PN AAF-867

Final Report to

Organization for Energy Planning
Cairo, Egypt
April 1988 isn 56183

Industrial Energy Audit Report
El Nasr Pharmaceutical Company
Abu Zabal, Egypt

Arthur D. Little Reference 59643

TABLE OF CONTENTS

	Page
List of Figures and Tables	iii
Acknowledgement	iv
Report Summary	v
SECTION 1 - Plant Description	1-1
1.1 Introduction	1-1
1.2 Plant Overview	1-1
1.3 Detailed Process Description	1-4
SECTION 2 - Audit Approach and Philosophy	2-1
2.1 Introduction	2-1
2.2 Audit Approach	2-1
2.3 Priorities at El Nasr	2-1
SECTION 3 - Plant Energy Profile	3-1
SECTION 4 - Main Engineering and Economic Data	4-1
4.1 Energy Prices and Cost Estimates	4-1
4.2 Plant Boilers - Basis for Recommendations 5.1, 5.2, and 6.7	4-1
4.3 Steam Distribution - Basis for Recommendation 5.1	4-6
4.4 Electric Users - Basis for Recommendations 6.4	4-10
4.5 Steam End Users - Basis for Recommendations 6.1, 6.2, 6.3, 6.4, and 6.6	4-12
SECTION 5 - Energy Management Improvements	5-1
5.1 Recommendation 5.1 - Energy Monitoring	5-1
5.2 Recommendation 5.2 - Block 23-Mazout Temperature	5-3
5.3 Preventative Maintenance	5-3
5.4 Energy Task Force	5-3
SECTION 6 - Energy Conservation Opportunities	6-1
6.1 Housekeeping and Low Cost/No Cost Recommendations	6-1
6.2 Capital Equipment Recommendations	6-4

APPENDICES:

Appendix A	People Contacted at El Nasr
Appendix B	Bill of Materials
Appendix C	Production Data
Appendix D	Power Factor/Boiler Flow Tests
Appendix E	Summary Boiler Data
Appendix F	Summary Calculations
Appendix G	Relationship Between Payback and IRR

List of Figures

Figure		Page
1-1	Plant Layout, El Nasr Pharmaceuticals	1-3
1-2	Block Flow Diagrams - Selected Products	1-5
3-1	Historical Energy Usage	3-3
3-2	Specific Steam Consumption for Selected Products	3-4
4-1	Boiler Arrangement	4-2
4-2	Boiler Feedwater	4-3
4-3	Typical Boiler Measurements	4-5
4-4	Block Steam Diagram, El Nasr Pharmaceuticals	4-7
5-1	Proposed Energy Monitoring	5-2
6-1	Block 2 Condensate Recovery Assembly	6-2
6-2	Block 5 Hot Water Loop	6-3
6-3	Low Pressure Air System	6-5

List of Tables

Table		
1-1	Major Products Produced at El Nasr Pharmaceutical	1-2
3-1	Historical Electrical Usage	3-2
3-2	Fuel Oil Usage	3-2
4-1	Basis for Steam Consumption by Block	4-9
4-2	Estimated Steam Consumption by Block	4-10
4-3	El Nasr Major Electric Motors	4-10
4-4	Electric Usage for Air	4-11
4-5	Heat Losses for 1-inch Steam Pipe	4-12
4-6	Distilled Water Usage	4-13
4-7	Plant Dryers and Steam Traps	4-14

Acknowledgement

This project could not have been completed without the active support of the Egyptian Organization for Energy Planning, who provided guidance throughout the project and insightful review of the draft report.

We are indebted to El Nasr Pharmaceutical Company management and their excellent cooperation and assistance during the course of this investigation. They were extremely cooperative in providing the wide range of information and data requested. Several are to be especially commended for their patience in explaining certain points repeatedly and in great depth, when requested. The friendly and helpful spirit on the part of all is much appreciated.

We also wish to express our appreciation to the U.S. Agency for International Development for providing guidance and support throughout the program. This project was funded under USAID Contract Number PDC-5730-I-00-7024-00.

REPORT SUMMARY

EL NASR PHARMACEUTICAL COMPANY
ABU ZABAL, EGYPT

INTRODUCTION

As part of a broader energy audit program, the Egyptian Organization for Energy Planning retained Arthur D. Little, Inc., Cambridge, Massachusetts, United States of America, to conduct an energy audit of the El Nasr Pharmaceutical Company facility located in Abu Zabal, Egypt. The field audit was conducted in February, 1988, and analysis of the information obtained continued in OEP's Cairo offices.

The audit consisted of a review of the process and plant's performance by interviewing various managers, by reviewing drawings, design information, and selected operating records. Based on this review, major sections of the various production areas were inspected, and a variety of tests and analyses were performed using both plant and portable instrumentation.

PLANT DESCRIPTION

El Nasr Pharmaceutical Company manufactures drugs for Egyptian consumption and sells processed intermediates to foreign companies. These intermediates are exchanged for feedstocks which are not available in Egypt. The plant was originally constructed in 1964.

The plant produces a large number of relatively low volume, high value products. For example, of the twenty or so major products, the highest production volume is for aspirin, which is about 350 tons/yr. Most product volumes are measured in tens of tons per year. The major products are shown in Table S-1.

For all practical purposes, each individual block at El Nasr is a small stand-alone chemical factory served by a common set of utilities (steam, chilled water, process water). The production in each block is small; the operations are batch processes; products are scheduled for production as needed, which means that some runs may be as short as days or weeks.

Additional details about the plant can be found in Section 1 of the main report

EATABLISHING AUDIT PRIORITIES AT EL NASR

At El Nasr Pharmaceutical, the initial survey revealed that:

- The plant is a physically large plant but consumes modest quantities of energy (6500 ton/yr mazout, 13 million kWh/yr electric).

- About 67% of process energy is in the form of mazout and 33% as electricity.

Table S-1
Major[1] Products Produced at El Nasr Pharmaceutical

Block 1	Tetracycline, oxytetracycline, industrial enzymes (kemilase, ladinase), penicillin
Block 2	Medical solutions
Block 3	Sulfaguanidine, sulfadimidine NA, metformin, tolbutamide
Block 4	Refampycillin, sodium acetate, specialty chemicals
Block 5	Thiamphenicol, chloramphenicol, chloramphenicol palmitate, chloramphenicol stearate, ampicillin, paracetamol
Block 6	Aspirin, methysalicylate, acetic acid, alumina-aspirin

[1]Includes only major tonnage products; other valuable products are produced but are not critical to energy consumption.

- The plant's energy housekeeping had substantial room for improvement.

- The plant is a multi-product, high value/low volume, batch process based facility, with products typically produced in short campaigns several times a year.

- Little instrumentation in the 23-year old plant is still functioning.

- The plant has significant electrical consumption for refrigeration and air compression.

These observations led to certain conclusions with regard to the energy audit priorities at El Nasr:

1. The opportunities for improvement are probably moderate.

2. Because of the nature of the products, there are only limited opportunities on the process side.

3. The low volume, spread-out nature of the plant, coupled with intermittent processes, limit the economically attractive opportunities in the utilities area.

4. The main focus will be to greatly tighten up energy housekeeping.

Accordingly, our primary focus in this audit has been on the places where energy housekeeping can be more efficient.

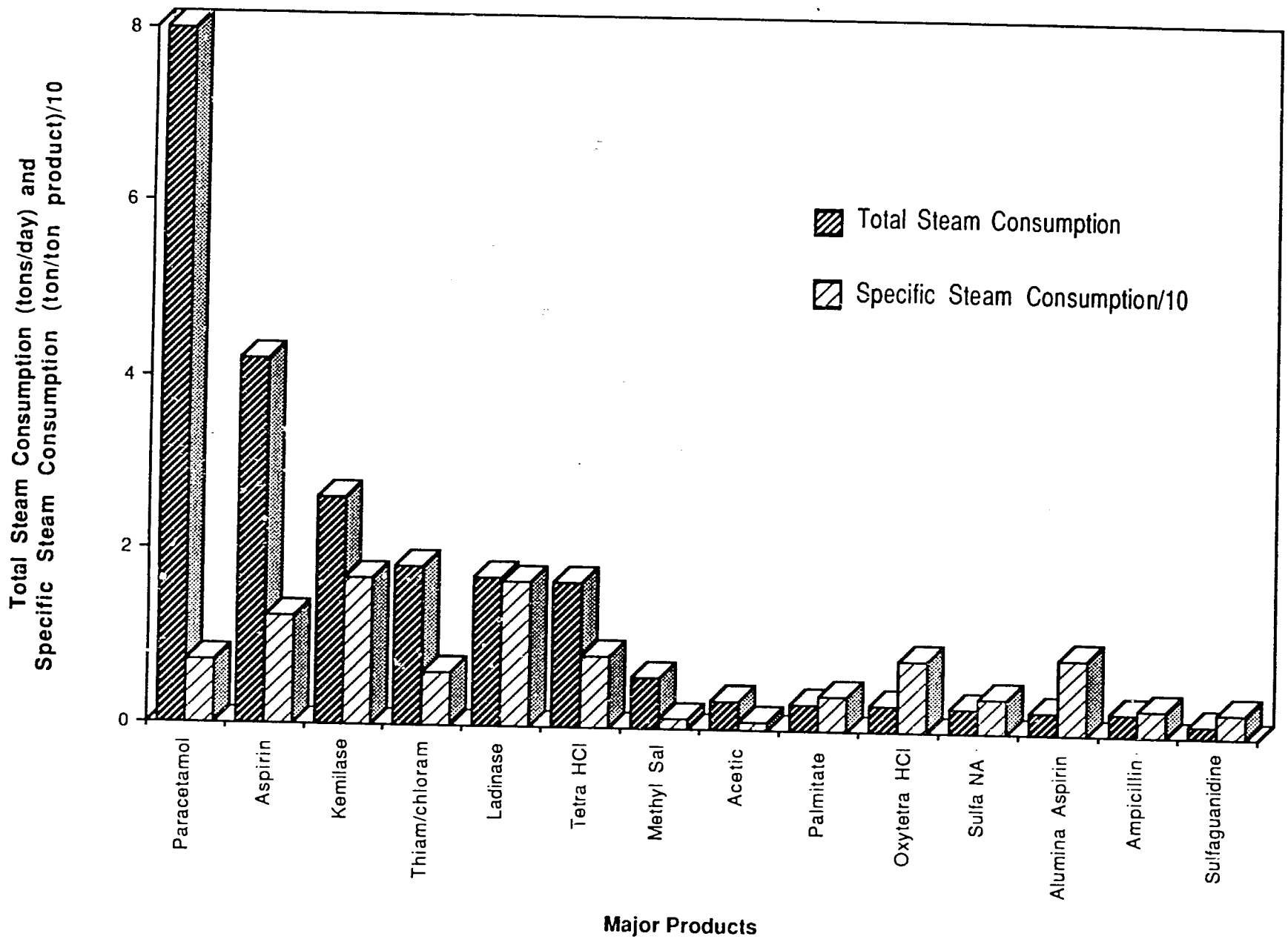
FINDINGS

Instrumentation. The plant in general suffers from a lack of instruments. The original installation was well-instrumented, but over the years all but a few of the most critical items have been abandoned. Instruments here refers to pressure, temperature, flow, and analytical devices on the equipment; to signal transmitters and controllers; and to control valves and actuators. The present situation is attributed to (1) lack of repair capability, and (2) a present lack of foreign currency to buy replacements or parts.

Energy Consumption. The El Nasr Pharmaceutical Co. uses heavy fuel oil (Mazout) to fire the steam boilers; and electric power to run lights, small motors, compressed air production, cooling tower motors, brine and cooling water pumps, ammonia refrigeration plant, and miscellaneous uses. Most of the electric users are (or should be) intermittent due to the batch production nature of the plant.

Because of the variety of products produced at the plant, the batch nature of the processes and the general lack of instrumentation, it is difficult to estimate specific energy consumption. Components which need to be considered include: mazout, used to generate steam; electric energy used in refrigeration; electric energy for compressed air; and electric energy for miscellaneous motors, mixers, and drives. Figure S-2 shows estimated

Figure S-2: Specific Steam Consumption for Selected Products
El Nasr Pharmaceuticals



specific energy consumption and total energy consumption based on steam consumption for some of the major products.

The basis for these numbers is discussed in detail in Section 3 of the main report.

RECOMMENDATIONS

Energy Monitoring. It is important that energy monitoring instrumentation at the plant be rehabilitated and some additional instrumentation be installed. It is also important that the plant have the necessary skills to repair and maintain the instrumentation. As a minimum, the plant should meter mazout consumption, boiler steam production, and steam flow to the main production Blocks. Cost is estimated at U.S. $20,000.

Energy Task Force. A concept which has proven effective in other operating plant environments is the energy task force. The task force chooses a block or user within the block for comprehensive analysis. The goal of the task force is to balance the energy cycle of the user and suggest modifications to lower energy usage. One of the first goals of the task force should be to tighten up steam housekeeping, especially failed or missing steam traps (see Recommendation 6.4) and flange or valve steam leaks.

Housekeeping and Low Cost/No Cost Recommendations. As defined in the study, housekeeping includes both traditional housekeeping type options (e.g., steam leaks, steam traps, etc.), as well as all retrofit options which require no (or minimal) foreign currency. Housekeeping options are summarized in Table S-3 under both local energy prices, as well as international price levels. Specific recommendations include:

- Recommendation 6.1 - Block 2-Condensate Recovery

Recovery of steam condensate from distilled water production in Block 2 appears to be the only area of the plant where condensate recovery appears economic at the present time. The condensate is clean and no boiler feedwater cleanup will be required.

The economics of Recommendation 6.1 are:

Annual energy (steam) savings: 7.3×10^8 KJ/yr (28 TOE)
Capital cost: $7,100
Annual savings: $3,230
Simple payback: 2.2 years
Internal rate of return: 44%

- Recommendation 6.2 - Block 5-Hot Water Loop

2.35 tons/day of steam are used for providing hot water flow to the reactors in Block 5. The process actually consumes or utilizes only 15% of this steam. A hot water loop could recover 75% of this excess or 1.5 ton/day of steam. The annual savings in mazout would be 58 tons.

