.0	0.0	1739.0	48.61
3	MAR	38.9	139.9	9.8	0.0	0.0	0.0	878.0	1691.0	40.3	0.0	0.0	0.0	1830.9	50.06
4	APR	40.4	145.5	10.2	0.0	0.0	0.0	838.0	1614.0	38.4	0.0	0.0	0.0	1759.5	48.62
5	MAY	39.9	143.7	10.1	0.0	0.0	0.0	708.0	1363.6	32.5	0.0	0.0	0.0	1507.3	42.53
6	JUN	46.5	167.2	11.7	0.0	0.0	0.0	800.0	1540.8	36.7	0.0	0.0	0.0	1708.0	48.40
7	JUL	20.1	72.2	5.1	0.0	0.0	0.0	300.0	577.8	13.8	0.0	0.0	0.0	650.0	18.81
8	AUG	18.5	66.6	4.7	0.0	0.0	0.0	263.0	506.5	12.1	0.0	0.0	0.0	573.1	16.72
9	SEP	26.7	96.2	6.7	0.0	0.0	0.0	419.0	807.0	19.2	0.0	0.0	0.0	903.2	25.95
10	OCT	60.7	218.5	15.3	0.0	0.0	0.0	696.0	1340.5	31.9	0.0	0.0	0.0	1559.0	47.22
11	NOV	29.4	105.8	7.4	0.0	0.0	0.0	514.0	990.0	23.6	0.0	0.0	0.0	1095.8	30.98
12	DEC	43.1	155.0	10.9	0.0	0.0	0.0	586.0	1128.6	26.9	0.0	0.0	0.0	1283.6	37.73
	ANNUAL TOTALS	420.7	1514.5	106.1	0.0	0.0	0.0	7060.0	13597.6	323.8	0.0	0.0	0.0	15112.1	429.81
	MONTHLY AVERAGE	35.1	126.2	8.8	0.0	0.0	0.0	588.3	1133.1	27.0	0.0	0.0	0.0	1259.3	35.82
	NOTES	3.6 X 10E9 J/MWH			1.7560 x 10E9 J/TON DELTA H			1.9260 x 10E9 J/TON DELTA H			0.00394 J x 10E9 / CU.M.			42.00 x 10E9 J/T.O.E.	

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

TABLE 1 E - MONTHLY ENERGY CONSUMPTION

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : DILUTE NITRIC ACID

		ELECTRICITY			PRODUCED 34 KG/CM2 STEAM *			16 KG/CM2 STEAM			BLAST FURNACE GAS			TOTAL ENERGY	
		PURCHASED ENERGY MWH	EQUIVALENT ENERGY J x 10E9	T.O.E.**	ENERGY PRODUCED TONS	EQUIVALENT ENERGY (Credit) J x 10E9	(Credit) T.O.E.	PURCHASED ENERGY TONS	EQUIVALENT ENERGY J x 10E9	T.O.E.	PURCHASED ENERGY CU. M.	EQUIVALENT ENERGY J x 10E9	T.O.E.	J x 10E9	T.O.E.**
1	JAN	1503.2	5411.7	379.0	6052.0	-10627.3	-253.0	0.0	0.0	0.0	0.0	0.0	0.0	-5215.6	125.94
2	FEB	1522.3	5480.2	383.8	6104.0	-10718.6	-255.2	0.0	0.0	0.0	0.0	0.0	0.0	-5238.5	128.55
3	MAR	1518.7	5467.2	382.8	5927.0	-10407.8	-247.8	0.0	0.0	0.0	0.0	0.0	0.0	-4940.6	135.04
4	APR	1232.9	4438.5	310.8	4898.0	-8600.9	-204.8	0.0	0.0	0.0	0.0	0.0	0.0	-4162.4	106.03
5	MAY	1270.0	4572.1	320.2	4025.0	-7067.9	-168.3	0.0	0.0	0.0	0.0	0.0	0.0	-2495.8	151.88
6	JUN	1363.6	4909.1	343.8	5412.0	-9503.5	-226.3	0.0	0.0	0.0	0.0	0.0	0.0	-4594.4	117.49
7	JUL	1318.4	4746.2	332.4	4491.0	-7886.2	-187.8	0.0	0.0	0.0	0.0	0.0	0.0	-3140.0	144.59
8	AUG	1470.2	5292.6	370.6	4984.0	-8751.9	-208.4	0.0	0.0	0.0	0.0	0.0	0.0	-3459.3	162.24
9	SEP	1473.2	5303.5	371.4	5567.0	-9775.7	-232.8	0.0	0.0	0.0	0.0	0.0	0.0	-4472.2	138.63
10	OCT	1326.9	4776.9	334.5	5660.0	-9939.0	-236.6	0.0	0.0	0.0	0.0	0.0	0.0	-5162.1	97.86
11	NOV	1326.9	4776.9	334.5	7001.0	-12293.8	-292.7	0.0	0.0	0.0	0.0	0.0	0.0	-7516.9	41.80
12	DEC	1166.8	4200.3	294.1	4742.0	-8327.0	-198.3	0.0	0.0	0.0	0.0	0.0	0.0	-4126.6	95.87
ANNUAL TOTALS		16493.1	59375.1	4157.8	0.0	-113899.4	-2711.9	0.0	0.0	0.0	0.0	0.0	0.0	-54524.3	1445.92
MONTHLY AVERAGE		1374.4	4947.9	346.5	0.0	-9491.6	-226.0	0.0	0.0	0.0	0.0	0.0	0.0	-4543.7	120.49
NOTES		3.6 X 10E9 J/MWH			1.7560 x 10E9 J/TON DELTA H			1.9260 x 10E9 J/TON DELTA H			0.00394 J x 10E9 / CU.M.			42.00 x 10E9 J/T.O.E.	

* NEGATIVE VALUES (-) INDICATE A CREDIT DUE TO THE PRODUCTION OF ENERGY.

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

TABLE 1F - MONTHLY ENERGY CONSUMPTION

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : AIR SEPARATION PLANT

		ELECTRICITY			# 6 FUEL OIL			COKE OVEN GAS			TAR OIL			TOTAL ENERGY	
		PURCHASED ENERGY MWH	EQUIVALENT ENERGY J x 10E9	T.O.E.**	PURCHASED ENERGY TONS	EQUIVALENT ENERGY J x 10E9	T.O.E.	PURCHASED ENERGY CU. M.	EQUIVALENT ENERGY J x 10E9	T.O.E.	PURCHASED ENERGY TONS	EQUIVALENT ENERGY J x 10E9	T.O.E.	J x 10E9	T.O.E.**
1	JAN	2142.4	7712.7	540.1	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	7712.7	540.1
2	FEB	1742.0	6271.0	439.1	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	6271.0	439.1
3	MAR	1483.2	5339.4	373.9	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	5339.4	373.9
4	APR	2283.4	8220.1	575.6	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	8220.1	575.6
5	MAY	1891.2	6808.4	476.8	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	6808.4	476.8
6	JUN	1853.3	6671.8	467.2	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	6671.8	467.2
7	JUL	2036.6	7331.9	513.4	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	7331.9	513.4
8	AUG	2073.5	7464.7	522.7	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	7464.7	522.7
9	SEP	2019.6	7270.7	509.2	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	7270.7	509.2
10	OCT	2153.0	7750.9	542.8	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	7750.9	542.8
11	NOV	2439.0	8780.4	614.9	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	3780.4	614.9
12	DEC	2518.8	9067.7	635.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	9067.7	635.0
ANNUAL TOTALS		24636.0	88689.8	6210.8	0.0	0.0	0.0	0	0.0	0	0.0	0.0	0.0	88689.8	6210.8
MONTHLY AVERAGE		2053.0	7390.8	517.6	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	7390.8	517.6
NOTES		3.6 X 10E9 J/MWH			40.7715 x 10E9 J/TON			18420635 J/CU. M.			31.3990 x 10E9 J/TON			42.00 x 10E9 J/T.O.E.	

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

TABLE 2A - MONTHLY ENERGY COSTS

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : COKE PLANT - BOILERS 1 THROUGH 6

		ELECTRICITY			# 6 FUEL OIL			COKE OVEN GAS			TAR OIL			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	135.2	2298	5812	1018.0	28504	114087	5980000	0	0	175.0	0	0	30802	119899
2	FEB	133.7	2272	5747	797.0	22316	89320	4960000	0	0	0.0	0	0	24588	95067
3	MAR	114.9	1954	4942	1108.0	31024	124174	3384000	0	0	200.0	0	0	32978	129116
4	APR	69.8	1187	3003	2048.0	57344	229519	4720000	0	0	352.0	0	0	58531	232522
5	MAY	59.1	1005	2543	1639.0	45892	183683	5780000	0	0	546.0	0	0	46897	186225
6	JUN	158.3	2690	6805	1485.0	41580	166424	4840000	0	0	674.0	0	0	44270	173229
7	JUL	291.2	4951	12523	1680.0	47040	188278	3560000	0	0	404.0	0	0	51991	200801
8	AUG	181.1	3078	7787	1855.0	51940	207890	3120000	0	0	225.0	0	0	55018	215677
9	SEP	174.1	2960	7487	1407.0	39396	157682	4655000	0	0	300.0	0	0	42356	165170
10	OCT	226.5	3850	9738	1000.0	28000	112070	4520000	0	0	325.0	0	0	31850	121808
11	NOV	174.2	2961	7490	657.0	18396	73530	6220000	0	0	120.0	0	0	21357	81120
12	DEC	188.7	3208	8113	342.0	9576	38328	5360000	0	0	80.0	0	0	12784	46441
ANNUAL TOTALS		1906.8	32415	81991	15036.0	421008	1685085	57099000	0	0	3201.0	0	0	453423	1767075
MONTHLY AVERAGE		158.9	2701	6833	1253.0	35084	140424	4758250	0	0	266.8	0	0	37785	147256

NOTES
17.0 L.E./MWH
43.0 US $/MWH
28.0 L.E./TON
112.07 US $/TON
0.0000 L.E./CU. M.
0.000 US $/CU. M.
0.0 L.E./TON
0.00 US $/TON

TABLE 28 - MONTHLY ENERGY COSTS

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : FERTILIZER COMPLEX - BOILERS 1 THROUGH 4

		ELECTRICITY			# 6 FUEL OIL			COKE OVEN GAS			TAR OIL			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	196.6	3342	8454	392.0	10976	43931	2589380.0	0	0	0.0	0	0	14318	52386
2	FEB	197.1	3351	8475	1510.0	42280	169226	1044085.0	0	0	0.0	0	0	45631	177701
3	MAR	192.4	3271	8274	1381.0	38668	154769	2016500.0	0	0	0.0	0	0	41939	163042
4	APR	201.2	3420	8650	761.0	21308	85285	3143900.0	0	0	0.0	0	0	24728	93936
5	MAY	197.0	3348	8470	343.0	9604	38440	2360990.0	0	0	0.0	0	0	12952	46910
6	JUN	197.0	3348	8470	334.0	9352	37431	2360990.0	0	0	0.0	0	0	12700	45901
7	JUL	198.1	3367	8516	1589.0	44492	178079	520230.0	0	0	0.0	0	0	47859	186595
8	AUG	197.7	3361	8501	1313.0	36764	147148	997360.0	0	0	0.0	0	0	40125	155649
9	SEP	197.2	3353	8480	1763.0	49364	197579	0.0	0	0	0.0	0	0	52717	206059
10	OCT	200.7	3412	8630	1829.0	51212	204976	0.0	0	0	0.0	0	0	54624	213606
11	NOV	196.0	3332	8428	891.0	24948	99854	1890590.0	0	0	0.0	0	0	26280	108283
12	DEC	198.4	3373	8532	618.0	17304	69259	2550950.0	0	0	0.0	0	0	20677	77791
ANNUAL TOTALS		2369.3	40278	101879	12724.0	356272	1425979	19474975	0	0	0.0	0	0	396550	1527858
MONTHLY AVERAGE		197.4	3356	8490	1060.3	29689	118832	1622915	0	0	0.0	0	0	33046	127321

NOTES
17.0 L.E./MWH
43.0 US $/MWH

28.0 L.E./TON
112.07 US $/TON

0.0000 L.E./CU. M.
0.000 US $/CU. M.

0.0 L.E./TON
0.00 US $/TON

TABLE 2C - MONTHLY ENERGY COSTS

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : CALCIUM AMMONIUM NITRATE

		ELECTRICITY			34 KG/CM2 STEAM			16 KG/CM2 STEAM			BLAST FURNACE GAS			TOTAL ENERGY COST	
		PURCHASED ENERGY MWH	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	PURCHASED ENERGY CU. M	COST LE	COST US $	TOTAL COST LE	TOTAL COST US $
1	JAN	298.8	5080	12849	1490.0	4857	17373	2153.0	6696	23877	93000.0	0	0	16633	54099
2	FEB	284.7	4840	12242	1394.0	4544	16254	2051.0	6379	22746	79000.0	0	0	15763	51242
3	MAR	295.4	5022	12703	1521.0	4958	17735	1561.0	4855	17311	90000.0	0	0	14835	47749
4	APR	255.8	4349	11001	1248.0	4068	14552	1932.0	6009	21426	54000.0	0	0	14426	46979
5	MAY	251.8	4281	10828	1260.0	4108	14692	1677.0	5215	18598	31000.0	0	0	13604	44117
6	JUN	268.0	4556	11524	1474.0	4805	17187	2408.0	7489	26705	45000.0	0	0	16850	55416
7	JUL	242.6	4124	10432	1332.0	4342	15531	1799.0	5595	19951	29500.0	0	0	14062	45914
8	AUG	271.5	4615	11673	1430.0	4662	16674	1981.0	6161	21969	31000.0	0	0	15438	50316
9	SEP	274.9	4674	11822	1402.0	4571	16347	2005.0	6236	22235	23500.0	0	0	15480	50405
10	OCT	296.7	5044	12759	1433.0	4672	16709	2044.0	6357	22668	15500.0	0	0	16073	52136
11	NOV	360.4	6127	15498	1565.0	5102	18248	2058.0	6400	22823	20500.0	0	0	17629	56569
12	DEC	272.8	4638	11731	1445.0	4711	16849	1614.0	5020	17899	13000.0	0	0	14368	46479
ANNUAL TOTALS		3373.5	57350	145062	16994.0	55400	198150	23283.0	72410	258208	525000.0	0	0	185161	601421
MONTHLY AVERAGE		281.1	4779	12089	1416.2	4617	16513	1940.3	6034	21517	43750.0	0	0	15430	50118
NOTES		17.0 L.E./MWH 43.0 US $/MWH			3.26 LE / TON 11.66 US $ / TON			3.11 LE / TON 11.09 US $ / TON			0.0 L.E./CU. M 0.00 US $/CU. M				

TABLE 2D - MONTHLY ENERGY COSTS

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : PURE AMMONIUM NITRATE

		ELECTRICITY			34 KG/CM2 STEAM			16 KG/CM2 STEAM			BLAST FURNACE GAS			TOTAL ENERGY COST	
		PURCHASED ENERGY MWH	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	PURCHASED ENERGY TONS	COST LE	COST US $	PURCHASED ENERGY CU. M	COST LE	COST US $	TOTAL COST LE	TOTAL COST US $
1	JAN	13.4	227	574	0.0	0	0	236.0	734	2617	0.0	0	0	961	3192
2	FEB	43.3	736	1861	0.0	0	0	822.0	2556	9116	0.0	0	0	3292	10977
3	MAR	38.9	661	1671	0.0	0	0	878.0	2731	9737	0.0	0	0	3391	11408
4	APR	40.4	687	1736	0.0	0	0	838.0	2606	9293	0.0	0	0	3293	11031
5	MAY	39.9	678	1716	0.0	0	0	708.0	2202	7852	0.0	0	0	2880	9568
6	JUN	46.5	790	1998	0.0	0	0	800.0	2488	8872	0.0	0	0	3278	10870
7	JUL	20.1	341	862	0.0	0	0	300.0	933	3327	0.0	0	0	1274	4189
8	AUG	18.5	314	795	0.0	0	0	263.0	818	2917	0.0	0	0	1132	3712
9	SEP	26.7	454	1149	0.0	0	0	419.0	1303	4647	0.0	0	0	1758	5796
10	OCT	60.7	1032	2610	0.0	0	0	696.0	2165	7719	0.0	0	0	3196	10329
11	NOV	29.4	500	1264	0.0	0	0	514.0	1599	5700	0.0	0	0	2098	6964
12	DEC	43.1	732	1851	0.0	0	0	586.0	1822	6499	0.0	0	0	2554	8350
	ANNUAL TOTALS	420.7	7152	18090	0.0	0	0	7060.0	21957	78295	0.0	0	0	29108	96385
	MONTHLY AVERAGE	35.1	596	1507	0.0	0	0	588.3	1830	6525	0.0	0	0	2426	8032
	NOTES	17.0 L.E./MWH						3.11 LE / TON			0.0 L.E./CU. M				

TABLE 2E - MONTHLY ENERGY COSTS

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : DILUTE NITRIC ACID

		ELECTRICITY			PRODUCED 34 KG/CM2 STEAM			16 KG/CM2 STEAM			BLAST FURNACE GAS			TOTAL ENERGY COST	
		PURCHASED ENERGY	COST	COST	ENERGY PRODUCED	COST (credit)	COST (credit)	PURCHASED ENERGY	COST	COST	PURCHASED ENERGY	COST	COST	TOTAL COST	TOTAL COST
		MWH	LE	US $	TONS	LE	US $	TONS	LE	US $	CU. M	LE	US $	LE	US $
1	JAN	1503.2	25555	64639	6052.0	-19730	-70566	0.0	0	0	0.0	0	0	5826	-5927
2	FEB	1522.3	25879	65458	6104.0	-19899	-71173	0.0	0	0	0.0	0	0	5980	-5715
3	MAR	1518.7	25818	65303	5927.0	-19322	-69109	0.0	0	0	0.0	0	0	6496	-3806
4	APR	1232.9	20959	53015	4898.0	-15967	-57111	0.0	0	0	0.0	0	0	4992	-4096
5	MAY	1270.0	21590	54611	4025.0	-13122	-46932	0.0	0	0	0.0	0	0	8469	7679
6	JUN	1363.6	23182	58636	5412.0	-17643	-63104	0.0	0	0	0.0	0	0	5539	-4468
7	JUL	1318.4	22413	56691	4491.0	-14641	-52365	0.0	0	0	0.0	0	0	7772	4326
8	AUG	1470.2	24993	63217	4984.0	-16248	-58113	0.0	0	0	0.0	0	0	8745	5104
9	SEP	1473.2	25044	63347	5567.0	-18148	-64911	0.0	0	0	0.0	0	0	6896	-1564
10	OCT	1326.9	22557	57057	5660.0	-18452	-65996	0.0	0	0	0.0	0	0	4106	-8939
11	NOV	1326.9	22557	57057	7001.0	-22823	-81632	0.0	0	0	0.0	0	0	-266	-24575
12	DEC	1166.8	19835	50171	4742.0	-15459	-55292	0.0	0	0	0.0	0	0	4376	-5121
	ANNUAL TOTALS	16493.1	280382	709203	64863.0	-211453	-756303	0.0	0	0	0.0	0	0	68929	-47100
	MONTHLY AVERAGE	1374.4	23365	59100	5405.3	-17621	-63025	0.0	0	0	0.0	0	0	5744	-3925

NOTES
17.0 L.E./MWH
43.0 US $/MWH

- Credit -
3.26 LE / TON
11.66 US $ / TON

0.0 L.E./CU. M
0.00 US $/CU. M

TABLE 2F - MONTHLY ENERGY COSTS

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

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : AIR SEPARATION PLANT

		ELECTRICITY			# 6 FUEL OIL			COKE OVEN GAS			TAR OIL			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	2142.4	36421	92124	0.0	0	0	0	0	0	0.0	0	0	36421	92124
2	FEB	1742.0	29613	74904	0.0	0	0	0	0	0	0.0	0	0	29613	74904
3	MAR	1483.2	25214	63776	0.0	0	0	0	0	0	0.0	0	0	25214	63776
4	APR	2283.4	38817	98185	0.0	0	0	0	0	0	0.0	0	0	38817	98185
5	MAY	1891.2	32151	81322	0.0	0	0	0	0	0	0.0	0	0	32151	81322
6	JUN	1853.3	31506	79690	0.0	0	0	0	0	0	0.0	0	0	31506	79690
7	JUL	2036.6	34623	87575	0.0	0	0	0	0	0	0.0	0	0	34623	87575
8	AUG	2073.5	35250	89162	0.0	0	0	0	0	0	0.0	0	0	35250	89162
9	SEP	2019.6	34334	86844	0.0	0	0	0	0	0	0.0	0	0	34334	86844
10	OCT	2153.0	36602	92581	0.0	0	0	0	0	0	0.0	0	0	36602	92581
11	NOV	2439.0	41463	104877	0.0	0	0	0	0	0	0.0	0	0	41463	104877
12	DEC	2518.8	42820	108309	0.0	0	0	0	0	0	0.0	0	0	42820	108309
	ANNUAL TOTALS	24636.0	418813	1059350	0.0	0	0	0	0	0	0.0	0	0	418813	1059350
	MONTHLY AVERAGE	2053.0	34901	88279	0.0	0	0	0	0	0	0.0	0	0	34901	88279

NOTES

17.0 L.E./MWH	28.0 L.E./TON	0.0000 L.E./CU. M.	0.0 L.E./TON
43.0 US $/MWH	112.07 US $/TON	0.000 US $/CU. M.	0.00 US $/TON

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

CLIENT: U.S. AID\OEP COMPANY: EL NASR FOR COKE AND CHEMICALS
DATA : JAN-DEC 1987 UNIT : COKE PLANT - BOILERS 1 THROUGH 6

		STEAM PRODUCTION	ENERGY COST PER UNIT		ENERGY PER UNIT	
		TONS	LE / TON	US $ / TON	J x 10E9/TON	T.O.E./TON
1	JAN	50850.0	0.61	2.36	3.10	0.074
2	FEB	48120.0	0.51	1.98	2.58	0.062
3	MAR	52802.0	0.62	2.45	2.16	0.052
4	APR	50350.0	1.16	4.62	3.61	0.086
5	MAY	52800.0	0.89	3.53	3.61	0.086
6	JUN	51120.0	0.87	3.39	3.35	0.080
7	JUL	52660.0	0.99	3.81	2.81	0.068
8	AUG	48645.0	1.13	4.43	2.89	0.070
9	SEP	49770.0	0.85	3.32	3.08	0.074
10	OCT	50455.0	0.63	2.41	2.55	0.062
11	NOV	49840.0	0.43	1.63	2.92	0.070
12	DEC	48400.0	0.26	0.96	2.39	0.058
	ANNUAL TOTALS	605812.0				
	MONTHLY AVERAGE	50484.3	0.75	2.91	2.92	0.070

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

CLIENT: U.S. AID\OEP COMPANY: EL NASR FOR COKE AND CHEMICALS
DATA : JAN-DEC 1987 UNIT : FERTILIZER COMPLEX - BOILERS 1 THROUGH 4

		STEAM PRODUCTION	ENERGY COST PER UNIT		ENERGY PER UNIT	
		TONS	LE / TON	US $ / TON	J x 10E9/TON	T.O.E./TON
1	JAN	22350.0	0.64	2.34	2.88	0.070
2	FEB	22611.0	2.02	7.86	2.90	0.070
3	MAR	20645.0	2.03	7.90	3.69	0.089
4	APR	20285.0	1.22	4.63	3.40	0.083
5	MAY	20823.0	0.62	2.25	3.49	0.085
6	JUN	22910.0	0.55	2.00	2.52	0.062
7	JUL	22898.0	2.09	8.15	3.28	0.080
8	AUG	20908.0	1.92	7.44	3.47	0.084
9	SEP	23370.0	2.26	8.82	3.11	0.075
10	OCT	24985.0	2.19	8.55	3.01	0.073
11	NOV	22301.0	1.27	4.86	3.22	0.078
12	DEC	21154.0	0.98	3.68	3.45	0.084
	ANNUAL TOTALS	265240.0				
	MONTHLY AVERAGE	22103.3	1.48	5.71	3.20	0.078

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

CLIENT: U.S. AID/OEP COMPANY: EL NASR FOR COKE AND CHEMICALS
DATA : JAN-DEC 1987 UNIT : CALCIUM AMMONIUM NITRATE *

		PRODUCTION	ENERGY COST PER UNIT		ENERGY PER UNIT	
		TONS *	LE / TON	US $ / TON	Jx10E9/TON	T.O.E./TON
1	JAN	6186.0	2.69	8.75	1.326	0.040
2	FEB	4766.0	3.31	10.75	1.623	0.049
3	MAR	4349.0	3.41	10.98	1.631	0.050
4	APR	3124.0	4.62	15.04	2.255	0.067
5	MAY	2524.0	5.39	17.48	2.564	0.078
6	JUN	4033.0	4.18	13.74	2.075	0.060
7	JUL	4217.0	3.33	10.89	1.611	0.048
8	AUG	4803.0	3.21	10.48	1.546	0.046
9	SEP	4963.0	3.12	10.16	1.492	0.045
10	OCT	4220.0	3.81	12.35	1.797	0.054
11	NOV	6057.0	2.91	9.34	1.336	0.042
12	DEC	3281.0	4.38	14.17	2.036	0.062
	ANNUAL TOTALS	52523.0				
	MONTHLY AVERAGE	4376.9	3.697	12.010	1.774	0.053

1.26% OF THE PRODUCTION TOTALS FOR JULY THROUGH DECEMBER WAS PURE AMMONIUM NITRATE.

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

CLIENT: U.S. AID/OEP COMPANY: EL NASR FOR COKE AND CHEMICALS
DATA : JAN-DEC 1987 UNIT : PURE AMMONIUM NITRATE

		PRODUCTION	ENERGY COST PER UNIT		ENERGY PER UNIT	
		TONS	LE / TON	US $ / TON	Jx10E9/TON	T.O.E./TON
1	JAN	452.0	2.13	7.06	1.112	0.0314
2	FEB	1568.0	2.10	7.00	1.109	0.0310
3	MAR	1878.0	1.81	6.07	0.975	0.0267
4	APR	1808.0	1.82	6.10	0.973	0.0269
5	MAY	1476.0	1.95	6.48	1.021	0.0288
6	JUN	1547.0	2.12	7.03	1.104	0.0313
7	JUL	549.3	2.32	7.63	1.183	0.0342
8	AUG	568.0	1.99	6.53	1.009	0.0294
9	SEP	809.0	2.17	7.16	1.116	0.0321
10	OCT	1743.0	1.83	5.93	0.894	0.0271
11	NOV	1271.0	1.65	5.48	0.862	0.0244
12	DEC	1650.0	1.55	5.06	0.778	0.0229
	ANNUAL TOTALS	15319.3				
	MONTHLY AVERAGE	1276.6	1.95	6.46	1.011	0.029

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

CLIENT: U.S. AID/OEP COMPANY: EL NASR FOR COKE AND CHEMICALS
DATA : JAN-DEC 1987 UNIT : DILUTE NITRIC ACID

		ACID PRODUCTION TONS	34 KG/CM2 STEAM PRODUCTION TONS	NET ENERGY COST PER UNIT LE / TON	NET ENERGY COST PER UNIT US $ / TON	NET ENERGY PER UNIT Jx10E9/TON	NET ENERGY PER UNIT T.O.E./TON
1	JAN	5263.0	6052.0	1.11	-1.13	-0.991	0.0239
2	FEB	5368.0	6104.0	1.11	-1.06	-0.976	0.0239
3	MAR	5388.0	5927.0	1.21	-0.71	-0.917	0.0251
4	APR	4259.0	4898.0	1.17	-0.96	-0.977	0.0249
5	MAY	3473.0	4025.0	2.44	2.21	-0.719	0.0437
6	JUN	4706.0	5412.0	1.18	-0.95	-0.976	0.0250
7	JUL	3905.0	4491.0	1.99	1.11	-0.804	0.0370
8	AUG	4334.0	4984.0	2.02	1.18	-0.798	0.0374
9	SEP	4841.0	5567.0	1.42	-0.32	-0.924	0.0286
10	OCT	4922.0	5660.0	0.83	-1.82	-1.049	0.0199
11	NOV	6088.0	7001.0	-0.04	-4.04	-1.235	0.0069
12	DEC	4123.0	4742.0	1.06	-1.24	-1.001	0.0233
	ANNUAL TOTALS	56670.0	64863.0				
	MONTHLY AVERAGE	4722.5	5405.3	1.29	-0.64	-0.947	0.027

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

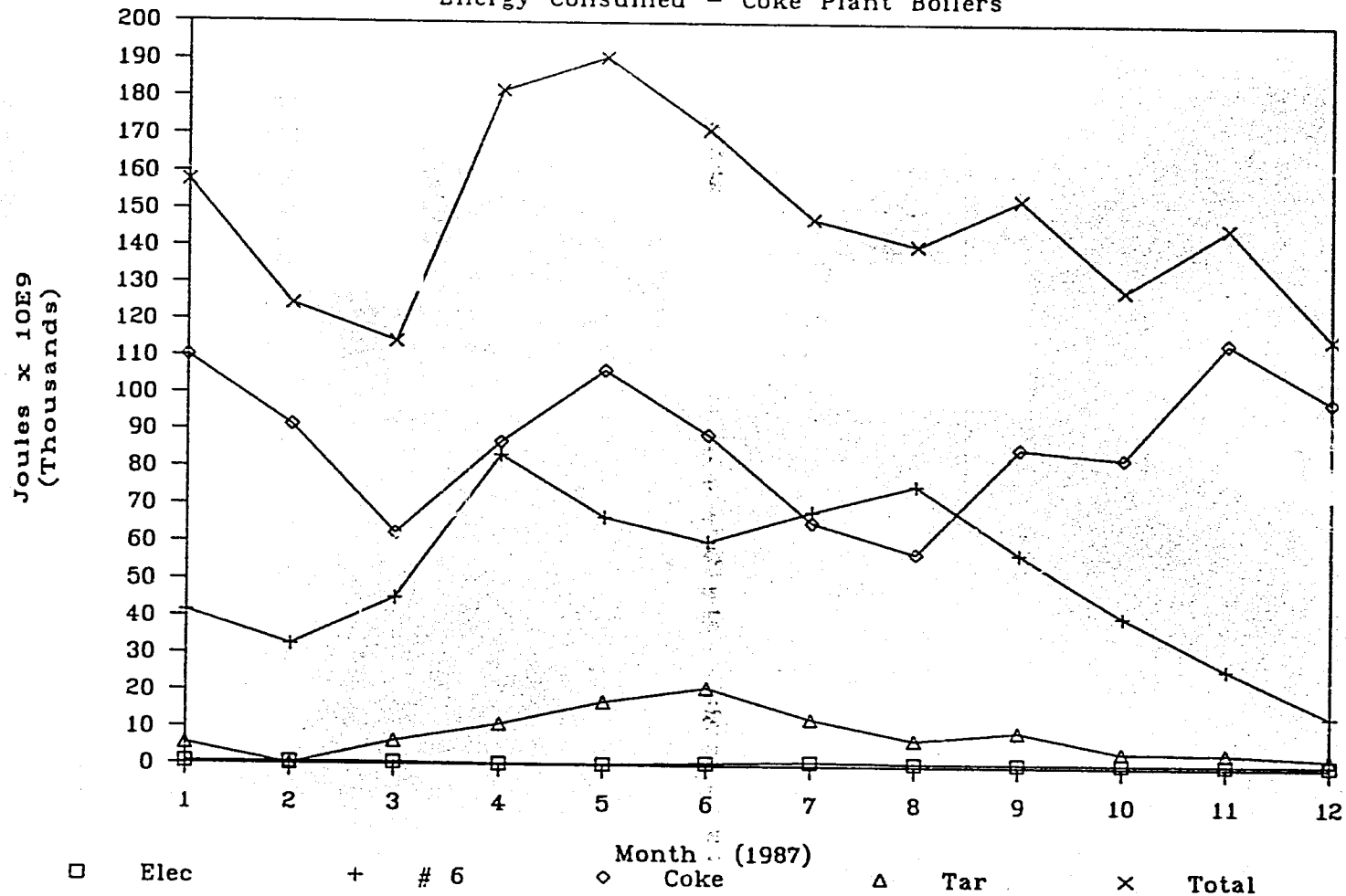
CLIENT: U.S. AID\OEP
DATA : JAN-DEC 1987

COMPANY: EL NASR FOR COKE AND CHEMICALS
UNIT : AIR SEPARATION PLANT

		PRODUCTION (Oxygen)	ENERGY COST PER UNIT (OXYGEN)		ENERGY PER UNIT (OXYGEN)	
		kM3	LE / kM3	US $ / kM3	Jx10E9/kM3	T.O.E./kM3
1	JAN	1328.7	27.41	69.33	5.80	0.406
2	FEB	1177.9	25.14	63.59	5.32	0.373
3	MAR	1225.7	20.57	52.03	4.36	0.305
4	APR	1231.4	31.52	79.73	6.68	0.467
5	MAY	1181.6	27.21	68.83	5.76	0.404
6	JUN	1223.7	25.75	65.12	5.45	0.382
7	JUL	1253.0	27.63	69.89	5.85	0.410
8	AUG	1274.6	27.66	69.95	5.86	0.410
9	SEP	1228.5	27.95	70.69	5.92	0.414
10	OCT	1309.9	27.94	70.68	5.92	0.414
11	NOV	1679.3	24.69	62.45	5.23	0.366
12	DEC	1869.1	22.91	57.95	4.85	0.340
	ANNUAL TOTALS	15983.4				
	MONTHLY AVERAGE	1332.0	26.36	66.69	5.58	0.391

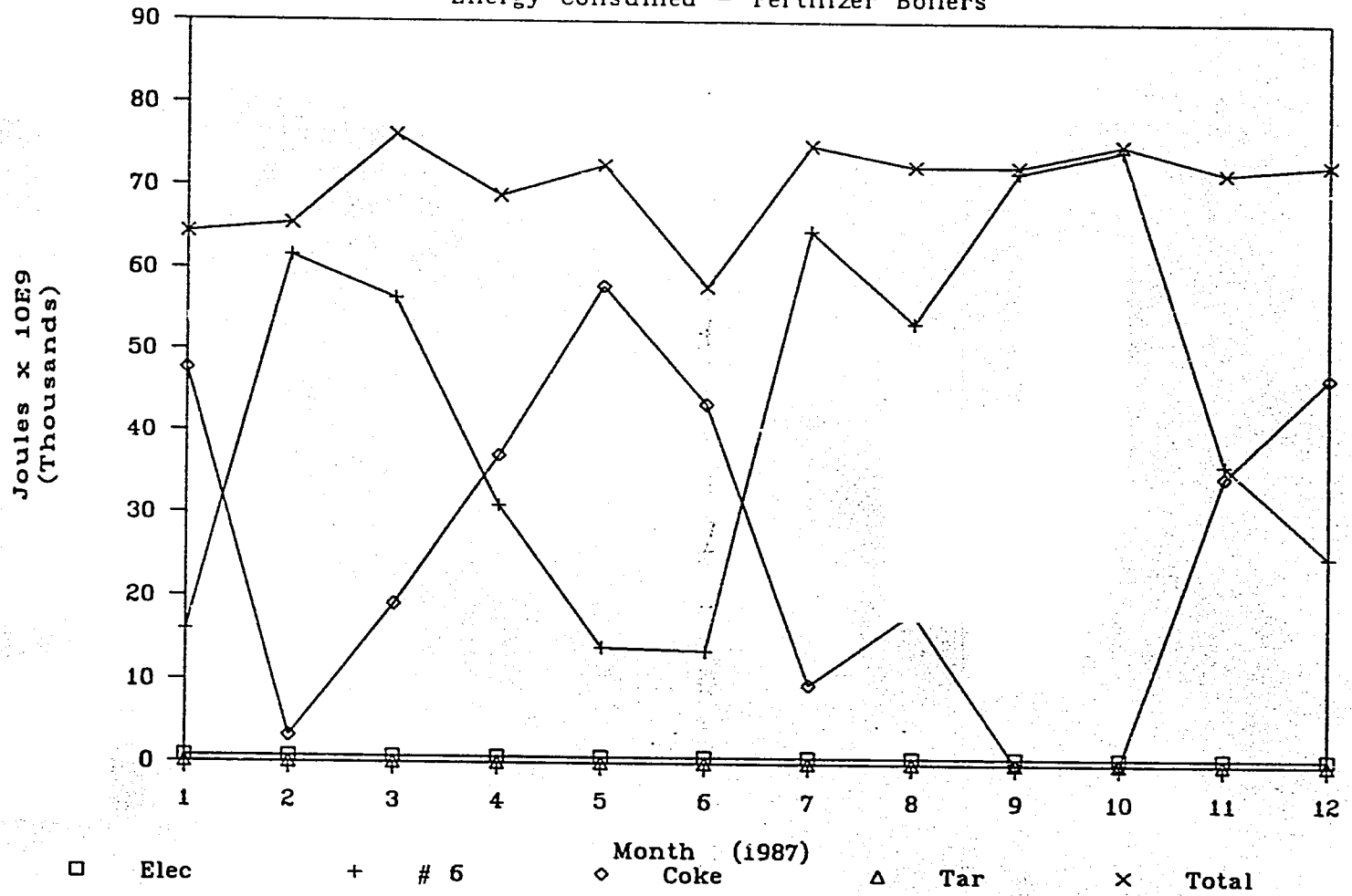
GRAPH – 1A (JOULES)

Energy Consumed – Coke Plant Boilers



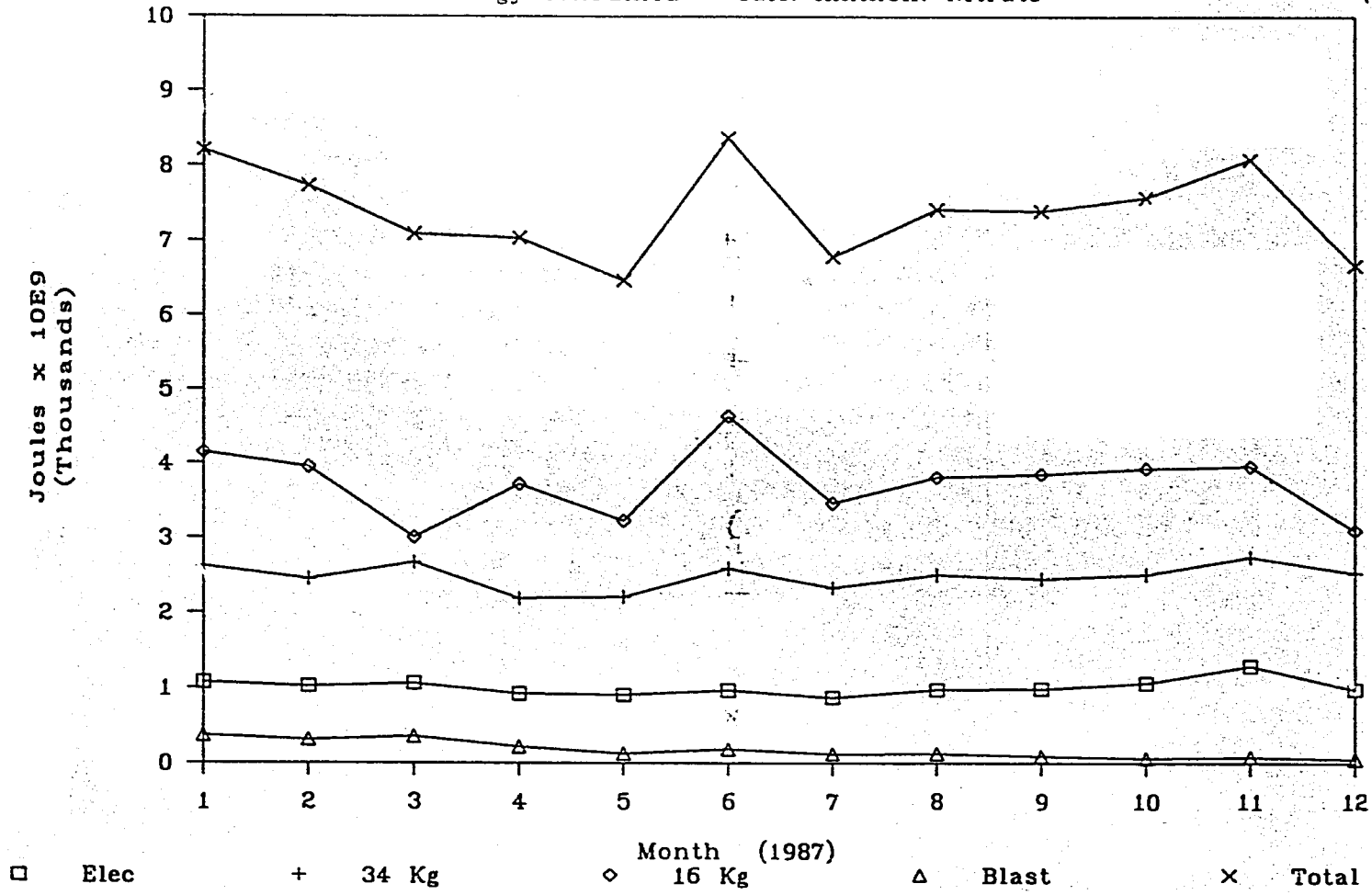
GRAPH – 1B (JOULES)

Energy Consumed – Fertilizer Boilers

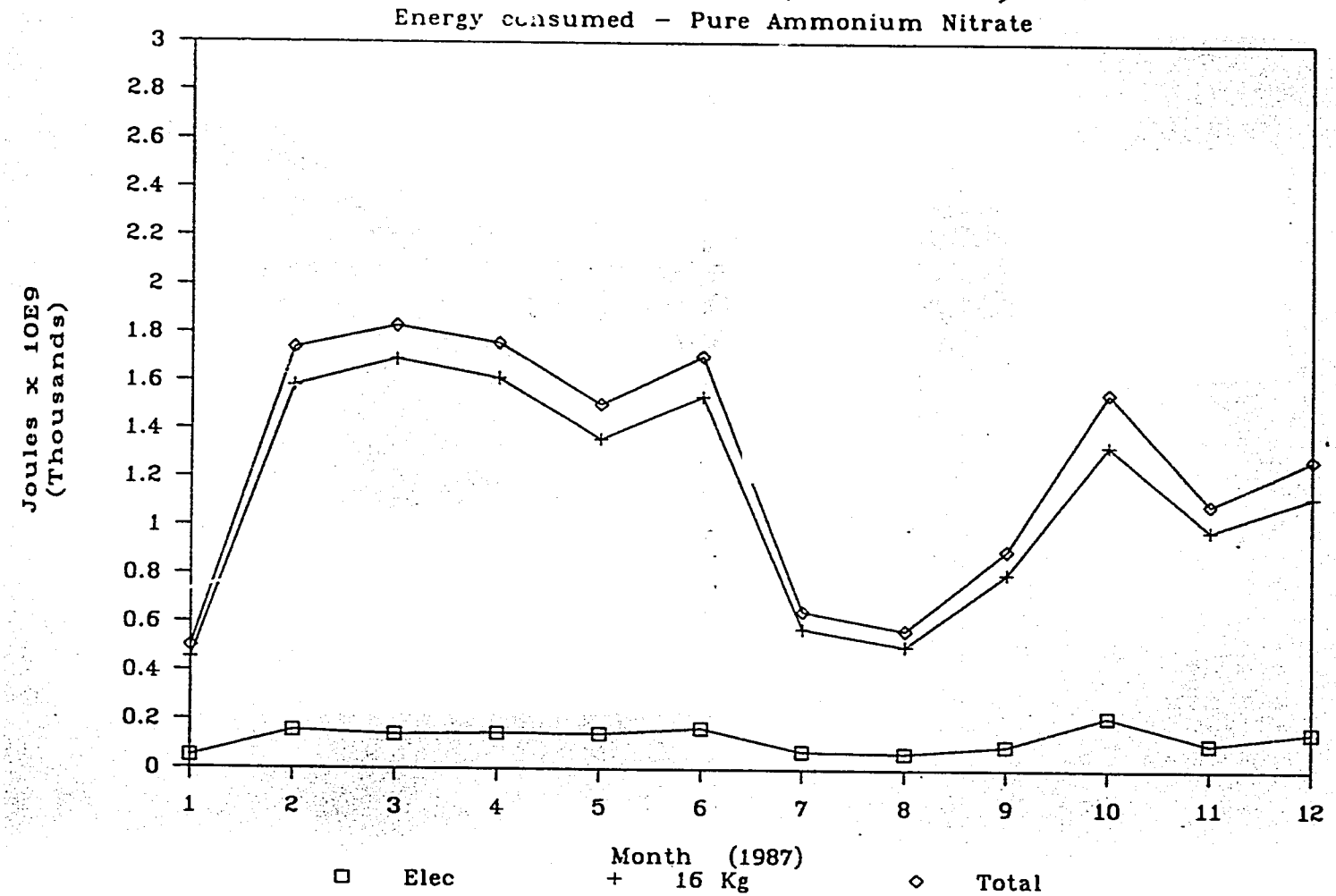


GRAPH – 1C (JOULES)

Energy consumed – Calc. Ammon. Nitrate

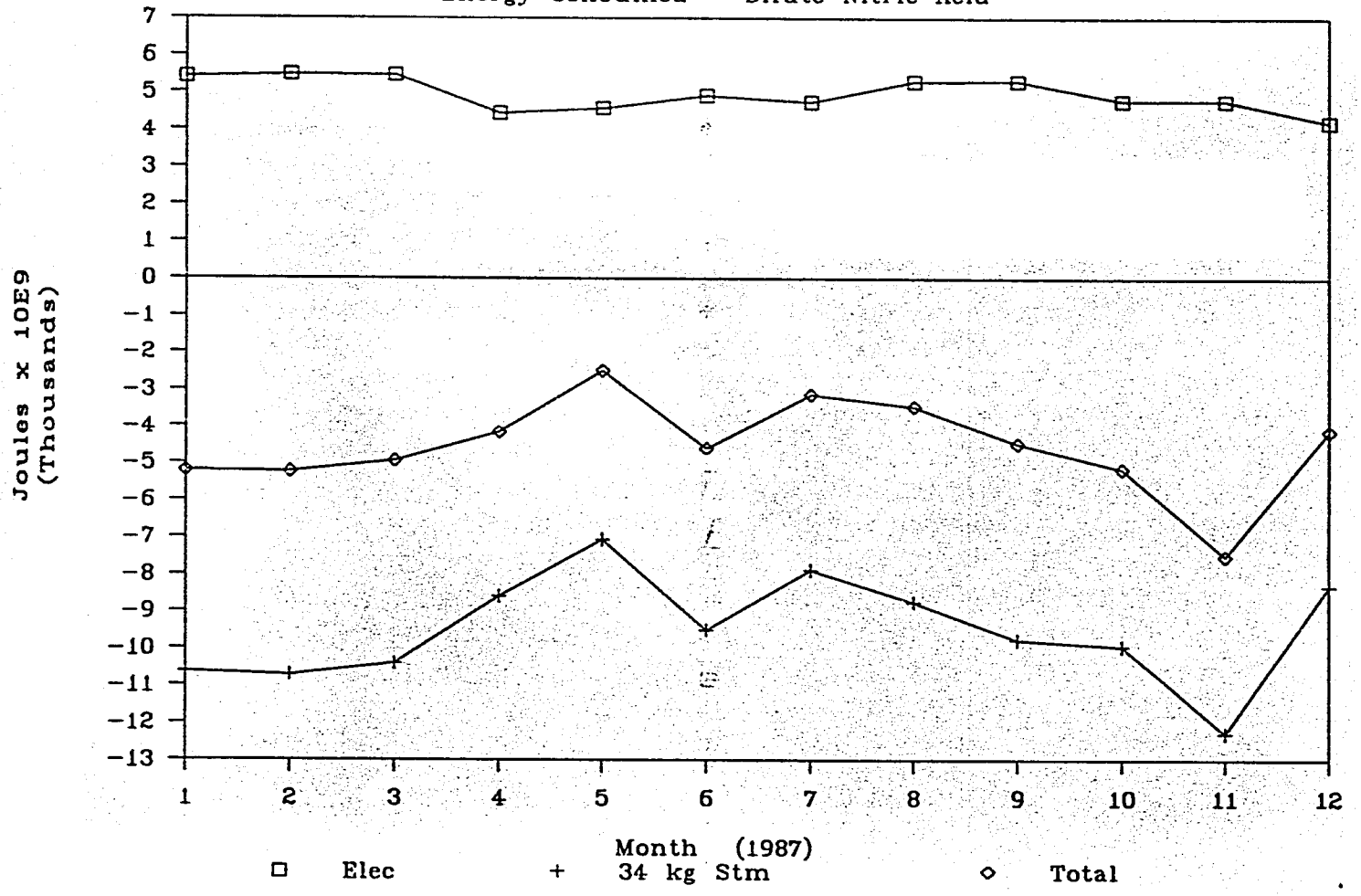


GRAPH – 1D (JOULES)

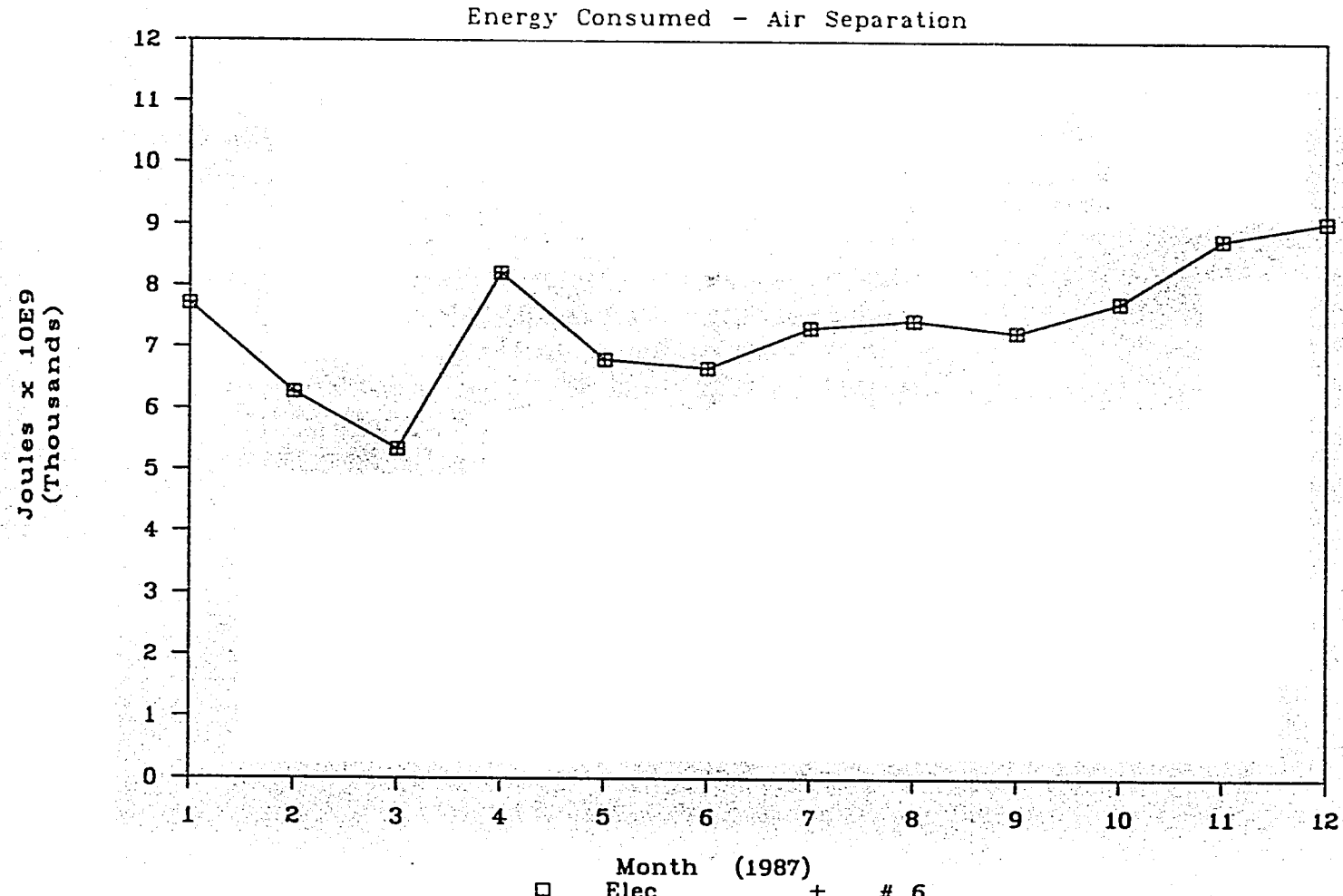


GRAPH – 1E (JOULES)

Energy Consumed – Dilute Nitric Acid

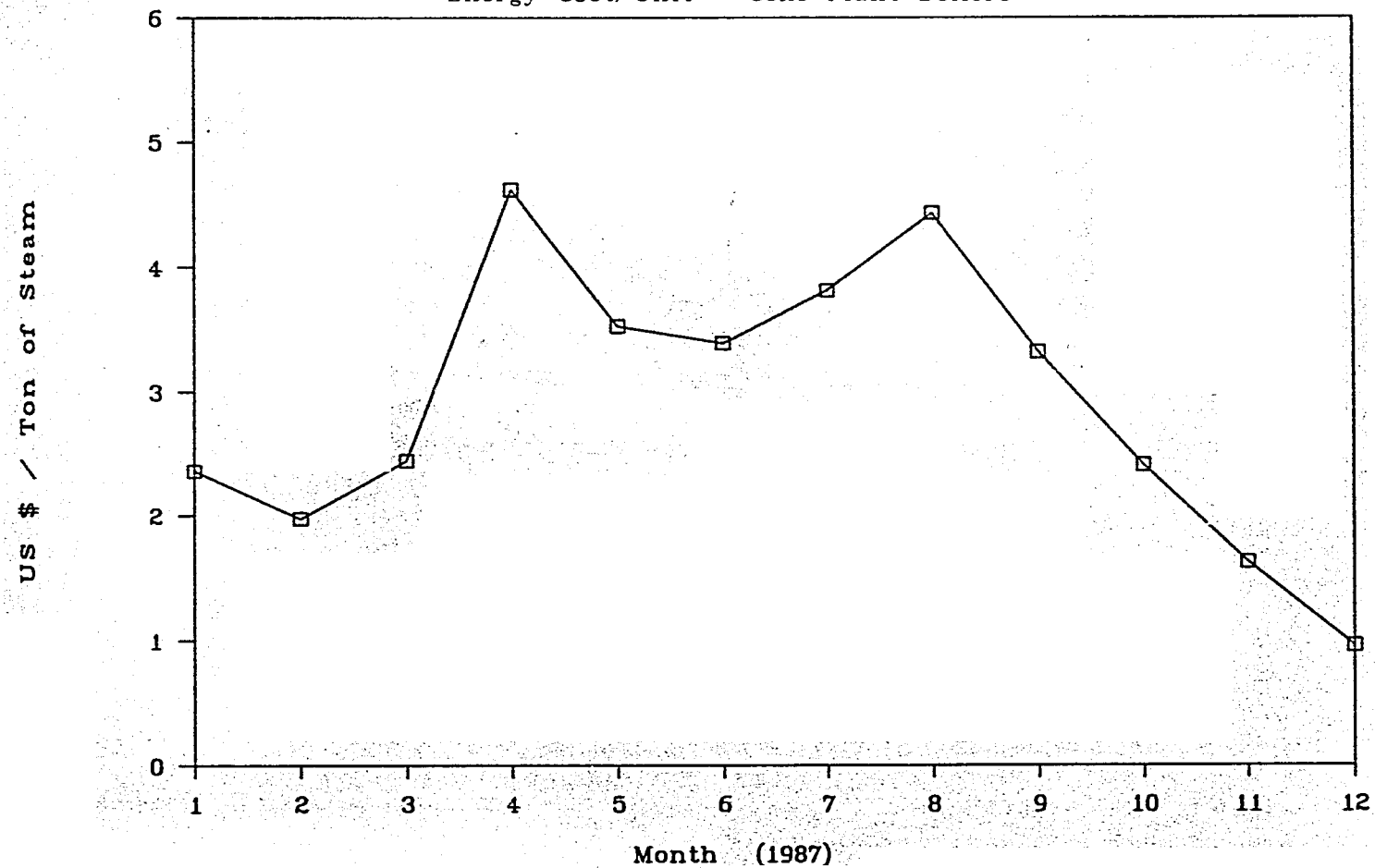


GRAPH – 1F (JOULES)



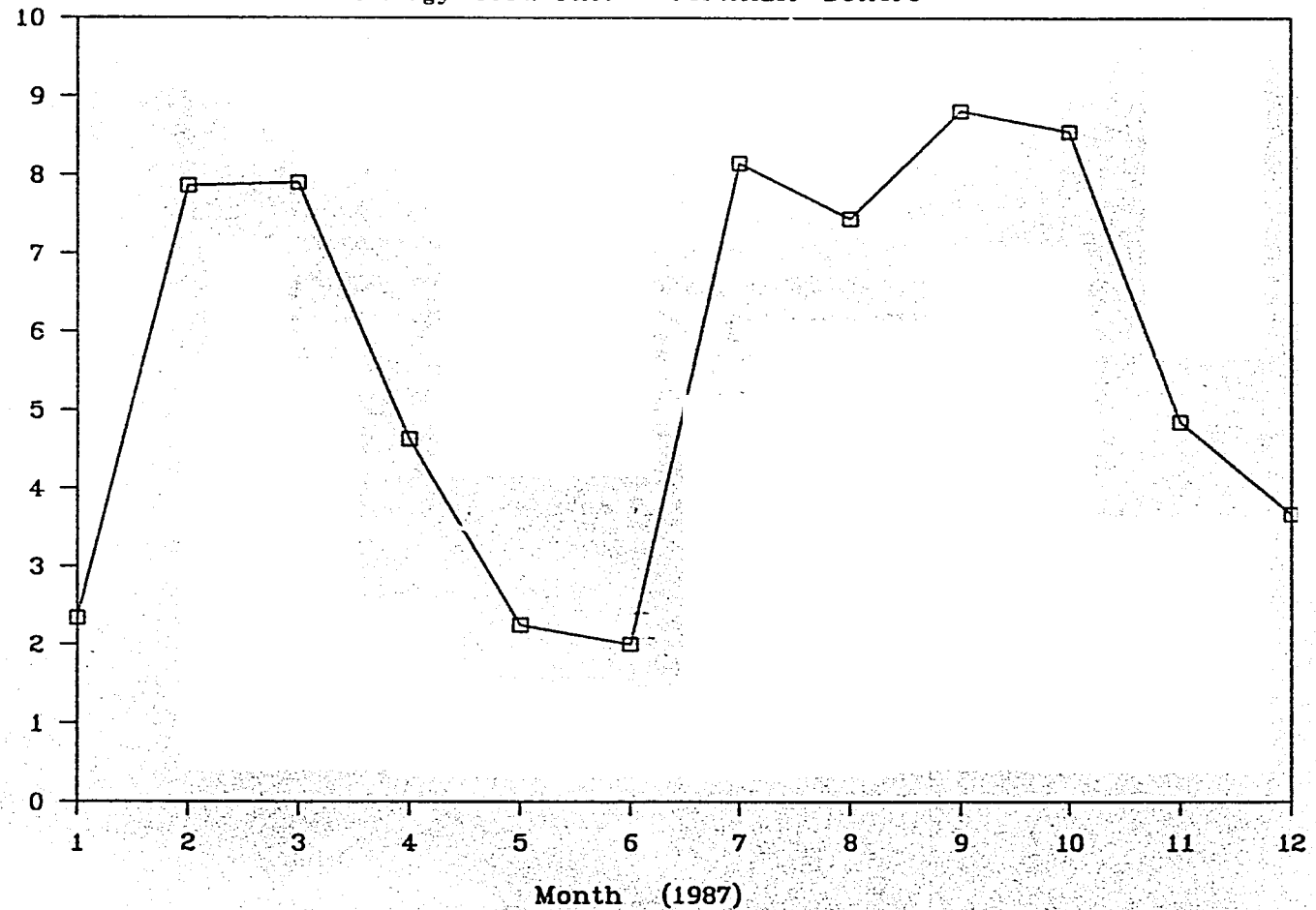
GRAPH – 2A (US $/TON)

Energy Cost/Unit – Coke Plant Boilers



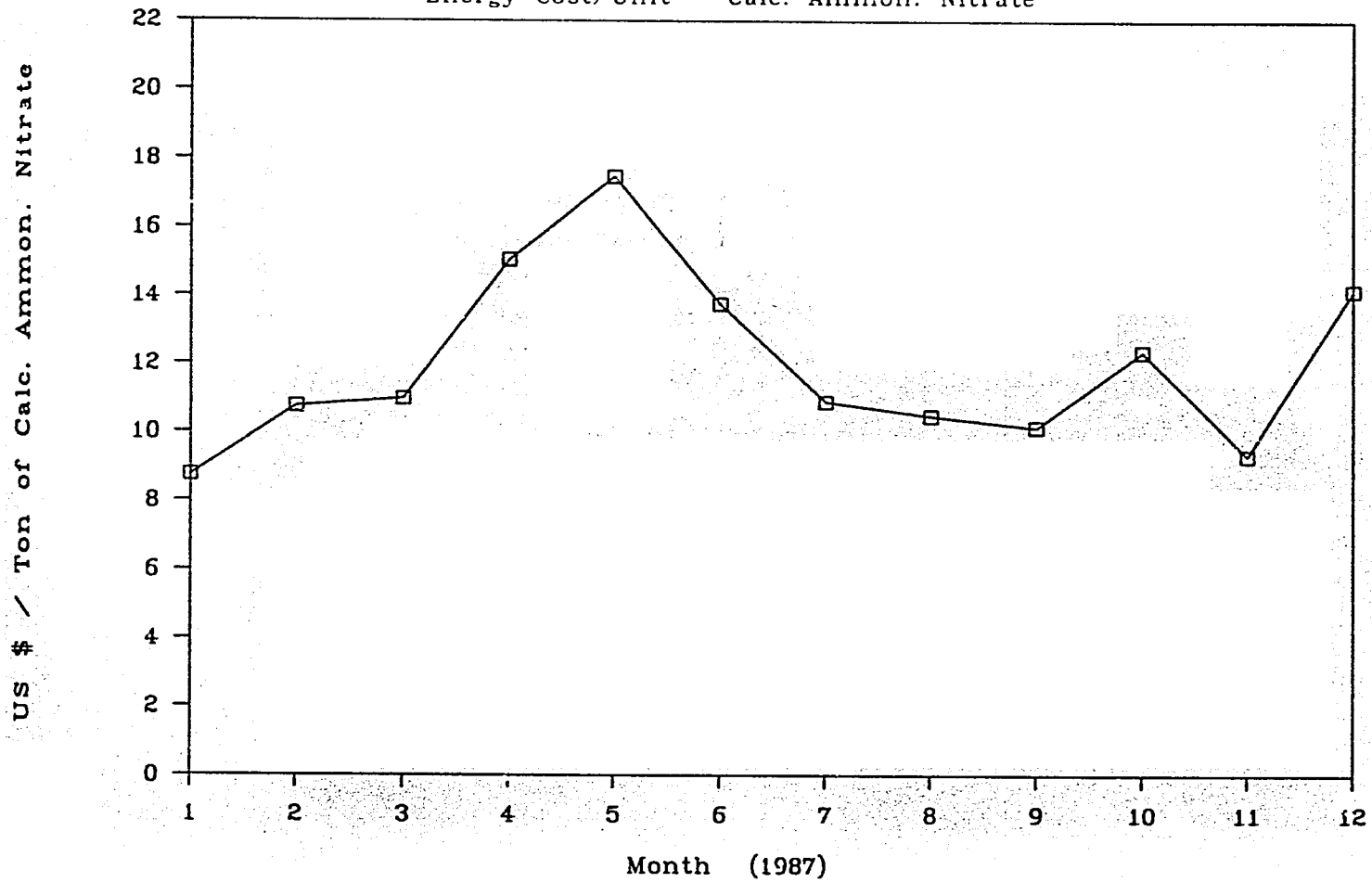
GRAPH – 2B (US $/TON)

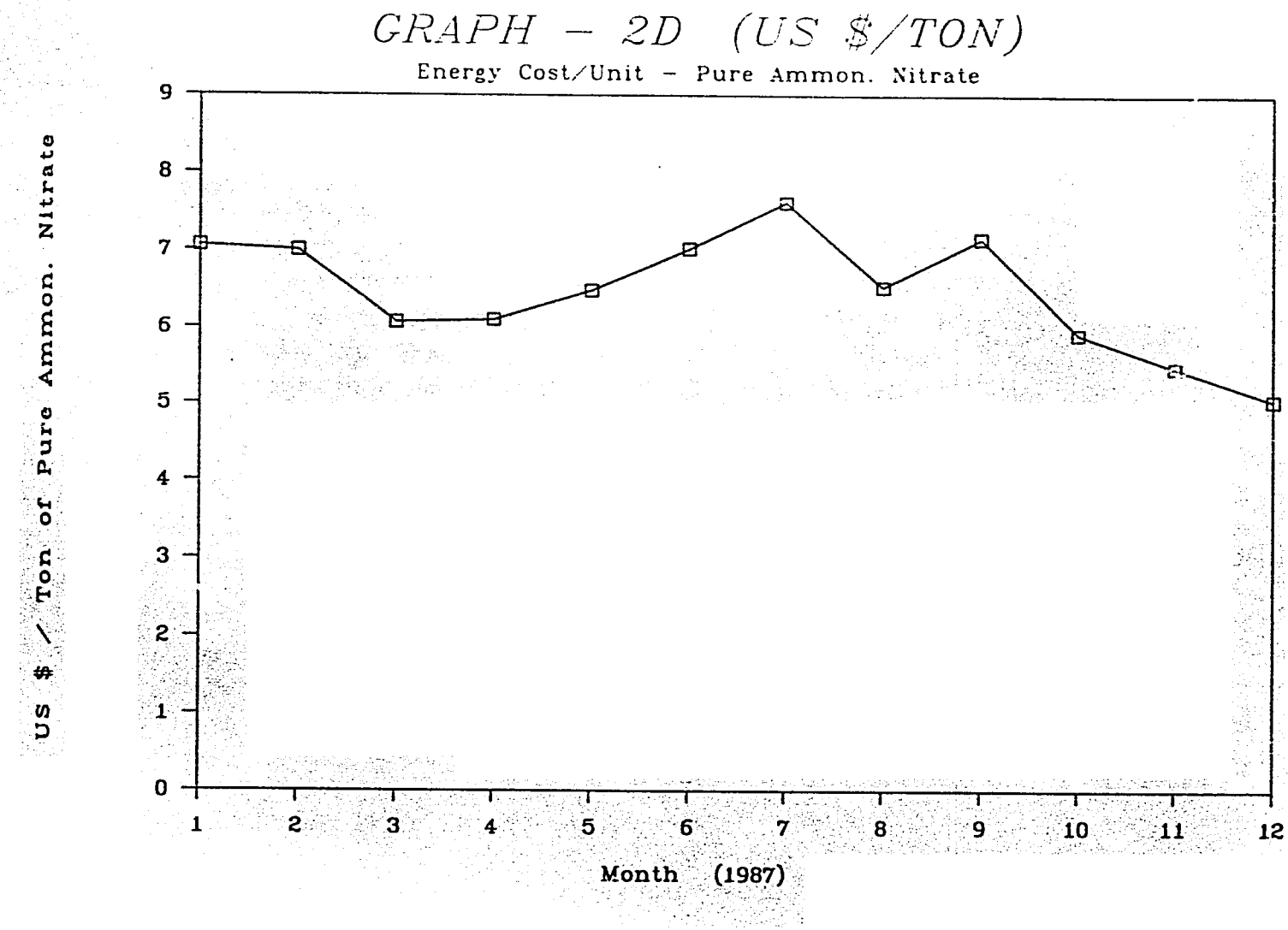
Energy Cost/Unit – Fertilizer Boilers



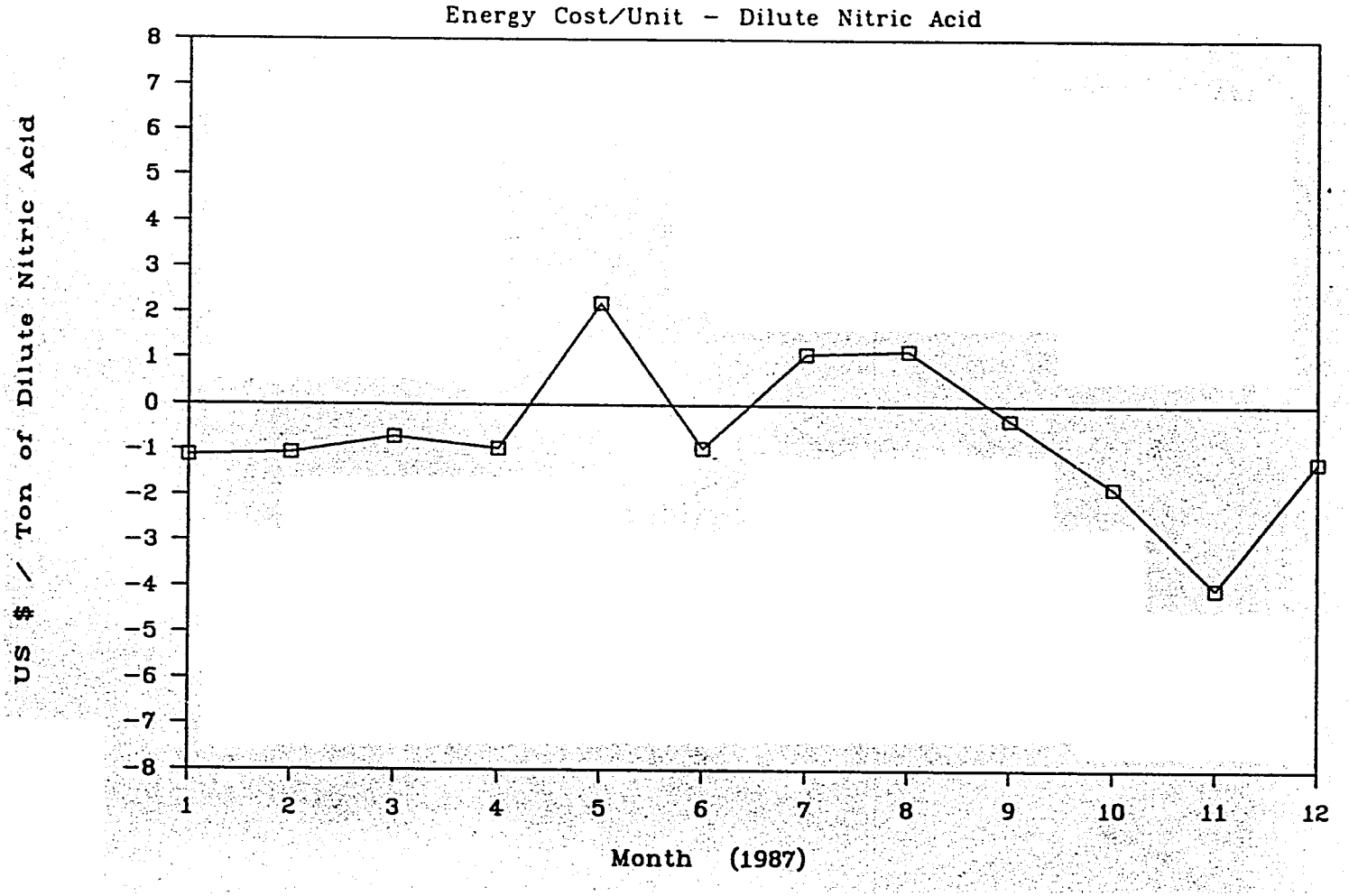
GRAPH – 2C (US $/TON)