The economics of Recommendation 6.2 are summarized below:

TABLE S-3

AUDIT RESULTS SUMMARY

EL NASR PHARMACEUTICAL

RECOMMENDATION	ANNUAL FUEL SAVINGS (1) (UNITS/YR)	ANNUAL ENERGY SAVINGS (1) (kj/yr)	(TOE/yr)	International Prices: ANNUAL VALUE OF SAVINGS ($/yr)	ANNUAL OPERATING COST ($/yr)	CAPITAL COST ($)	PAYBACK (years)	LIFETIME (years)	IRR (%)	Local Prices: ANNUAL VALUE OF SAVINGS (L.E./yr)	CAPITAL COST (2) (L.E.)	PAYBACK (years)
MONITORING												
5.1 Blk 1 Instrumentation	N/A	N/A	N/A	N/A	N/A	$3,000	N/A	5	N/A			
5.1 Blk 3 Instrumentation	N/A	N/A	N/A	N/A	N/A	$3,000	N/A	5	N/A			
5.1 Blk 4 Instrumentation	N/A	N/A	N/A	N/A	N/A	$3,000	N/A	5	N/A			
5.1 Blk 23 Instrumentation	N/A	N/A	N/A	N/A	N/A	$11,000	N/A	5	N/A			
SUBTOTAL	N/A	N/A	N/A	N/A	N/A	$20,000	N/A	5	N/A			
HOUSEKEEPING												
6.1 Blk 2 Condensate Recovery	29 ton mazout	7.3E+08	28	$3,230	neg	$7,100	2.2	10	44%	807	15620	19.3
6.2 Blk 5 Hot Water Loop	53 ton mazout	1.3E+09	52	$5,970	neg	$15,500	2.6	15	38%	1492	28160	18.9
6.3 Blk 6 Steam Trap	497 ton mazout	1.3E+10	481	$55,688	neg	$310	0.0	5	>1000%	13922	682	0.0
6.4 Blk 11 Low Pressure Air Controller (3)	965 MWH	9.7E+09	223	$44,390	neg	$3,500	0.1	5	1268%	25090	7700	0.3
SUBTOTAL	N/A	2.4E+10	783	$109,278	neg	$26,410	0.2	N/A	414%	41312	114756	2.8
CAPITAL IMPROVEMENTS												
6.5 Block 5 Dryers	228 ton mazout	5.7E+09	220	$25,505	neg	$3,310	0.1	5	771%			
6.6 Pipe Insulation	227 ton mazout	5.7E+09	219	$25,394	neg	$21,500	0.8	10	118%			
6.7 Excess Air Control (4)	273 ton mazout	1.1E+10	264	$30,553	neg	$24,000	0.8	10	127%			
SUBTOTAL	N/A	2.3E+10	704	$81,452	neg	$48,810	0.6	N/A	166%			
TOTAL	N/A	4.7E+10	1,487	$190,730	neg	$95,220	0.5	N/A	200%			

Note: 1) Energy savings for steam must be adjusted for boiler efficiency to get equivalent mazout and TOE.
2) Assumes that local labor supplied by plant at no incremental cost.
3) Electric conversion at 10,000 kj/kwh, incorporates a central power station efficiency of about 36%.
4) at 15 % equivalent availability of old boilers.

Assumptions:

Energy conversion	4.3E+07 kj/TOE
Currency conversion	2.20 LE/$
Boiler Efficiency	60.0%

Annual energy (steam) savings: 1.3×10^9 KJ/yr (52 TOE)
Capital cost: $15,500
Annual savings: $5,970/yr
Simple payback: 2.6 years
Internal rate of return: 38%

- Recommendation 6.3 - Block 6-Steam Traps

During the audit, the steam trap on the main feed to Block 6 was observed to be malfunctioning. In addition, the flange upstream of the trap was passing steam around the entire flange surface. The estimated steam loss from this one trap in the high pressure line is 0.6 ton/hr or 560 ton/yr of mazout.

The economics of this Recommendation are summarized below:

Annual energy (steam) savings: 1.3×10^{10} KJ/yr (481 TOE)
Capital cost: $310
Annual savings: $55,700/yr
Simple payback: immediate
Internal rate of return: >1000%

- Recommendation 6.4 - Block 11-Low Pressure Air System

Since only two fermentation are run per week in Block 1 and each fermentation is only 20 hours, the low pressure air is only required for 24% of the time that the compressor is actually running. This compressor should be turned off when fermentation is not in operation. This will reduce the power consumption by this compressor by 75%, which will result in a significant decrease in the overall electric consumption by the plant.

The economics for Recommendation 6.4 are summarized below:

Annual energy savings: 9.7×10^9 KJ/yr (223 TOE)
Capital cost: $3,500
Annual savings: $44,390
Simple payback: .1 year
Internal rate of return: >1000%

Capital Equipment Recommendations. These include the hard currency options. Capital equipment recommendations are evaluated only under international energy price levels.

- Recommendation 6.5 - Block 5-Dryers

The old tray dryer used for paracetamol in Block 5 uses significant quantities of steam; measured efficiency is 1.8%, normal efficiency should be 10-15%. The main problems are lack of a steam trap and the use of superheated steam in the dryer (instead of saturated steam). Recommended corrective action is to use sufficient water in the desuperheater to supply saturated steam to the dryer.

The economics of Recommendation 6.5 are summarized below:

Annual energy (steam) savings: 5.7×10^9 KJ/yr (220 TOE)
Capital cost: $3,310
Annual savings: $25,500/yr
Simple payback: 0.1 years
Internal rate of return: 771%

- Recommendation 6.6 - Insulation of Steam Lines

Although the main steam distribution lines at El Nasr are reasonably well-insulated, many of the Block's steam service lines are uninsulated. These lines, predominantly 1 and 2 inch diameter, should be insulated. Calcium silicate insulation is preferred for longer life and durability.

The economics of Recommendation 6.6 are summarized below:

Annual energy (steam) savings: 5.7×10^9 KJ/yr (219 TOE)
Capital cost: $21,500
Annual savings: $25,400
Simple payback: 0.8 years
Internal rate of return: 118%

- Recommendation 6.7 - Block 23-Air Infiltration and Excess Air Control

Current boiler efficiency is estimated to be about 54% (LHV basis). The main factor influencing this value appears to be the very high level of air infiltration into the boiler. Proper adjustment should allow this value to be decreased. This would improve boiler efficiency to 75%. Depending upon capacity utilization of the old boilers after the #4 boiler is on line, annual savings for both boilers are estimated to be:

Annual energy savings: 1.1×10^{10} KJ/yr (264 TOE)
Capital cost: $24,000
Annual savings: $30,600
Simple payback: 0.8 years
Internal rate of return: 127%

Section 1
Plant Description

1.1 Introduction

El Nasr Pharmaceutical Company manufactures drugs for Egyptian consumption and sells processed intermediates to foreign companies. These intermediates are exchanged for feedstocks which are not available in Egypt. The plant was originally constructed in 1964.

The plant produces a large number of relatively low volume, high value products. For example, of the twenty or so major products, the highest production volume is for aspirin, which is about 350 tons/yr. Most product volumes are measured in tens of tons per year.

The major processing areas of the plant are listed in Table 1-1.[1] A general layout of the major energy consuming areas of the plant is shown in Figure 1-1.

1.2 Plant Overview

For all practical purposes, each individual block at El Nasr is a small stand-alone chemical factory served by a common set of utilities (steam, chilled water, process water). The production in each block is small; the operations are batch processes; products are scheduled for production as needed, which means that some runs may be as short as days or weeks.

Block 1. Tetracycline HCl and oxytetracycline HCl are manufactured in Block 1 by reaction of the hydroxide salt of each with ammonium chloride in hot water jacketed vessels. The product is precipitated, filtered and washed, and finally dried. Block 1 also manufactures industrial enzymes. The enzyme is precipitated with ammonium sulfate and dried. Penicillin derivatives are also compounded at Block 1.

Block 2. Medical solutions are produced in Block 2. Sterile water for the solutions is produced in aqua purifiers. After the medical solutions have been mixed and bottled, the plastic bottles are autoclaved.

Block 3. The starting raw material for sulfa drugs manufactured at Block 3 is sulfanilamide. This is mixed with guanidine hydrochloride in m-cresol solution and refluxed. Then, the m-cresol is removed and tapwater is added. The solution is filtered and cooled and pure crystals of sulfaguanidine are obtained. The sulfaguanidine is refluxed and water and sodium hydroxide are added. The product is sulfadimidine sodium.

Block 4. Refampicyln and sodium acetate are the major products from Block 4, however numerous speciality chemicals are produced. Sodium acetate

---

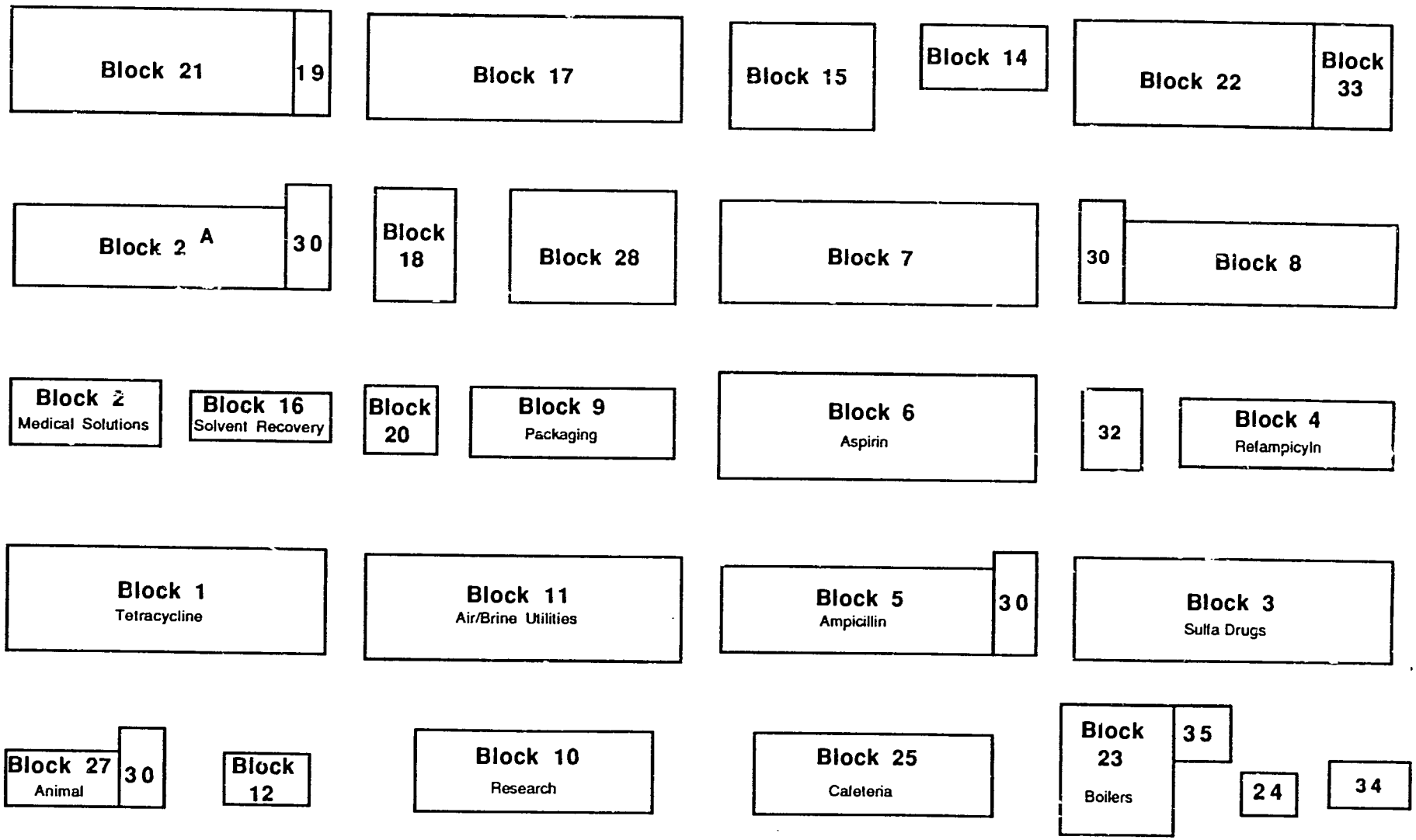
[1] The custom at the factory is to refer to the various sections or departments in the plant by the term "Block".

Table 1-1
Major[1] Products Produced at El Nasr Pharmaceutical

Block 1	Tetracycline, oxytetracycline, industrial enzymes (kemilase, ladinase), penicillin
Block 2	Medical solutions
Block 3	Sulfaguanidine, sulfadimidine NA, metformin, tolbutamide
Block 4	Refampycillin, sodium acetate, specialty chemicals
Block 5	Thiamphenicol, chloramphenicol, chloramphenicol palmitate, chloramphenicol stearate, ampicillin, paracetamol
Block 6	Aspirin, methysalicylate, acetic acid, alumina-aspirin

[1]Includes only major tonnage products; other valuable products are produced but are not critical to energy consumption.

Figure 1-1: Plant Layout
El Nasr Pharmaceuticals



production involves mixing concentrated sodium hydroxide solution with glacial acetic acid and crystalline product is obtained from centrifuge.

Block 5. The pharmaceutical drugs produced in Block 5 are ampicillin, chloramphenicol and its addition product with acid chlorides, and paracetamol. Ampicillin anhydrous is made by dehydrating ampicillin hydrate in a heated solution of isopropyl alcohol. Chloramphenicol or thiamphenicol is dehydrated in anhydrous methanol. Chloramphenicol palmitate or stearate is made by addition reaction of chloramphenicol anhydrous, the acid chloride and pyridine.

Block 6. Block 6 produces aspirin, alumina aspirin, sodium salicylate, and methyl salicylate. Acetic acid is a byproduct of aspirin production. Salicyclic acid is purchased from Europe. The aspirin is produced from salicyclic acid and acetic anhydride. Alumina aspirin is a new product. Aluminum sulfate and sodium carbonate solution are mixed to produce an active aluminum hydroxide slurry. Aspirin is added to the slurry and the mixture is agitated. The alumina aspirin is then dried.

Block 11. Block 11 supplies cold brine to various blocks for cooling and crystallizations. Brine is chilled via an ammonia refrigeration system. The 4°C brine is pumped to the users. The low pressure air system turbines are also housed in this block.

Block 21. Block 21, the water treatment plant, takes water from a canal pumping station. Aluminum sulfate and limestone are added to the water, which is then clarified. Six sand and gravel filters are used to clean the water. El Nasr sells water to other companies in the area.

Block 23. Steam for the entire El Nasr complex is produced in Block 23 from three identical firetube boilers, which burn heavy fuel oil (Mazout). A fourth larger firetube boiler has recently been contracted from Egyptian Boiler Co. and is expected to come on line within the next several months.