Energy Cost/Unit – Calc. Ammon. Nitrate



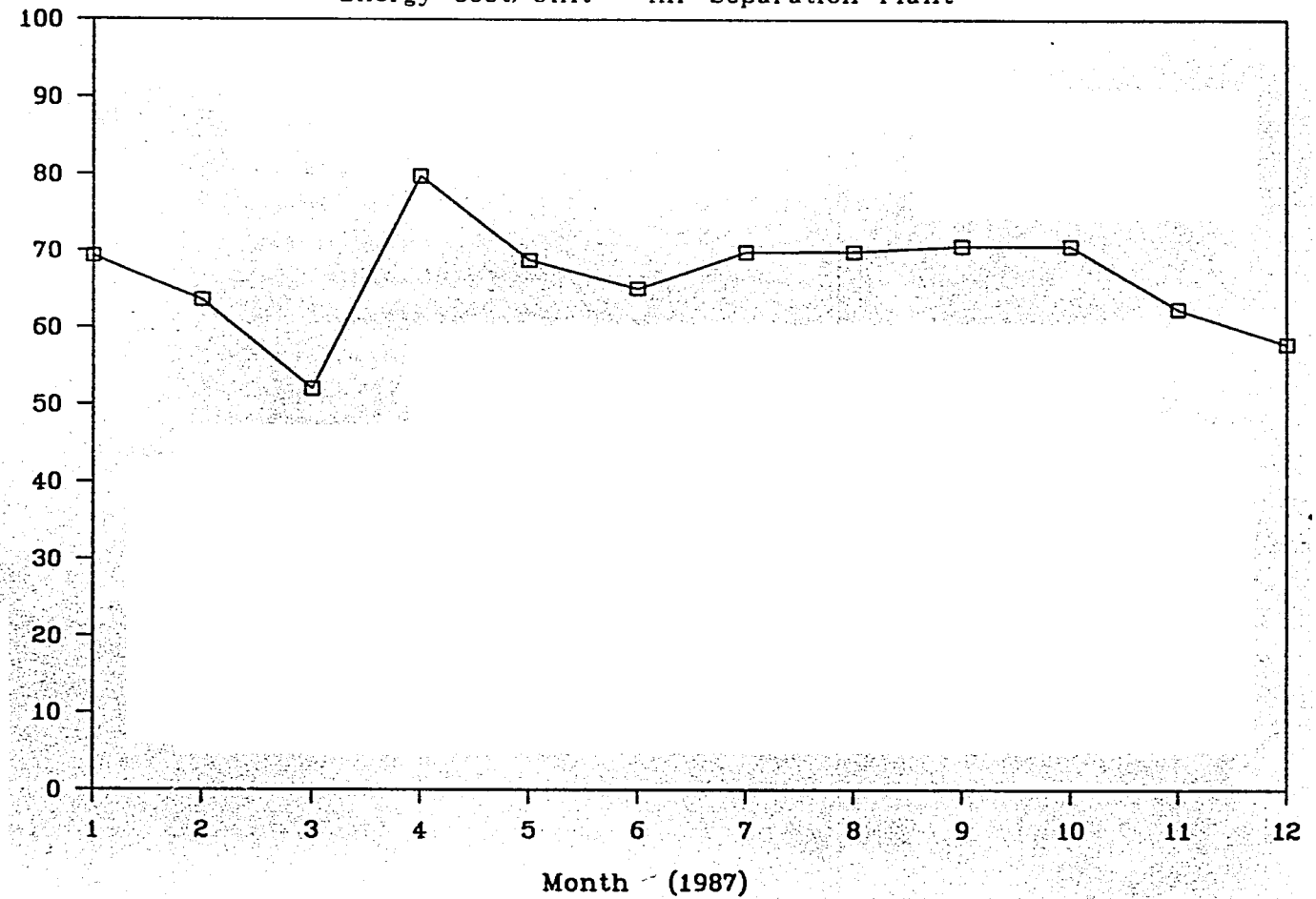

GRAPH - 2D (US $/TON)
Energy Cost/Unit - Pure Ammon. Nitrate
US $ / Ton of Pure Ammon. Nitrate
0
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
10
11
12
Month (1987)

GRAPH – 2E (US $/TON)



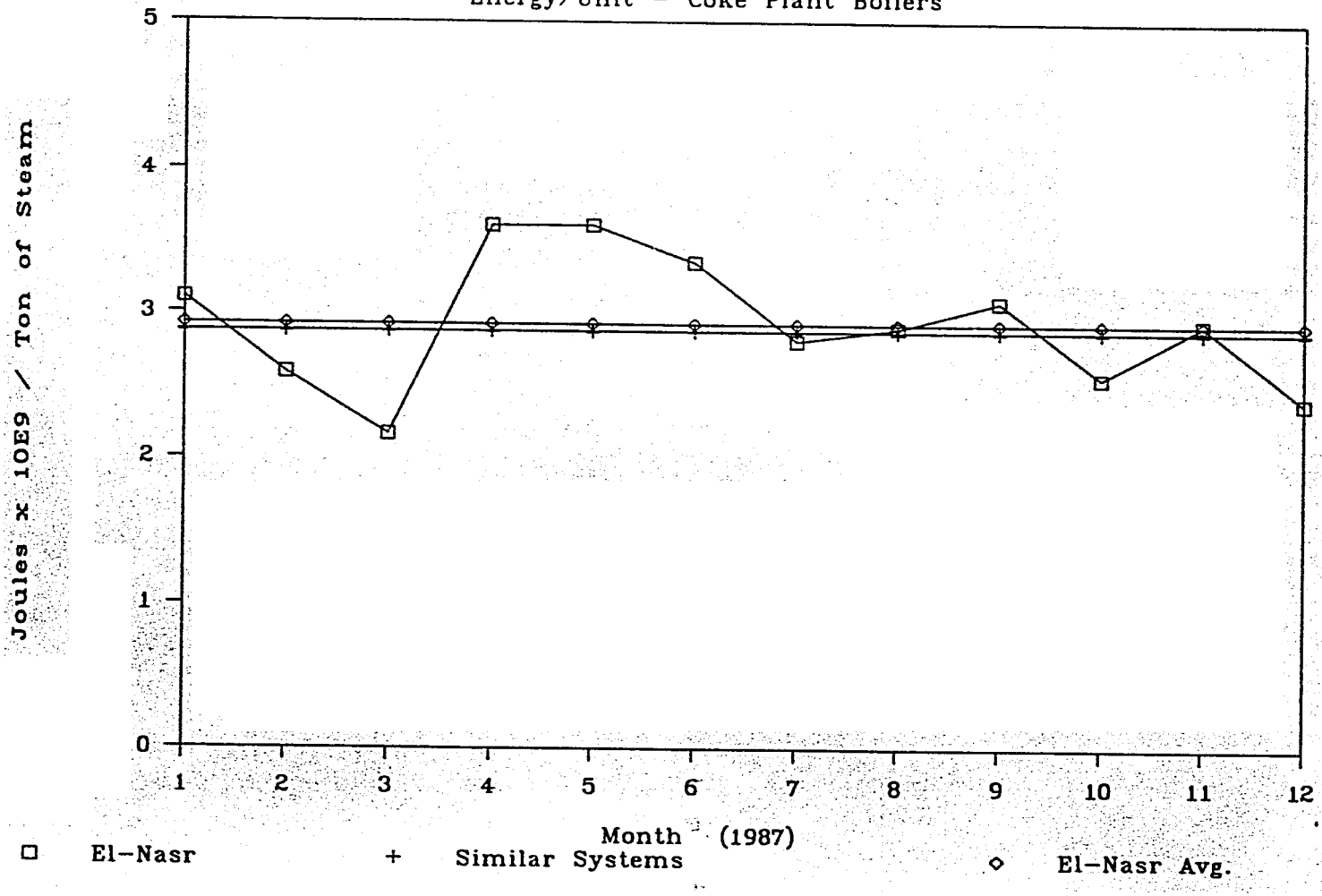
GRAPH – 2F (US $/kM3)

Energy Cost/Unit – Air Separation Plant

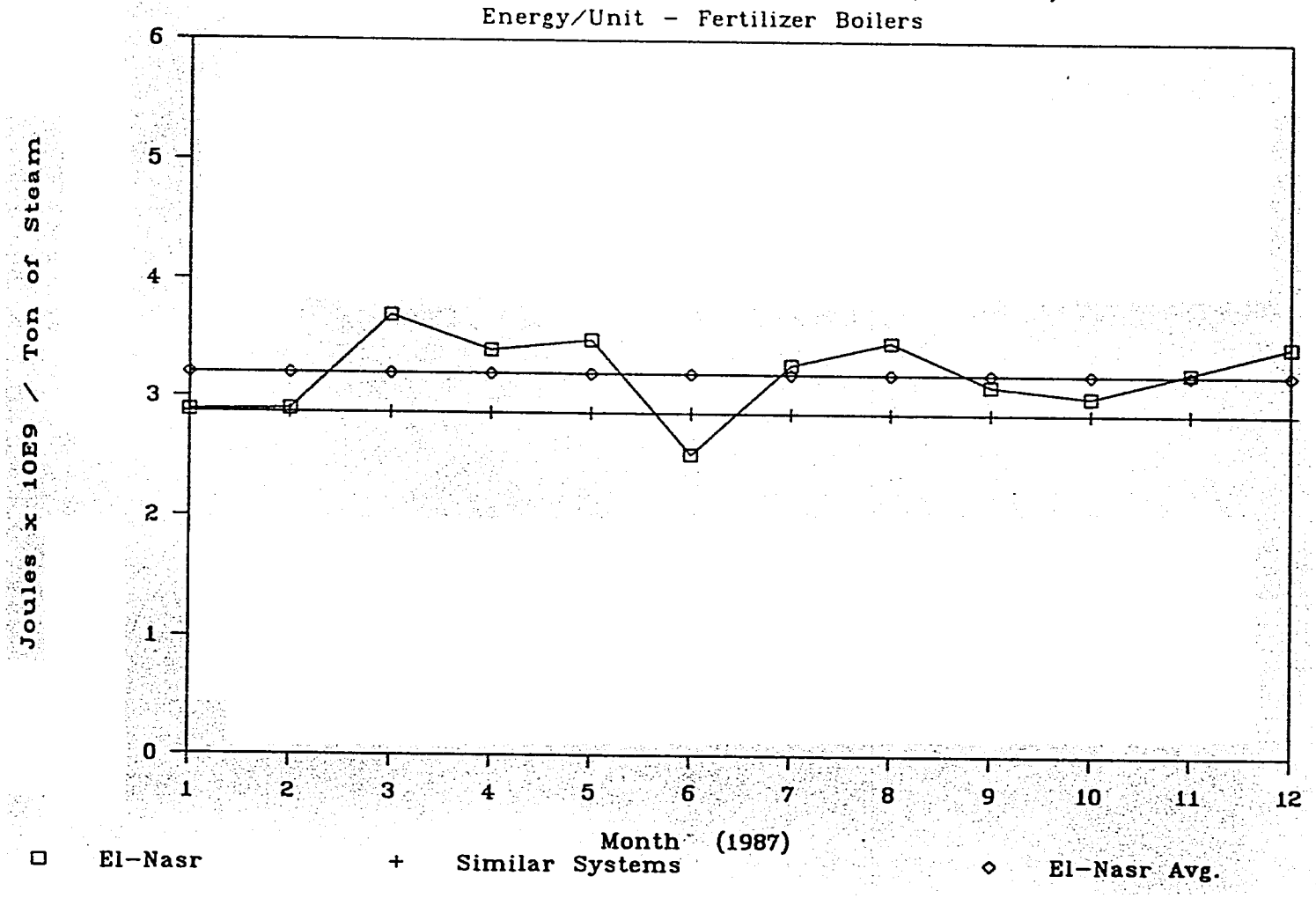


GRAPH – 3A (JOULES/TON)

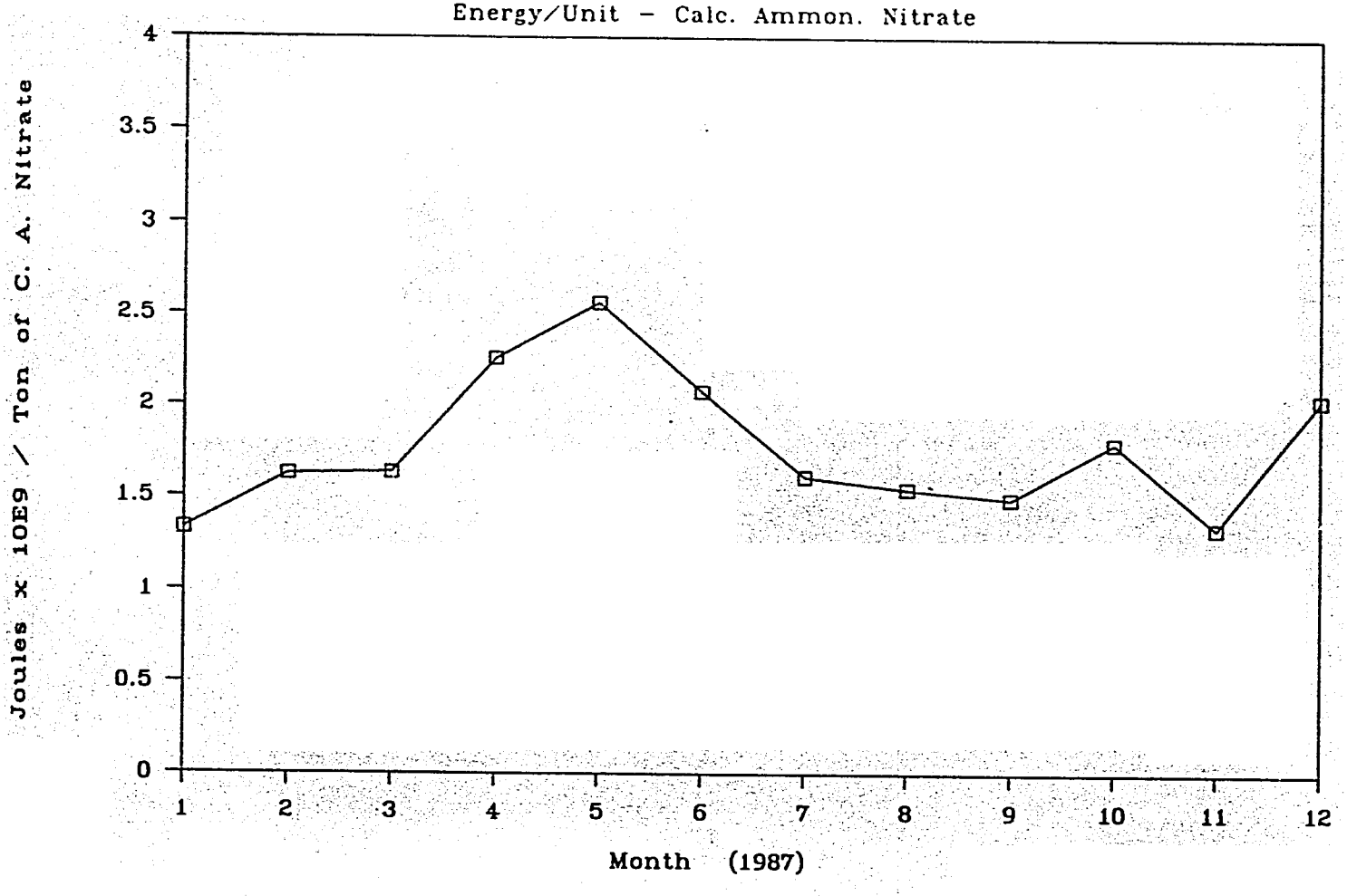
Energy/Unit – Coke Plant Boilers



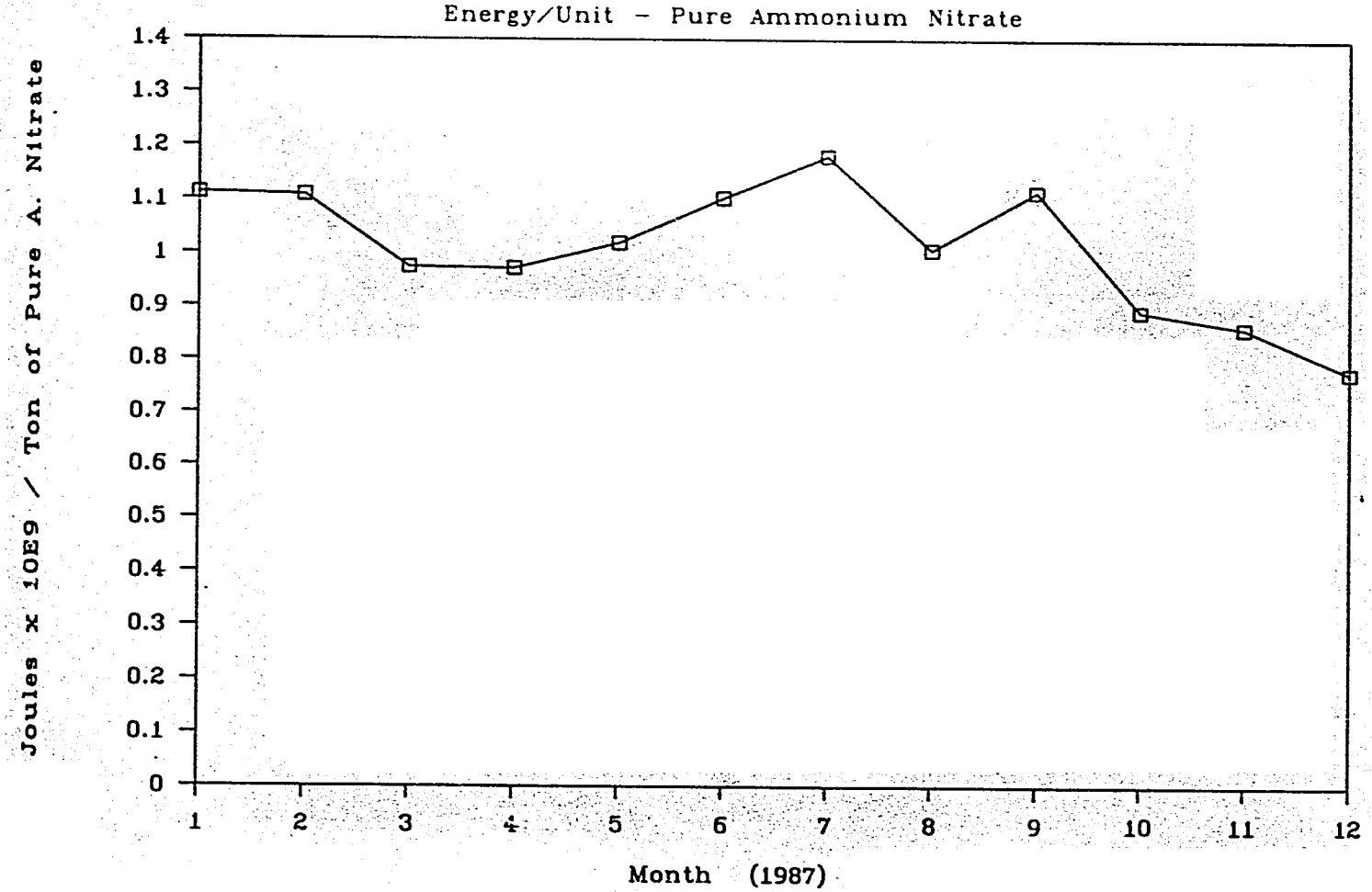
GRAPH – 3B (JOULES/TON)



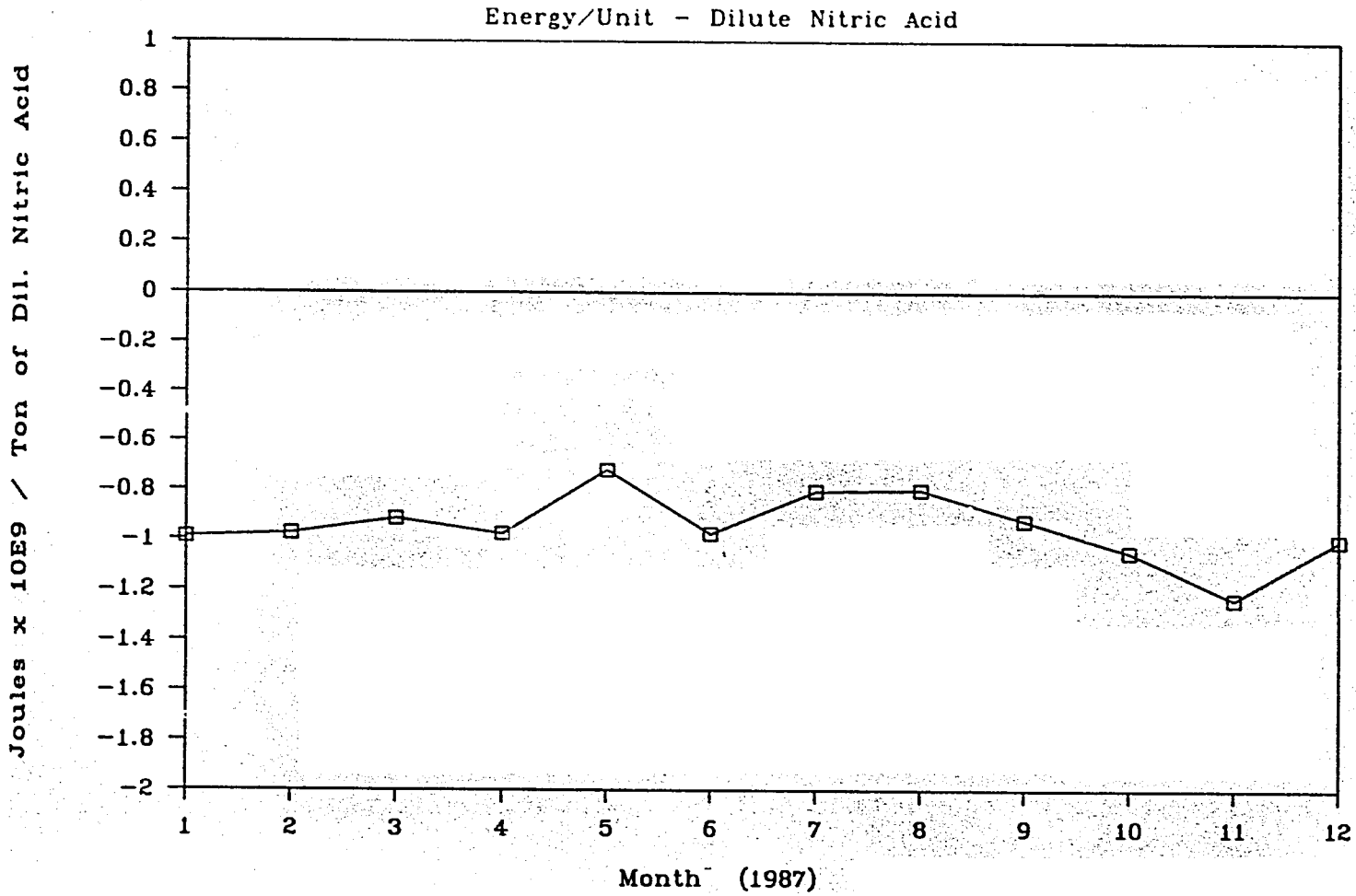
GRAPH – 3C (JOULES/TON)



GRAPH – 3D (JOULES/TON)

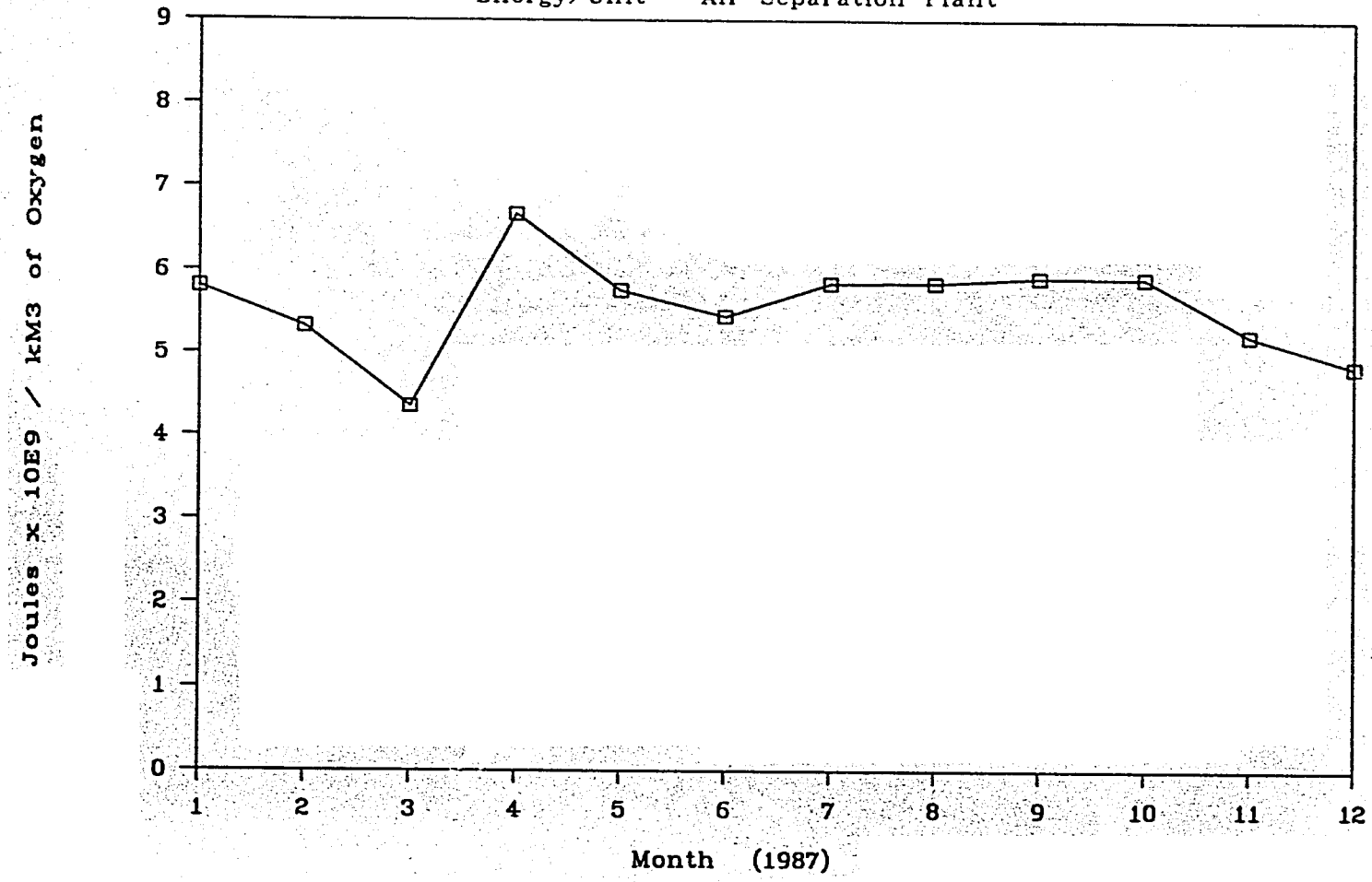


GRAPH – 3E (JOULES/TON)



GRAPH – 3F (JOULES/kM3)

Energy/Unit – Air Separation Plant



2.4.1 Discussion of Tables

Tables 1A, 2A, 3A - Coke Plant Boilers

The monthly energy consumption varied from a high of 190,652 x 10^9 joules in May to a low of 114,204 x 10^9 joules in March. On average, 59% of the total energy consumed was derived from coke oven gas, while No. 6 fuel oil accounted for 34.6%, tar oil contributed 6%, and electricity contributed 0.4%.

Coke oven gas and tar oil are byproducts of the Coke Plant. Together, coke oven gas and tar oil should be, and are, the major sources of energy to the Coke Plant boilers. The wide variation in monthly energy costs per ton of steam directly reflects the variation in the consumption of coke oven gas.

An average of 2.92 x 10^9 joules was needed to make one ton of steam. This figure is consistent with worldwide energy consumption rates of similar systems. The average energy cost per ton was LE 0.75 or $2.91 based on local and worldwide utility costs, respectively.

Tables 1B, 2B, 3B - Fertilizer Plant Boilers

The monthly energy consumption varied from a high of 76,176 x 10^9 joules in March to a low of 57,818 x 10^9 joules in June. On average, 61% of the total energy consumed was derived from No. 6 fuel oil, while coke oven gas accounted for 38%, and electricity accounted for 1%.

Coke oven gas is a byproduct of the Coke Plant. Its use should be maximized at all times. The months of September and October show a dramatic rise in the cost of energy due to the absence of coke oven gas as a fuel.

An average of 3.20 x 10^9 joules was needed to make one ton of steam. This value is approximately 11% higher than similar worldwide figures. The average energy costs per ton was LE 1.48 or $5.71 based on local and worldwide utility costs, respectively.

Tables 1C, 2C, 3C - Calcium Ammonium Nitrate

The monthly energy consumption was relatively flat for the year 1987, varying from a high of 8204.8 x 10^9 joules in January to a low of 6471 x 10^9

joules in May. On average, energy derived from steam accounted for 84% of the total energy consumption, while electricity accounted for 14% and blast furnace gas added 2%.

An average of 1.77 x 10^9 joules was needed to produce one ton of calcium ammonium nitrate.

Tables 1D, 2D, 3D - Pure Ammonium Nitrate

The monthly energy consumption was sporadic in 1987 and was directly related to production figures. As a result, energy consumption varied from a high of 1830.9 x 10^9 joules in March to a low of 502.6 x 10^9 joules in January. On average, energy derived from steam accounted for 90% of the total energy consumption, and electricity made up the remaining 10%.

An average of 1.01 x 10^9 joules was needed to produce one ton of pure ammonium nitrate.

Tables 1E, 2E, 3E - Dilute Nitric Acid

Electricity accounted for all of the energy consumed in the dilute nitric acid unit. The Dilute Nitric Acid Plant is, however, a net energy producer due to the energy of the steam produced in the waste heat boiler. Net energy production varied from a low of -2496 x 10^9 joules in May to a high of -7517 x 10^9 joules in November.

An average of -0.947 x 10^9 joules of energy was produced in making one ton of dilute nitric acid at an average energy cost of LE 1.29 or -$ 0.64 using local and worldwide utility costs, respectively, and including a cost credit for the production of steam.

Tables 1F, 2F, 3F - Air Separation Plant

Electricity accounted for all of the energy consumed in the Air Separation Plant. After varying considerably in the early months of the year, energy consumption was relatively constant from July through October and then experienced a rise due to a coinciding rise in production. Energy consumption varied from a high of 9068 x 10^9 joules in December to a low of 5339 x 10^9 joules in March.

An average of 5.58 x 10^9 joules was required to produce 1000 cubic meters of oxygen at an average

cost of LE 26.36 or $66.69 using local and worldwide utility costs, respectively.

2.4.2 Discussion of Graphs

Eighteen graphs have been developed from monthly energy and production data for 1987 and are included above in this section. They show, for each of the plants audited, how much energy was used in each of its basic forms, the cost of energy per unit of product, and the total energy per unit of product.

Graphs 1A through 1F show the energy consumption of the Coke Plant Boilers, Fertilizer Plant Boilers, Calcium Ammonium Nitrate Plant, Pure Ammonium Nitrate Plant, Dilute Nitric Acid Plant, and Air Separation Plant respectively.

Graphs 2A through 2F show the cost of energy per unit of product for each of the audited processes.

Graphs 3A through 3F are significant in that they show the actual energy consumption per unit of product at the El-Nasr Company for Coke and Chemicals.

The expected energy consumption figures for the steam boiler systems in the Coke Plant and the Fertilizer Plant has been shown along with the actual energy consumption figures on Graphs 3A and 3B. The current scope of work is such that similar plots of expected versus actual energy consumptions per unit of product are not possible to develop. The soon to be replaced ammonia production plant was excluded from the scope of work in this audit, and therefore comparison of the energy necessary to make calcium ammonium nitrate, dilute nitric acid, and pure ammonium nitrate against worldwide figures is not possible to develop.

Graphs 1A, 2A, 3A - Coke Plant Boilers

These graphs show the contribution of the various forms of energy consumed, energy costs and energy per unit for the Coke Plant boilers. The total energy consumption rose drastically from March to June due to high steam production rates. Fuel oil consumption was minimized during the latter part of the year, because coke oven gas consumption was maximized.

The ratio of fuel oil to coke oven gas directly affects the production cost for one ton of steam. The fluctuations in Graph 2A shows this effect in which we see the cost per ton vary from a high of $4.62 in April to a low of $0.96 in December. To keep the energy costs down, maximum use should be made of tar oil and coke oven gas, which are byproducts of the Coke Plant.

Graph 3A shows the monthly fluctuation of steam cost as compared to other similar steam systems. It is interesting to note that the shape of this graph and the total energy consumed graph appear to be identical. This is the result of relatively stable steam production throughout the year with fluctuations in energy consumption resulting from changes in thermal efficiency, rather than from swings in monthly steam production rates.

Graphs 1B, 2B, 3B - Fertilizer Plant Boilers

These graphs illustrate the contribution of the various forms of energy consumed, energy costs and energy per unit for the Fertilizer Plant boilers. The total energy consumption was high, compared to other months, from February to April. Fuel oil consumption was high in these months due to non-availability of coke oven gas. The ratio of fuel oil to coke oven gas directly affects the production cost for one ton of steam. The fluctuations in Graph 2B shows this effect. Coke oven gas is a byproduct of the Coke Plant; therefore, its use should be maximized to minimize purchased energy.