1.3 Detailed Process Description

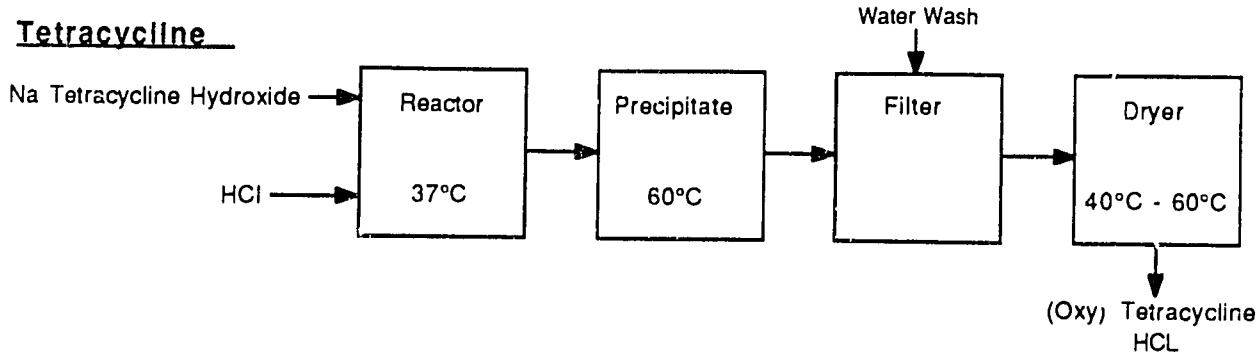
1.3.1 Block 1 - Tetracycline

Tetracycline HCl and Oxytetracycline HCl are manufactured in this block by reaction of the hydroxide salt of each with ammonium chloride in hot water jacketed vessels (see Figure 1-2). The hot water is produced by direct injection of steam into cold water. The reaction takes four hours at 37°C. The product is precipitated when the temperature is raised to 60°C for 1 hour. The product is filtered and washed and finally dried in four dryers, which are heated with hot water from a steam heater. Four hot water tray dryers are run for 2 hours with air at ambient temperature, then 2 hours at 40°C, and finally 3 hours at 60°C. Solvents used for tetracycline are isopropyl alcohol, acetone, ethanol and methanol, butanol for oxytetracycline. These solvents are sent to Block 16 for recovery. The batch size is 80 kg.

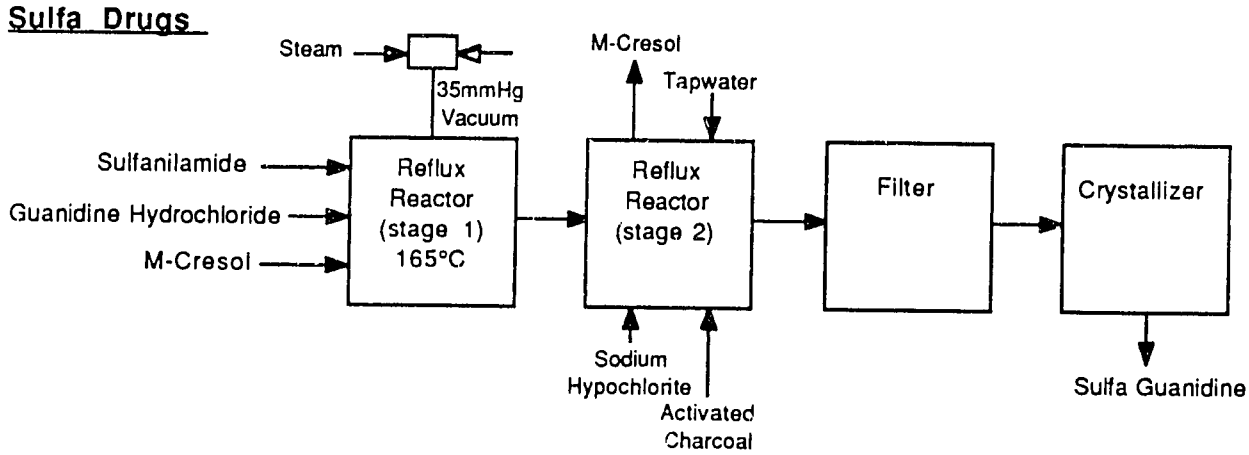
Industrial enzymes are also manufactured at Block 1. Each batch starts in a 1 M^3 seeder vessel, which is later added to a 10 M^3 vessel kept at 37°C. Fermentation takes 20 hours and two batches are run per week. The liquor

Figure 1-2: Block Flow Diagrams - Selected Products
El Nasr Pharmaceuticals

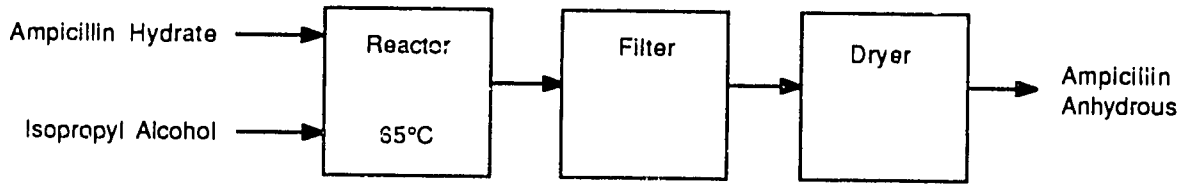
Tetracycline



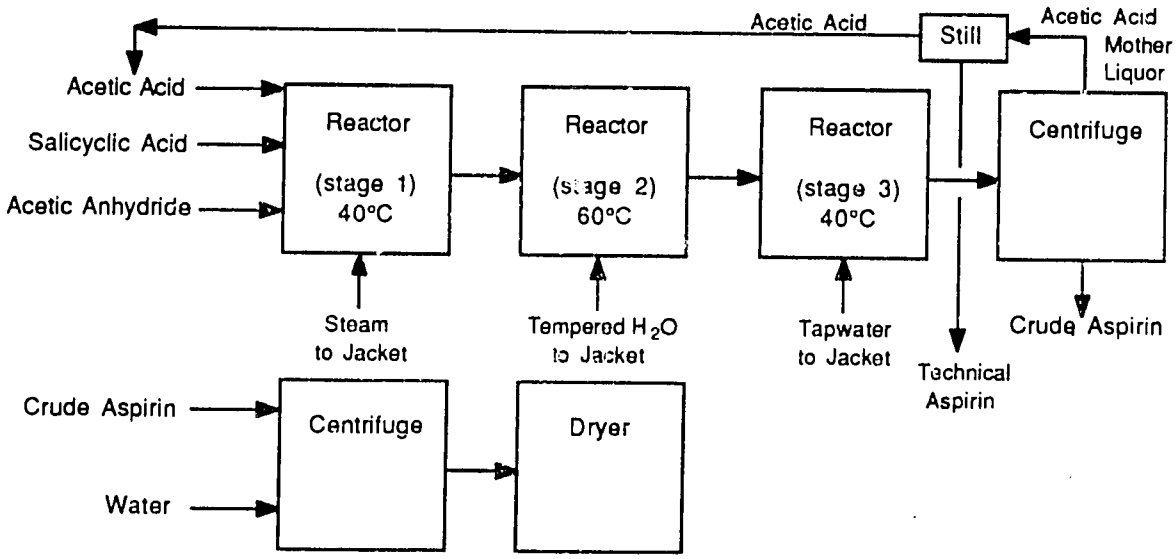
Sulfa Drugs



Ampicillin



Aspirin



is filtered and concentrated by vacuum evaporation at 40-45°C. The concentration is threefold, and vacuum is supplied from a vacuum pump. The enzyme is then precipitated with ammonium sulfate and dried by ambient air. The vessels are sterilized between runs by holding at 125°C for 45 minutes during a two hour heating procedure. Penicillin derivatives are also compounded at Block 1.

1.3.2 Block 2 - Medical Solutions

Medical solutions are produced in this block. Sterile water for the solutions is produced in aqua purifiers. These purifiers use steam at 5.5 bar and could produce 2 m^3/hr of pure water. The feedwater to the purifier is heated to 145°C, and the column reboils at 130°C and 2.65 bar. The sterile water is condensed at 90°C, and column blowdown is at 84°C. The steam condensate is estimated to be at 140°C and 3.7 bar. After the medical solutions have been mixed and bottled, the plastic bottles are autoclaved. These autoclaves are run 24 hours a day. The annual production is 4,633,317 liters of solutions.

1.3.3 Block 3 - Sulfa Drugs

The starting raw material for sulfa drugs manufactured at this block is sulfanilamide (see Figure 1-2). This is mixed with guanidine hydrochloride in m-cresol solution and refluxed at 165°C for twenty hours under 35 mm Hg vacuum. The vacuum is supplied by steam ejectors. Then, the m-cresol is removed in fifteen hours, and tapwater is added to the solution. The solution is heated to dissolve the crystals and sodium hypochlorite and activated charcoal added before filtering. The filtrate is then cooled and pure crystals of sulfaguanidine are obtained. The batch size is 600 kg and approximately 52 batches are run per year.

The sulfaguanidine is refluxed in acetone for 72 hours at atmospheric pressure. Water and sodium hydroxide are added. The crystalline product is sulfadimidine sodium. The batch size is 300 kg and approximately 56 batches are run per year.

1.3.4 Block 4 - Refampicyln

Refampicyln and sodium acetate are the major products from this block, however numerous speciality chemicals are produced in the adjacent building and are felt to be the major consumers of energy. Only 1.1 ton of refampicyln is produced each year. Three sequential steps in the production involve heating the reactor with hot water from steam injection. The temperature and times are 24 hours at 50°C, 10 hours at 55°C, and drying for 17 hours at 70°C. Each batch requires 13 ton of steam. Thirty batches are run per year.

Sodium acetate production is 35 tons per month and involves mixing concentrated sodium hydroxide solution with glacial acetic acid and filtering the hot liquid. The filtrate is cooled and crystalline product is obtained by centrifuging.

1.3.5 Block 5 - Ampicillin

The pharmaceutical drugs produced in this block are ampicillin, chloramphenicol and its addition product with acid chlorides, and paracetamol. Ampicillin anhydrous is made by dehydrating ampicillin hydrate in a heated solution of isopropyl alcohol (see Figure 1-2). It takes about 1 hour to bring the solution and 1000 liter reactor to 60-65°C, and the batch is held at this temperature for 30 minutes. The anhydrous material is removed by filtration and dried for 2 hours. The isopropyl alcohol is sent to Block 16 for recovery.

Chloramphenicol or thiamphenicol is dehydrated in a solution of anhydrous methanol at 55-60°C for 2-1/2 hours in a 500 liter reactor. The water-methanol azeotrope is then distilled at 90°C for 30 minutes. The chloramphenicol is dried in a steam dryer for approximately 8 hours. This dryer has a functional steam trap, but it is sometimes bypassed. The batch size is 100 kg.

Chloramphenicol palmitate or stearate is made by addition reaction of chloramphenicol anhydrous, the acid chloride and pyridine in a 1000 liter reactor. The reaction media is either methylene chloride or dichloroethylene. The reaction is exothermic and requires 30-45 minutes. The mixture is then vacuum distilled to remove water of reaction and recover the reaction media. This requires 3 hours under vacuum (vacuum pump) and heat supplied by hot water at 50-55°C. The crude product is further refined in a heated media of carbon tetrachloride for three hours. Hot water at 60-70°C is supplied from the steam heater. The filtrate is self-cooled and then tapwater cooled to 35-40°C. Brine cooling is used to finish crystallization at 8-10°C. The approximate batch size is 300 kg.

1.3.6 Block 6 - Aspirin

Block 6 produces aspirin, alumina aspirin, sodium salicylate, and methyl salicylate. Acetic acid is a byproduct of aspirin production. Salicyclic acid is purchased from Europe at a cost of L.E. 7/kg.

The aspirin is produced in three reactors, two 2000 liter and one 1000 liter. The recycled acetic acid mother liquor from technical aspirin recovery, salicylic acid and acetic anhydride are placed in a reactor and heated to 40°C with steam to the jacket (see Figure 1-2). This takes approximately 1 hour. The steam is removed and reactor temperature rises exothermically to 80°C. The reactors then self-cool to 65°C. Tempered water at 60°C is then used for three hours to remove the heat of crystallization. This tempered water is produced by direct steam injection into the tapwater. The reactor is then cooled for three hours with tapwater to 40°C. Ideal crystal size would be achieved by 2-3°C drop/hour. The crude aspirin is centrifuged from the mother liquor, acetic acid.

The crude aspirin is mixed with tapwater and recentrifuged. The cake is 10% moisture and is dried in a new fluidized dryer with steam heated air. Batch size is 360 kg from the 1000 liter reactor, and the dryer holds 120 kg. Drying time is 30 minutes per charge.

Acetic acid and technical aspirin are recovered from the mother liquor. The still (500 liter) is heated to 80°C and vacuum distillation of acetic acid occurs. This takes 4 hours and produces 60 kg of technical aspirin and 225 kg of acetic acid. The technical aspirin is dissolved in mother liquor and filtered through charcoal before being returned to the reactors.

Alumina aspirin is a new product. Aluminum sulfate and sodium carbonate solution are heated and mixed at 60-70°C to produce an active aluminum hydroxide slurry. Aspirin is added to the slurry, and the mixture is agitated for 7-8 hours with hot tempered water at 70°C in the jacket. The alumina aspirin is centrifuged from the sodium sulfate solution and dried. Three dryers can be used for this drying--one uses steam-heated air, two have tempered hot water heating. The product must not be heated over 70°C, since it will melt. Drying takes 7 hours; if the steam dryer is used, the steam is turned on about 7-14 times for about 5 minutes each time.

1.3.7 Block 11 - Air/Brine Utilities

Block 11 supplies cold brine to various blocks for cooling and crystallizations. One synchronous motor-driven reciprocating compressor is always running, and a second is required during the summer operation. Each motor is 320 kW. This compresses the ammonia used as refrigerant to produce the cold brine. The cold brine is pumped to the user by a 75 kW turbine pump with a capacity of 360 m3/hr. The cold temperature of brine discharge is -4.0°C, and the warm return temperature was -2.7°C. Therefore, the maximum cooling load is 544 kW. The COP of the refrigerant system is 2.5.

The low pressure air system turbines are housed in this block and one air turbine is always running. The air turbine motor is 235 kW. The temperature of the discharge was measured and found to be 220°C. An ampere meter was connected to the compressor, and the average current draw of the compressor was measured to be 260 A; the measured electric load was 145 kW. This air is supplied to Block 1 for fermentation, however no fermentation was running that day. On another day the meter read 300 A and fermentation was running one fermenter; the electric load was 167 kW.

1.3.8 Block 21 - Water Treatment

The water treatment plant takes about 500 m3/hr from a canal pumping station (based upon pump discharge capacity). El Nasr sells approximately 200 m3/hr of water to other companies in the area for L.E. .4/m3. Aluminum sulfate and limestone are added to the water, which is then clarified. Six sand and gravel filters are used to clean the water. Each filter can treat 100 m3/hr and each is backwashed for 15 minutes every 7 hrs with clean water and air. The plant uses 1.5 ton of chlorine per month. Five pumps are available to pump but only two 100 liter/sec (90 kW each) are used in the winter and three 75 liter/sec (75 kW each) are used in the summer. The water discharge header is at 5-7 bar.