Graphs 1C, 2C, 3C - Calcium Ammonium Nitrate Plant

These graphs show the contribution of various forms of energy consumed, total energy costs in U.S. dollars per ton of product and energy per unit of calcium ammonium nitrate. The energy cost per ton and the energy consumption per ton is high in the months of April, May and June, due to high consumption of 16 Kg/cm^2 steam in the plant during these months. Steam use should be carefully controlled to keep the energy costs low. Low production rates should coincide with low utility consumption rates.

Graph 1D, 2D, 3D - Pure Ammonium Nitrate Plant

These graphs show the contribution of various forms of energy consumed, total energy costs in U.S. dollars per ton of product, and energy per

unit of pure ammonium nitrate. The monthly energy consumption during July, August and September was exceptionally low due to significantly reduced production rates. Figures of energy consumption per ton remained relatively constant, showing some improvement at the end of the year.

Graph 1E, 2E, 3E - Dilute Nitric Acid Plant

These graphs show the contribution of energy, both produced and consumed, total net energy costs in U.S. dollars per ton of product and net energy per ton of Dilute Nitric Acid Plant. The low net energy production per ton of product in May is most likely due to low production rates while using the same constant quantity of electricity. Low production rates should coincide with low utility consumption rates.

Graphs 1F, 2F, 3F - Air Separation Plant

These graphs show the contribution of energy (electricity only) consumed, total energy costs in U.S. dollars per ton of product and energy per unit for the Air Separation Plant. The lowest monthly consumption of energy is during February and March. The amount of energy per ton was relatively constant from May through December.

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 project, and a "front end" engineering package as a technical basis, on major projects.

3.0 ENERGY CONSERVATION OPPORTUNITIES (ECO's)

3.1 Summary List

Fertilizer Plant Steam System

ECO-01. Produce steam from continuous boiler blowdown in Dilute Nitric Acid plant.

ECO-02. Eliminate the use of high pressure steam and use desuperheated 16 atm steam for total steam requirements in Calcium Ammonium Nitrate plant.

ECO-03. Installation of a condensate recovery system for the Ammonia, Nitric Acid, Calcium Ammonium Nitrate, and Pure Ammonium Nitrate plants.

ECO-04. Check combustion efficiency of steam boilers.

ECO-05. Repair turbogenerator and generate electricity when letting down steam pressure.

ECO-06. Test, repair, replace steam traps.

ECO-07. Add new or repair existing insulation on steam and condensate lines.

ECO-08. Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.

ECO-09. Combustion air preheat through stack gas heat recovery.

ECO-10. (Number not used)

Coke Plant Steam System

ECO-11. Delete boilers #1, #2, #3, and #4, and replace by a single high efficiency 75 ton/hour package boiler.

ECO-12. Combustion air preheat through stack gas heat recovery at boilers #5 and #6.

ECO-13. Operate the turbogenerator at design capacity and recover energy that is otherwise wasted across the letdown station.

ECO-14. Check combustion efficiency of steam boilers.

ECO-15. Installation of a condensate recovery system for the Coke Plant.

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

ECO-17. Repair steam, air, water, and condensate leaks from valves, lines, flanges, etc.

ECO-18. Test, repair, replace steam traps.

ECO-19. Complete commissioning of new demineralized water plant and put it into service.

ECO-20. Fix tubes in boiler #4 economizer and superheater.

ECO-21. Improve insulation and add drip legs to low and high pressure steam headers in order to reduce pressure drop and heat loss.

ECO-22. (Number not used)

ECO-23. Recover heat and produce steam from continuous boiler blowdown.

ECO-24. Repair heat exchanger leaks and install necessary non-return valves to avoid steam and condensate contamination.

General

ECO-25. Institute a permanent program for steam trap testing.

ECO-26. Study the effect of insulation on heat loss from pipes.

ECO-27. Provide automatic fuel/air ratio controllers for steam boilers.

ECO-28. Installation of capacitors as required to improve power factor in the Fertilizer Plant.

ECO-29. Installation of capacitors as required to improve power factor in the Coke Plant.

ECO-30. Investigate energy savings by changing drive controls of variable load equipment to variable frequency (speed) controllers in the Fertilizer Plant.

ECO-31. Investigate energy savings by changing drive controls of variable load equipment to variable frequency (speed) controllers in the Coke Plant.

ECO-32. Improve, add, or fix instrumentation to be able to properly monitor and control energy consumption.

ECO-33. Develop and implement a formal equipment maintenance program.

ECO-34. Form a committee to plan and implement an energy conservation program in the plant.

ECO-35. 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 housekeeping items and each of the investment 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 of ECO is given an identification number, 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.

FERTILIZER PLANT
STEAM SYSTEM

PRODUCE STEAM FROM CONTINUOUS BOILER BLOWDOWN IN DILUTE NITRIC ACID PLANT

Annual Savings, TOE	:	216
Annual Savings, $	:	24,935
Investment Cost, $	:	28,240
Payout: Simple, Yrs	:	1.13
DCF , %	:	--

ECO-01

1.0 PURPOSE

The purpose of this ECO is to produce steam from hot continuous boiler blowdown.

2.0 PROCESS DESCRIPTION

The present system is to send the hot continuous blowdown directly to drainage. The blowdown rate is 500 Kg/hr. The system shown on the attached sketch will recover steam from boiler blowdown, thereby reducing the energy consumption of boilers.

Due to the very low blowdown rate, it is not believed that investment in a boiler feedwater/blowdown exchanger is warranted. For larger blowdown rates, a considerable amount of energy can be recovered by preheating boiler feedwater using continuous blowdown.

3.0 EQUIPMENT LIST/SIZE

The following equipment is necessary to implement this ECO:

Drum:

16" OD pipe x 1100 mm T/T
5.5 Kg/cm^2 (540 kPa), 175°C. design

Instrumentation:

As shown on sketch, plus 1 - 1 x 1/2" PSV.

Piping:

2" : 25 M

4.0 PREDICTED ENERGY SAVINGS

The anticipated annual energy savings after this system is installed are below:

Annual Energy Savings	
T.O.E.	Tons Mazout
216	222.5

-10

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
28,240	63,258	24,935	6,230

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.

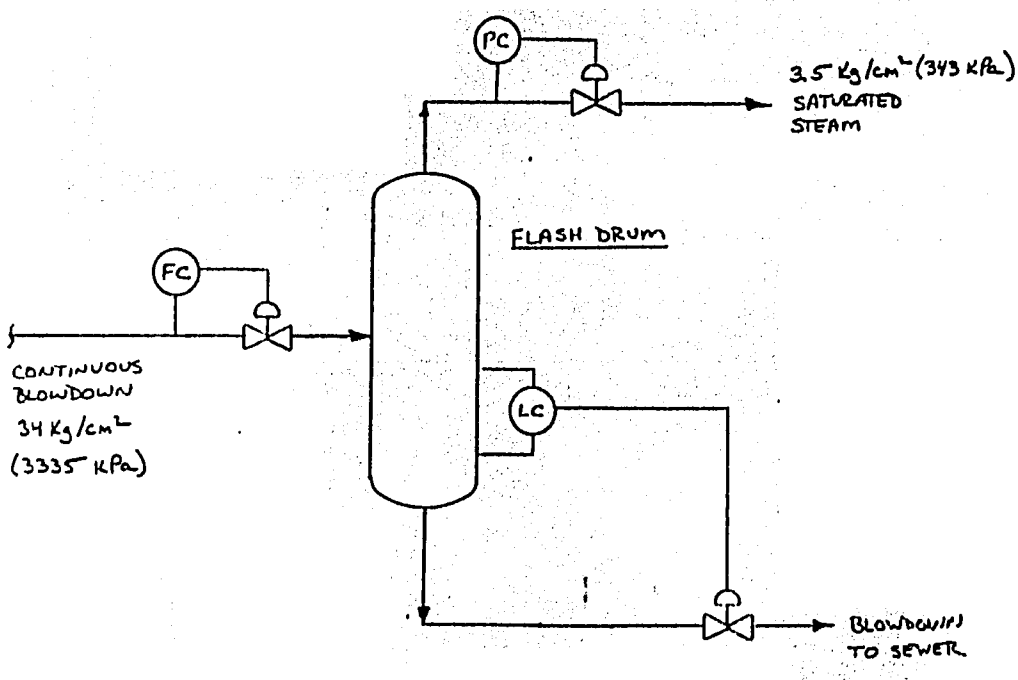
7.0 RECOMMENDATION

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

41

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: EL-NASR CO.

REF. 11-36598
DATE MAY 1988
PAGE
REV.



NOTE: ENTIRE SYSTEM IS NEW

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:
ECO 01

PLANT EL-NASR CO.

LOCATION HELWAN, EGYPT

72

FERTILIZER PLANT
STEAM SYSTEM

ELIMINATE THE USE OF HIGH PRESSURE STEAM AND USE ONLY DESUPERHEATED 16 ATM STEAM IN C.A.N. PLANT

Annual Savings, TOE	:	556.
Annual Savings, $	:	64,216.
Investment Cost, $	:	13,952.
Payout: Simple, Yrs	:	0.22
DCF , %	:	--

ECO-02

1.0 PURPOSE

The purpose of this ECO is to eliminate the use of high pressure superheated 34 atm (3,446 kPa) steam in the Calcium Ammonium Nitrate Plant and use only 16 atm saturated steam for the total plant requirements.

2.0 PROCESS DESCRIPTION

Steam required in the 1st Stage Evaporator requires 4.3 tons/hr of 7 Kg/cm^2 (687 kPa) steam. This steam is produced by letting down and desuperheating 16 Kg/cm^2 (1570 kPa) steam. Steam required in the 2nd Stage Evaporator requires 2.3 tons/hr of 14 Kg/cm^2 (1373 kPa) saturated steam. This steam is produced by letting down and desuperheating 34 Kg/cm^2 (3446 kPa) steam.

Both evaporators require steam levels lower than 16 Kg/cm^2. This steam level should be used to satisfy the needs of both evaporators.

At present there would appear to be no savings in using only 16 Kg/cm^2 steam since this steam would be created through the letdown of 34 Kg/cm^2 steam. However, once the Spanish Concentrated Nitric Acid plant is commissioned, there will be a waste heat boiler producing 16 Kg/cm^2 steam, and at that time there can be a savings of fuel necessary to produce 34 Kg/cm^2 steam.

3.0 EQUIPMENT LIST/SIZE

Refer to attached sketch.

1 Pressure control valve (3" line).
5 M 3" piping.

4.0 PREDICTED ENERGY SAVINGS

The energy savings is derived from the energy required to make 34 Kg/cm^2 steam in a fired boiler versus the energy required to make 16 kg/cm^2 steam in a waste heat boiler.

Annual Energy Saving	
T.O.E.	Tons Mazout
556	573

73

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost to purchase and install the equipment listed is below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Energy Cost Saving	
$	LE	$	LE
13,952	31,253	64,216	16,044

6.0 CONCLUSIONS

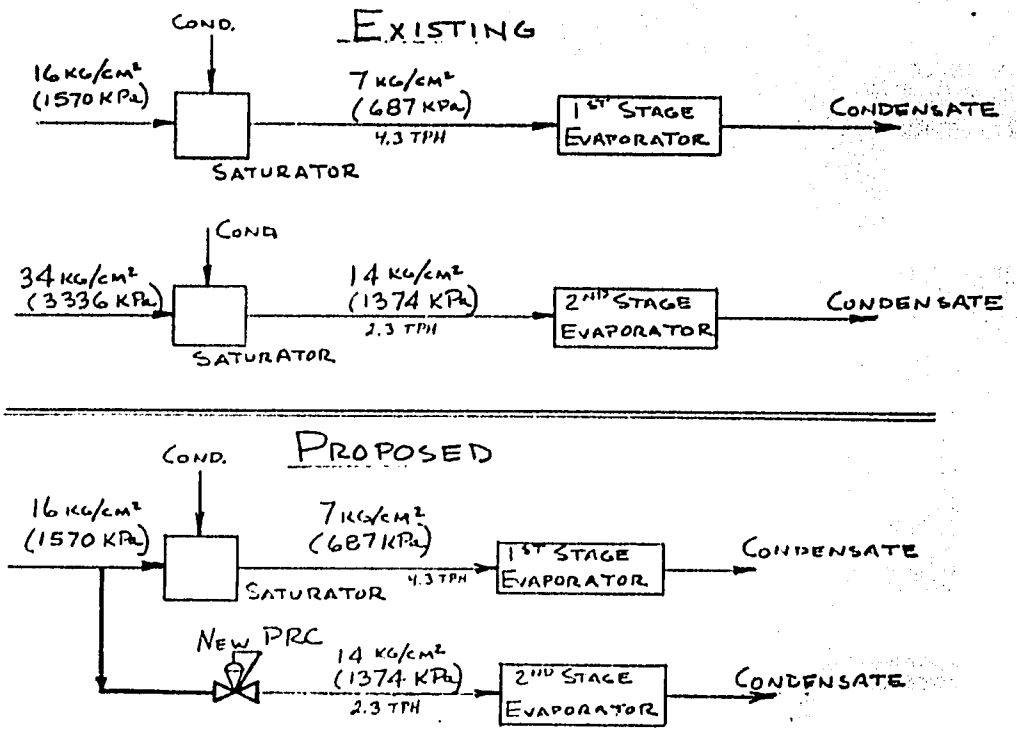
This ECO has a very attractive payout period. It is good engineering practice to use steam as economically as possible. Energy should not be wasted by using higher levels of steam than are actually necessary.

7.0 RECOMMENDATIONS

This ECO should be implemented after the Spanish Concentrated Nitric Acid plant comes onstream.

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: EL-NASR

REF. 11-36548
DATE MAY 1988
PAGE
REV.



- ELIMINATE USE OF 34 ATM. STEAM IN C.A.N. PLANT

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:
ECO 02

PLANT EL NASR COKE

LOCATION HELWAN, EGYPT

FERTILIZER PLANT
STEAM SYSTEM

INSTALLATION OF A
CONDENSATE RECOVERY
SYSTEM

Annual Savings, TOE	:	2,644.
Annual Savings, $	:	305,166.
Investment Cost, $	:	233,480.
Payout: Simple, Yrs	:	0.77
DCF , %	:	--

ECO-03

1.0 PURPOSE

The purpose of this ECO is to collect the steam condensate from the various units of the Fertilizer Plant and send it hot to the deaerator. This helps conserve energy by minimizing the need to demineralize raw water make up and by lowering the steam requirment for heating the water sent to the deaerator to its operating temperature.

2.0 PROCESS DESCRIPTION

At present, all the condensate from the Fertilizer Plant is sent hot to the sewer. It is now proposed to provide for the plant a new condensate return piping system, a new condensate collection drum, a vent condenser to condense flash steam and the pump(s) to return the condensate to the existing deaerator. The normal condensate rate that can be collected is 43 tons/hr. The steam condensate collection system is shown in the sketches and tabulations which follow.

3.0 EQUIPMENT LIST/SIZE

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

1. Drum

Item No:	D-1
Service:	Condensate Collection Drum
Size :	1.85 M Dia. x 3.4 M long.
Design Pressure:	3.5 Bar (345 kPa)
Design Temperature:	160 ^{o}C.
Material :	C.S
Insulation :	None

2. Pumps

Item No :	P-1 A/B
Service :	Condensate Pump & Spare
Capacity:	51 M^3/hr.
Head :	46 M
Motor H.P.:	15
Type :	Centrifugal
Material:	C.S

76

3. Vent Condenser

Type :	Shell & Tube
Area :	153 M^2
Design:	5.0 Kg/cm^2 (490 kPa) 125 °C shell & tube

4. Piping

A. Condensate Piping from Various Units:

Line Size Inches	Estimated Length Meters
1 1/2"	40
2	45
3	90
4	50
6	45

B. Condensate Header on the Main Pipe Rack:

Line Size Inches	Estimated Length Meters
6"	100
8	100
10	200

4.0 PREDICTED ENERGY SAVINGS

The anticipated annual energy savings after this system is installed is below:

Annual Energy Savings	
T.O.E.	Tons Mazout
2,644	2,723

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

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

Investment Cost		Annual Energy Cost Saving	
$	LE	$	LE
233,480	523,000	305,166	76,244

6.0 CONCLUSIONS

Installation of a condensate recovery system has a rapid payout and is therefore a very attractive ECO.

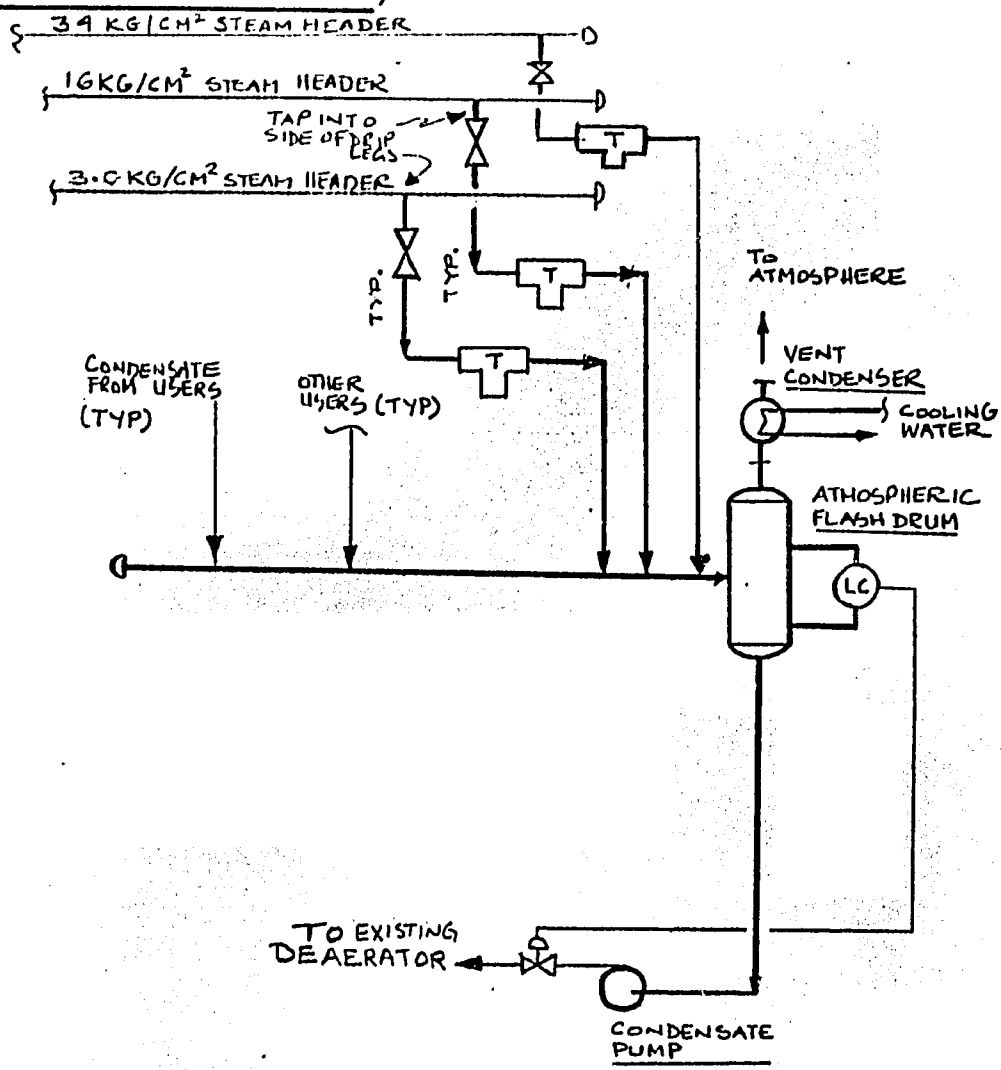
7.0 RECOMMENDATIONS

This ECO should be implemented immediately.

77

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: ELNASR COMPANY

REF. 11-3659B
DATE MAY 1988
PAGE
REV.



NOTE: ALL EQUIPMENT SHOWN IS NEW.

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 03

PLANT ELNASR COMPANY FOR COKE & CHEMICALS

LOCATION HELWAN, EGYPT

FERTILIZER PLANT
STEAM SYSTEM

CHECK COMBUSTION EFFICIENCY OF STEAM BOILERS

Annual Savings, TOE	:	759
Annual Savings, $	:	87,648
Investment Cost, $	:	27,000
Payout: Simple, Yrs	:	0.31
DCF, %	:	--

ECO-04

1.0 PURPOSE

The purpose of this ECO is to improve the overall Efficiency of the fertilizer plant utility boilers. Combustion efficiency of the fertilizer utility boilers is highly effected by the oxygen content of the flue gas. Additionally, combustion efficiency is affected 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 register 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 register by way of a forced draft fan. When normal load changes of the boiler are made, air should be adjusted with the damper located on the forced draft fan.

As the level of excess air is increased more fuel must be fired to the boiler to heat up the additional air. The excess air simply passes through the boiler and up stack releasing only a small portion of its energy to the process. Stoichiometric combustion is not possible (zero percent excess air) therefore, a small amount of excess air is required to allow for complete combustion. This small amount of excess air not only helps to force the combustion reaction to completion, but also acts to aid in the fuel-air mixing process.

The condition and design of the burners must be such that complete mixing of the oil and air streams occurs. If a high 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 therefore, do not liberate heat. The net result is an effective reduction in the heating value of the fuel oil that is supplied.

Visible smoke in the stack exhaust or in the combustion chamber of the boiler is an indication that combustion is not complete. The existence of carbon monoxide is also an indication of this condition. Monitoring of the flue gas oxygen and combustibles provides the operator of the boiler with the information that is needed so that

71

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 local to the boiler firing controls.

Installation of oxygen analyzers in the stack of each boiler and the possible replacement of the burners will make it possible to operate the fertilizer plant utility boilers at a stack oxygen level of 3.7 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 it is later found that 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 or repair may be implemented at that time.

3.0 EQUIPMENT LIST/SIZE

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

4.0 PREDICTED ENERGY SAVINGS

Provided that the flue gas oxygen level for boiler #1 is reduced from 6.1 percent to 3.7 percent the overall efficiency will increase from 85.6 percent to 86.6 percent. For boiler #2 a flue gas oxygen reduction from 14 percent to 3.7 percent will increase the boiler efficiency from 72.5 percent to 86.6 percent. Boiler #4 cannot have a flue gas oxygen reduction as the present flue gas oxygen is 0.6 percent representing 88.4 percent efficiency. The following shows the total cumulative savings:

ANNUAL ENERGY SAVINGS	
T.O.E.	TONS MAZOUT
759	782

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
27,000	60,480	87,648	21,896

6.0 CONCLUSIONS

This ECO will provide a rapid and considerable payout.

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.

91

FERTILIZER PLANT
STEAM SYSTEM

REPAIR TURBOGENERATOR AND GENERATE ELECTRICITY WHEN LETTING DOWN STEAM PRESSURE

Annual Savings, TOE	:	2,995.
Annual Savings, $	:	510,840.
Investment Cost, $	:	16,780.
Payout: Simple, Yrs	:	12 days
DCF , %	:	--

ECO-05

1.0 PURPOSE

The purpose of this ECO is to repair the existing turboexpander/generator for letting down high pressure 34 Kg/cm^2 steam and recovering energy in the form of electricity that is currently wasted across the pressure letdown control valve.

2.0 PROCESS DESCRIPTION

Due to a broken lube oil pump associated with the turboexpander/generator, high pressure steam (34 Kg/cm^2) is now let down to 16 and then to 4 Kg/cm^2 through control stations. The intent of this ECO is to replace the existing lube oil pump and enable the plant to operate the turboexpander/generator and produce electricity.

3.0 EQUIPMENT LIST/SIZE

- Lube Oil Pump And Spare
  10.2 M^3/Hr
  4 Kg/cm^2 (392 kPa) differential.

4.0 PREDICTED ENERGY SAVINGS

By allowing approximately 17 tons per hour of 34 Kg/cm^2 steam into the turboexpander/generator and letting it down to 4 Kg/cm^2, 1.5 MW of power can be generated. This power would otherwise be purchased from the electric company.

Additional Electricity Generated		Annual Energy Savings	
MW	MWH/Year	T.O.E.[1]	MWH
1.5	11,880 (7920 Hr/Yr)	2,995	11,880

[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 investment required for this ECO is below. This must be paid for in foreign currency, as the pump should be imported from West Germany (original manufacturer was AEG/Seimens).

Investment	Savings per MWH		Annual Cost Savings	
$	$	LE	$	LE
16,780	43.0	17.0	510,840	201,960

6.0 CONCLUSIONS

The payout for this ECO is very attractive. The electricity generated will be more significant in summer months when electrical consumption countrywide is extremely high and power shedding may be required.

7.0 RECOMMENDATIONS

This ECO should be implemented immediately.

FERTILIZER PLANT
STEAM SYSTEM

TEST, REPAIR, REPLACE
STEAM TRAPS

Annual Savings, TOE	:	1,562
Annual Savings, $	:	180,321
Investment Cost, $	:	22,500
Payout: Simple, Yrs	:	0.12
DCF , %	:	--

ECO-06

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 has failed open, a continuous high frequency sound can be heard due to steam blowing through its orifice.

84

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.

3.0 EQUIPMENT LIST/SIZE

Forty (40) steam traps were found during the energy audit of the Fertilizer Plant. Only eight (8) were observed to be in the working condition. The remaining thirty-two (32) were either blowing excessive quantities of steam or were cold. The following are the details of the survey with recommended trap types for the defective traps:

Location	Replacement Trap Type	Number	Failed	Satisfactory
Steam Main Drip Legs	T.D.	16	14	2
Boiler House Drains	T.D.	9	8	1
Fuel Oil Tanks/Heaters	Bimetallic	5	5	0
Calcium Ammon. Nitrate	Float & T.S.	4	3	1
Pure Ammon. Nitrate	Bimetallic	6	2	4
TOTAL		40	32	8

The bypass and upstream/downstream block valves are also in poor condition and need to be replaced.

The total steam loss for the Fertilizer Plant is estimated at 2224 Kg/hr.

Based on the results of the trap survey 32 out of 40 traps required replacement.

4.0 PREDICTED ENERGY SAVINGS

The energy savings that will result from proper operation of all steam traps is below.

Annual Energy Savings	
T.O.E.	Tons of mazout
1562	1609

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

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

Investment Cost		Annual Cost Savings	
$	LE	$	L.E.
22,500	50,400	180,321	45,052

96

6.0 CONCLUSIONS

The steam straps in the entire Fertilizer Plant, with the notable exception of the Pure Ammonium Nitrate (P.A.N.) Unit, are in extremely poor condition. The testing, repair and replacement of team traps has a rapid payout and is therefore a very attractive ECO.

7.0 RECOMMENDATION

This ECO should be implemented immediately.

87

FERTILIZER PLANT
STEAM SYSTEM

ADD NEW OR REPAIR EXISTING INSULATION ON STEAM AND CONDENSATE LINES

Annual Savings, TOE	:	1,494.
Annual Savings, $	:	172,475.
Investment Cost, $	:	42,341.
Payout: Simple, Yrs	:	0.25
DCF , %	:	--

ECO-07

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 and 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 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 tabulation summary lists the insulation requirement by pipe size, insulation thickness, length and annual energy savings.

Line Size	Insulation Thickness (mm)	Meters	Annual Energy Savings, KJ
1/2"	25	1	4,345,280
1"	25	53	373,350,730
	75	28	1,521,219,510
2"	25	62	531,340,240
	37.5	6	97,575,370
	50	56	1,125,955,980
	75	42	4,020,293,415

98

Line Size	Insulation Thickness (mm)	Meters	Annual Energy Savings, KJ
3"	37.5	104	1,590,324,800
	75	.22	12,282,662,800
	87.5	26	3,383,670,810
4"	37.5	29	692,408,560
	100	74	11,213,566,600
6"	25	9	224,506,220
	50	.27	5,615,673,000
8"	100	7	2,100,513,970
12"	67.5	9	590,234,090
	75	5	499,707,390
14"	37.5	7	171,542,060
16"	67.5	5	448,288,220
Bare surface (vessels)	50	35 M^2	562,520,850
Total Energy Savings			47.05 x 10^9 kJ/year

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 Energy Savings	
T.O.E.	Ton mazout
1494	1539

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
42,341	61,395	172,475	43,092

09

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.

90

FERTILIZER PLANT
STEAM SYSTEM

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

Annual Savings, TOE	:	1,852
Annual Savings, $	:	213,800
Investment Cost, $	:	5,333
Payout: Simple, Yrs	:	9 days
DCF, %	:	--

ECO-08

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, boiler feed water and condensate leaks in the fertilizer 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. An estimated quantity of steam was assigned to each size of leak based upon published figures and experience for the various hole sizes that were estimated. Air leaks were noted but not quantitatively estimated, as the quantity of each was small as compared to the steam, boiler feedwater, and condensate leaks.

3.0 NUMBER OF STEAM AND CONDENSATE LEAKS

We noticed a total of 144 leaks, which were identified by means of 81 red tags within the various units of the fertilizer plant. The source of the leaks are distributed as follows:

Valves	82
Pipe lines	15
Flanges	47
TOTAL	144

Leaks from valves are through the glands and/or gaskets. Leaks from pipelines are largely through fittings and holes in the pipes. Note also that steam trap leaks are not included here as they are covered separately under ECO-06.

91

The leaks are further categorized by size as follows:

Type	Est. Leakage per leak tag Kg/hr	Number of Leak Tags: 34 Kg/cm² Steam	16 Kg/cm² Steam	3 Kg/cm² Steam	Cond. & B.F.W.
Small	8	19	9	3	2
Medium	20	14	5	2	3
Large	35	4	3	3	2
Ex-large	80-160	6	5	1	0
TOTAL		43	22	9	7

Type	TOTAL LEAKAGE RATE, Kg/hr
Small	264
Medium	480
Large	420
Ex-large	1,600
TOTAL	2,764

Annual leakage based on 330 operating days, per year is estimated to be 21,891 metric tons.

4.0 PREDICTED ENERGY SAVINGS

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

ANNUAL ENERGY SAVINGS	
T.O.E.	Tons mazout
1852	1908

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
5,333	11,945	213,800	53,424

6.0 CONCLUSIONS

For very little investment this ECO is extremely attractive.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

92

FERTILIZER PLANT
STEAM SYSTEM

STUDY THE FEASIBILITY OF COMBUSTION AIR PREHEAT FOR STEAM BOILERS

Annual Savings, TOE	:	517
Annual Savings, $	:	59,733
Investment Cost, $	:	1,350,000
Payout: Simple, Yrs	:	>10
DCF, %	:	--

ECO-09

1.0 PURPOSE

The purpose of this ECO is to study the feasibility of combustion air preheat for the fertilizer plant utility 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 process sink does not exist to cooldown the flue gases and thus sensible heat is lost to the atmosphere. Combustion air at ambient temperature provides a good cold sink.

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

Please note that the equipment listed is for only one air preheat system although the investment represents the total price for three air preheat systems:

1 (one) forced draft fan

1 (one) induced draft fan

1 (one) forced draft oil burner
[2 (two) forced draft burners for boiler #4]

1 (one) cast iron recuperative air preheater

Air and flue gas duct work

Associated instrumentation and electricals

4.0 PREDICTED ENERGY SAVINGS

The predicted energy savings when the stack temperature of boiler #4 is reduced from 272 °C to 160 °C and boilers #1 and #2 stack temperatures are reduced from 302 °C to 160 °C are represented here. The approximate efficiency for the three boilers would then be 89.0 percent. The figures shown below represent the total for the three boilers:

ANNUAL ENERGY SAVINGS	
T.O.E.	TONS MAZOUT
517	533

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
1,350,000	3,240,000	59,733	14,924

The above figures are based on a conceptual estimate.

6.0 CONCLUSIONS

Although energy can be saved by installing air preheaters, this ECO is not economically justified.

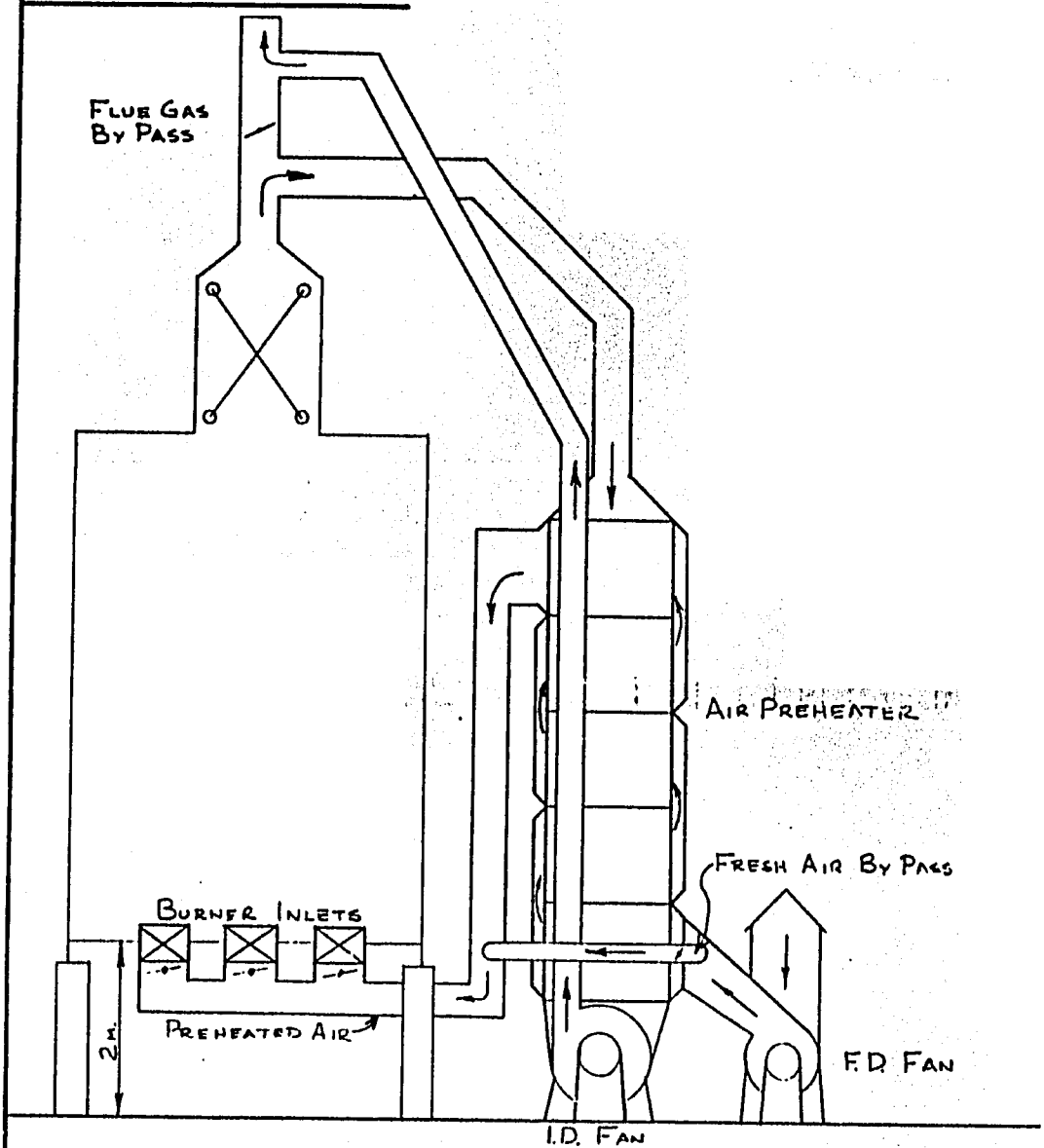
7.0 RECOMMENDATIONS

This evaluation finds that this ECO should not be implemented.

gk

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: EL-NASR

REF. 11-36598
DATE MAY 1988
PAGE
REV.



PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 09

PLANT EL-NASR CO.

LOCATION HELWAN, EGYPT

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

95

ECO-10

(ECO NUMBER NOT USED)

COKE PLANT STEAM SYSTEM	Annual Savings, TOE :	4,072
	Annual Savings, $:	470,021
DELETE BOILERS #1,#2,#3,#4	Investment Cost, $:	3,041,000
AND REPLACE WITH A SINGLE	Payout: Simple, Yrs :	6.47
HIGH EFFICIENCY 75 TON/HR	DCF , % :	6.5
PACKAGE BOILER		

ECO-11

1.0 PURPOSE

The purpose of this ECO is to ensure that a reliable steam supply is available at all times for the Coke Plant.

2.0 PROCESS DESCRIPTION

Boilers #1, #2, #3, #4 were designed to produce 25 tons per hour each of 14 Kg/cm2 steam at 330 °C. These boilers are 19 to 24 years old and keep breaking down, requiring extensive mechanical maintenance. Instrumentation on these boilers is non-existent. Boiler #1 was shutdown over a year ago. Parts needed to fix the boiler are no longer available. Even after comprehensive repairs, the operation of the boilers is far from reliable. Since steam is extensively used in the Coke complex, its supply must be dependable to avoid process downtime. This in turn will improve overall productivity.

In general, only two (and no more than three) of these boilers operate at any one time. Therefore, the new boiler package should have a capacity of 75 tons/hour.

3.0 EQUIPMENT LIST/SIZE

One Package Boiler.
- 75 Ton/Hr Design 14Kg/cm2, 350 °C

This boiler should be able to fire # 6 fuel oil, tar oil, coke oven gas, or blast furnace gas.

Boiler package to be energy efficient (91% or greater).

4.0 PREDICTED ENERGY SAVINGS

Considerable energy will be saved by using a modern, energy efficient package boiler. It is anticipated that this new boiler will be more reliable and give trouble free operation. Based on ECO-14, the fuel savings by operating one high efficiency boiler versus two of the existing boilers is as follows:

a1

Annual Energy Savings	
T.O.E.	Tons Mazout
4072	4194

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The investment required and annual energy savings for this ECO are below. This package boiler must be paid for in foreign currency.

Investment	Annual Energy Cost Savings	
$	$	LE
3,041,000	470,021	117,432

6.0 CONCLUSIONS

Substantial savings and process stability can be achieved by installing a modern, energy efficient boiler in place of existing boilers #1, #2, #3 and #4.

7.0 RECOMMENDATIONS

This ECO should be investigated further. Consideration should be given to the age and condition of the present boilers, as well as the present and future needs for a reliable steam supply in the Coke Plant.

COKE PLANT STEAM SYSTEM	Annual Savings, TOE :	Not
	Annual Savings, $:	Required
STUDY THE FEASIBILITY OF COMBUSTION AIR PREHEAT FOR #5 AND #6 STEAM BOILERS	Investment Cost, $:	(See Text)
	Payout: Simple, Yrs :	
	DCF, % :	

ECO-12

1.0 PURPOSE

The purpose of this ECO is to study the feasibility of combustion air preheat for the #5 and #6 coke 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 at ambient temperature provides a good cold sink.

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. Refer to Section 4.0.

4.0 PREDICTED ENERGY SAVINGS

No energy savings can be realized for #6 boiler. The stack temperature is 170 °C and therefore nominal heat is available for heat transfer. During this study #5 boiler was not in operation and therefore it is not possible to make any definitive comments with respect to this boiler, although in all probability the stack temperature is not high enough to justify air preheat due to the more modern design of this boiler.

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. Acid dew point problems can occur at temperatures lower than this range.

7.0 RECOMMENDATIONS

This evaluation finds that this ECO should not be implemented.

COKE PLANT STEAM SYSTEM

OPERATE THE TURBOGENERATOR AT DESIGN CAPACITY AND RECOVER ENERGY THAT IS OTHERWISE WASTED ACROSS A LETDOWN STATION

Annual Savings, TOE	:	1,398
Annual Savings, $	:	238,392
Investment Cost, $	:	717,183
Payout: Simple, Yrs	:	3.01
DCF , %	:	19.5

ECO-13

1.0 PURPOSE

The purpose of this ECO is to utilize Coke Plant steam in the most efficient manner. This can be done by maximizing power generation to the design output of 3.2 MW and maximizing the exhaust steam header pressure to 5 Kg/cm^2.

The plant personnel at El-Nasr advised FWUSA during the comment phase of the report presentation that although additional electric generation is possible, the present electrical system would not be able to distribute this additional electricity.

2.0 PROCESS DESCRIPTION

At present, 14 Kg/cm^2 steam drives the turboexpander/ generator to generate 2.5 MW of power versus a design power output of 3.2 MW. The steam backpressure is now maintained at approximately 3.5Kg/cm^2. By operating the turboexpander at design throughput, more power can be generated. In addition, increasing the steam backpressure to approximately 5 Kg/cm^2 will allow the pressure in the main low pressure steam header to increase to approximately 5 Kg/cm2.

The new, higher, steam flow through the turbogenerator associated with a higher pressure in the low pressure header will eliminate the injection of 14 Kg/cm^2 steam into the low pressure steam header.

It is estimated that about 20 to 30 tons per hour of 14 Kg/cm^2 steam are injected into the low pressure steam header to satisfy the need of its users. It is also estimated that no excess 5 Kg/cm^2 steam will be available for export to the Fertilizer Plant after elimination of 14 Kg/cm^2 steam injection into the 5 Kg/cm^2 steam header. If 5 Kg/cm^2 steam is then required in the Fertilizer Plant, then the letdown station may need to be used.

101

3.0 EQUIPMENT LIST/SIZE

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

4.0 PREDICTED ENERGY SAVINGS

The overall steam balance in the Coke Plant will remain unchanged. However, an additional 0.7 MW of power will be generated.

Additional Electricity Generated		Annual Energy Savings	
MWH	MWH/Year	T.O.E.[1]	MWH
0.7	5544 (7920 Hr/Yr)	1398	5544

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The investment cost for implementation of the electrical equipment necessary to implement this ECO is conceptual due to the late information from the plant personnel at El-Nasr.

The savings for generating the additional 0.7 MW of power are below.

Investment	Savings per MWH		Savings per Year	
$	$	LE	$	LE
717,183	43.0	17.0	238,392	94,248

6.0 CONCLUSIONS

The payout for this ECO is attractive. This ECO will provide electrical power at no cost to the Coke Plant. This ECO will also reduce wasted energy by eliminating 14 Kg/cm^2 steam letdown through a control valve station.

7.0 RECOMMENDATIONS

This electrical system modification required by this ECO should be investigated further before implementation. The steam balance in the Coke Plant should be monitored so as to maximize power generation and minimize steam energy that is wasted across a control valve letdown station.

---

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

COKE PLANT STEAM SYSTEM	Annual Savings, TOE :	7881
	Annual Savings, $:	909,784
CHECK COMBUSTION EFFICIENCY OF STEAM BOILERS	Investment Cost, $:	54,000
	Payout: Simple, Yrs :	22 days
	DCF, % :	--

ECO-14

1.0 PURPOSE

The purpose of this ECO is to improve the overall efficiency of the coke plant boilers. Combustion efficiency of the coke boilers is highly effected by the oxygen content of the flue gas. 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 register 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 register by way of a forced draft fan. When normal load changes of the boiler are made, air should be adjusted with the damper located on the forced draft fan.

As the level of excess air is increased more fuel must be fired to the boiler to heat up the additional air. The excess air simply passes through the boiler and up the stack releasing only a small portion of its energy to the process. Stoichiometric combustion is not possible (0 percent excess air) therefore, a small amount of excess air is required to allow for complete combustion. This small amount of excess air not only helps to force the combustion reaction to completion, but also acts to aid in the fuel/air mixing process.

The condition and design of the burners must be such that complete mixing of the oil and air streams occurs. If a high 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 therefore do not liberate heat. The net result is an effective reduction in the heating value of the fuel oil that is supplied. Visible smoke in the stack exhaust or in the combustion chamber of the boiler is an indication that combustion is not complete. The existence of carbon monoxide is also an indication of this condition.

Monitoring of the flue gas oxygen and combustibles 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

703

absolutely imperative that all boilers with a significant load have permanently installed and operating oxygen analyzers local to the boiler firing controls.

Installation of oxygen analyzers in the stack of each boiler and the possible replacement of the burners will make it possible to operate the coke plant boilers at a stack oxygen level of 4.0 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 or repair may be required.

Referring exclusively to coke plant boilers #1, #2, #3, and #4 it is likely that the oxygen level cannot be reduced appreciably. Although it is difficult to quantify, it appears that the boilers may have considerable casing leaks. If the leaks are considerable it may not be possible to reduce the oxygen level in the flue gas. Increased energy and material cost have caused major advances in the design of boilers since the time that these boilers where constructed. If it is not possible to reduce the flue gas oxygen levels of these boilers, replacement of the boilers may be necessary.

3.0 EQUIPMENT LIST/SIZE

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

4.0 PREDICTED ENERGY SAVINGS

Provided that the flue gas oxygen level for boiler #6 is reduced from 16.0 percent to 4.0 percent the overall efficiency will increase from 77.3 percent to 91.4 percent. For boilers #1 ,#2, #3, and #4 a flue gas oxygen reduction from 18.5 percent to 4.0 percent will increase the boiler efficiency from 68.5 percent to 91.9 percent. It was not possible to take measurements on boiler #5. The following shows the total cumulative savings considering that boiler #6 and any two of boilers #1, #2, #3, and #4 are operating at any given time:

ANNUAL ENERGY SAVINGS	
T.O.E.	TONS MAZOUT
7881	8118

Although the above savings is quoted in terms of tons of mazout each of these boilers fires coke oven gas in combination with mazout and tar oil. Provided that the overall energy consumption is reduced the firing of mazout can be reduced first. Therefore, the savings can be

104

realized in mazout cost.

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
54,000	120,960	909,784	227,304

6.0 CONCLUSIONS

The efficient firing of the Coke Plant Boilers will save a large amount of energy for a very modest amount of money. The payout period is immediate.

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.

Attempts to reduce that oxygen level in boilers #1, #2, #3, and #4 should be made first with portable oxygen analyzers. Possibly, additional sealing of the boilers casing can be done. If these attempts are unsuccessful than it may be necessary to replace the boilers with one large boiler of modern design.

105

COKE PLANT STEAM SYSTEM	Annual Savings, TOE :	3,122.
	Annual Savings, $:	360,417.
CONDENSATE COLLECTION SYSTEM	Investment Cost, $:	464,820.
	Payout: Simple, Yrs :	1.29
	DCF , % :	--

ECO-15

1.0 PURPOSE

The purpose of this ECO is to collect the steam condensate from the various units of the Coke Plant and send it hot to the deaerator. This helps conserve energy by minimizing the need to demineralize raw water make up and by lowering the steam requirment for heating the water sent to the deaerator to its operating temperature.

2.0 PROCESS DESCRIPTION

At present, all the condensate from the Coke Plant is sent hot to the sewer. It is now proposed to provide for the plant a new condensate return piping system, a new condensate collection drum, a vent condenser to condense flash steam and the pump(s) to return the condensate to the existing deaerator. The normal condensate rate that can be collected is 55 ton/hr. The steam condensate collection system is shown in the sketches and tabulations which follow.

3.0 EQUIPMENT LIST/SIZE

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

1. Drum

Item No:	D-1
Service:	Condensate Collection Drum
Size :	1.85 M Dia. x 3.7 M long.
Design Pressure:	3.5 Bar (345 kPa)
Design Temperature:	160° C.
Material :	C.S
Insulation :	None

2. Pumps

Item No :	P-1 A/B
Service :	Condensate Pump & Spare
Capacity:	55 M^3/hr.
Head :	54 M
Motor H.P.:	20
Type :	Centrifugal
Material:	C.S

106

3. Vent Condenser

Type :	Shell & Tube
Area :	126 M^2
Design:	5 kg/cm^2 (490 kPa), 125°C shell & tube

4. Piping

A. Condensate Piping from Various Units:

Line Size Inches	Estimated Length Meters
3	110
4	230
6	60

B. Condensate Header on the Main Pipe Rack:

Line Size Inches	Estimated Length Meters
4	50
6	80
8	400
10	500

4.0 PREDICTED ENERGY SAVINGS

The anticipated annual energy savings after this system is installed is below:

Annual Energy Savings	
T.O.E.	Tons Mazout
3,122	3,216

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

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

Investment Cost		Annual Energy Cost Saving	
$	LE	$	LE
464,820	1,041,200	360,417	90,048

6.0 CONCLUSIONS

Installation of a condensate recovery system has a rapid payout and is therefore a very attractive ECO.

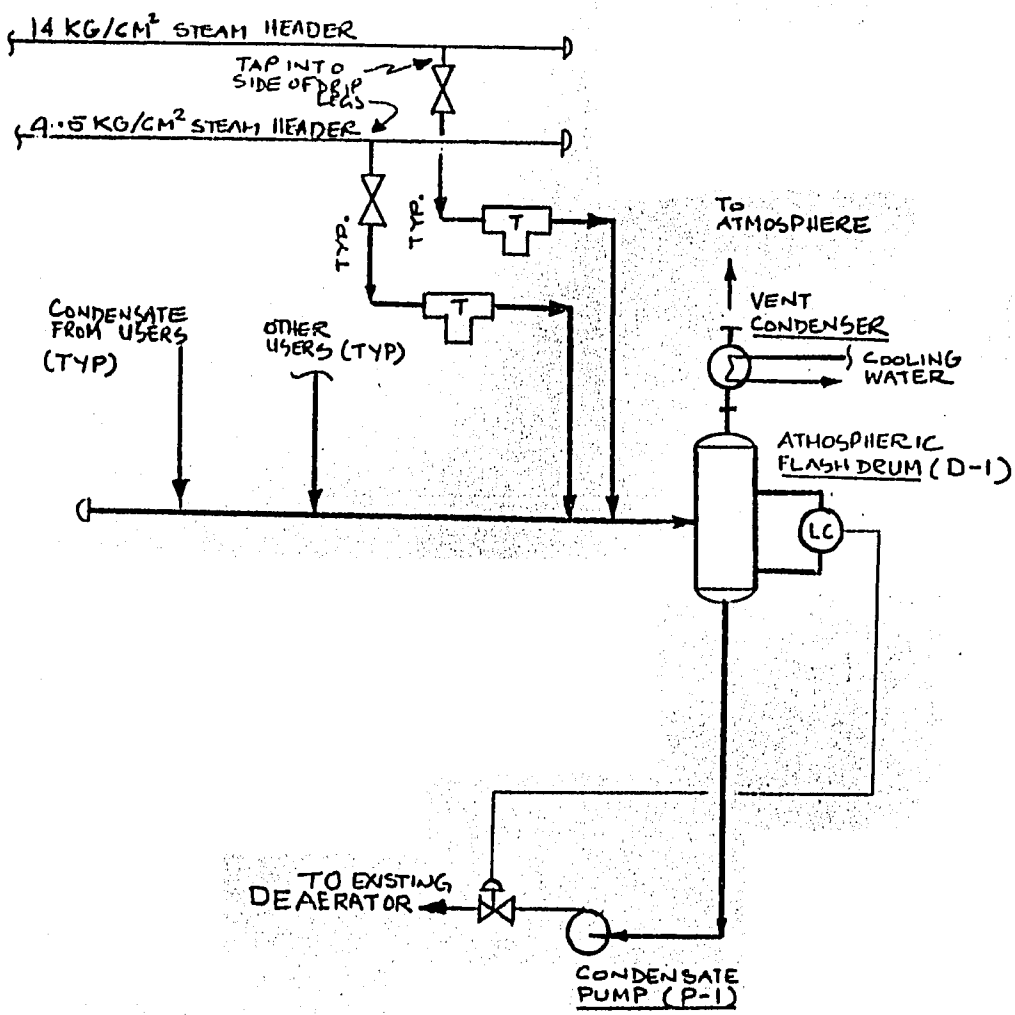
7.0 RECOMMENDATIONS

This ECO should be implemented immediately.

107

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: ELNASR COMPANY

REF. 11-36518
DATE MAY 1988
PAGE
REV.



NOTE

ALL EQUIPMENT SHOWN IS NEW.

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:

ECO 15-COKE

PLANT ELNASR COMPANY FOR COKE & CHEMICALS

LOCATION HELIWAN, EGYPT

COKE PLANT STEAM SYSTEM

ADD NEW OR REPAIR EXISTING INSULATION ON STEAM AND CONDENSATE LINES

Annual Savings, TOE	:	1,513.
Annual Savings, $	:	174,605.
Investment Cost, $	:	44,603.
Payout: Simple, Yrs	:	0.26
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 and 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 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 tabulation summary lists the insulation requirement by pipe size, insulation thickness, length and annual energy savings.

Line Size	Insulation Thickness (mm)	Meters	Annual Energy Savings, KJ
0.75"	37.5	92	1,575,164,600
	75	49	1,560,438,920
1"	37.5	12	244,011,700
1.5"	25	3	13,228,970
	37.5	2	22,028,160
	62.5	13	396,724,214
	75	3	167,534,750

169

Line Size	Insulation Thickness (mm)	Meters	Annual Energy Savings, KJ
2"	37.5	18	327,344,550
	62.5	01	3,677,737,750
	75	30	2,073,785,660
3"	37.5	87	3,284,791,510
	75	37	7,863,873,450
4"	37.5	43	3,530,155,080
	75	28	1,805,609,364
	100	18	2,244,820,780
6"	75	18	1,831,777,620
	100	19	3,338,129,850
8"	87.5	2	246,546,450
	100	21	5,751,342,250
12"	100	9	3,161,554,500
14"	100	8	2,868,187,640
Bare Surface	75	8.9 M^2)	1,262,017,150
	100	1.3 M^2)	403,819,420
Total Energy Savings			47.651 x 10^9 kJ/year

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 Energy Savings	
T.O.E.	Ton mazout
1513	1558

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
44,603	64,674	174,605	43,624

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.

COKE PLANT STEAM SYSTEM

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

Annual Savings, TOE	:	1,105
Annual Savings, $	:	127,536
Investment Cost, $	:	5,278
Payout: Simple, Yrs	:	15 days
DCF, %	:	--

ECO-17

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 coke 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. An estimated quantity of steam was assigned to each size of leak based upon published figures and experience for the various hole sizes that were estimated. Air leaks were noted but not quantitatively estimated, as the quantity of each was small as compared to the steam and condensate leaks.

3.0 NUMBER OF STEAM AND CONDENSATE LEAKS

We noticed a total of 122 leaks, which were identified by means of 77 red tags within the various units of the coke plant. The source of the leaks are distributed as follows:

Valves	58
Pipe lines	14
Flanges	50
TOTAL	122

Leaks from valves are through the glands and/or gaskets. Leaks from pipelines are largely through fittings and holes in the pipes. Note also that steam trap leaks are not included here as they are covered separately under ECO-18.

112

The leaks are further categorized by size as follows:

Type	Est. Leakage per Leak Tag Kg/hr	NUMBER OF LEAK TAGS 14.5 Kg/cm² Steam	4.5 Kg/cm² Steam	Cond.	Total Leakage Kg/hr
Small	8	1	6	3	80
Medium	20	13	19	5	740
Large	35	6	16	7	1015
Ex-large	80	0	1	0	80
TOTAL		20	42	15	1915

Annual leakage based on 330 operating days, per year is estimated to be 15,167 metric tons.

4.0 PREDICTED ENERGY SAVINGS

The anticipated energy savings after all the leaks are repaired or replaced is below:

ANNUAL ENERGY SAVINGS	
T.O.E.	Tons mazout
1105	1,138

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
5,278	11,822	127,536	31,864

6.0 CONCLUSIONS

For very little investment this ECO is extremely attractive.

7.0 RECOMMENDATION

This ECO should be initiated immediately.

113

COKE PLANT STEAM SYSTEM

TEST, REPAIR, REPLACE STEAM TRAPS

Annual Savings, TOE	:	3,059.
Annual Savings, $	:	353,107.
Investment Cost, $	:	48,120.
Payout: Simple, Yrs	:	0.14
DCF , %	:	--

ECO-18

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 has failed open, a continuous high frequency sound can be heard due to steam blowing through its orifice.

114

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.

3.0 EQUIPMENT LIST/SIZE

Thirty-three (33) steam traps were found during the energy audit of the Coke Plant. Nineteen (19) traps were found to be either blowing excessive amounts of steam or were cold. Fourteen (14) traps were in the satisfactory operating condition. We noticed that the traps have been disconnected at a number of locations. The plant personnel informed that the original plant design required approximately eighty (80) steam traps in the following size ranges:

Trap Size	Number Required
1"	48
1 1/2"	1
2"	31

Most of the steam traps in the plant are in the process service. Only a few drip traps were noticed on the steam headers in the boiler area. There are no drip steam traps on the long steam headers on the main interconnecting and the unit pipe racks.

The following are the results of the trap survey:

Location	No. of Traps	Failed	Satisfactory
Sulfate - Line 1	2	2	0
Acid - Line 1	4	4	0
Benzol - Line 1	1	1	0
Battery #1 & #2	1	0	1
Battery #3	8	0	8
Boiler Area	2	2	0
Tar Distillation	5	1	4
Benzol - Line 2	2	1	1
Acid - Line 2	1	1	0
Sulfate - Line 2	7	7	0
TOTAL	33	19	14

The total steam loss for the Coke Plant is estimated at 3,568 Kg/hr.

Based on the results of the trap survey, 66 out of 80 traps required replacement.

4.0 PREDICTED ENERGY SAVINGS

The energy savings that will result from proper operation of all steam traps is below.

Annual Energy Savings	
T.O.E.	Tons of mazout
3059	3151

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

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

Investment Cost		Annual Cost Savings	
$	LE	$	L.E.
48,120	107,800	353,107	88,228

6.0 CONCLUSIONS

The steam straps in the entire Coke Plant are in very poor condition. A majority of the traps have been disconnected or removed over a period of time. Only about 40% of the traps that still remain on line are in working condition. The testing, repair and replacement of steam traps has a rapid payout and is therefore a very attractive ECO.

7.0 RECOMMENDATION

This ECO should be implemented immediately.

117

COKE PLANT STEAM SYSTEM	Annual Savings, TOE	: 2,211.
	Annual Savings, $	: 255,183.
COMPLETE COMMISSIONING OF NEW DEMINERALIZED WATER PLANT AND PUT IT INTO SERVICE	Investment Cost, $	: 0.0
	Payout: Simple, Yrs	: Immediate
	DCF , %	: --

ECO-19

1.0 PURPOSE

The commissioning and start-up of the 90 ton/hr British water demineralization plant will increase the quality of boiler feed water to the coke plant boilers. This will consequently reduce the extremely high continuous blowdown rate of approximately 20 tons per hour to an estimated blowdown rate of 5 tons per hour, or approximately 5%.

2.0 PROCESS DESCRIPTION

The coke plant is equipped with three water treatment plants for boiler feed water service. Plants #1 and 2 (the Russian & Italian plants) are relatively old and do not produce a sufficient amount of high quality boiler feed water. As a result, a very high continuous blowdown rate is necessary to maintain the total dissolved solids in the boiler at an acceptable level. Plant # 3 (the new British plant) has been erected and partly commissioned, but due to contractual differences, the commissioning phase has not been completed. It is our understanding that El Nasr is in the process of expediting the commissioning of this new facility. Once commissioned, this plant alone should produce sufficient high quality boiler feed water for the coke plant boilers.

3.0 EQUIPMENT LIST/SIZE

Once commissioned, no new equipment will be required to implement this ECO.

4.0 PREDICTED ENERGY SAVINGS

It is conservative to assume that new Plant #3 will operate using the amount of energy consumed by Plants #1 and #2 together, or less. Therefore, the energy savings is equal to the heat that is lost to excessive blowdown.

Annual Energy Savings	
T.O.E.	Tons Mazout
2211	2277

112

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

Once commissioned, there will be no further investment cost. Only regular maintenance should be carried out to keep the plant in good operating condition.

Estimated Plant Cost to Complete Commissioning	Annual Energy Cost Savings	
$	$	L.E.
0	255,183	63,756

6.0 CONCLUSIONS

The payout for this ECO is immediate. A considerable amount of energy is wasted every day that the new demineralized water plant remains idle.

7.0 RECOMMENDATIONS

We recommend that this ECO be carried out as soon as

119

COKE PLANT STEAM SYSTEM	Annual Savings, TOE :	0
	Annual Savings, $:	0
FIX TUBES IN BOILER #4	Investment Cost, $:	13,035.
ECONOMIZER AND SUPERHEATER	Payout: Simple, Yrs :	--
	DCF , % :	--

ECO-20

1.0 PURPOSE

The purpose of this ECO is to evaluate the effect of the 14 plugged economizer tubes and the 13 plugged superheater tubes in Boiler #4.

2.0 PROCESS DESCRIPTION

Due to leaks in the tubes, the plant has plugged 14 economizer and 13 superheater tubes in Boiler #4. The net effect of doing this is a reduction in the steam production due to colder water leaving the economizer section. Since the steam production is lower, less surface in the superheater is required, therefore, the superheater is now of adequate size due to the loss of economizer surface. The overall efficiency of the boiler remains unchanged, as it takes the same amount of energy to make a ton of superheated steam, and the fuel firing rate will decrease.

3.0 EQUIPMENT LIST/SIZE

Economizer tubes:

14 - 3.4M, 28mm OD, Carbon Steel

Superheater:
13 - 3.4M, 38mm OD, Carbon Steel

4.0 PREDICTED ENERGY SAVINGS

No energy savings will result from replacing the plugged tubes listed in Section 3.0.

The boiler will, however, be able to produce approximately 0.32 tons per hour more steam. This is a 2% increase in steam production and will require that 2% more fuel be fired.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The investment cost to repair Boiler #4 is below, and is listed in worldwide and local pricing.

Investment Cost		Annual Cost Savings	
$	LE	$	L.E.
13,035	29,198	0	0

120

6.0 CONCLUSIONS

Although no increase in boiler efficiency will result from replacing the plugged tubes, boiler capacity will increase.

7.0 RECOMMENDATIONS

This ECO should be implemented if an increase in steam production is required.

121

COKE PLANT STEAM SYSTEM

IMPROVE INSULATION OF LOW AND HIGH PRESSURE STEAM HEADERS, AND ADD DRIP LEGS

Annual Savings, TOE	:	1,995.
Annual Savings, $	:	230,303.
Investment Cost, $	:	410,877.
Payout: Simple, Yrs	:	1.78
DCF , %	:	39.

ECO-21

1.0 PURPOSE

The purpose of this ECO is to reduce the amount of heat lost from the high and low pressure steam headers by improving the insulation. Improved insulation and the addition of drip legs with steam traps will reduce the system pressure drop and also reduce the amount of steam condensed in these headers.

2.0 PROCESS DESCRIPTION

There are two low pressure (5 Kg/cm^2) steam headers, sizes 8" and 12". The steam to the low pressure header is supplied through the turbogenerator. Steam from the 14 Kg/cm^2 steam header is also let down into the low pressure header. Due to poor insulation, the amount of steam condensed in the low pressure header is significant.

The 12" high pressure (14 Kg/cm^2) steam header is also poorly insulated, and the amount of steam condensed in this header is significant.

Due to the length and importance of these headers, this ECO recommends that the existing insulation be replace with durable, imported, calcium silicate block insulation with aluminum jacketting.

3.0 EQUIPMENT LIST/SIZE

The following is a list of insulation and drip leg requirements for the three steam headers in the Coke Plant:

Insulation

12" High Pressure	1100 Meters,	4" thick (100 mm)
12" Low Pressure	1100 Meters,	3.5" thick (87.5 mm)
8" Low Pressure	550 Meters,	3" thick (75 mm)

All insulation is calcium silicate with aluminum jacketting.

New Drip Legs

12" High Pressure	10 required (every 100 Meters)
12" Low Pressure	14 required (every 70 Meters)
8" Low Pressure	7 required (every 70 Meters)

122

4.0 PREDICTED ENERGY SAVINGS

It is assumed that the new calcium silicate insulation will be 10% more efficient than the existing insulation. This higher efficiency is due to the poor condition of the existing insulation and not directly due to the insulating value of calcium silicate. The energy losses have been calculated using the "Heatalyzer Economic Thickness" computer program.

Header	Length, M	Heat Saved, kJ/year
HP 12"	1100	3.791×10^{10}
LP 12"	1100	1.846×10^{10}
LP 8"	550	0.648×10^{10}
Total		6.285×10^{10} kJ/year

This is energy that need not be put into making steam since less steam will now be condensed.

	Annual Savings	
	T.O.E.	Ton mazout
HP 12"	1203	1239
LP 12"	586	604
LP 8"	206	212
	1995	2055

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

	Investment Cost		Annual Cost Savings	
	$	LE	$	LE
Insulation	359,137	520,749	230,303	57,540
Drip Legs & Traps	51,740	115,900	--	--
	410,877	636,649	230,303	57,540

6.0 CONCLUSIONS

This ECO shows the detrimental effect that poor insulation has on system heat loss. In addition, drip legs and steam traps will remove condensate that accumulates in the header and prevent excessive pressure drop through the header.

7.0 RECOMMENDATIONS

The condition of the insulation should be improved immediately. The drip legs should be added during the next turnaround/shutdown.

ECO-22

(ECO NUMBER NOT USED)

COKE PLANT STEAM SYSTEM

RECOVER HEAT AND PRODUCE STEAM FROM CONTINUOUS BOILER BLOWDOWN

Annual Savings, TOE	:	372.
Annual Savings, $	:	42,945.
Investment Cost, $	:	98,570.
Payout: Simple, Yrs	:	2.30
DCF , %	:	--

ECO-23

1.0 PURPOSE

The purpose of this ECO is to produce steam from the continuous blowdown of boilers 1 through 6, and to preheat boiler feed water using hot continuous blowdown. This will help conserve energy to that would otherwise be wasted by disposing of blowdown directly.

2.0 PROCESS DESCRIPTION

The present system is to pump boiler feed water directly to economizer while hot continuous blowdown is sent to drainage. The normal blowdown rate is 8 tons/hr; however, rates as high as 20 tons/hour have been experienced. The heat recovery system on the attached sketch will recover heat from boiler blowdown thereby reducing the energy consumption of each boiler.

3.0 EQUIPMENT LIST/SIZE

The design of the proposed blowdown system is 20 tons/hour.

The following equipment is necessary to implement this ECO:

Flash drum

1250 mm diameter x 2800 mm T/T
220 ^{o}C, 7 kg/cm^2 g (686 kPa) design

Heat Exchanger

Area : 120 M^2
12 Kg/cm^2 (1177 kPa), 350 ^{o}C tubes
18 Kg/cm^2 (1765 kPa), 125 ^{o}C shell
Carbon steel shell and tubes

Piping

15 M - 3" pipe (liquid)
5 M - 4" pipe (vapor)

Instrumentation

As shown on sketch.
plus: 1 - 1 x 1 1/2" PSV

126

4.0 PREDICTED ENERGY SAVINGS

The anticipated annual energy saving after this system is installed is below, and is based on the normal blowdown rate of 8 tons/hour.

Annual Energy Saving	
T.O.E.	Tons Mazout
372	383

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost to purchase and install the equipment listed 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 Saving	
$	LE	$	LE
98,570	220,800	42,945	10,730

6.0 CONCLUSIONS

This ECO has a very attractive payout. It is a good engineering practice to recover heat from blowdown through heat exchange and/or low pressure flash drums to produce steam.

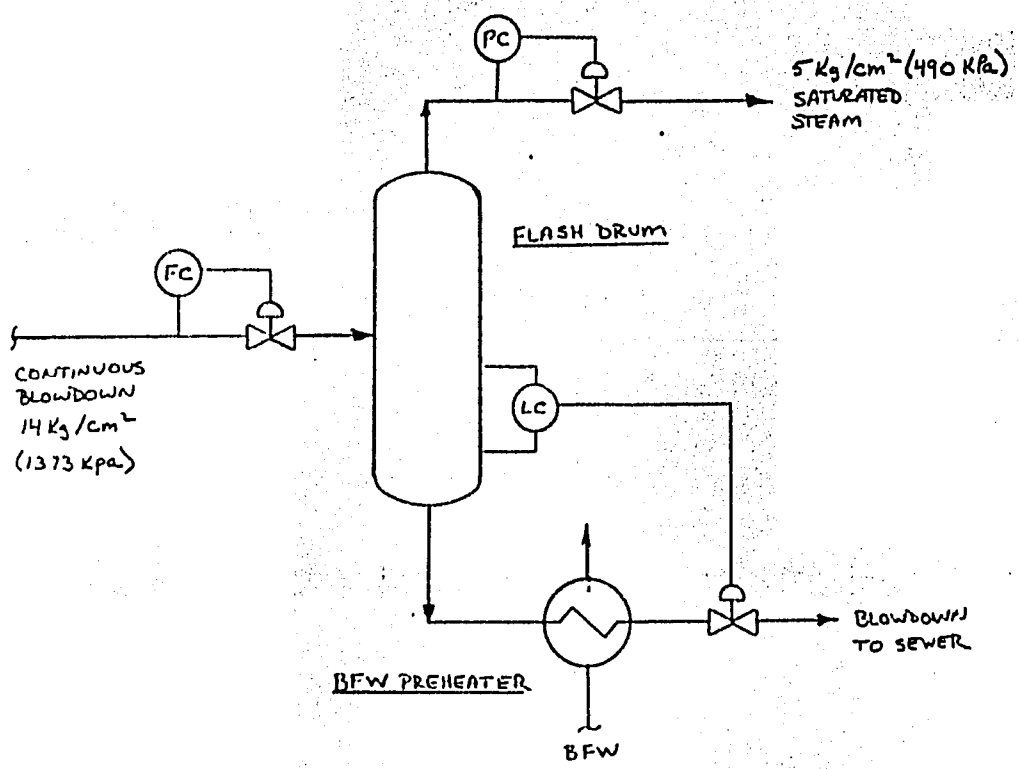
7.0 RECOMMENDATIONS

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

127

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: EL-NASR Co.

REF. 11-36598
DATE MAY 1988
PAGE
REV.



NOTE: ENTIRE SYSTEM IS NEW

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY:
ECO 23

PLANT EL-NASR Co.