1.3.9 Block 23 - Boilers

Steam for the entire El Nasr complex is produced in Block 23 from three identical boilers which burn heavy furnace oil (Mazot). Boilers #1-#3 are

watertube units of Russian design and construction and were built in 1964. The nominal capacity of each Russian boiler is 10 ton/hour at 10 bar. These units are balanced draft units with both forced draft and induced draft fans.

A fourth larger firetube boiler has recently been contracted from Egyptian Boiler Co. and is expected to come on line within the next several months. The new boiler has a nominal capacity of 12 ton/hr at 16 bar. Steam is distributed to all of the Blocks except Block 6 in a nominal 10 bar supply system; Block 6 has a separate but similar steam supply line since it was once the major steam user in the plant.

Section 2
Audit Approach and Philosophy

2.1 Introduction

The field survey was conducted at El Nasr Pharmaceuticals in Abu Zabal, ARE, in February 1988. Analysis of the information gathered in the field and preparation of this report continued in the office of OEP (Cairo).

The survey consisted of a review of the process and plant's performance by interviewing various managers, by reviewing drawings, design information, and selected operating records. Major sections of the individual Objects were inspected. A variety of process measurements/tests were undertaken, for example brine temperatures, condensate flow rates, compressor electric consumption, etc. A field survey of power plant operations was performed and selected measurements were made.

Appendix A contains a directory of all persons contacted in the course of this investigation.

2.2 Audit Approach

The energy audit began with a plant inspection and preliminary identification of energy conservation opportunities. During this initial evaluation, a wide variety of opportunities were identified and a qualitative screening analysis was performed to identify ECO's which had significant potential for energy savings (relative to other ECO's at the plant) and which warranted further investigation. Through this prioritization process, we focused on those ECO's which were of greatest importance to the plant.

For each of the priority ECO's, sufficient data was gathered to allow engineering design of the ECO and economic evaluation. The specific data gathered varied depending on the nature of the ECO. Data included plant logs and historical records, readings from plant instrumentation, and readings from portable instrumentation brought with the auditors. During the data analysis, all data collected was generally cross-checked and, where necessary, engineering judgment was applied. The level of engineering detail varied by ECO. Less detail was required for simple, inexpensive ECO's; more detail was required for complex or more expensive ECO's. In all cases, engineering judgment was used to direct the nature and extent of data evaluation.

2.3 Priorities at El Nasr

At El Nasr Pharmaceutical, the initial survey revealed that:

- The plant is a physically large plant but consumes modest quantities of energy (6500 ton/yr mazot, 13 million kWh/yr electric).

- About 67% of process energy is in the form of mazot and 33% as electricity.

- The plant's energy housekeeping had substantial room for improvement.

- The plant is a multi-product, high value/low volume, batch process based facility, with products typically produced in short campaigns several times a year.

- Little instrumentation in the 23-year old plant is still functioning.

- The plant has significant electrical consumption for refrigeration and air compression.

These observations led to certain conclusions with regard to the energy audit priorities at El Nasr:

1. The opportunities for improvement are probably moderate.

2. Because of the nature of the products, there are only limited opportunities on the process side.

3. The low volume, spread-out nature of the plant, coupled with intermittent processes, limit the economically attractive opportunities in the utilities area.

4. The main focus will be to greatly tighten up energy housekeeping.

Accordingly, our primary focus in this audit has been on the places where energy housekeeping can be more efficient.

Section 3
Plant Energy Profile

The El Nasr Pharmaceutical Co. uses heavy fuel oil (Mazot) to fire the steam boilers; and electric power to run lights, small motors, compressed air production, cooling tower motors, brine and cooling water pumps, ammonia refrigeration plant, and miscellaneous uses. Most of the electric users are (or should be) intermittent due to the batch production nature of the plant.

Tables 3-1 and 3-2 and Figure 3-1 present the historical electrical and fuel oil consumption of the plant. The power factor at the plant generally runs about 0.85. This seems reasonable based on selected power factor measurements made at the plant (see Appendix D). The refrigeration compressor drives are synchronous machines, which significantly helps the power factor.

Because of the variety of products produced at the plant, the batch nature of the processes and the general lack of instrumentation, it is difficult to estimate specific energy consumption. Components which need to be considered include: mazot, used to generate steam; electric energy used in refrigeration; electric energy for compressed air; and electric energy for miscellaneous motors, mixers, and drives. Figure 3-2 shows estimated specific energy consumption and total energy consumption based on steam consumption for some of the major products.

Table 3-1
Historical Electrical Usage
(kWh)

	Year 84/85 kWh	Year 85/86 kWh	Year 86/87 kWh	Year 87/88 kWh
July	1,006,400	905,100	893,400	1,322,900
Aug	949,000	1,168,300	1,315,700	1,293,800
Sept	1,020,000	984,000	1,313,300	793,500
Oct	1,585,500	1,134,000	2,291,792	1,409,500
Nov	1,026,800	964,800	1,110,000	855,200
Dec	932,500	715,300	1,288,700	1,102,700
Jan	1,164,900	1,032,000	1,800,800	
Feb	928,100	1,123,400	1,020,100	
Mar	996,000	429,400	1,161,700	
Apr	996,000	742,500	1,351,400	
May	1,161,600	1,455,500	991,700	
June	867,100	760,000	1,360,500	
Total	12,633,900	11,414,300	15,899,092	6,777,600
Power Factor	0.8	0.88	0.85	0.85
Cost, L.E.	175,906	240,334	333,934	177,918

Table 3-2
Fuel Oil Usage
(ton)

	Year 84/85 ton	Year 85/86 ton	Year 86/87 ton	Year 87/88 ton
July	511	551	552	479
Aug	533	557	521	457
Sept	560	528	519	460
Oct	588	573	568	524
Nov	619	519	540	526
Dec	760	531	627	563
Jan	620	526	604	
Feb	579	492	542	
Mar	625	576	575	
Apr	575	552	527	
May	549	576	518	
June	455	514	412	
Total	6,974	6,495	6,505	3,009
Cost, L.E.	195,572	181,860	182,140	84,252

Figure 3-1: Historical Energy Usage
El Nasr Pharmaceuticals

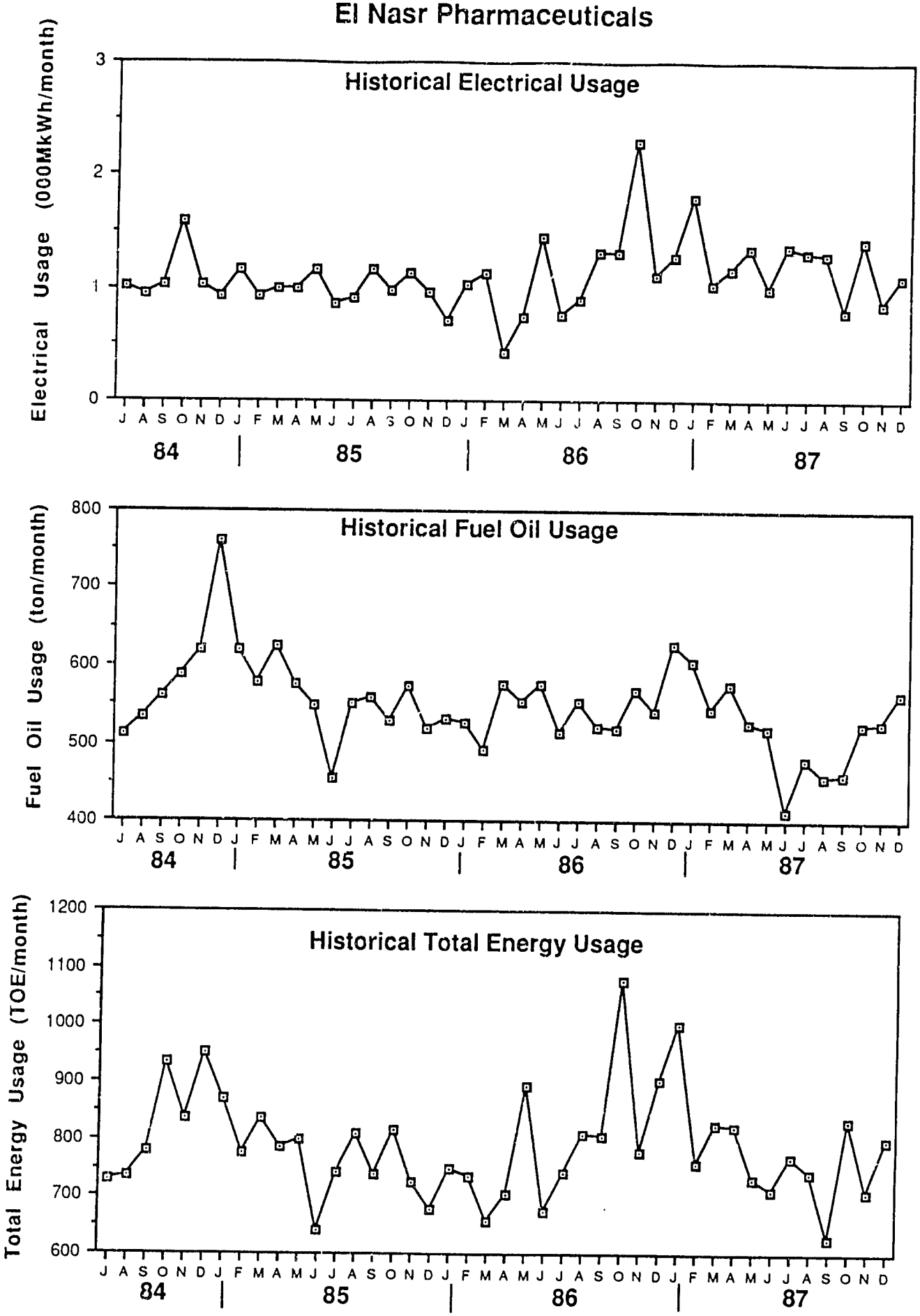
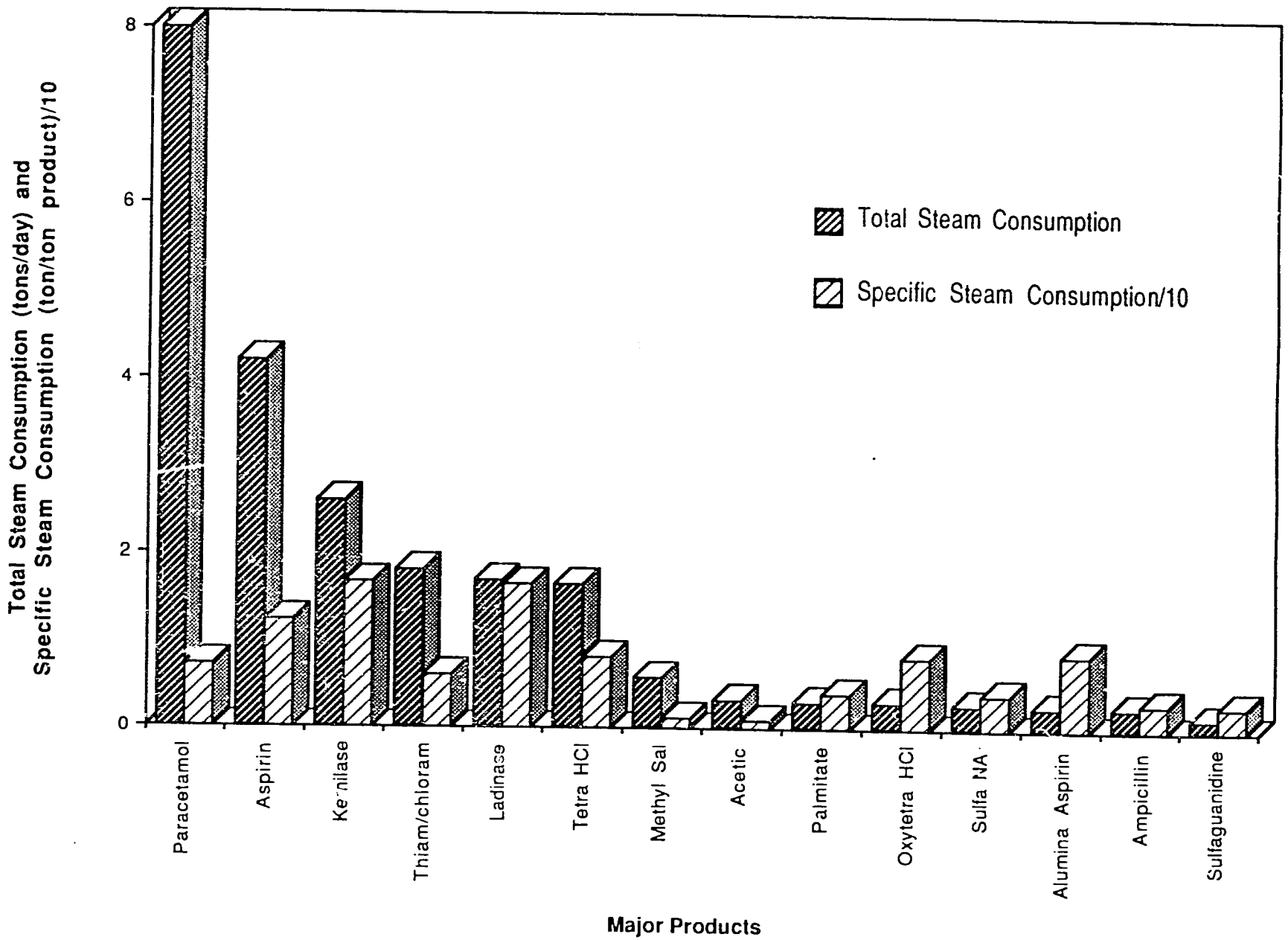


Figure 3-2: Specific Steam Consumption for Selected Products
El Nasr Pharmaceuticals



Section 4
Main Engineering and Economic Data

4.1 Energy Prices and Cost Estimates

For purposes of this analysis, the following fuel data has been used consistently throughout the various audits:

Fuel	Heating Value (GJ/unit)	Local Price (L.E./unit)	International Price ($/unit)
Fuel oil (Mazout)	41.9/ton	L.E. 28/ton	$112/ton
Diesel oil (Sular)	44.2/ton	L.E. 78/ton	$151/ton
Coke	29.0/ton	L.E. 193/ton	$ 88/ton
Electricity(1)	10.0/MWh	L.E. 26/MWH	$ 46/MWh

To convert from kilojoules (KJ) to tons oil equivalent, divide by 43.3 x 10^6 KJ/TOE.