LOCATION HELWAN, EGYPT

-12-

COKE PLANT STEAM SYSTEM

Annual Savings, TOE	:	1,460.
Annual Savings, $	:	168,553.
Investment Cost, $	:	9,111.
Payout: Simple, Yrs	:	20 days
DCF , %	:	--

REPAIR HEAT EXCHANGER LEAKS AND INSTALL NECESSARY NON-RETURN VALVES TO AVOID STEAM AND CONDENSATE CONTAMINATION

ECO-24

1.0 PURPOSE

The purpose of this ECO is to avoid condensate and steam contamination by process streams. This will help conserve energy by allowing the reuse of hot clean condensate, which is presently contaminated by process streams.

2.0 PROCESS DESCRIPTION

The 5 Kg/cm^2 live steam used in the Coke Plant is now operated at 3.5 Kg/cm^2 and sometimes even lower. This results in the flow of higher pressure process streams into the steam system, thereby contaminating the steam/condensate system. This problem can be avoided by installing non-return valves in stripping steam lines.

Moreover, some of the heat exchangers in reboiler service are leaking process fluids into the condensate thereby contaminating the condensate return. Contaminated condensate is presently drained to grade. If the condensate were clean it could be recovered using the present plant condensate collection header. This problem can be solved by repairing the leaking tubes in the heat exchangers.

3.0 EQUIPMENT LIST/SIZE

Suspected leaky exchangers are:

1. Benzol plant #1 Reboiler
2. Benzol plant #2 Reboiler
3. Tar Plant #1 Reboiler
4. Tar Plant #2 Reboiler

Non-return valves required:

5 - 3" size
2 - 4" size
1 - 6" size

4.0 PREDICTED ENERGY SAVINGS

The anticipated annual energy saving after implementing above changes would be:

Annual Energy Savings	
T.O.E.	Ton mazout
1460	1504

Energy losses were calculated only due to leaky exchangers. Energy savings achieved due to addition of non-return valves are indirect and therefore no calculations were performed.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The total investment cost to repair the leaky heat exchangers and install 8 non-return valves and associated piping is listed below. Figures are based on worldwide and local equipment and utility costs.

Investment Cost		Annual Cost Savings	
$	LE	$	LE
9,111	20,408	168,553	42,112

6.0 CONCLUSIONS

Condensate contamination should be eliminated by repairing the leaking tubes and by installing non return valves in the stripping steam lines.

7.0 RECOMMENDATIONS

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

GENERAL

INSTITUTE A PERMANENT PROGRAM FOR STEAM TRAP TESTING

Annual Savings, TOE	:	347
Annual Savings, $	:	40,009
Investment Cost, $	:	14,610
Payout: Simple, Yrs	:	0.37
DCF , %	:	--

ECO-25

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 ECO-06 and ECO-18, 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.

Frequency: As noted on Page 1.

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-6 and ECO-18, it was noted that the estimated steam loss at this time from defective traps for the entire plant is 5792 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 408 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
347	357

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	17
Cost to replace traps, $	11,950
Cost to tag traps and purchase ultrasonic test equipment, $	2,660

Total Investment		Annual Cost Savings	
$	LE	$	LE
14,610	32,873	40,009	9,996

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 there are only 120 steam traps in El-Nasr, the cost of testing the steam traps either by plant personnel or by the manufacturer's representative, is low.

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.

134

GENERAL

STUDY THE EFFECT OF INSULATION ON HEAT LOSS FROM PIPES.

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

ECO-26

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	3675	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.

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-27

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

138

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 are properly attended by operating staff the same savings can be realized without investment in a fuel air ratio control system. In the coke and fertilizer plants 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.

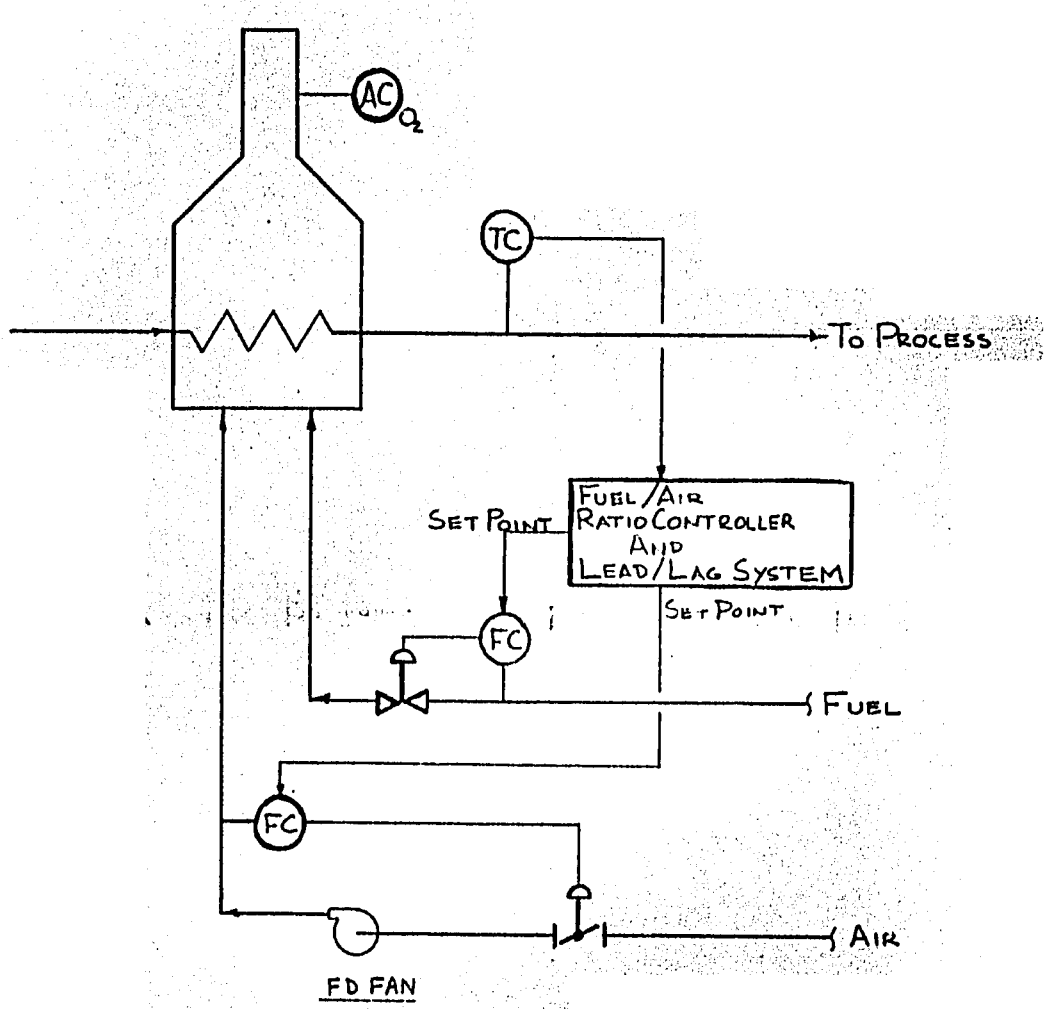
7.0 RECOMMENDATIONS

This ECO is not recommended. 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.

140

JOINT ENGINEERING GROUP
OEP / FWEC
FOR: EL-NASR Co.

REF. 11-36598
DATE MAY 1988
PAGE
REV.



PROCESS SKETCH

ENERGY CONSERVATION OPPORTUNITY

ECO 27

PLANT EL-NASR

LOCATION HELWAN, EGYPT

LEGEND

EXISTING EQUIPMENT
NEW EQUIPMENT

GENERAL	Annual Savings, TOE	: Not
	Annual Savings, $	: Required
CAPACITOR INSTALLATION	Investment Cost, $	: (See Text)
TO IMPROVE POWER FACTOR	Payout: Simple, Yrs	: "
IN THE FERTILIZER PLANT	DCF , %	: "

ECO-28

1.0 PURPOSE

The purpose of this ECO is to improve the existing electrical system power factor from the current value.

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-30 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

The El Nasr chemical plant electrical system consists of two 66 kV incoming feeders to the utility 66 - 6.3 transformer substation which feeds the plant via four 1000 amp, 10% reactors.

The metering, though perhaps adequate for operation, is not suitable for power profile monitoring and needs calibration and updating.

The plant operations utilize several synchronous motors and capacitors on 2 substations to supply plant and kVAr demand. The meters indicated a 0.98 power factor, though by calculation it appears to be approximately 0.95.

3.0 EQUIPMENT LIST/SIZE

Not applicable.

4.0 PREDICTED ENERGY SAVINGS

Not applicable.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATIONS

Not applicable.

6.0 CONCLUSIONS

A power factor of 0.95 is excellent. Further improvement would be unrealistic. No capacitors are required in the Fertilizer Plant.

7.0 RECOMMENDATIONS

This ECO need not be implemented.

143

GENERAL	Annual Savings, TOE :	299.
	Annual Savings, $:	51,027.
CAPACITOR INSTALLATION	Investment Cost, $:	565,600.
TO IMPROVE POWER FACTOR	Payout: Simple, Yrs :	11.08
IN THE COKE PLANT	DCF , % :	< 1.

ECO-29

1.0 PURPOSE

The purpose of this ECO is to improve the existing electrical system power factor from the current value.

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-31 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

The present Coke Plant 6.3 kV distribution system appears in need of up-grading. Replacement with modern gear should include proper metering for power flow monitoring and two 2-step capacitors for each double ended switchgear and/or variable frequency drives for power factor improvements. Based on verbal information, there are plans for upgrading.

Based on observations and verbal information, the plant gas exhausters, pumps and crushers are running at 2/3 and below of full load, thus contributing to a low power factor of approximately 0.7.

Lacking proper documentation, this ECO can only provide approximate guidelines for a power factor correction 2-step capacitor system, connected to a 6.3 kV bus via switch gear breakers, and controlled by power factor (55) relays.

3.0 EQUIPMENT LIST/SIZE

The electrical equipment required for this ECO will be two 2-step capacitor banks of required kVAr and voltage rating, P.F. relay controlled circuit breakers, fused switches and cabling as required.

144

The equipment required is listed below.

	Capacitor Banks kVAr	kV	Steps	Switch gear Units	Controllers Units
SWGR1	4x750,	6.3	2	4	2
SWGR2	4x750,	6.3	2	4	2

4.0 PREDICTED ENERGY SAVINGS

Based on old plant estimates of a 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.

Coke Plant Annual kWH	Reduced estimated system losses	Annual Energy Savings kWh	T.O.E.[1]
29,667,000	4%	1,187,000	299

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
565,600	51,027	20,174

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 can be implemented with 6.3 kV switch gear upgrading work.

---

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

M5

GENERAL		
	Annual Savings, TOE	: Not
	Annual Savings, $	: Required
INVESTIGATE ENERGY	Investment Cost, $	: (See Text)
SAVINGS BY CHANGING DRIVE	Payout: Simple, Yrs	: "
CONTROLS IN FERTILIZER PLANT	DCF , %	: "

ECO-30

1.0 PURPOSE

The purpose of this ECO is to incorporate variable frequency speed controllers into the plant electrical distribution system. The variable frequency/voltage controllers (VFC) will match kW consumption to load requirements and thus provide considerable kW/kVAr savings.

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.

2.0 PROCESS DESCRIPTION

Based on verbal information received from plant personnel, and visual observations of running ammeters, there are no apparent requirements for variable frequency controllers at the El-Nasr Fertilizer Plant. All running motors appear to run above 80% of full load.

3.0 EQUIPMENT LIST/SIZE

Not applicable.

4.0 PREDICTED ENERGY SAVINGS

Not applicable.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC ANALYSIS

Not applicable.

6.0 CONCLUSIONS

No significant energy saving is achievable through upgrading of existing drive controls.

7.0 RECOMMENDATIONS

This ECO should not be implemented.

146

GENERAL

INVESTIGATE ENERGY SAVINGS BY CHANGING DRIVE CONTROLS IN FERTILIZER PLANT

Annual Savings, TOE	:	435
Annual Savings, $	:	74,242
Investment Cost, $	:	2,192,100
Payout: Simple, Yrs	:	29.5
DCF		<1.0

ECO-31

1.0 PURPOSE

The purpose of this ECO is to incorporate variable frequency (speed) controllers into plant electrical distribution system. The variable frequency/voltage controllers (VFC) will match kW consumption to load requirements and thus provide considerable kW/kVAr savings.

This ECO as well as ECO-29 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 verbal information and power factor (PF) spot checks, the motor drives in coke plant appear under-utilized at apparent 2/3 of full load or less.

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

a) Soft start i.e., no star-delta or start-up resistor controllers are required.
b) Corrected motor power factor.
c) Energy savings by matching power consumption to load requirements.
d) Savings by eliminating restrictive control vanes, throttling valves, recirculation systems.

Controllers do require reasonably clean, ventilated rooms, as in a normal substation area. The variable frequency controller (VFC) would replace existing 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 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 loads.

	kW	Controller kW	kV
2 pumps	400 ea.	500 ea.	6.3
2 initial crushers	250 ea.	300 ea.	6.3
2 crushers	500 ea.	600 ea.	6.3
1 crusher	400	500	6.3
1 gas exhauster	400	500	6.3
2 gas exhauster	630 ea.	750 ea.	6.3

4.0 PREDICTED ENERGY SAVINGS

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

Depending on load, a 5-15% savings of the power consumption is a reasonable expectation.

Annual Energy Savings	
T.O.E.[1]	kWh
435	1,726,560

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

The final economic evaluation would be part of the power distribution system revamp, hence the below investment evaluation will serve as a guide only.

The investment cost is based on worldwide pricing. The energy cost savings is based on worldwide and local utility costs.

Investment Cost	Annual Energy	
	Cost	Savings
$	$	LE
2,192,100	74,242	29,352

---

[1] Electrical 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

The incorporation of VFC's into new plant distribution system will:

a) reduce power losses in distribution system and in processing equipment;
b) reduce capacitor's size, as recommended in ECO-29;
c) eliminate need for reduced voltage starting equipment;
d) improve process equipment control.

7.0 RECOMMENDATION

This ECO could be implemented as part of the electrical power distribution system upgrading, or by installing individual controllers selectively.

GENERAL	Annual Savings, TOE	:	1,489.
	Annual Savings, $	:	185,537.
IMPROVE, ADD OR FIX INSTRUMENTATION TO BE ABLE TO PROPERLY MONITOR AND CONTROL ENERGY CONSUMPTION	Investment Cost, $	:	750,970.
	Payout: Simple, Yrs	:	4.05
	DCF , %	:	12.00

ECO-32

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 estimated equipment and material required is described below. The material of construction is carbon steel, except where it is specified differently. Refer to Appendix 8 for location of individual instruments.

6 Temperature Recorders
1 Multi-point temperature indicator
66 Temperature indicators
2 Flow Recording controllers
64 Flow indicating controllers
4 4" Rotameters - armored
13 2" Rotameters
4 3" Rotameters
12 Level Recording Controllers
10 Pressure Recorders
76 Pressure Indicators
3 Alarms
7 Conveyor Rope Switches
6 2" Control Valves

Electrical:

Permanent metering and recording equipment to monitor MW, kVAr and current (amperes) in both the Coke and Fertilizer Plants.

150

4.0 PREDICTED ENERGY SAVINGS

The instrumentation in the Coke and Fertilizer Plants is in very poor condition and require majors revamping to effectively monitor energy consumption.

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

Electrical Annual Energy Savings	
T.O.E.[1]	MWh
248	984

Mazout Annual Energy Savings	
T.O.E.	Tons
540	556

Coke Oven Gas Annual Energy Savings	
T.O.E.	Cu. M.
652	1,487,680

Blast Furnace Gas Annual Energy Savings	
T.O.E.	Cu. M.
1.0	10,500

Tar Oil	
T.O.E.	Tons
48	64

TOTAL		
T.O.E.	Ton Mazout	MWH
1489	1278	984

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

Annual cost savings are based on the total energy saved having the cost of purchased mazout.

The total investment cost to purchase and install the necessary instruments and the associated piping and materials described is below:

Investment		Annual Cost Savings	
$	LE	$	L.E.
750,970	1,682,170	185,537	52,512

---

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

6.0 CONCLUSIONS

We strongly recommend that all the instruments shown in the preceding tabulations be added or repaired, not only to help conserve energy, but to properly monitor its consumption.

7.0 RECOMMENDATIONS

This ECO should be implemented without any delay.

GENERAL

DEVELOP AND IMPLEMENT A FORMAL EQUIPMENT MAINTENANCE PROGRAM

Annual Savings, TOE	:	Extensive
Annual Savings, $	:	"
Investment Cost, $	:	0
Payout: Simple, Yrs	:	Immediate
DCF , %	:	"

ECO-33

1.0 PURPOSE

The purpose of this ECO is to outline some basic elements of a formal equipment maintenance program for a chemical plant, such as that of El Nasr Coke and Chemical Company.

2.0 PROCESS DESCRIPTION

Maintenance is a very important and essential adjunct to efficient and profitable operations in a chemical plant. If maintenance is neglected, unexpected and untimely failures occur with costly interruptions to plant operations. It has been demonstrated by world class chemical plants that the availability of operating facilities producing a premium product can be increased to a very high level, approaching 100 percent, with a well planned preventive maintenance program. This remarkable achievement has been brought about in part by careful inspection and meticulous documentation of operating hours, service life and failures. With a quantitative data base and the application of statistical analysis, breakdowns or component failure are accurately predictable, and scheduled repairs are made in a minimum amount of time without interruption to operating schedules and unnecessary delays. These efforts payback in terms of superior product quality, performance and profitability.

ADMINISTRATION

There are a few basic elements that makeup an effective maintenance program. For one, it is assumed that a structured organization is in place to provide the administrative and supervisory skills required on a day-to-day basis. As a separate and distinct administrative unit, the maintenance organization generally functions independently, but cooperatively with operating management to achieve cost and production standards as well as mutually satisfactory scheduling requirements.

SPARE PARTS

At the heart of any maintenance program is an adequate complement of spare parts, which can be provided either as in-house spare or by immediate access to pre-arranged vendor stocks. Spare parts should be categorized as critical spares and consumable spares. Critical spares are those long delivery items identified with key operating units, whereas

19

consumable spares are those components with a predictable or rated service life, such as bearings, etc., that are usually available "off the shelf" from suppliers. It is obvious that it is the critical spare part that must be ordered well ahead and kept on hand in the event of an unscheduled maintenance failure.

SPARES CONTROL

All spares should be cataloged, using something as simple as a manually maintained card index file, where the spare part is completely identified and, where appropriate, related to a bill of material on an engineering drawing. This kind of system will allow for inventory control and repurchases. A more sophisticated system would store this type of information in a computer along with a drawing index for each facility. It is vital that management knows what spares are on hand and their location to avoid the time-consuming search for a missing part.

CENTRAL SPARES STORAGE

It has been demonstrated that a central storage area for plant-wide spares is very cost effective, as opposed to scattering spares all over the plant in unprotected and poorly secured environments without any particular control. A central spares concept avoids duplication of parts, thereby minimizing the number of spares on hand with consequent savings in inventory costs. A central spares storage enhances the ability to control disbursements and purchase of replacement parts. Typically, a central spares storage area is a warehouse type of structure equipped with numerous bins and racks for such items as gears, couplings, shafts, motor coils, contactors, relays and many other such items. Central spares functions separately and independently of the plant storehouse. It is usually manned around-the-clock with clerical type workers who maintain spare part records as well as dispense spare parts on a shift-by-shift basis. As an example, many chemical plants maintained spares on a departmental basis, with each department handling its own procurement and storage. It was found that this practice resulted in much duplication from one department to another. For instance, each department kept its own complement of spare motors, when many of the motors were duplicated in other areas. With the consolidation of spare motors into a central pool, the total plant inventory could be reduced by as much as 50 percent with consequent savings. This same principle generally holds true for every commodity used in the plant. It is apparent that the central spares concept allows for better housekeeping and the protection of an expensive inventory of spare parts.

STANDARDIZATION

There are inherent advantages and cost savings associated with standardizing equipment and component design throughout the plant. This is primarily an engineering responsibility working with maintenance and operating personnel on new designs or rearrangements as well as procurement. A standardization program will facilitate the training of maintenance personnel and technicians because there are fewer dissimilar types of equipment to work with, which should reduce the total amount of work. Over time, a standardization program will reduce the amount of spares required to support the operations, but it must be remembered that any standardization program must be tempered by the usual competitive nature of purchasing. It is unlikely that anyone would want a single source of supply for any commodity, except in very unusual situations.

TRAINING

One important but often neglected facet of a maintenance program is training a work force. Acquainting maintenance personnel with proper job procedures and making them familiar with operating facilities is aided by formal classroom instruction, using competent teachers, service manuals and as much hands-on experience as a classroom can provide. This is particularly important where new and more sophisticated facilities are introduced into the plant, which can only operate at an acceptable level of performance and product quality with adequate routine maintenance of the machine and instrumentation. This can best be achieved by taking the time to train the whole work force, because the same philosophy pertains not only to maintenance personnel but to operating crews as well.

TOOLS

Together with trained workers and adequate spares, it is equally important to have sufficient tools and supplies for effectively accomplishing the routine maintenance tasks or repairing of major breakdowns. Many times, tool and supplies are housed in an attended maintenance tool room to provide close control. Tool repairs are usually done in this type facility, also.

INSPECTION

Inspection programs implemented on a regular basis are vital to ongoing plant maintenance activity. This enables work to be scheduled in an orderly manner, and many times potential problems can be uncovered before breakdowns occur or resources are wasted. This is the antithesis of the "if it isn't broken, don't fix it"

philosophy. Periodic inspections and good records lay the groundwork for a viable preventive maintenance program.

LUBRICATION

Lubrication schedules should be established for all operating facilities, including overhead cranes. Catastrophic failures can occur through simple neglect of lubrication.

HOUSEKEEPING

Cleaning schedules are setup, particularly for rotating electrical equipment. Motor and generators are blown clean with air, thoroughly checked and painted, many times on annual basis. This is done to remove a buildup of dust, common in coke plants, that can cause motors to fail. Housekeeping standards are enforced for motor rooms and substations and most other areas of the plant.

With a dedicated maintenance organization in place, supported by the factors discussed above, good maintenance becomes a ritual or accepted philosophy, particularly when the benefits become visible to senior plant management.

2.1 PHYSICAL WORK REQUIRED

It is not expected that there will be any quantifiable amount of physical work associated with the initial implementation of the ECO. However, as the plant expands in the coming years, additional maintenance facilities will be required for spares storage, specialized repair areas, tools and miscellaneous test instruments for maintenance of new facilities.

3.0 EQUIPMENT LIST/SIZE

No new equipment is required for the initial implementation of the ECO.

4.0 PREDICTED ENERGY SAVINGS

Good maintenance practices will unquestionably yield generous cost savings. Although the savings may be unquantifiable, as viewed in total scope. However, as individual cost reduction projects are undertaken, they can be individually evaluated in terms of payout.

5.0 INVESTMENT AND ASSOCIATED ECONOMIC EVALUATION

Not applicable.

6.0 CONCLUSIONS

Good maintenance practices should be adopted immediately as a matter of course, because sophisticated machinery will not operate if neglected. Controllers and instrumentation must be regularly calibrated and adjustments continually made. The sooner new practices are adopted and old habits abandoned, the greater the likelihood of high levels of performance and profitability.

7.0 RECOMMENDATION

This ECO should be implemented.

GENERAL		
	Annual Savings, TOE :	Not
	Annual Savings, $:	Applicable
FORM A COMMITTEE TO PLAN	Investment Cost, $:	(See Text)
AND IMPLEMENT AN ENERGY	Payout: Simple, Yrs :	"
CONSERVATION PROGRAM	DCF , % :	"

ECO-34

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 both the in-country housekeeping items, in-country investment items, and 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 concrete plan for energy conservation implementation. Its first priority is to begin implementation of in-country housekeeping items 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 continue to closely 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, $	:	(See Text)
Payout: Simple, Yrs	:	"
DCF , %	:	"

ECO-35

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 the Appendix.

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 as the second implemented in-country housekeeping ECO.

161

ORGANIZATION for
ENERGY
PLANNING

PD-AAY-012
ISN 56877

جهاز تخطيط الطاقة

263-0123.01

ENERGY AUDIT

of the

El-Nasr Company for Coke and Chemicals

Helwan, Egypt

May, 1988

VOLUME 2 of 2 - APPENDICES

Produced through the joint engineering effort of:

* EL-NASR COMPANY FOR COKE AND CHEMICALS (EL-NASR)
* FOSTER WHEELER USA CORPORATION (FWUSA)
* ORGANIZATION FOR ENERGY PLANNING (OEP)

O.E.P. تلكس دولى ٢٣٤٠٤ ١ شارع عائشة التيمورية - جاردن سيتى - القاهرة
1, Aisa. El-Taymorya — Garden City, Cairo Phone 355-7113 356-4576 Telex. 23404 O.E.P.

162

APPENDICES

APPENDIX

1 BASIC ENGINEERING DATA

2 PORTABLE INSTRUMENT LIST

3 FERTILIZER PLANT FLOW DIAGRAMS

4 ECO-34 : FORM A COMMITTEE TO PLAN AND IMPLEMENT ECO's (Pg. 269-326)

5 ECO-35 : PUBLICITY TO MAKE EMPLOYEES AWARE OF IMPORTANCE OF ENERGY CONSERVATION (Pg. 327-331)

6 ECO-28,29 : TECHNICAL ARTICLES REFERRING TO POWER FACTOR CORRECTIONS

7 DISCOUNTED CASH FLOW GRAPH

8 ECO-32 : LIST AND LOCATION OF INSTRUMENTS NECESSARY TO PROPERLY MONITOR ENERGY CONSUMPTION

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 330

2.1.2 Number of shifts per day 3, 7 days/week

2.1.3 Normalized number of operating hours per year 7920

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)

165

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 the steam price.

166

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	

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 Indicator
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 Ampere
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

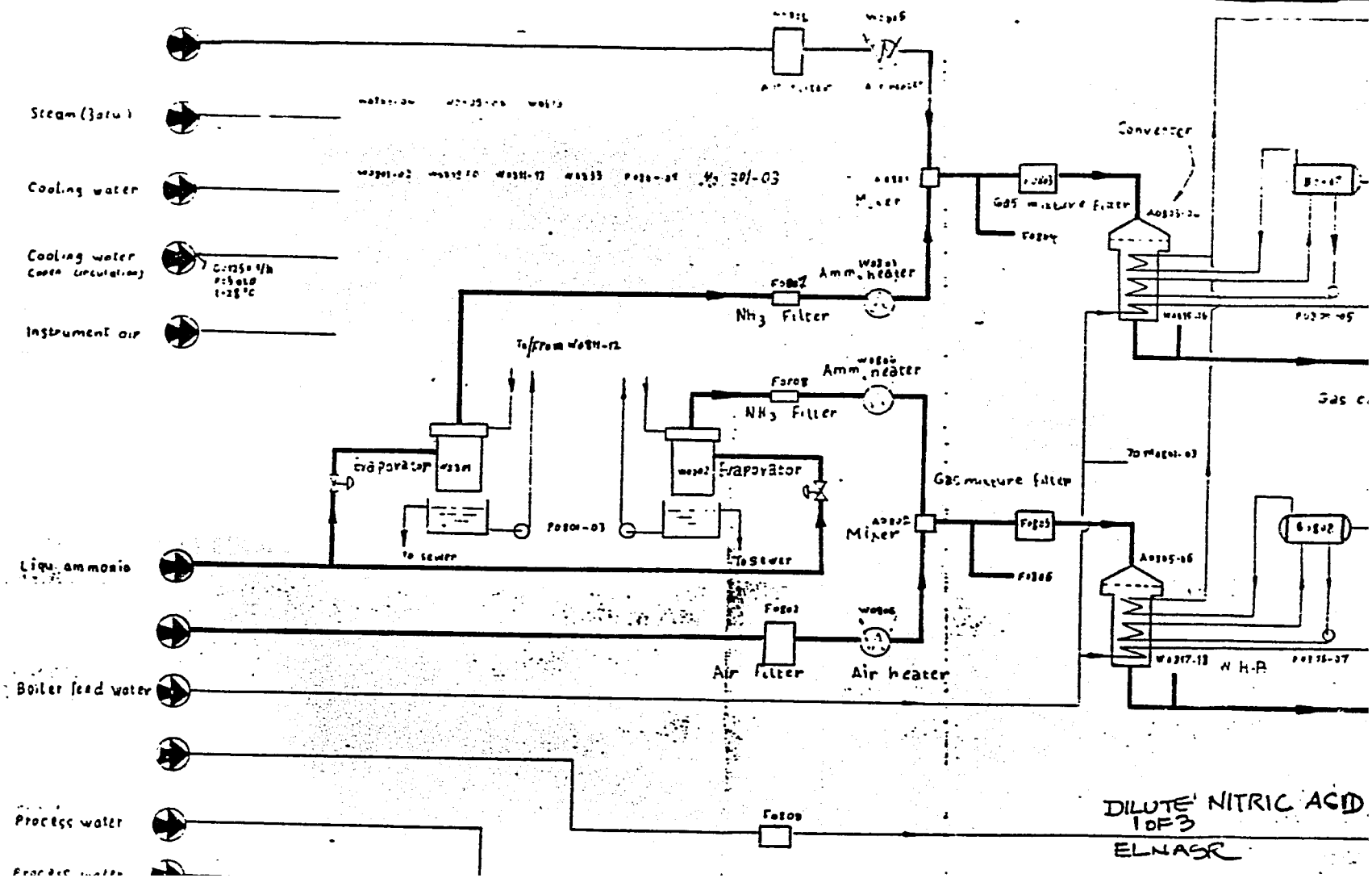
** Includes extra chart paper(10 rolls amp/10 rolls volt)

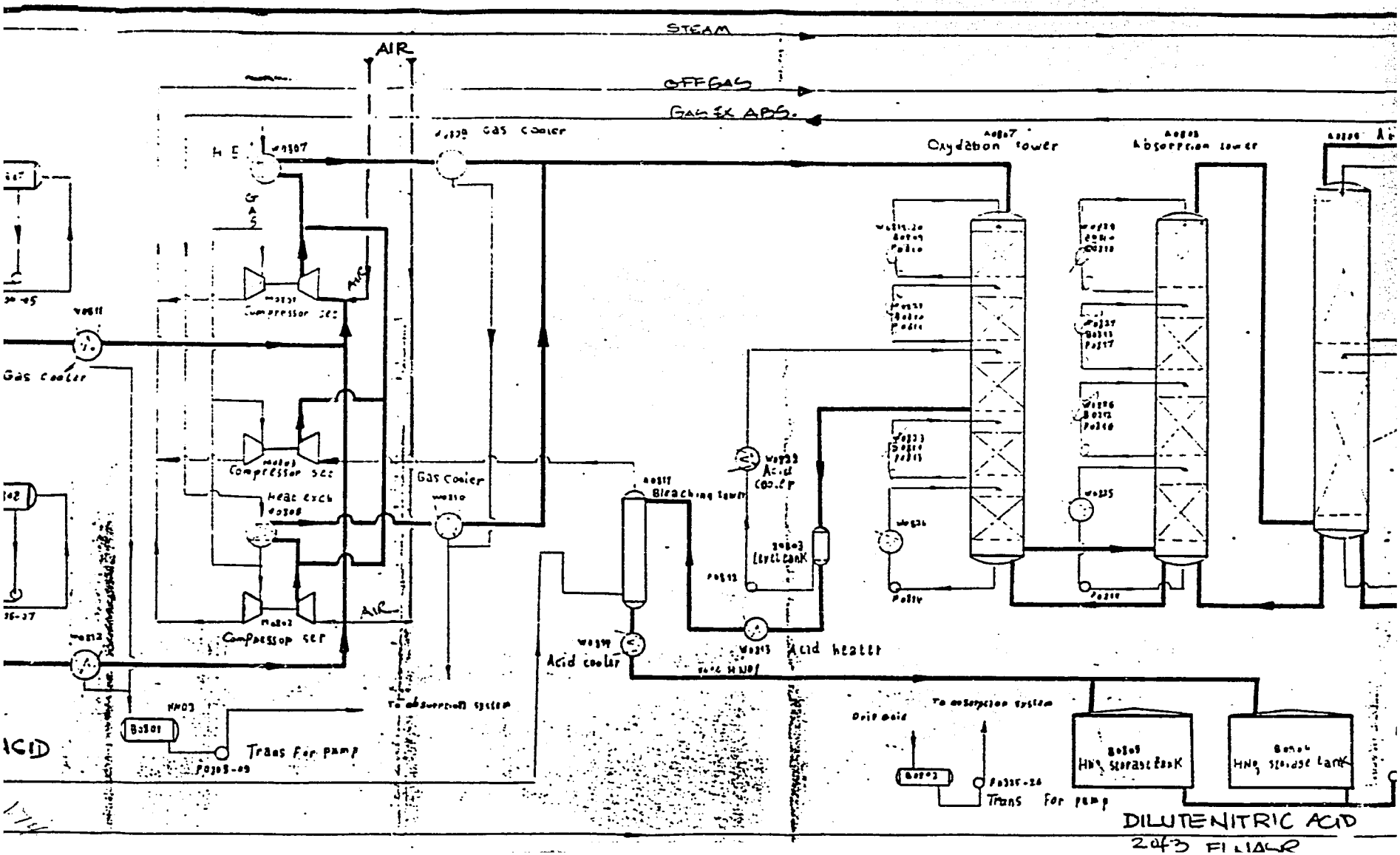
*** Includes additional red gauge oil (1 quart bottle and 5ea 3/4oz. bottle

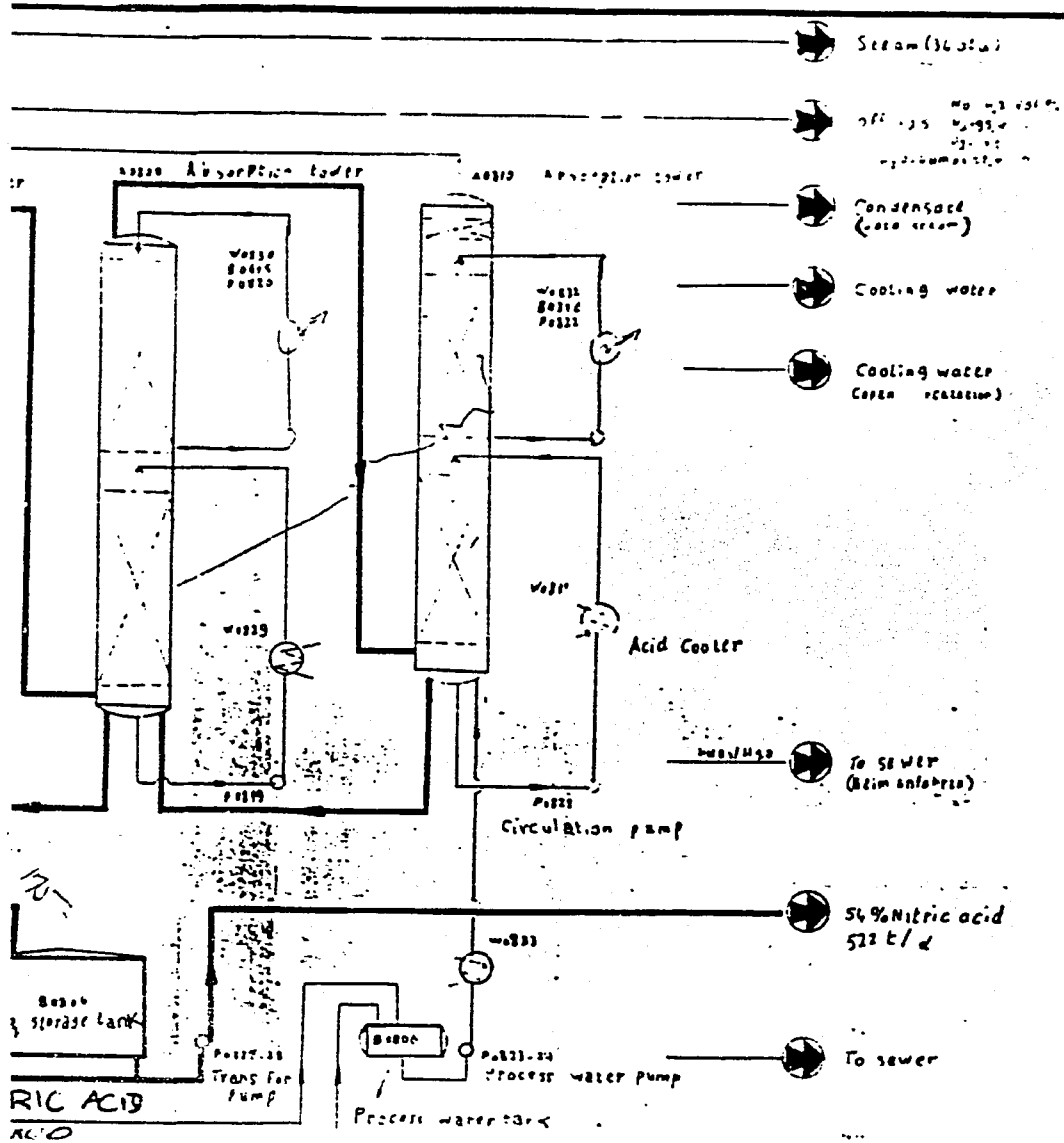
*** Includes following consummables:

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)

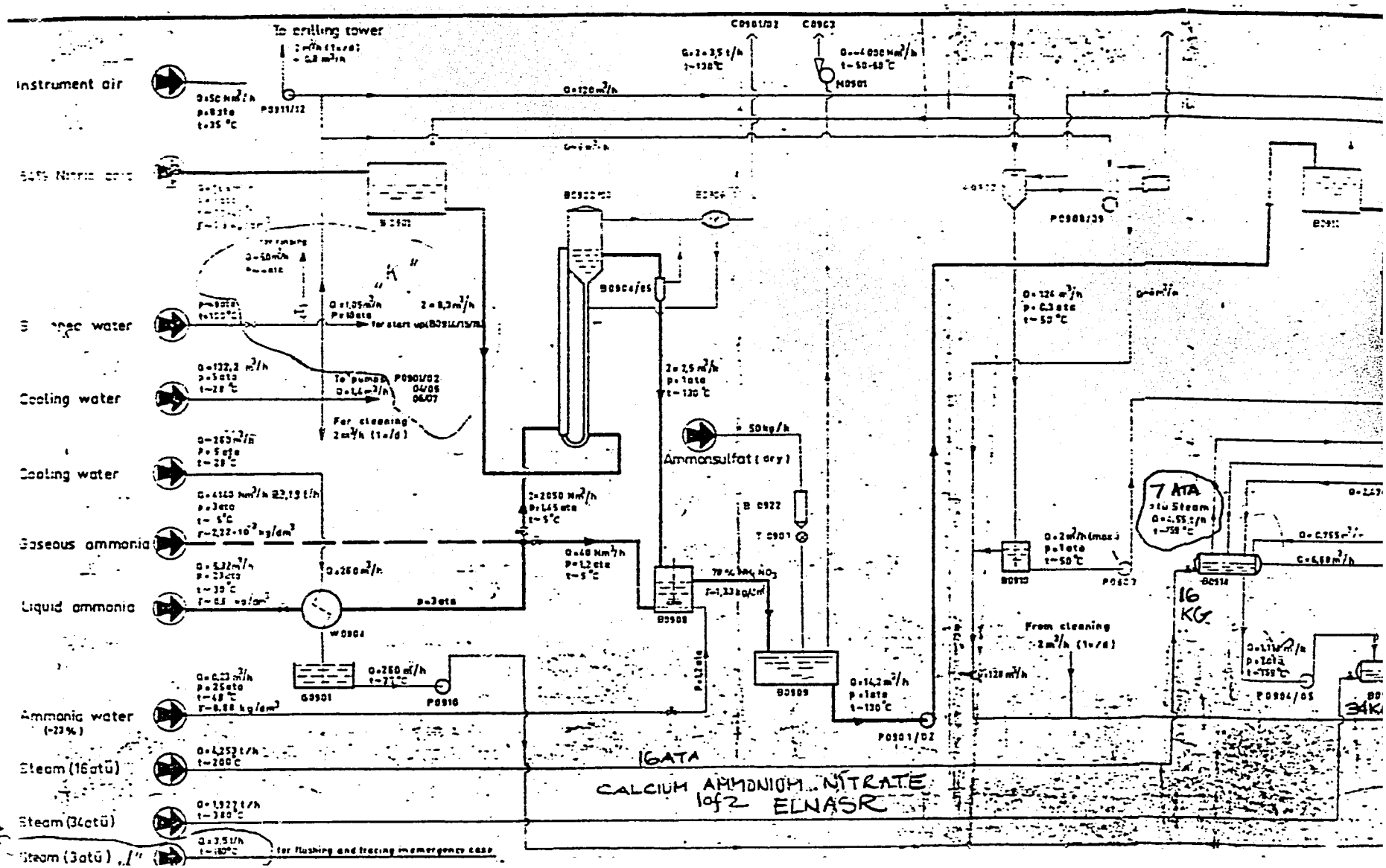
172

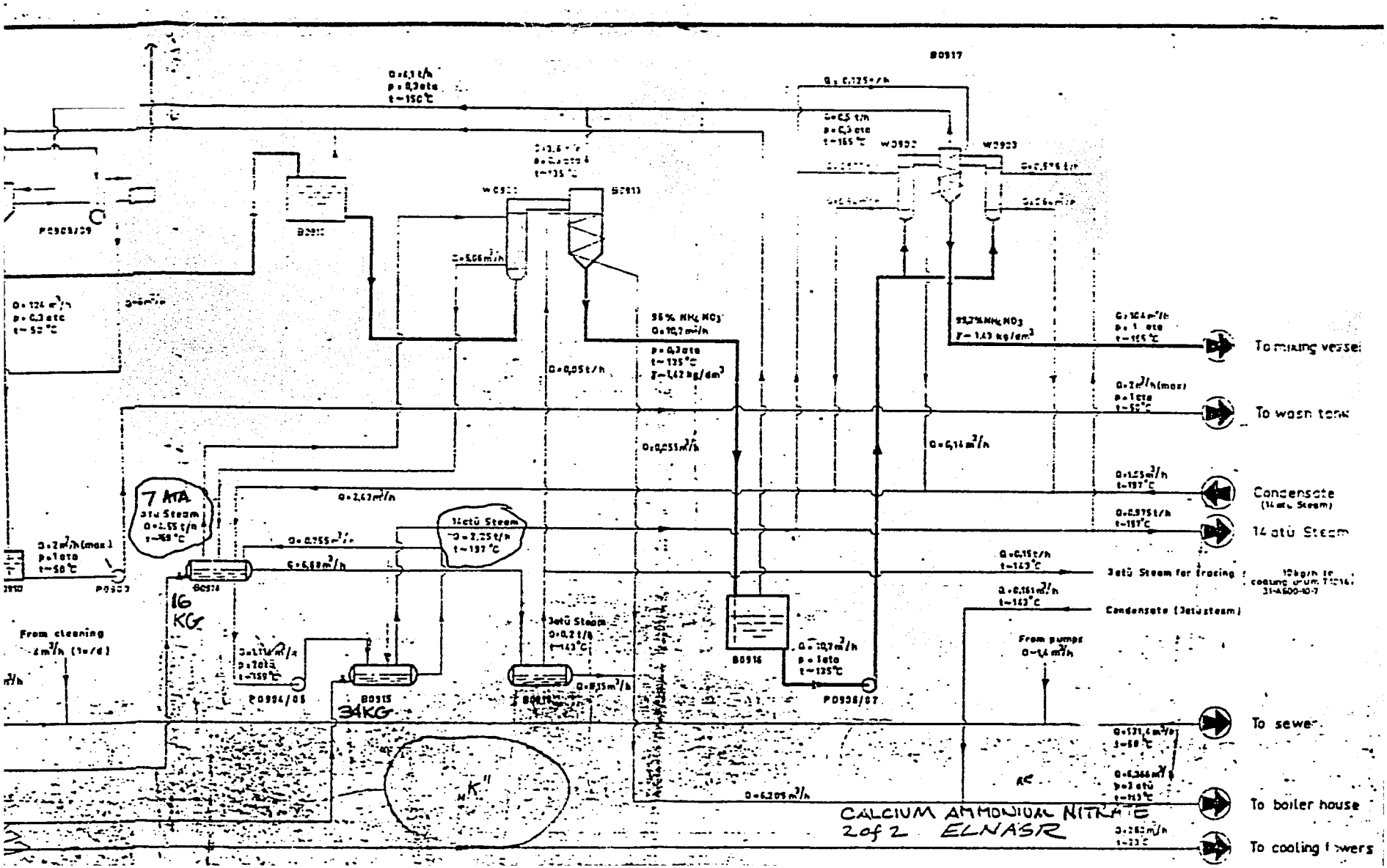

Steam (3atu)
Cooling water
Cooling water
Instrument air
Liqu. ammonia
Boiler feed water
Process water
Converter
Gas mixture filter
Mixer
Amm. heater
NH3 Filter
Evaporator
To sewer
Air filter
Air heater
N H-P
DILUTE NITRIC ACID
1 OF 3
ELNASR

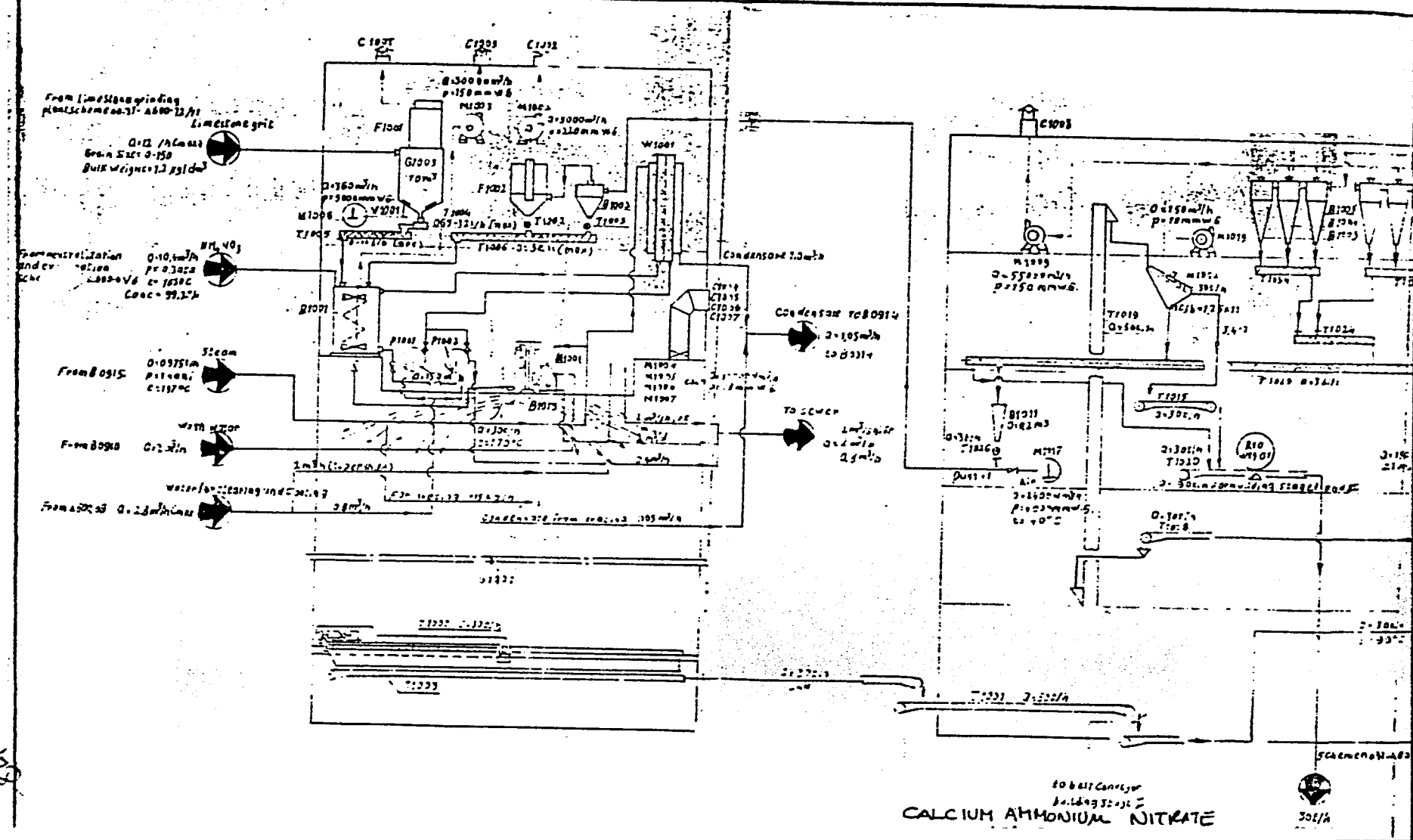

STEAM
AIR
OFFGAS
GAS EX ABS.
Gas Cooler
Oxydation tower
Absorption tower
Compressor set
Compressor set
Compressor set
Gas Cooler
Gas Cooler
Bleaching tower
Acid cooler
Level tank
Acid cooler
Acid heater
To absorption system
Trans for pump
To absorption system
Trans for pump
HNO3 Storage tank
HNO3 Storage tank
DILUTE NITRIC ACID
2043 FILLAR

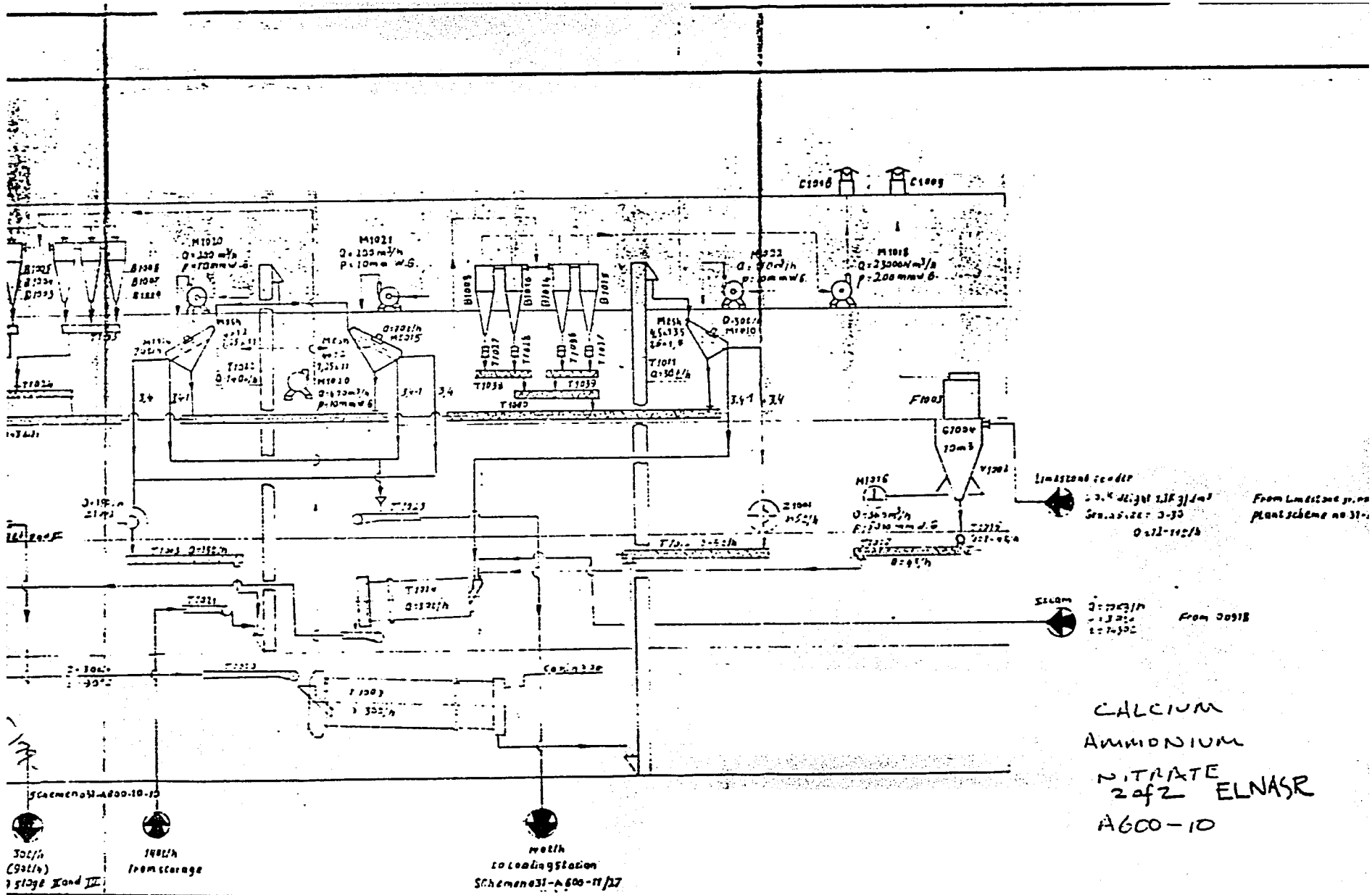


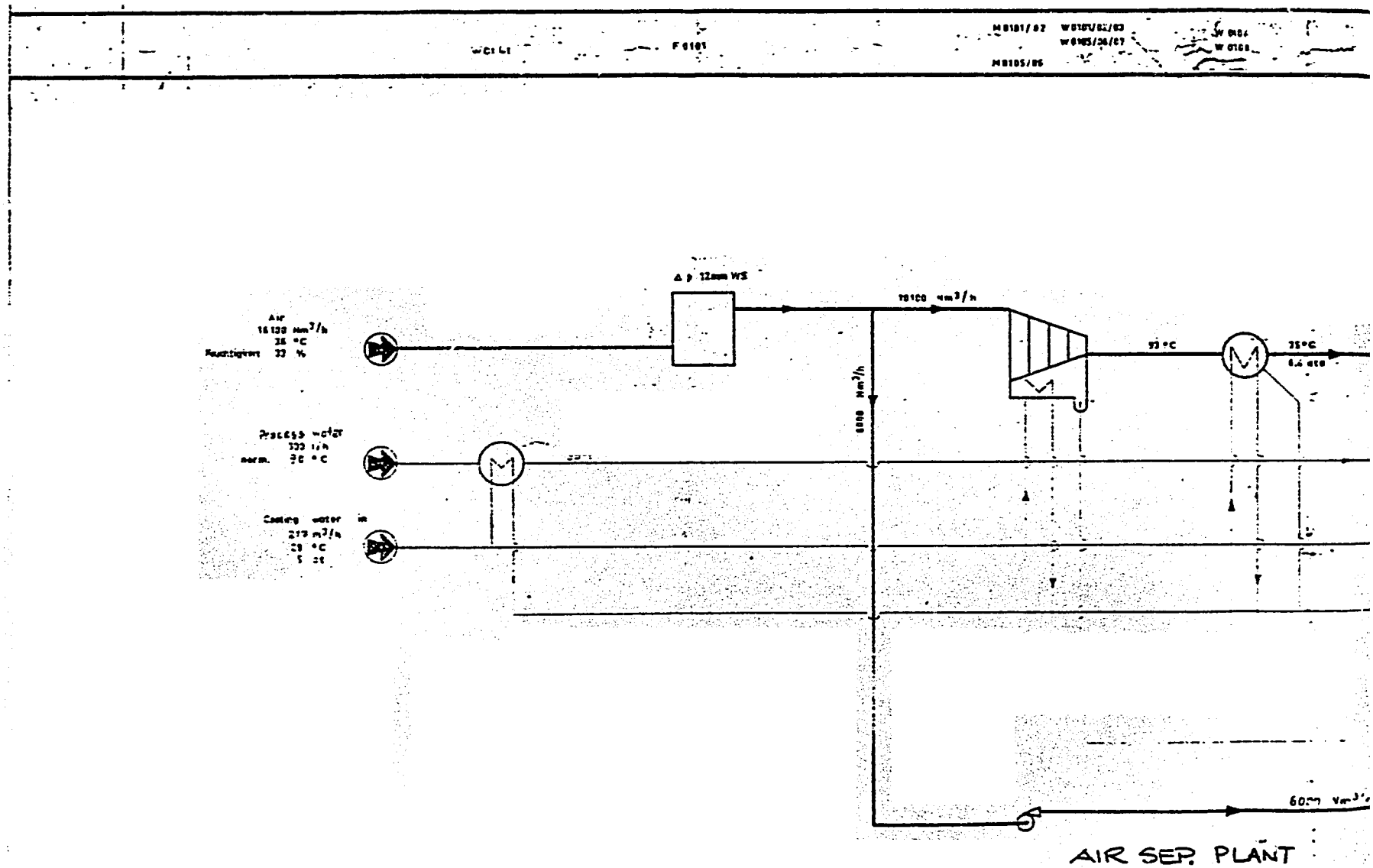
DILUTE NITRIC ACID.
PAGE 3 OF 3
ELNASR
DWG. No 8/5

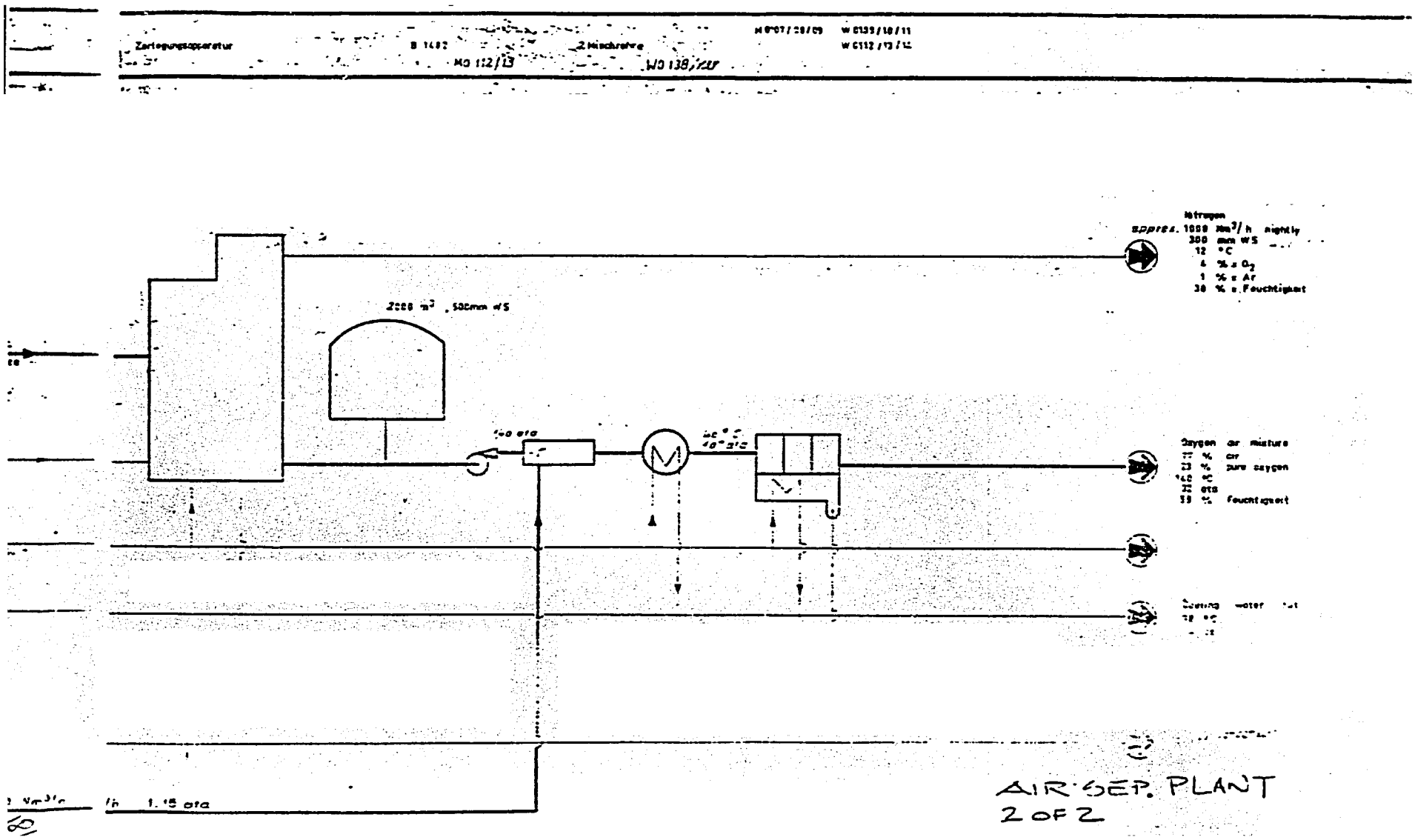

To prilling tower
Instrument air
Cooling water
Cooling water
Gaseous ammonia
Liquid ammonia
Ammonia water
Steam (16atü)
Steam (34atü)
Steam (3atü)
Ammonsulfat (dry)
7 ATA
16 KG
34 KG
16ATA
CALCIUM AMMONIUM NITRATE
1of2 ELNASR


To mixing vessel
To wash tank
Condensate
(14 atü Steam)
14 atü Steam
3atü Steam for freezing
Condensate (3atü steam)
To sewer
To boiler house
To cooling towers
From cleaning
From pumps
7 ATA
3atü Steam
14atü Steam
3atü Steam
16 KG
34KG
95% NH4NO3
CALCIUM AMMONIUM NITRATE
2 of 2 ELNASR


CALCIUM AMMONIUM NITRATE


CALCIUM
AMMONIUM
NITRATE
2 of 2 ELNASR
A600-10
From Limestone
plant scheme no 31-
From 3091B
Steam
Limestone feeder
Scheme no 31-A600-10-10
Scheme no 31-A600-11/17
from storage
to loading station


Air
Process water
Cooling water in
93 °C
AIR SEP. PLANT



AIR SEP. PLANT
2 OF 2

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

182

2. ENERGY CONSERVATION PROGRAM IMPLEMENTATION

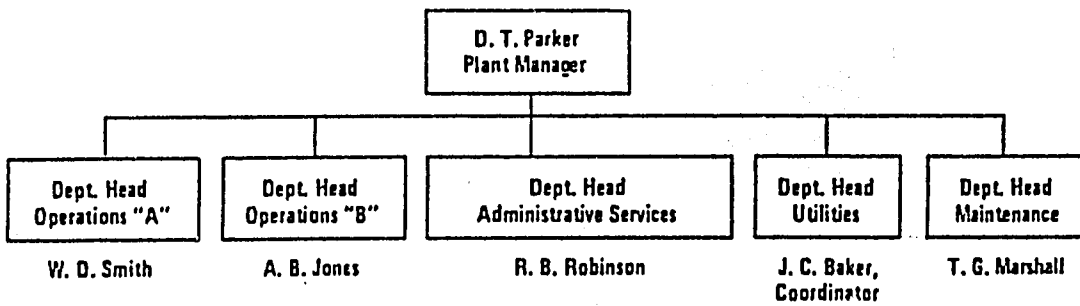
2.0 INTRODUCTION

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	

	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	2.3.1, 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.
D. Analyze all process energy balances in depth:	2.5.
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 2.5
F. Plan surveys on specific systems and equipment, such as:	2.5
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
B. List all energy conservation projects evolving from energy balance analyses, surveys, etc. Evaluate and select projects for implementation:	

184

	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	

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.

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.

savEnergy

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.

232

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.

savEnergy

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.

savEnergy

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

savEnergy

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

savEnergy
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

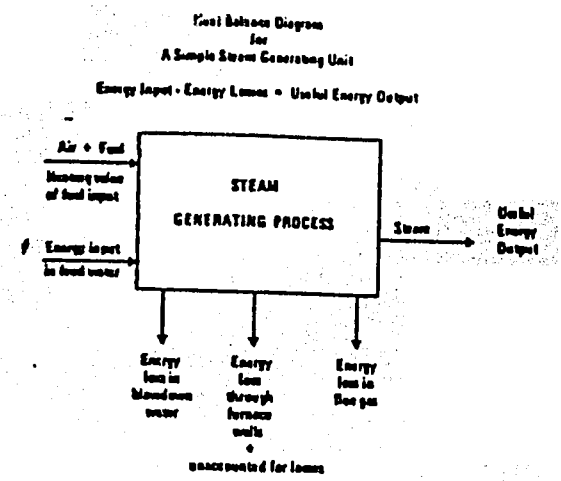
From: Energy Saving Survey Team
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

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.

savEnergy

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 wat . Identify all sources of condensate and evaluate economic feasibi ty of installing pump and insulated piping to return condensate to b ler feedwater tank. If condensate is contaminated, evaluate possible ean-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

savEnergy

ECONERGY COMPANY

INTER-OFFICE CORRESPONDE

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 savi 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 Bt of heat. But due to power plant inefficiency, approximately 10,000 Bt 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 equivalen 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	$_____/MBt
Fuel Oil	$_____/gal	_____Btu/gal	$_____/MBt
Coal	$_____/ton	_____Btu/lb	$_____/MBt

280

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

savEnergy

201

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

202

2.5.6

ECONERGY COMPANY

INTER-OFFICE CORRESPONDE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinat
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

203

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.

savEnergy

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.
PRODUCT 1
PRODUCT I.D. NO. 2

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			

TOTAL UNITS PRODUCED 3

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.
REPORTED BY: R. G. Snyder, Jr.
PRODUCT: 1 Ethylene
PRODUCT I.D. NO.: 2 007-23-1

RAW MATERIAL ENERGY (LIST MAJOR RAW MATERIALS)

4 RAW MATERIAL	5 TOTAL UNITS	x 6 BTU'S UNIT	= 7 TOTAL BTU'S
A: Ethane	32.29×10^6	27,304/lb	1166.3×10^9
B: Caustic Soda	252×10^3	12,500/lb	3.2×10^9
C: Hydrogenation Cat	6.048×10^3	75,000/lb	5×10^9
D: Desiccant	1.112×10^3	50,000/lb	1×10^9
E:			

TOTAL BTU'S 8 1170.1×10^9

TOTAL UNITS PRODUCED 3: 42,000,000

UNITS OF PRODUCTION (LB., GAL., PIECES, ETC.): Pounds

CONVERSION ENERGY (LIST ALL MAJOR UTILITIES)

9 UTILITY	10 TOTAL UNITS	x 11 BTU'S UNIT	= 12 TOTAL BTU'S
A: Steam, 150 psig	181.31×10^6	1077/lb	195.3×10^9
B: Electricity, KWH	0.71×10^6	10,000/KWH	7.1×10^9
C: Natural Gas, ft.^{3}	269.4×10^6	1030/ft.^{3}	277.5×10^9
D: Cooling Water, gal.	1764×10^6	10/gal.	17.6×10^9
E: Process Water, gal.	1.974×10^6	15/gal.	Negligible

TOTAL BTU'S 13 497.5×10^9

WASTE DISPOSAL ENERGY

14 WASTE	15 TOTAL DISPOSAL BTU'S	17 TOTAL WASTED UNITS
A: Oily, Caustic Water	Disposal Plant 1.8×10^9	Water: 5.92×10^6 gal.
B:	Muriatic Acid 4.9×10^9	Oil in water: 11,200 lbs.
C:		Muriatic Acid to neutralize
D:		Caustic: 699,120 lbs.
E:		

TOTAL BTU'S 16 6.9×10^9

GROSS ENERGY CONTENT OF PRODUCT (SUM OF ITEMS 8, 13 AND 16) BTU'S 18 1673.5×10^9

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: Residue Gas	6.048×10^3	20,000	121.0×10^9
B: Pyrolysis Gas	1.722×10^3	17,986	31.0×10^9
C: C_3-C_4 Fraction	2.436×10^3	20,873	50.7×10^9
D:			
E:			

TOTAL BTU'S 23 202.7×10^9 BTU'S

NET ENERGY CONTENT OF PRODUCT (ITEM 18 LESS ITEM 23) 24 1470.8×10^9 BTU'S

ENERGY CONTENT PER UNIT OF PRODUCTION (ITEM 24 DIVIDED BY ITEM 3) 25 35,018 BTU'S/UNIT

GOAL (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 GOAL

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 .0135

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.

1 The BTU'S per unit of steam are available from steam tables. In the 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/ft^3 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/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 butene.

The basic information in this example was taken from the Stanford Research Institute report on "Ethylene" dated August, 1967, page 210.