Throughout this report, the term ton is used to indicate metric tons of 1000 kg. Annual operating hours are taken at 8000 hours/yr.

Capital cost estimates for the various energy conservation opportunities (ECO's) were developed using standard engineering factored cost techniques. Costs for key pieces of equipment were based on vendor quotes (either U.S. or Egyptian) or from our own internal cost files. All capital equipment cost estimates have been converted to equivalent US dollars at an exchange rate of L.E. 2.2/US$. Equipment cost estimates do not include import duties or taxes.

4.2 Plant Boilers - Basis for Recommendations 5.1, 5.2, and 6.7

Operation - (Basis for Recommendations 5.2 and 6.7)

The plant has three identical boilers which burn heavy fuel oil (mazout). The boilers are watertube units of Russian design and construction built in 1964. The nominal capacity of each is 10 ton/hr at 10 bar. Each boiler has an operating mazout flow meter, but there are no steam flow meters (see Figure 4-1). The boilers are blown down continuously, and they are also blown down manually every three hours. There is no separate boiler feedwater treatment at the plant. There is no condensate recovery. Although the plant was originally designed for condensate recycle, contamination problems resulted in its discontinuance. The boilers are balanced draft (FD/ID fans) and are equipped with economizers. They have one feedwater heater (deaerator), although little feedwater heating is accomplished. Apparently, in the original design, feedwater pump NPSH concerns led to a heat exchanger to cool the hot feedwater from the deaerator before entering the feedwater pump. Bsed on audit measurements, 100°C feedwater from the deaerator is cooled to as low as 30°C before entering the boiler feedwater pumps (see Figure 4-2).

The boilers are generally in reasonable condition considering their age and design. However, as is true for the plant in general, boiler instrumentation is almost completely lacking, with the exception of mazout

Figure 4-1: Boiler Arrangement
El Nasr Pharmaceuticals

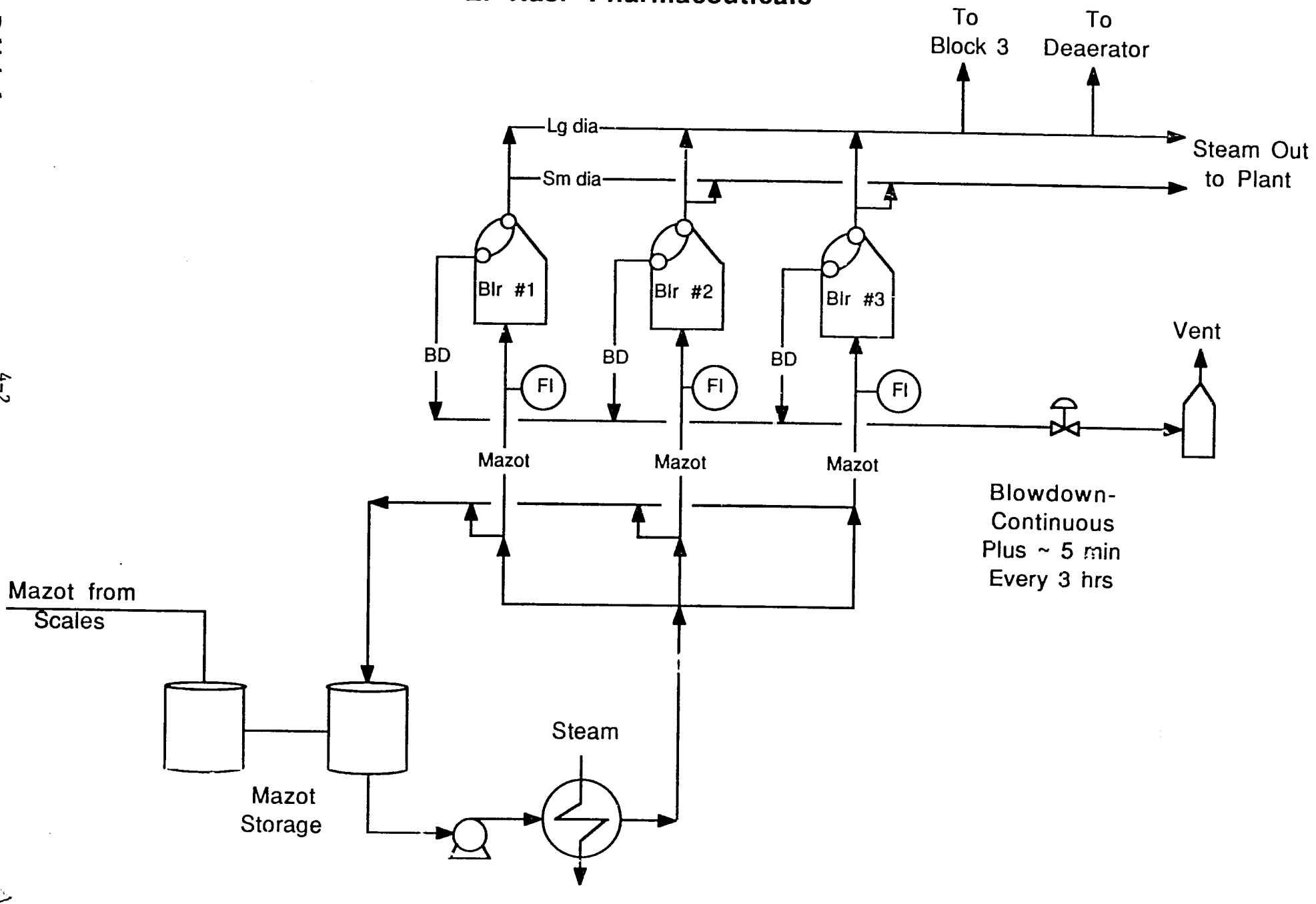
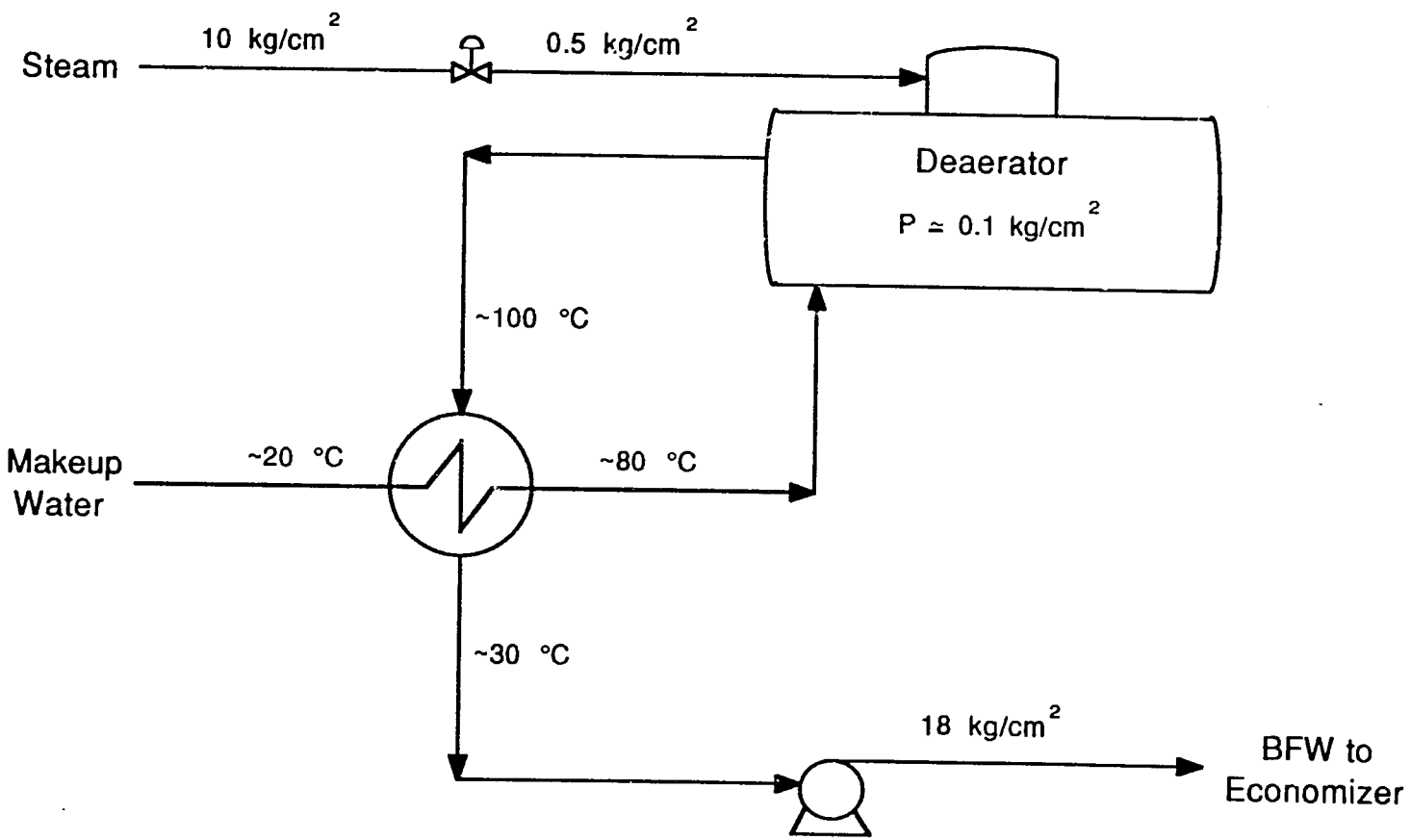


Figure 4-2: Boiler Feedwater
El Nasr Pharmaceuticals



flow meters to each boiler which were working, although they had not been calibrated for some time. Missing instrumentation included flow measurement for boiler feedwater and steam, temperature, furnace draft, etc. In addition, the air control dampers on both the FD and ID fans were no longer operational.

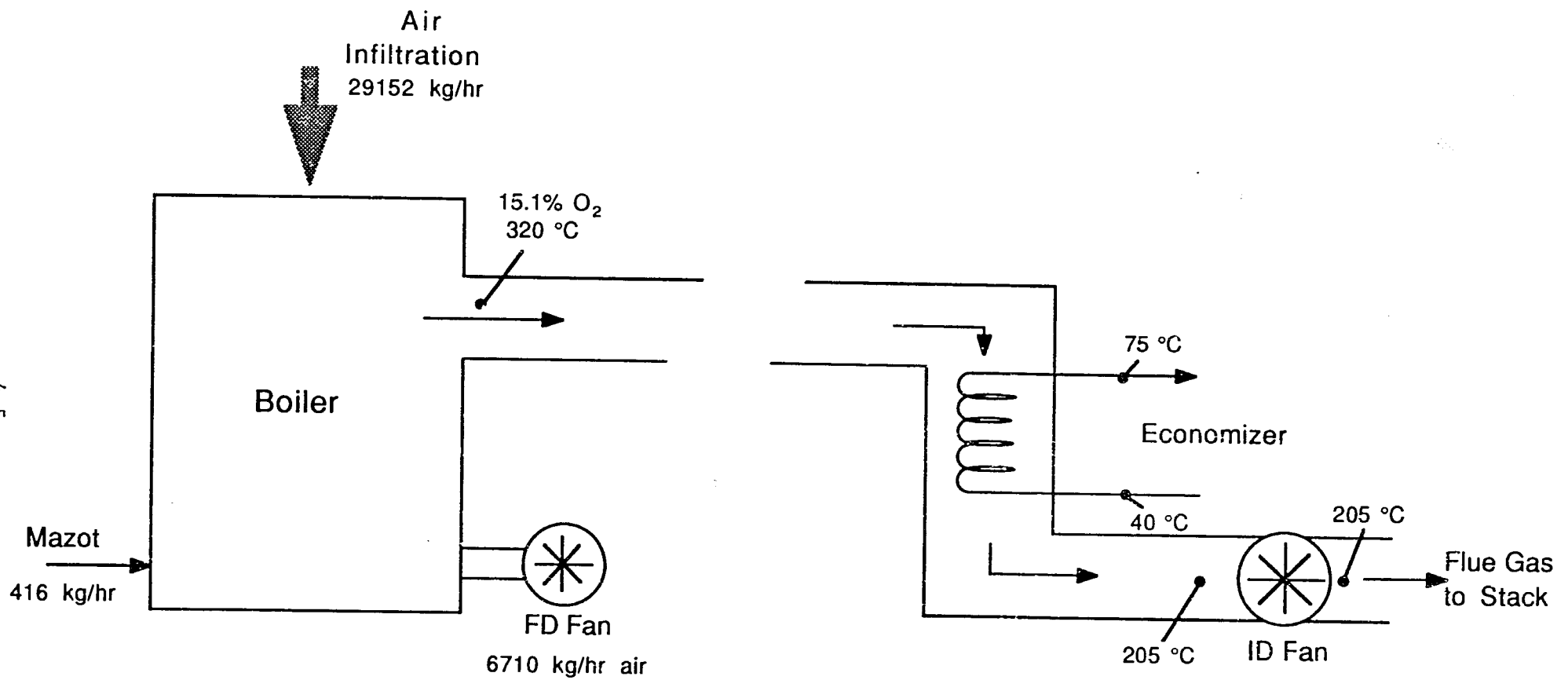
An attempt was made to measure boiler efficiency, but air infiltration appears to be extremely high. Along with the lack of instrumentation, this makes it difficult to get good boiler efficiency estimates. Primary data collected on boilers #2 and #3 are shown in the Appendix. Measurements of temperature and oxygen (O2) in the boiler backend (after the economizer) showed extremely high levels of air infiltration, when compared to the flow of air supplied by the FD fan. This would distort boiler efficiency calculations based solely on backend temperature measurements. The flow rate of combustion air was measured at the inlet to the FD fan and showed 20% excess air for boiler #2 and 38% excess air for boiler #3. Based on this, a simple material balance shows that air infiltration is substantial, possibly as high as 475% (see Figure 4-3). This appears to be due to excessive draft being created by the ID fan (since the measured FD fan air flow rate is not unreasonable for estimated mazout consumption).

To estimate likely boiler efficiency, an assessment was done evaluating boiler efficiency and mazout consumption as a function of air infiltration. Results are shown in Figure 4-3. Based on these results, boiler efficiency is estimated to be about 54% (LHV basis), versus a more normal level of about 85% for this type of furnace (new and clean). The main problems appear to be air infiltration and the resulting excess air which cools the flue gas, and low mazout temperature and worn out fuel nozzles which cause soot which limits heat transfer and represents lost energy.