20

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

	psig STEAM			psig STEAM			CONDENSATE USED OR LOST			WATER			TOTAL CONVERSION Btu	NUMBER OF UNITS PRODUCED	CONVERSION Btu PER UNIT OF PRODUCTION
1973	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 _____

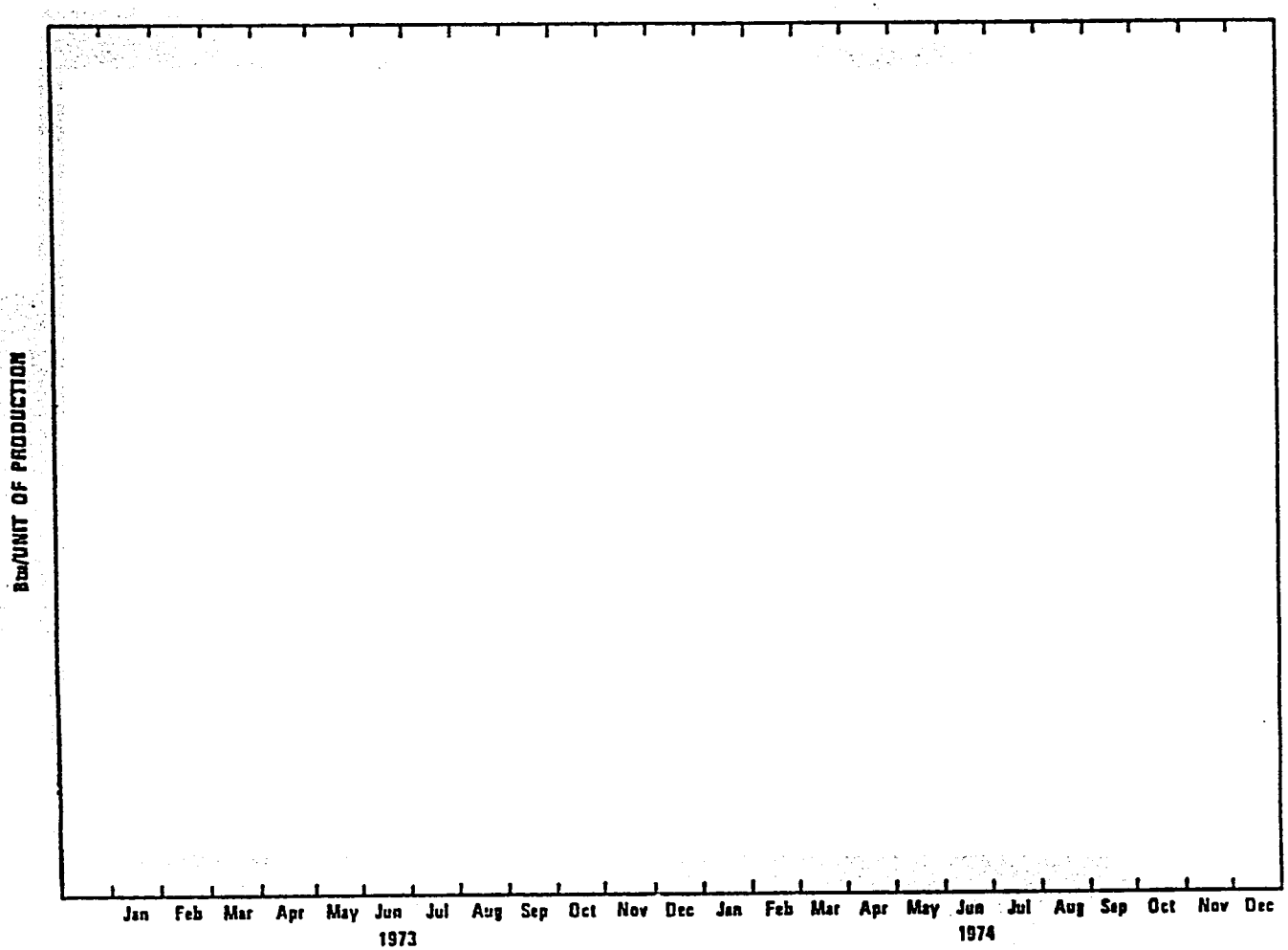
MONTHLY DEPARTMENT ENERGY USE

	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
1973	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 CORRESPONDENCE

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 time-table 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 a. . : as practical.

cc: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

271

2.6.2

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 1, 1974

To: Department Heads

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
2-36

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 "D"

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

Department: [illegible] SAVING SURVEY

Date: _____

Surveyed by: W.D. SMI

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
		post #1 furnace									Furnaces	
					#2 furnace lining						Furnaces	
						Parts Storage					Shop	
										Broken Vi[illegible]	Shop	
#3 furnace									#1 furnace		Heat Treating	
								#2 furnace			Heat Treating	
	Bldg. Heat-er Trap							#1 conveyor			Heat Treating	
						Storage Area					Assembly	
											Assembly	
										Doors need weatherstrip	Shipping	
						Above Shelves		Elan cooler fan			Shipping	
											Receiving	
								Fume hood fan			Receiving	
				safety showers							Laboratory	
						Chemical Storage					Laboratory	
	boiler										Laboratory	
					#2 steam line						Utilities	
		#2 compressor									Utilities	
	#1 reboiler										Utilities	
			#2 reboiler								Chemicals	
							steam jets				Chemicals	
						Hallways					Chemicals	
											Administration Building	
				Men's rm. faucet						reheat air conditioner	Administration Building	
											Administration Building	

2.6.4

E CONE. . . OMPANY

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

221

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 summary
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

savEnergy

2-42

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

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	Expense 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 _____ _____

Btu/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 rating: _____

_____

_____

Planned authorization request date: _____

229

ECOLERGY 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

230

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

221

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENC

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

Z-CO

232

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

236

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

2.3.2

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 27, 19 1

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 communicati 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.

Conversions "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.

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

EMPLOYEE MOTIVATION AND COMMUNICATION METHODS

David M. Heller
Air Products and Chemicals, Inc.
Paulsboro, New Jersey

ABSTRACT

This paper discusses the compelling reasons fu involving all employees in the plant energy conservation effort, offers suggestions on how to implement and maintain a plant-wide, people oriented con- vation program and provides examples to illustrate methods involved and benefits possible. Three area will be stressed: publicity, or communicating down the ladder, through newsletters and the use of distinctive logos; communicating up the ladder, by ns 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 involvement of the entire plant in the conservation effort can 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. Paulsboro Plant is part of the Chemicals Group of Products. We are located in Southern New Jersey in the Greater Philadelphia area. Of our employees 35 are exempt and the balance hourly non-exempt. We produce various types of industrial gases, with our major product being DABCO, the foam catalyst.

The Paulsboro Plant has seen sharply spiraling energy costs over the last few years, as we all have. From to 1981, our average cost for energy rose more than 50 percent. The impact of these costs

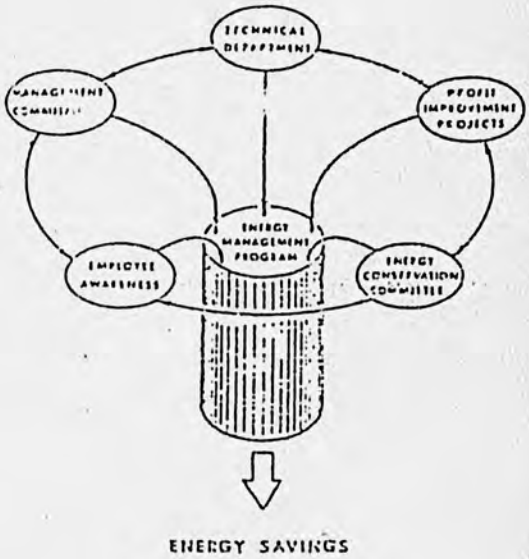


FIGURE 1

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-

240

PAULSBORO ENERGY REPORT

NUMBER 10
JULY 1981

ENERGY USAGE REMAINS DOWN

Plant energy usage was 4.0% less than the same period ... ber 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

... round 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 ... about ,500 a year on our steam bill. Plant stea... every three months.

OXIDIZER SAVINGS

... in on the Thermal Oxidizer saved $20,000 in natural ... or $80,000 over the entire year. A f ... bugs cropped ... would 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 ... to light the bulb. The amount of light is measured ... example - you need six 25-watt bulbs to equal the ... 150-watt bulb.

... wive's tale that there is a surge of power when you ... ght . If you leave a room, even for a minute, turn ...

* *

... HAVE ANY SUGGESTIONS FOR IMPROVING THIS ... DROP THEM IN THE SUGGESTION BOX. ... YOUR IDEAS. THANKS.

FIGURE 3

241

ga.ized 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 corp 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.

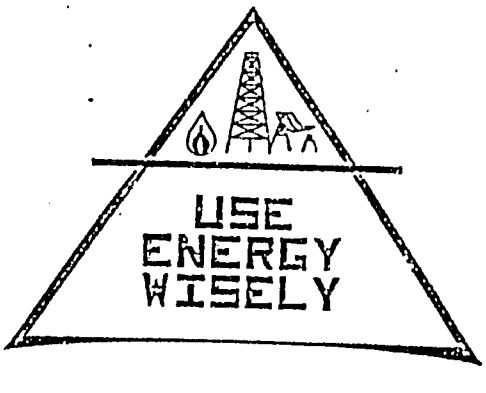


FIGURE 3

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

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 would 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

E1-31

ENERGY CONSERVATION SUGGESTION

TO SAVE ENERGY IN THE PLANT, I SUGGEST:

SHUT OFF GLYCOL CIRCULATING PUMP FOR DABCO II STILL WHEN NOT IN USE.

PUMP RAN 22 DAYS 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 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 Paulsboro 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 tie-ins, the operation of energy users, examples of energy wasters - such as steam leaks, and uninsulated lines, methods for saving 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.

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:

$$I_s = (\sqrt{2})\left[\frac{\text{CkVAR}}{(\sqrt{3})(V_L)}\right]\text{amps}$$

$$I_{PK} = (I_s)\left[1 + \frac{\text{Short Ckt. kVA}}{\text{CkVAR}}\right]\text{amps}$$

$$f_T = f_s\left[\frac{\text{Short Ckt. kVA}}{\text{CkVAR}}\right]\text{Hz}$$

Where:

I_s = steady state peak current (crest value)
I_{PK} = peak inrush current
f_T = 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

245

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.

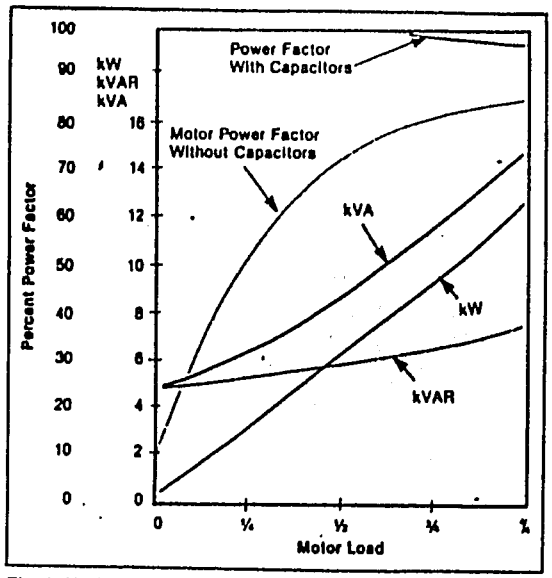


Fig. 3. Typical characteristics of a 15 hp induction motor. Changes in load affect all the parameters.

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

246

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

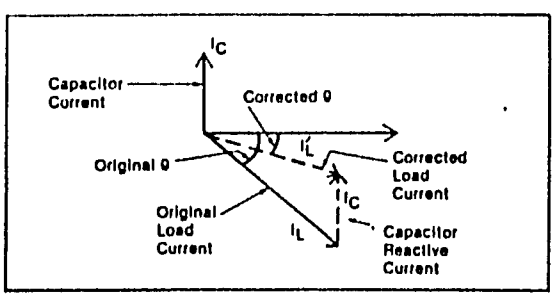


Fig. 4. A phasor diagram. The power factor, which equals cosine θ, is improved when the reactive load is decreased.

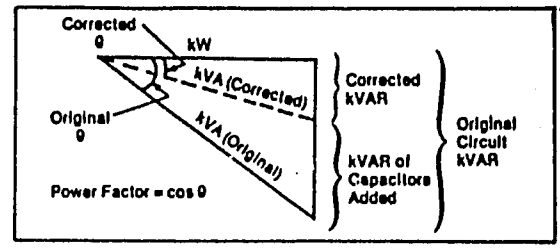


Fig. 5. A power triangle. Using some of the known parameters, trigonometric calculations will reveal missing data.

$\sin^2\theta$ where θ is the power factor angle. For example, if the power factor is .75, $\theta = 41.4$ 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

257

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.

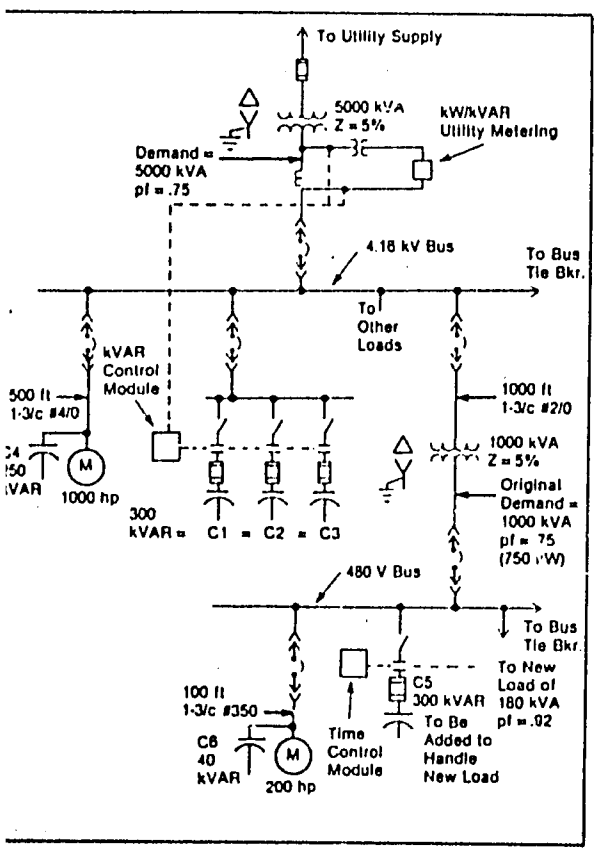
Capacitor Release

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:

$$\text{CkVAR} = \sqrt{(\text{kVA}_2)^2-(\text{kW}_2)^2} - \sqrt{(\text{kVA}_1)^2-(\text{kW}_2)^2}$$

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:

$$\text{CkVAR} = \sqrt{(1153)^2-(915)^2} - \sqrt{(1000)^2-(915)^2} = 298$$

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.

248

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

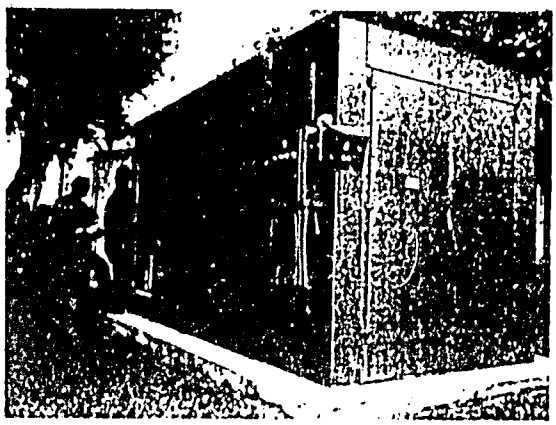
1st year monthly savings = $41 + $206 + $1875 + $1309 = $3431
2nd year monthly savings = $3431 × 12% rate increase = $3843
3rd year monthly savings = $3843 × 12% rate increase = $4304

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	.985	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	.978	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	1.228	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	.184	.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.

349



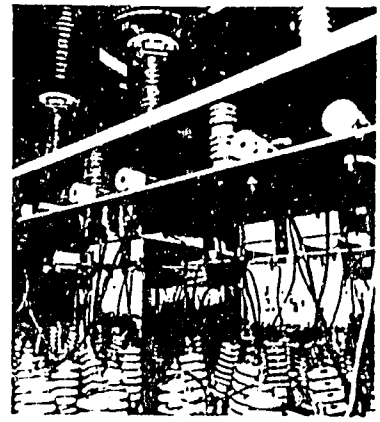


Fig. 8 An automatic power factor control unit. The far left photo shows the cabinet and the adjacent photo looks into the interior where the capacitors, oil switches and current limiting reactors are shown. Photos courtesy of H.K. Porter Co., Inc. Electrical Div.

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:

$$I_{rms}\,total = \sqrt{(I_{1,rms})^2 + (I_{3,rms})^2 + (I_{5,rms})^2 + \ldots}$$

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 kilov . 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)

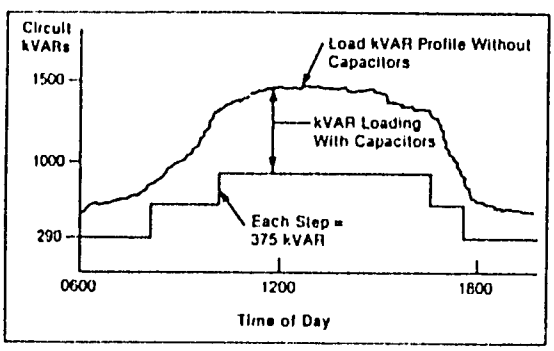


Fig. 9. Load kVAR profile with power factor correction using a multi-step capacitor bank. In the above plot, a peak demand of 2500 kW is corrected to .92 from .75 pf.

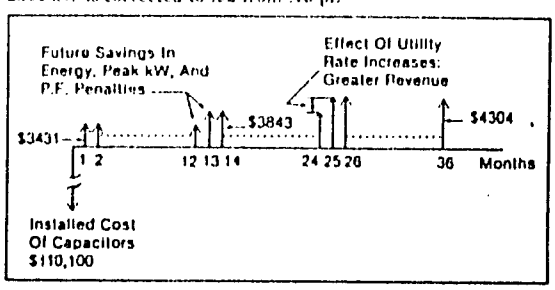


Fig. 10. Cash flow diagram showing the present value of future savings that can be invested in capacitors to improve the power factor to .92 in the circuit shown in Fig. 6.

250

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

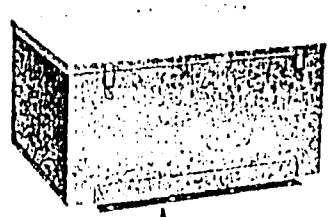
Power capacitors can frequently offer benefits for an industrial/commercial facility. They are available in various ratings and can be connected to control systems to closely follow the power factor performance of an electrical system. Before installing capacitors, an economic analysis should be carried 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

Joseph W. Fay is a project engineer with Syska & Hennessy, consulting engineers (San Francisco office). He specializes in electrical engineering for commercial and light industrial projects. Fay has a BSEE degree from the University of Illinois at Urbana-Champaign and is a Registered Professional Engineer in California. He is a member of IEEE and IES.

AVOID...
...HIGH ELECTRIC COSTS
...PENALTY ELECTRICAL CHARGES
...LIMITED SYSTEM CAPACITY
...VOLTAGE FLUCTUATIONS

INSTALL...
AEROVOX POWER FACTOR CORRECTION CAPACITORS



Specifically engineered for low voltage industrial applications, AeroVar® power factor correction capacitors will reduce electrical energy costs and increase electrical system capacity. You'll save valuable dollars by eliminating penalty charges and premium demand rates.

AeroVar power factor correction capacitors feature a metallized film dielectric system for greater energy efficiency, lower operating temperatures and extended life. Supplied in heavy gauge steel enclosures in ratings from 5 to 150 KVAR at 240, 480 and 600 Volts, 3 phase, 60 Hz U.L. listed and CSA Approved.

Send for new AeroVar catalog.

AEROVOX INCORPORATED
AN AVX COMPANY
NEW BEDFORD MASS 02745

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. ■

References:

Harry M. Philo, *Lawyers Desk Reference*, 6th Ed., Bancroft-Whitney Co., San Francisco, 1979.

1980 Forensic Service Directory: The National Register of Forensic Experts, Litigation Consultants and Legal Support Specialists. Fairlawn, NJ. National Forensic Center. 1980.

Manual of Practice for Forensic Laboratories, American Council of Independent Laboratories, Inc., Washington, D.C. 1982.

The Author

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.

251

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-

(continued on page 28)

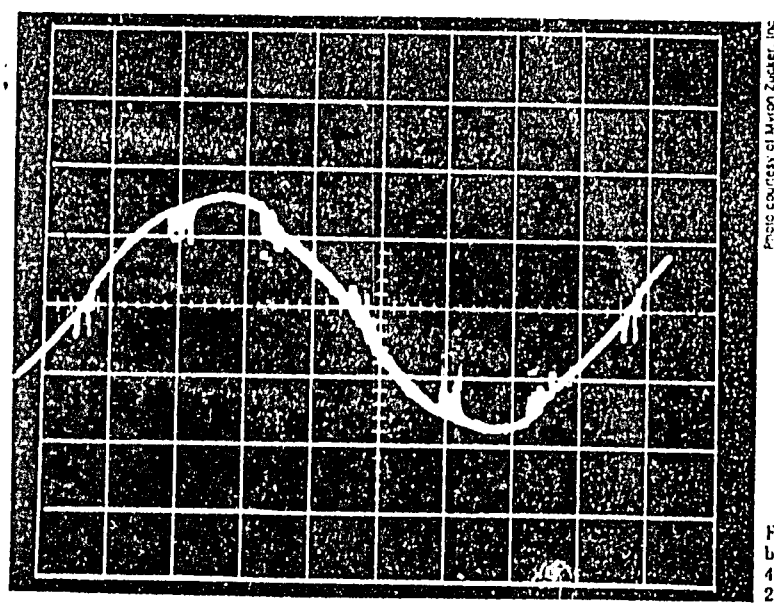


Photo courtesy of Myron Zucker, Inc.

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.

252

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

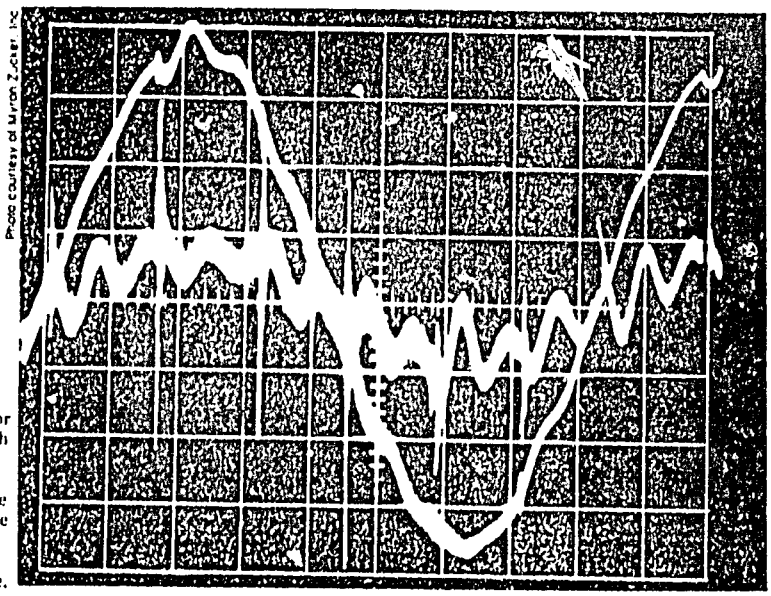


Photo courtesy of Myron Zucker, Inc

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.

McGRAW-EDISON

Electrical Apparatus Sales Representatives

Atlantic Region
Power-McClinton, Inc.
Bridgeville, PA (412) 941-4800
Hurricane, WV (304) 757-6845
Frazier & Company
Richmond, VA (804) 784-4125
Hyland & May Associates
Norwood, MA (617) 762-2485
L.E. Markle Company
North Boston, NY (716) 649-7700
Fairport, NY (716) 223-4820
National Electric Power Agencies
New York, NY (212) 594-3152
Stallings & Associates, MHT, Inc.
Brookhaven, PA (215) 872-3880
Trautmann Associates
Central Valley, NY (914) 928-9431
John E. Wennogle & Associates
Summit, NJ (201) 277-6024
Wilson Associates, Inc
Baltimore, MD (301) 256-4200

Gulf/Southeast Region
Arkansas Industrial Machinery Inc
North Little Rock, AR (501) 758-2745
Memphis, TN (901) 363-2200
Austin Brown Associates, Inc.
Atlanta, GA (404) 457-6381
Pelham, AL (205) 663-4820
Gallaher & Associates, Inc
Maryville, TN (615) 984-7340
Charles R. Lee Associates, Inc
Miami, FL (305) 444-7414
Polytech Services, Inc
Charlotte, NC (704) 372-4161
Schell-Hanna Company Inc
Metairie, LA (504) 837-7837
Baton Rouge, LA (504) 291-1655
Clinton, MS (601) 924-7894
Van & Smith Company
Tampa, FL (813) 877-8393
Jacksonville, FL (904) 384-2376
Orlando, FL (305) 898-8520

Mid-West Region
Powertech
Worthington, OH (614) 888-5522
Ohio Watts (1-800) 282-6010
Lee Butler & Associates, Inc
Elk Grove Village, IL (312) 437-7600
Antioch, IL (312) 395-0480
Marquette Heights, IL (309) 382-2011
Couchman-Conant, Inc
Noblesville, IN (317) 849-9890
Cubbedge Controls
Toledo, OH (419) 535-5530
George R. Horne & Company
Dearborn, MI (313) 581-1300
ICI Sales
St. Paul, MN (612) 227-2425
Qualtech Systems, Inc
Maryland Heights, MO (314) 878-5335
Jerry C. Shumway & Associates, Inc
Des Moines, IA (515) 285-0704

Pacific Region
Arbell Electric, Inc
Burlingame, CA (415) 347-9804
Cunningham Company Inc
Rosemead, CA (213) 350-1461
A.R. Neal Sales
Phoenix, AZ (602) 254-3113
Stevens Sales Company
Salt Lake City, UT (801) 487-8971
Boise, ID (208) 336-8304
Specialty Products, Inc
Honolulu, HI (808) 531-0596
J.A. Tudor & Associates, Inc
Seattle, WA (206) 682-7444
Spokane, WA (509) 327-3328
Eugene, OR (503) 689-1252
Portland, OR (503) 288-5154
Anchorage, AK (907) 243-4641

Plains/Southwest Region
Electrical & Instrument Sales Company
Tulsa, OK (918) 664-0990
Hubert Kaub & Company
Englewood, CO (303) 781-5881
R.E. Martin Sales Agency
Albuquerque, NM (505) 262-2474
George Pearson Company Inc
Prairie Village, KS (913) 341-6210
Wichita, KS (316) 265-4791
J.R. Woodruff Company
Houston, TX (713) 467-8463

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-

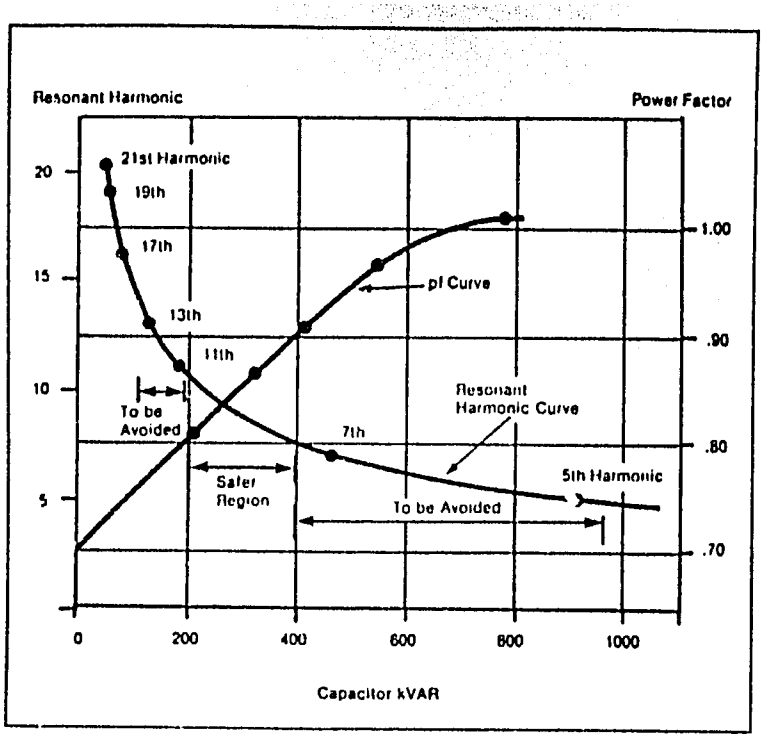


Fig. 3. Chart showing resonant frequency vs. amount of capacitance (blue curve) in a circuit fed from a 1500 kVA substation with a 1000 A, 200 ft bus with reactors. Also shown are the resonant harmonic frequencies that should be avoided. The red curve shows how pf is improved as capacitance is increased. 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, [illegible] 660 and 720 Hz respectively and [illegible] the primary problem frequencies. [illegible] 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 for 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.

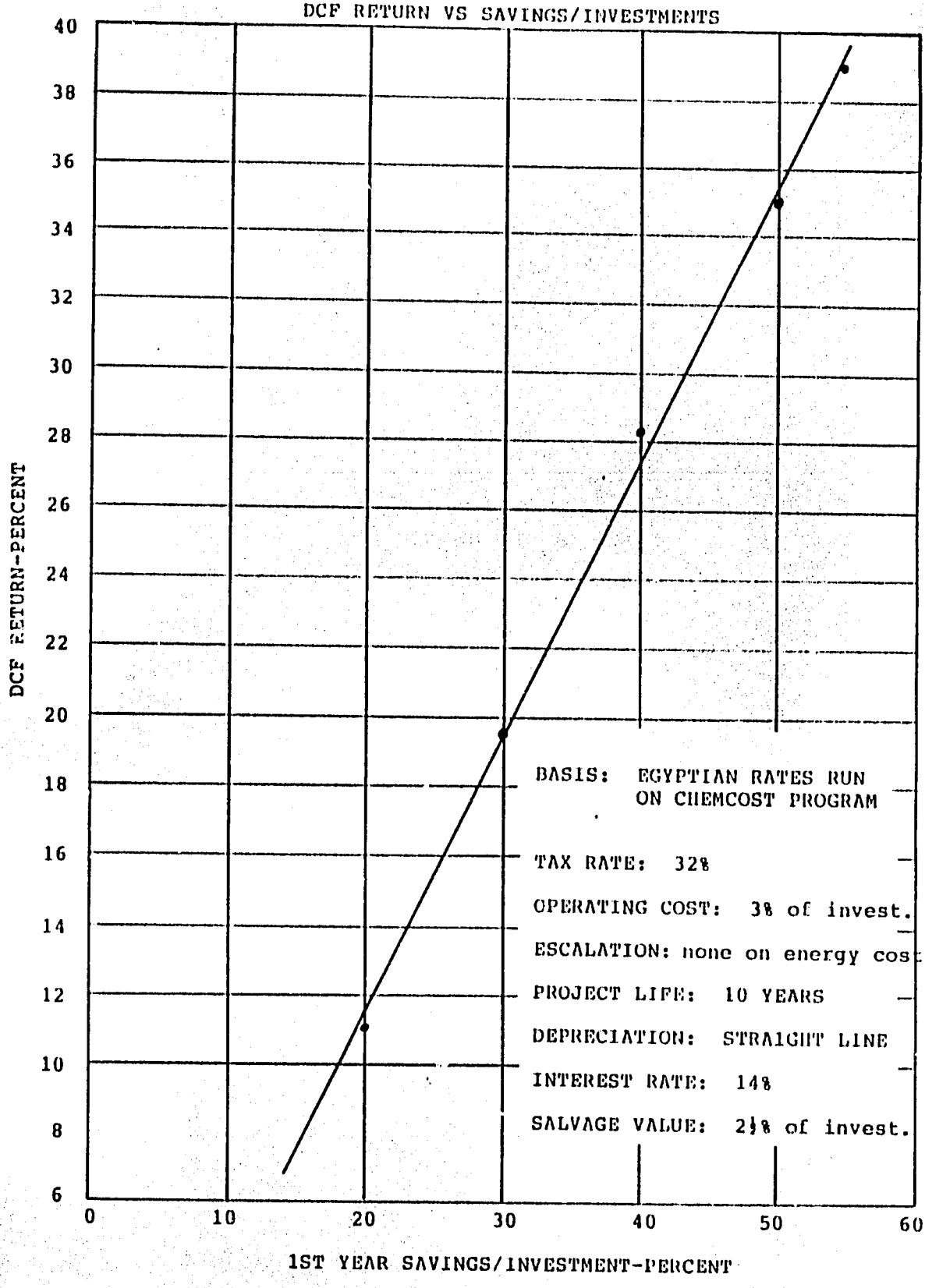
Of course, the best time to analyze over-motoring is when you select motors. The next thing to remember is a possible rearrangement of induction motors in your plant. Along these same lines, think of the synchronous motor when selecting motors for slow-speed application.

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. ■

JOINT ENGINEERING GROUP: OEP/FWUSA
DCF RETURN VS SAVINGS/INVESTMENTS



revised 17 Apr 88

ELNASR COKE

ECO DATA RECEIVED

ECO No. 37

ECO DESCRIPTION. IMPROVE ADD/FIX INSTRUMENTATION (CONDENSED LIST)

	STEAM SYS FEBT	STEAM SYS COKE	DIL. NITRIC ACID	CAL AMMONIA NITRATE	PURE AMM NITRATE	AIR SEP	COOLING WATER TOWER				COST ESTIMAT REFERENC
INST											
FR	16	27		4	3	6	8				12B
FRC					2						12A
TR	4		2								11I
TRC											—
PR	4		2	4							14E
PRC											—
PG/PI	20	12	16	10	6	6	6				14J
TI	20	4	12	12	4	6	8				11S
ROTOMETER			4" 4								12S
ΔP INSTS											—
LR	4 2" CV 4		3	2" 3	2						13C
* O2 ANALYZERS	2	5									
FI	3" 4	2" 6	2"-7								12T
TEMP /ALARM MODULES	2										
DRAFT GAGES		4									14S
MULTI TEMP POINT			1								11N
ALARM SYSTEM			1								
ROPE SWITCH for CONVEYOR BELTS				4	3						

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRUMEN

PLANT / AREA BOILER / STEAM SYS FERTILI

THERMOMETERS	(TI)	20
LEVEL LR'S	CV 2"	4
PRESS PR		4
FR STEAM PRODUCED + USERS	NO CV	12
FR BFW	NO CV	4
O_2 ANALYSERS		2
TEMP TR	NO CV	4
FI for BFW	3"	4
~~TEMP~~ ALARM MODULES		2
PRESS GAGES (PI)		20

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRUMC

PLANT / AREA BOILERS COKE PLANT & WATER TREATMENT

OXYGEN ANALYSERS (BOILERS 1,2,3 & 4,5)		5
STEAM FLOW RECORDERS PRODUCED + USERS	No CV	14
BFW RECORDERS	NO CV	4
AIR flow RECORDERS	NO CV	3
PRESS GAGES (PI)		6
Thermometers (TI)		4
COKE OVEN GAS FR'S	No CV	4
DRAFT GAGES		4
WATER TREATMENT		
WATER FR'S	NO CV	2
PRESS GAGES (PI)		6
FLOW INDICATORS (2" FI)		6

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRUMEN

PLANT / AREA DILUTE NITRIC ACID

MULTI TEMP. POINT CONSOLE (18 POINTS)	1
PRESSURE GAGES (A)	16
PR for Steam ex WHB No CV	2
PR for BFW No CV	1
Water Rotameters 4"	4
LI & Alarms for 2 Steam drums.	2
Temperature Indicators	12
LI for Dil HNO_3 Product Tanks.	2
LI for Process Water Tank	1
TR for WHB	2
Air to Bleacher FR No CV	1
Steam export FR No CV	1
Steam Dumpout FR No CV	1
Furnace Alarms	6
Flow Indicators for Various service 2" (Water to absorbers)	6

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRUMENTS

PLANT / AREA CALCIUM AMMONIUM NITRATE [CAN]

PRESS. GAGES	PI		10
THEMOMETERS	TI		12
FLOW RECORDERS	FR	NoCV	4
PRESS RECORDERS	PR		4
LEVEL	LIC	CV – 2"	3
ROPE SWITCHES for CONVEYOR BELTS			4

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRU

PLANT / AREA PURE AMMONIUM NITRATE PLA

FLOW TRANSMITTER FOR STEAM	NICV	1
LEVEL RECORDERS	NO CV	2
PRESS. GAGES	PI	6
THERMOMETERS	TI	4
FLOW RECORERS	NO CV	2
ROPE SWITCHES for CONVEYOR BELTS		3

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRUMEN

PLANT / AREA AIR SEP PLANT

PRESS. GAGES	PI	6
FLOW RECORDERS	FR	4
THERMOMETERS	TI	6

ELNASR COKE

ECO DATA RECEIVED

ECO No. 32

ECO DESCRIPTION. LIST OF MISSING / DAMAGED INSTRUMENT

PLANT / AREA COOLING WATER FERTILIZE

PRESS. GAGES PI	6
TEMP. INDICATORS	8
FLOW RECORDERS (NO CV)	8