As shown in Figure 4-1, mazout feed to the boiler is heated in a steam oil heater. These units are typically designed to heat the furnace oil to about 100°C to achieve proper oil viscosity for proper atomization. The measured oil temperature at the burners on #2 and #3 boilers was 70°C. Visual observation indicated substantial soot formation, which represents an energy loss. The stack at the plant indicated soot at 20% Ringleman black (a measure of opacity).

Recommendations for the boiler are complicated by the new 12-ton/hr boiler coming on-line in 1988. The new boiler has the capability to meet all of the plant's steam needs when it is operational. If the old boilers are used very little (after the new boiler is on-line), then it is uneconomic to perform any major rehabilitation work on them. On the other hand, if the old boilers are used a significant percentage of time when the new boiler is on-line, then improvements to the old boilers probably are warranted. For a new mazout firetube boiler such as this, we would expect a forced outage rate of about 5% initially, and a scheduled maintenance outage rate of about 5%-10%. However, we suspect that the plant will have the new boiler on-line whenever physically possible. If it does and maintenance is deferred, then we expect downtime to average about 15% after the first few years. We have assumed (1) that the new boiler will become the primary boiler at the plant, operating at as high an operating factor as is practicable (probably 90%-95%); (2) that two of the existing 10-ton boilers will remain in service, but normally will be on cold standby or at

Figure 4-3: Typical Boiler Measurements
El Nasr Pharmaceuticals



minimal load, except when the new boiler is down for forced outage maintenance.

Based on this we feel that two recommendations are justified:

- Recommendation 5.2: Increase mazout temperature.
- Recommendation 6.7: Excess air control

These recommendations are discussed in Section 6.

Monitoring - (Basis for Recommendation 5.1)

Total plant steam production is reported by the plant to range between 336 to 432 ton/day. However, total steam production is not verifiable through direct steam flow measurements due to the lack of instrumentation. However, during the course of the audit, a steam balance has been calculated, based upon a combination of field measurements and engineering calculations, and cross-checked by furnace efficiency calculations and fuel oil consumption.

We do not believe the plant estimates, i.e., that it is producing 336-432 ton/day of steam on an average basis, for three reasons:

First, the company has a contract to purchase 150 tons of mazout per week for 47 weeks; this quantity is weighed and billed through the shippers' weight records. This quantity agrees with the plant annual mazout consumption. Even if the boilers could consume this fuel at 85% efficiency (which they cannot), the maximum amount of steam that this quantity of mazout is capable of generating is only 285 ton/day. During the audit of Block 23, the actual efficiency of the boilers was measured to be between 55% to 60%.

Second, the overall plant steam production calculated from the steam production values measured during the audit indicated production levels of about 150 ton/day.

Third, boiler flow tests taken on #3 boiler indicated a maximum steam production rate of about 3.75 ton/hr (see Appendix D) giving a total production of two on-line boilers of about 180 tons/day.

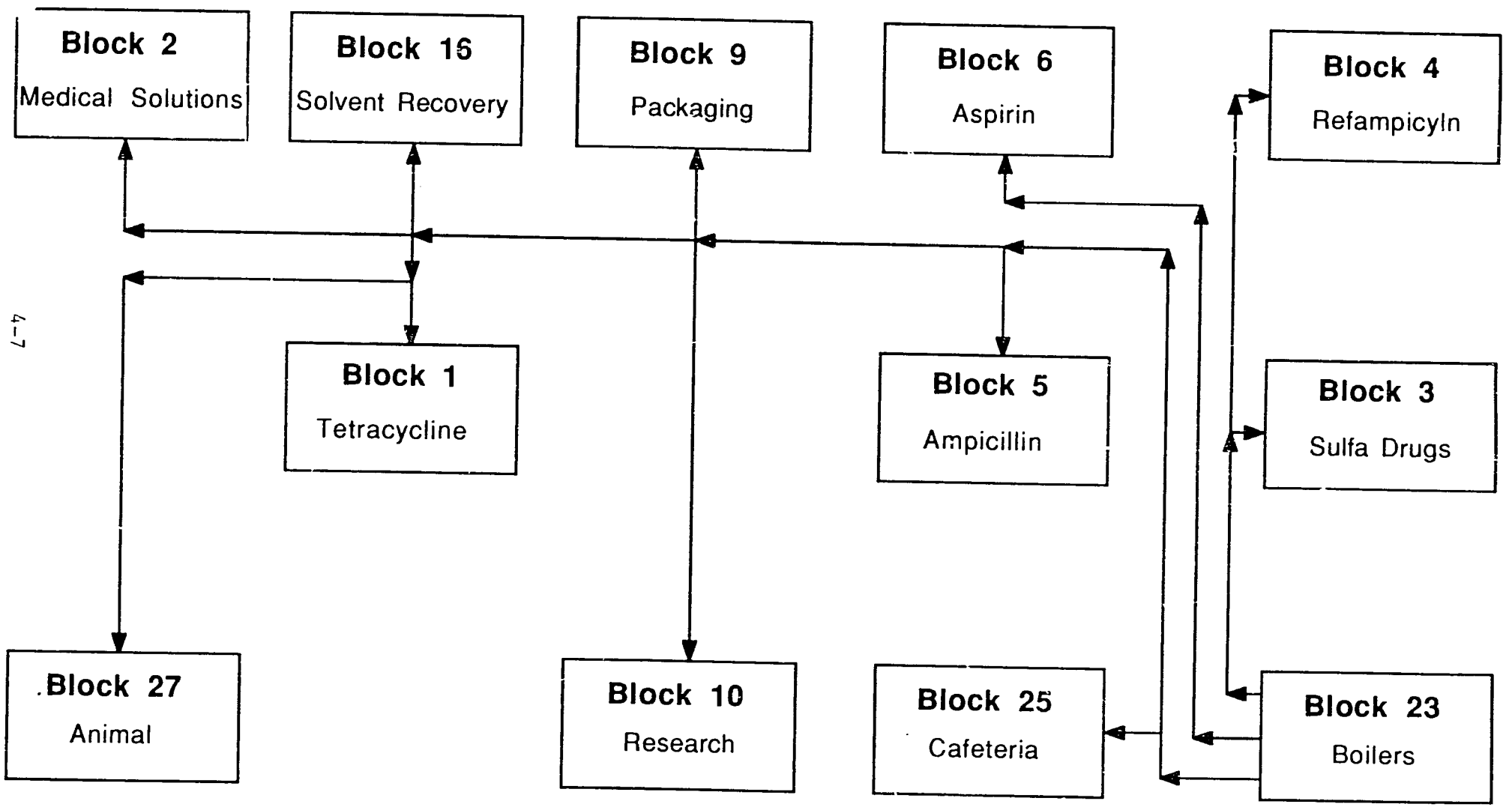
Thus, on an annual average, we believe the boiler plant is producing between 175-200 tons/day of steam.

Based on this, we feel it is appropriate for the plant to install additional metering at the boiler house (they already have mazout flow meters) to bring their steam generation numbers more in-line with reality. This is covered by Recommendation 5.1, Block 23, discussed in Section 5.

4.3 Steam Distribution - Basis for Recommendation 5.1

The steam distribution system to the primary users at El Nasr are shown in Figure 4-4. The boiler plant estimates the consumption of steam by the various users based upon monthly pharmaceutical production (weight) from

Figure 4-4: Block Steam Diagram
El Nasr Pharmaceuticals



each Block. The calculated steam production is then distributed by weight fraction to each Block. We do not believe this procedure produces useful results from an energy point of view.

We estimated consumption of steam by Block by determining how much steam was utilized in the present production of products. Table 4-1 presented below provides the annual production of products and the amount of steam apparently being consumed for production heating or reaction, drying, and distilled water for formulation. The detailed basis for this Table is presented in Appendix B.

Table 4-1
Basis for Steam Consumption by Block

Block 1	Tetra HCl	Oxy Tetra HCl	Penicillin	Kemilase	Ladinase	Total
Total Production (ton/yr)	30.355	5.485	18.708	18.6	12.15	
Steam/day	1.64	0.29		2.6	1.7	6.23
Steam for distilled water/day						2.4
Total steam ton/day						8.63

Block 3	Sulfa-guanidine	Sulfa-dimidine NA	Total
Total Production (ton/yr)	31.0	17.1	
Steam/day	0.15	0.28	0.43
Steam for distilled water/day			2.1
Total steam/day			2.53

Block 5	Thiam Chloram	Palmitate Stearate	Ampicillin	Paracetomol	Total
Total Production (ton/yr)	46.2	16.5	33.3	156.5	
Steam/day	1.8	0.3	0.25	8.0	10.35
Steam for distilled water/day					5.3
Total steam/day					15.65

Block 6	Aspirin	Acetic Acid	Methyl Salicylate	Alumina Aspirin	Total
Total Production (ton/yr)	353	69	84	3.2	
Steam/day	4.2	0.33	.58	0.26	5.37
Steam for distilled water/day					1.86
Total steam/day					7.23

Based on the estimated total steam production and various measurements made during the audit, an estimated distribution of steam consumption among the various blocks is shown below in Table 4-2.

Table 4-2
Estimated Steam Consumption by Block
El Nasr Pharmaceuticals

Block	Product	Steam Consumption
1	Tetracycline	9 ton/day
2	Medical solutions	20 ton/day
3	Sulfa drugs	3 ton/day
4	Refampycillin	1 ton/day
5	Ampicillin	16 ton/day
6	Aspirin	7 ton/day
9	Packaging	negligible
11	Air, brine utilities	negligible
16	Solvent recovery	negligible
21	Water Treatment	negligible
23	Boiler Plant	10 tone/day
34	Waste Water	negligible
	Insufficient insulation	20 ton/day
	Faulty steam traps and leaks	40 ton/day
	Miscellaneous and unaccounted	49 tonne/day

Recommendations covering energy monitoring instrumentation desirable at the plant to more accurately determine the steam balance are covered by Recommendation 5.1, Blocks 1, 3, and 4, discussed in Section 5.

4.4 Electric Users - Basis for Recommendation 6.4

The plant uses electric power for lighting, refrigeration, compressed air, cooling tower/cooling water/brine pumps, and in various small motor drives. The major electric loads at the plant are shown in Table 4-3.

Table 4-3

El Nasr Major Electric Motors
(connected load-kW)

Air Compressors	
High pressure	159
Low pressure	235
NH_3 Refrigeration Compressors	320
Brine pump	75
Water Treatment	
(2) 100 liter/sec (winter)	180
(3) 75 liter/sec (summer)	225
Waste Treatment	40

The ammonia refrigeration system was originally built with six 220 kW synchronous motor driven ammonia compressors; at most, only two units are presently operated at one time. Only one compressor is used in winter, a second comes on-line in summer. These units compress the ammonia used as refrigerant to produce the cold brine. The cold brine is pumped to the user by a 75 kW turbine pump with a capacity of 360 m^3/hr. The cold temperature of brine discharge is -4.0°C, and the warm return temperature was -2.7°C. Therefore, the observed cooling load is 544 kW. The COP of the refrigerant system is 2.5. The refrigeration system was reasonably well-maintained and operated, and no priority recommendations were identified.

There are six low pressure (2 bar) turbine air compressors; one is always running. The rated size of the air turbine motor is 235 kW. Low pressure air is now primarily used for fermentation in Block 1. Most of the other compressed air is produced by local-higher pressure-machines (see Table 4-4).

Table 4-4
Electric Usage for Air
1987 Calendar

	# Units Avail.	# on	Power kW	Delivery Pressure Bar	Flow M^3/min
Plastic	1	1	52	8	6.3
Block 2	2	1	43.5	8	5.2
Blocks 3,4	3	2	7.5	8	0.97
Block 5	1	1	7.5	10	0.9
Block 6	4	3	7.5	8	0.97
Block 10	3	2	11,7.5	8-10	
Block 11	5	1	235	2	30.0

Annual Power Consumption 3,152,000 kWh

Since there is no pressure control on the low pressure air receiver, the air compressor runs all the time, even when it is not needed. Since fermentation only runs about 40 hours per week, the air compressor is needlessly running about 75% of the time.

The temperature of the air compressor discharge was measured and found to be 220°C. (It should be about 120°C). This is another indication that the compressor is not producing useful work. An ampere meter was connected to the compressor, and the average current draw of the compressor was measured to be 260 A. Therefore, the measured electric load was 145 kW. This air is supplied to Block 1 for fermentation, however no fermentation was running that day. On another day, the measured current draw was 300 A, and fermentation was running one fermenter; this gives an electric load of 167 kW.

By shutting the compressor off when it is not needed, significant electrical savings will result. This is covered by Recommendation 6.4 discussed in Section 6.

4.5 Steam End Users - Basis for Recommendations 6.1, 6.2, 6.3, 6.4 and 6.6

Insulation - (Basis for Recommendation 6.6)

The main steam distribution lines at El Nasr are reasonably well-insulated. However, many of the local service lines from the main to the individual blocks are uninsulated as is much of the piping within the blocks. The steam service lines in El Nasr are predominantly 1 and 2 inches in diameter, containing saturated steam at about 6-8 Bar, corresponding to a line temperature of 170°C. The plant contains about 3000 feet of steam service lines. Insulation prices for 1-inch pipe was determined for calcium silicate insulation (a different type of local insulation may be available but calcium silicate is preferred due to life expectancy and insulating value) with an aluminum jacket. The installed prices for 1-inch diameter pipe per meter are: for 1-inch thick $ 23.55, for 1.5-inch thick $27.00, for 2-inch thick $ 33.82. If fiberglass insulation is available, installed prices are estimated per meter to be: for 1-inch thick $7.55; for 2-inch $9.25.

The overall heat losses for insulated pipe are given in Table 4-5:

Table 4-5
Heat Losses for 1-inch Steam pipe

	Insulation Thickness in Inches			
	0.0	1.0	1.5	2.0
Heat loss, kj/hr/m	879	104	90	83

The resulting savings per meter of pipe were then calculated in USD per year based on 8000 hours of operation per year. The payback period for various thickness can then be calculated. This calculation determined that the highest payback occurred for 1-inch thick insulation. Recommendation 6.6 addresses insulating steam service piping and is discussed in Section 6.

Condensate Losses and Distilled Water - (Basis for Recommendation 6.1)

At the present time, the Blocks return no condensate to the boilers. In evaluating the condensate for boiler return, several factors must be weighed--the quantity or heat value of condensate, the equipment cost for condensate return, the distance (for heat losses), cost for cleanup of suspect or dirty condensate. At El Nasr, the plant layout makes heat losses from piping runs significant, and return piping expensive per unit condensate returned. Since the same reactor heating jackets are used for brine cooling and steam heating, cleanup costs of condensate is high. Thus, condensate from jacket heating steam is not economic to recover, without expensive modifications to the reactors.

On the other hand, condensate produced from distilled water production has little potential for contamination. Thus, recovery of condensate from distilled water production looks attractive, as long as quantities available vs. return distance to boiler is reasonable. The table presented

below presents the plant use of distilled water and summarizes the associated clean condensate available for return to the boilers at El Nasr.

Table 4-6

Distilled Water Usage
1987 Calendar

	M3/day	M3/hr	Ton/yr
Block 1	2.0		666.6
Block 2		2.0	4637.3
Block 3	1.14		379.9
Block 5	4.5		1499.9
Block 6	1.0		333.3
Total			7517.0

The condensate available from the Block 2 Aqua Purifier for return to the boilers is 20 ton/day at 140°C. The piping distance is 550 m and either 1/2- or 1-inch diameter pipe is sufficient for the flow rate. The smaller pipe has less heat loss per meter but cannot be recommended on a structural integrity basis. The condensate will cool to 79°C, if 1/2-inch pipe is used and to 44°C if 1-inch pipe is used.

Block 5 is the second largest producer of condensate from distilled water make. However, the equipment is different from Block 2, and the condensate is only at 100°C, and the quantity is about one third that available from Block 2. Even though Block 5 is located closer to the boiler plant, the piping energy losses make its recovery unattractive. The calculations are in the Appendix.

A condensate recovery system for Block 2 is attractive under international energy prices and is covered in Recommendation 6.1, and discussed in Section 6.

Dryer Losses - (Basis for Recommendation 6.5)

Performance data for typical tray and compartment dryers indicate a thermal efficiency of between 20% to 50%. If drying to a very low moisture content, this efficiency may drop to 10%. The tray dryer in Block 5, which is used to dry paracetamol crystal, was consuming 1 ton/hr of steam based on a series of field measurements. The 1987 annual production of paracetamol was 156.54 tons, and the average moisture content of the wet cake is 30%. The dryer total annual water load is 47 tons, and drying time is 5 hr/batch. A production or dryer batch is 300 kg, therefore approximately 520 batches are dried, and total drying time is 2600 hours. At 1 ton steam/hr, annual steam consumption is 2600 ton/yr. The thermal efficiency of this dryer is 47 divided by 2600 or 1.8%. Factors contributing to this low efficiency which were observed during the audit were (1) the lack of a steam trap, (2) the use of superheated steam, (3) the lack of air damper control, and (4) the lack of any observable air flow through the dryer.

Improvement of drying efficiency in the tray dryers is covered by Recommendation 6.5 and discussed in Section 6.

In addition to this dryer, which we believe to be the major steam user among the plant dryers based on the levels of products produced, there are a number of other dryers which were not operating during the audit.

The table below presents the breakdown of major dryers and indicates whether or not they have steam traps. The plant has old swing-open door dryers. One of the main reasons the Block 5 paracetamol dryer was found to be wasting energy was due to lack of steam traps. The new dryers are in better condition, use smaller flows of steam, and have functional steam traps.

Table 4-7
Plant Dryers and Steam Traps

Type Dryer	New	Old
Block 1	+1	+4
Block 2		
Block 3	+1	+5
Block 4		+2-2
Block 5	+3	+4-2
Block 6	+1	-4
Block 9	+2	+5

Notes: + is with steam trap
- is without steam trap
All blocks have steam traps in main line feed

We recommend that the operation of Block 4 dryers be studied and changed (see Recommendation 6.5) if found to operate like Block 5.

Reactor Heating - (Basis for Recommendation 6.2)

From Table 4-1, it has been estimated that 2.35 tons/day of steam are used for providing hot water flow to the reactors in Block 5 (ampicillin, chlorampenicol, palmitate/stearate lines). This is made up in an indirect heat exchanger (hot water heater) heated by steam. The reactor jacket heating water is used once and discarded instead of heating. However, the heating water exiting the reactor could be recycled to the hot water heater and reheated. The process currently only utilizes 15% of the steam energy; a hot water loop could recover 75% of the current losses. A hot water loop is discussed in Recommendation 6.2, Section 6.

Steam Traps - (Basis for Recommendation 6.3)

During our audit of the facility, a number of steam traps in various blocks were observed to be bypassed, out of operation, or simply missing. Significant quantities of steam can be lost through leaking traps, leaking valves, and leaking flanges. Especially in a batch plant such as this, operating for short campaigns, these types of losses can result in a sizable fraction of total steam production, and they are easily repaired.

As an example of a major leak, the steam trap on the main steam feed has failed. This one trap is estimated to loose about 0.6 ton/hr of steam or over 5% of actual steam produced. This trap should be fixed immediately as discussed in Recommendation 6.3 and a plant-wide steam housekeeping program should be started.

Section 5
Energy Management Improvements

5.1 Recommendation 5.1 - Energy Monitoring

There is presently very little functioning on-line instrumentation for monitoring energy at El Nasr. To understand energy consumption in the plant it is imperative that instrumentation be functioning and that the resulting data is recorded and analyzed. In order for the instrumentation to be functioning it is also important that the plant have the necessary skills to repair and maintain the instrumentation. The major benefit from regular energy monitoring and data evaluation is steam consumption control in the various production areas. We recommend that local steam flow be monitored at the following locations (see Figure 5-1).

Block 1. The estimated use of steam (8.6 ton/day) for Block 1 is far less than has been calculated by the boiler plant and we recommend that a flow element be added to the steam supply to ascertain the energy consumption of this Block. The estimated cost for this flow element and local recorder is $3,000.

Block 3. The estimated use of steam (2.53 ton/day) for Block 3 is far less than has been calculated by the boiler plant and we recommend that a flow element be added to the steam supply to ascertain the energy consumption of this Block. The energy consumption for two products was not available at this time. The cost of this flow element and recorder is $3,000.

Block 4. The estimated use of steam for Block 4 is far less than has been calculated by the boiler plant and we recommend that a flow element be added to the steam supply to ascertain the energy consumption of this Block. The energy consumption for two products does not represent the complex use of steam in this Block. The cost of this flow element and recorder is $3,000.

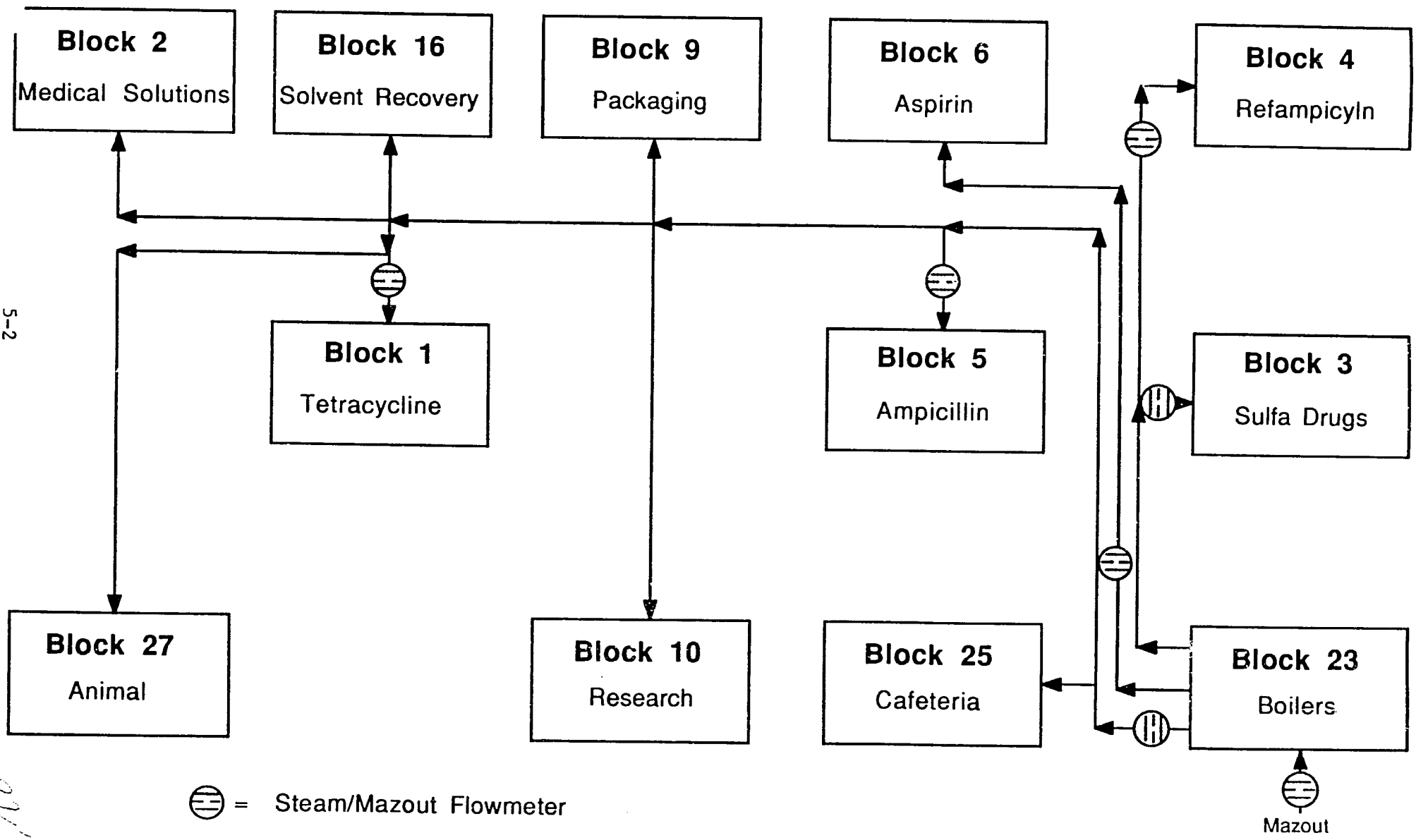
Block 23. As a minimum level of instrumentation to be maintained for monitoring basic energy consumption information at the boilerhouse, we recommend that the following instruments be repaired, maintained in working order, or added:

(1) Mazout flow meter - Total
(3) Mazout flow meter - Boiler #1, #2, #3 (calibrate)
(1) Mazout flow meter - Boiler #4
(1) Steam flow meter - 10 bar header (to Block 6)
(1) Steam flow meter - 10 bar header (to all other blocks)
(3) Boiler feedwater flow - to each boiler

Capital costs are estimated to be $11,000.

In addition to the meters outlined above, the meters to individual objects should also be rehabilitated (5 meters). At the same time, the plant should ensure that it has sufficient spare parts to maintain the steam flow meters, mazout meters, and O_2 analyzers on the new #4 boiler.

Figure 5-1: Proposed Energy Monitoring El Nasr Pharmaceuticals



5.2 Recommendation 5.2 - Block 23-Mazout Temperature

The temperature of the mazout at the boiler burners was 70°C. The mazout is heated by steam from the boilers. Low pressure air atomizers are usually designed to handle oil at 100 SSU. For various grades of #6 fuel oil the temperature required to achieve 100 SSU is between 91-129°C. The maximum allowable atomization temperature is 146°C. Firing the mazout at cold temperature decreases boiler efficiency by forming soot (lost energy) and by fouling heat transfer area. The stack at the plant indicated soot at Ringleman 20% black.

Based upon these conditions we recommend that (1) the steam flow be increased to the mazout heaters, (2) if this does not increase the temperature, and /or in addition, that the exchanger transfer area be thoroughly cleaned, (3) if above not effective that another heat exchanger be added.

5.3 Preventative Maintenance

Preventative maintenance for both energy conservation and instrument reliability should be established. The plant has the personnel necessary to accomplish this task and the expertise is available, since critical instrument control loops for production are repaired. Instruments, which focus attention on energy usage, must be given similar attention in order to control energy costs. A proven byproduct of preventative maintenance is increased plant reliability and production.

5.4 Energy Task Force

A concept which has proven effective in other operating plant environments is the energy task force. The task force chooses a block or user within the block for comprehensive analysis. The goal of the task force is to balance the energy cycle of the user and suggest modifications to lower energy usage. However, in the first phase of establishing a energy task force at a plant such as El Nasr, the energy balance may not close to better than an order of magnitude. The task force should add required energy monitoring equipment or consider alternate temporary measuring techniques to determine if the equipment is consuming excessive energy. Such non-elegant methods as buckets and stopwatches for measuring flow, manometers across broken flow orifice recorders or even elbow flow taps can yield surprising energy saving methods or ideas. One of the first goals of the Task Force should be to tighten up steam housekeeping, especially failed or missing steam traps (see Recommendation 6.4), and flange or valve steam leaks.

Section 6
Energy Conservation Opportunities

6.1 Housekeeping and Low Cost/No Cost Recommendations

An important part of energy management, and one of the most cost effective ways to reduce energy costs, is good energy housekeeping. Minimizing leaks, keeping heat transfer surfaces clean, and properly maintaining steam traps and instruments are all important to minimizing energy costs. There are several areas in particular that are important to El Nasr in keeping its energy costs under control.

6.1.1 Recommendation 6.1 - Block 2-Condensate Recovery

Recovery of steam condensate from the Aqua Purifiers in Block 2 appears to be the only area of the plant where condensate recovery appears economic at the present time. The condensate is clean and no boiler feedwater cleanup will be required. The proposed condensate receiver is shown in Figure 6-1.

The capital cost is $7,100 which consists of $5,500 for piping, $1,000 for pump, $500 for drum and $100 for simple level control.

The economics of recommendation 6.1 are summarized below:

Annual energy (steam) savings: 7.3×10^8 KJ/yr (28 TOE)
Capital cost: $7,100
Annual savings: $3,230
Simple payback: 2.2 years
Internal rate of return[1]: 44%

The bill of materials for the required equipment is shown in Appendix B; capital cost estimates are also broken down in Appendix B.

6.1.2 Recommendation 6.2 - Block 5-Hot Water Loop

From Table 4-1 presented in Section 4, it has been estimated that 2.35 tons/day of steam are used for providing hot water flow to the reactors in Block 5 (chloramphenicol, chloramphenicol palmitate/stearate lines). The process actually consumes or utilizes only 15% of this steam. A hot water loop could recover 75% of this excess or 1.5 ton/day of steam. The annual savings in mazout would be 58 tons. The hot water loop is shown in Figure 6-2. The total hot water circuit would cost $15,500. This is comprised of 3 temperature control loops at $9,000, a recycle tank of 2.5 m3 at $5,000, and a water pump for $1,500. The payout period is 53 months on world pricing.

The economics of Recommendation 6.2 are summarized below:

Annual energy (steam) savings: 1.3×10^9 KJ/yr (52 TOE)
Capital cost: $15,500
Annual savings: $5,970/yr
Simple payback: 2.6 years
Internal rate of return: 38%

---

(1) Internal rate of return and simple payback are discussed in Appendix G.

Figure 6-1: Block 2 Condensate Recovery Assembly
El Nasr Pharmaceuticals

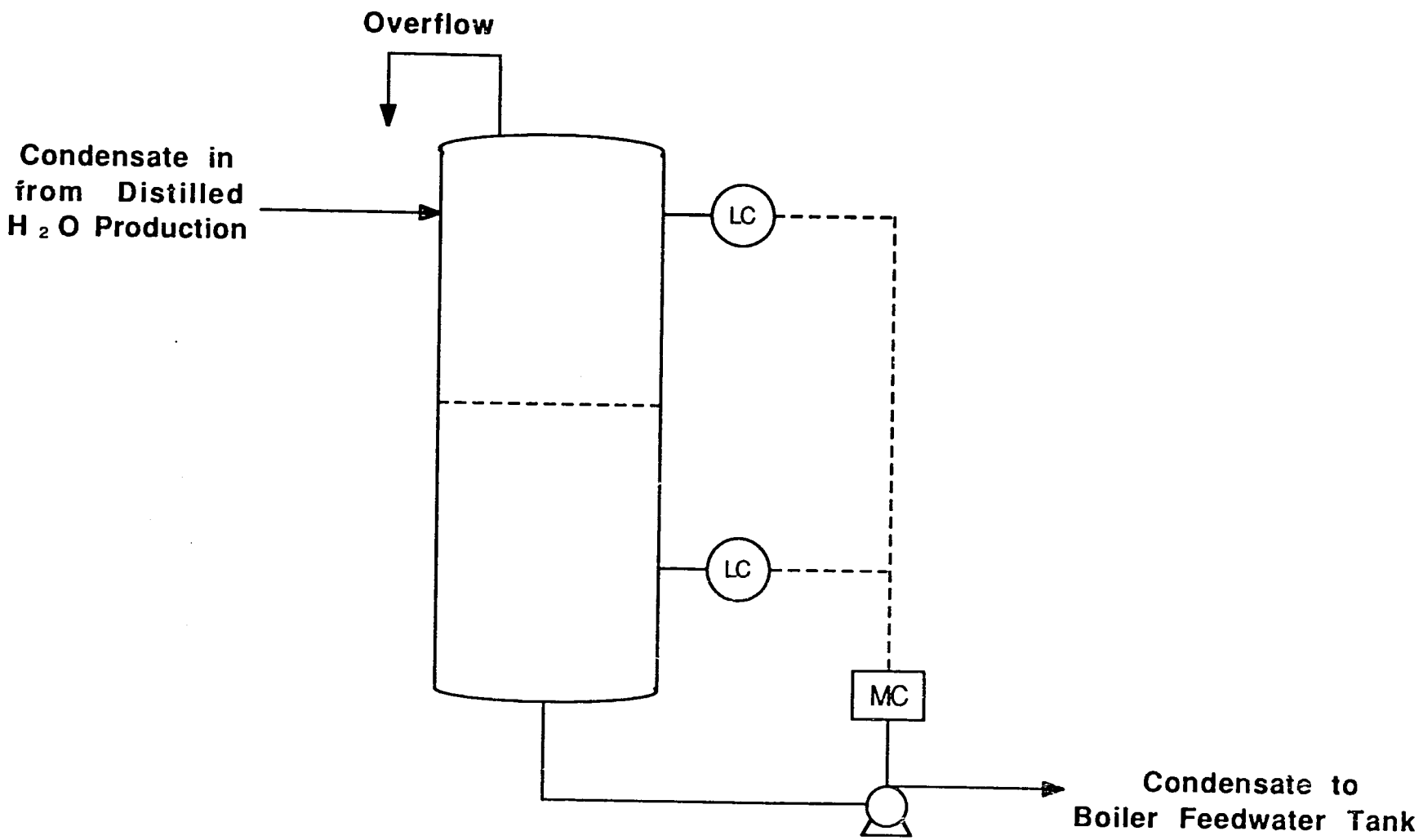
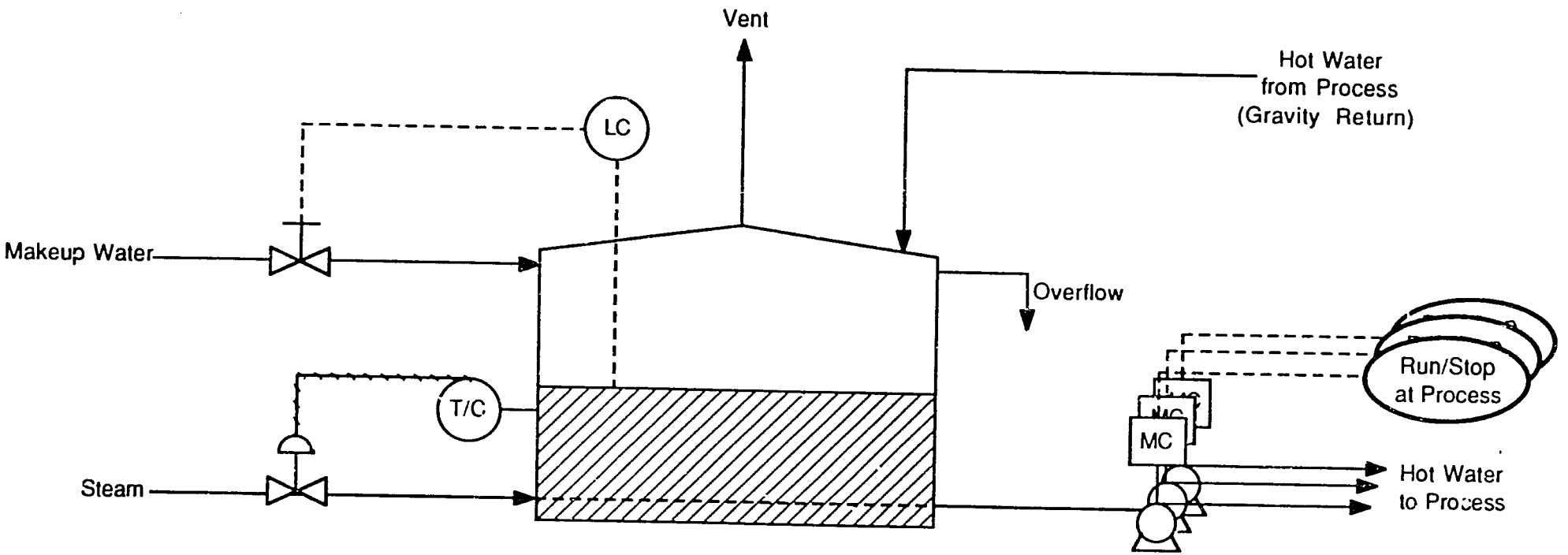


Figure 6-2: Block 5 Hot Water Loop
El Nasr Pharmaceuticals



The bill of materials for the required equipment is shown in Appendix B; capital cost estimates are also broken down in Appendix B.

6.1.3 Recommendation 6.3 - Block 6-Steam Trap

During the audit, the steam trap on the main feed to Block 6 was observed to be malfunctioning. In addition, the flange upstream of the trap was passing steam around the entire flange surface. The measured steam loss from this one trap in the high pressure line is 0.6 ton/hr or 560 ton/yr of mazout. The cost for replacing the trap with a standard inverted bucket trap is $300.

The economics of this recommendation are summarized below:

Annual energy savings: 1.3×10^{10} KJ/yr (481 TOE)
Capital cost: $310
Annual savings: $55,700/yr
Simple payback: immediate
Internal rate of return: >1000%

6.1.4 Recommendation 6.4 - Block 11-Low Pressure Air System Phase 1

Since only two fermentation are run per week in Block 1 and each fermentation is only 20 hours, the low pressure air is only required for 24% of the time that the compressor is actually running. This compressor should be turned off when fermentation is not in operation. This will reduce the power consumption by this compressor by 75%, which will result in a significant decrease in the overall electric consumption by the plant.

The expected annual savings to the plant are about 1,000,000 kWh/yr or 6.1% of plant annual electric consumption. As an alternative, if it is difficult to turn this compressor on and off manually, a pressure control loop could be added to the low pressure air receiver to perform the same function automatically (see Figure 6-3).

The economics for Recommendation 6.4 are summarized below:

Annual energy savings: 9.7×10^{9} KJ/yr (223 TOE)
Capital cost: $3,500
Annual savings: $44,390
Simple payback: immediate
Internal rate of return: >1000%

The bill of materials for the required equipment is shown in Appendix B; capital cost estimates are also broken down in Appendix B.

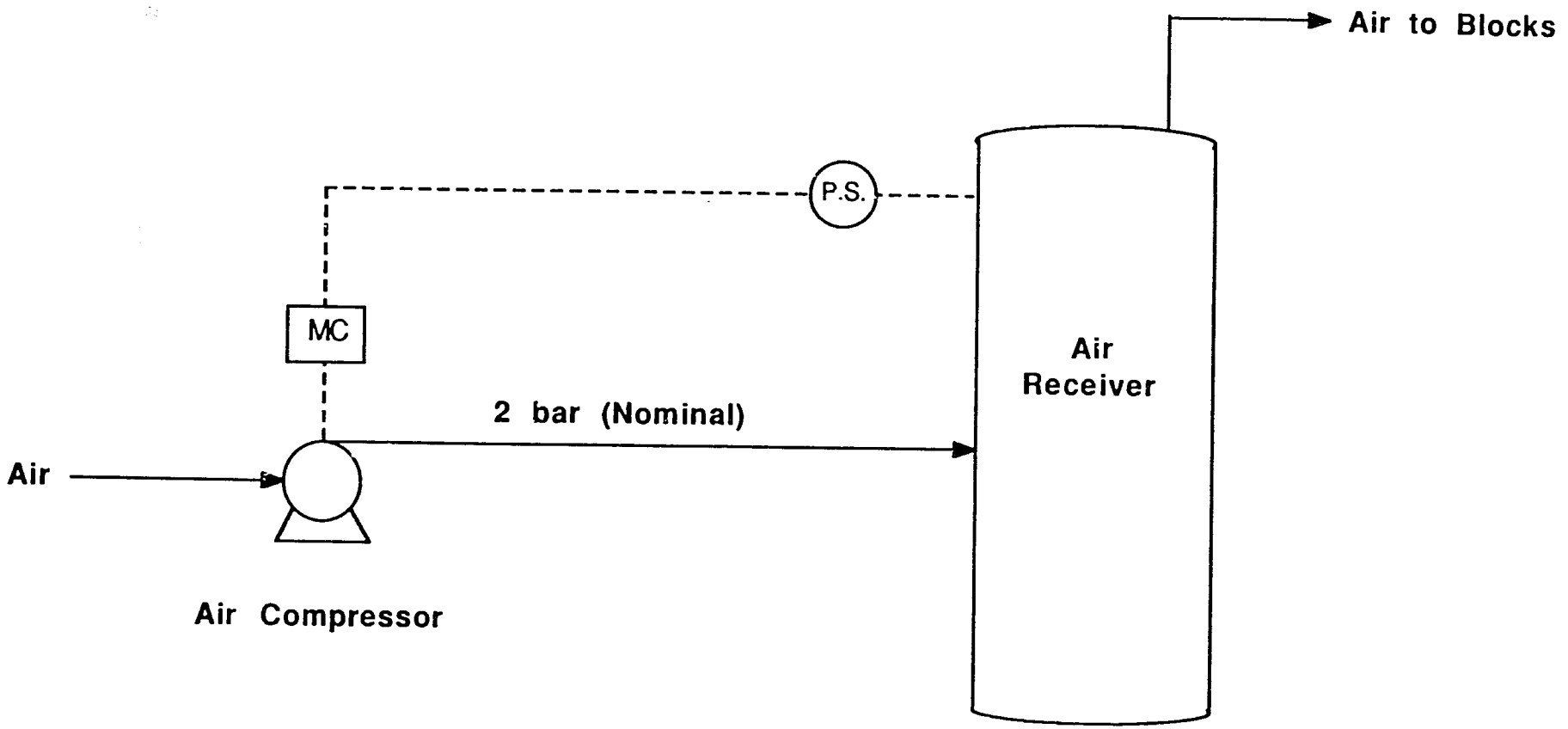
6.2 Capital Equipment Recommendations

6.2.1 Recommendation 6.[illegible] - Block 5-Dryers

The old tray dryer used for paracetamol in Block 5 uses significant quantities of steam; measured efficiency is 1.8%, normal efficiency should be 10-50%. The main problems are lack of a steam trap and the use of superheated steam in the dryer (instead of saturated steam).

Recommended corrective action is to use sufficient water in the desuper-

Figure 6-3: Low Pressure Air System
El Nasr Pharmaceuticals



heater to supply saturated steam to the dryer. This will increase the heat transfer coefficient in the air heater and reduce the LMTD. The net result is to transfer the same hourly heat into the dryer air flow but significantly reduce steam consumption. The use of saturated steam will also allow the addition of a steam trap to this dryer. A temperature control loop on the saturated steam flow will ensure the supply of saturated steam. The total cost for this is $3310. This is comprised of $310 for the steam trap and $3000 for the temperature control loop. The efficiency of dryer will be raised by a minimum factor of six, which will save 2130 tons/yr of steam or 228 ton/yr of mazout.

The economics of Recommendation 6.5 are summarized below:

Annual energy (steam) savings: 5.7×10^9 KJ/yr (220 TOE)
Capital cost: $3,310
Annual savings: $25,500/yr
Simple payback: 0.1 years
Internal rate of return: 771%

The bill of materials for the required equipment is shown in Appendix B; capital cost estimates are also broken down in Appendix B.

6.2.2 Recommendation 6.6 - Insulation of Steam Lines

Although the main steam distribution lines at El Nasr are reasonably well-insulated, many of the Block's steam service lines are uninsulated. These lines, predominantly 1 and 2 inch diameter, should be insulated. Calcium silicate insulation is preferred for longer life and durability. However, if fiberglass is available locally at a substantially lower price, it could be investigated as an alternative.

The economics of Recommendation 6.6 are summarized below:

Annual energy (steam) savings: 5.7×10^9 KJ/yr (219 TOE)
Capital cost: $21,500
Annual savings: $25,400
Simple payback: 0.8 years
Internal rate of return: 118%

The bill of materials for the required equipment is shown in Appendix B; capital cost estimates are also broken down in Appendix B.

6.2.3 Recommendation 6.7 - Block 23-Air Infiltration and Excess Air Control

Current boiler efficiency is estimated to be about 54% (LHV basis). The main factor influencing this value appears to be the very high level of air infiltration into the boiler, caused by the high draft created by the FD fan and cracks and openings in boilers. Air infiltration may be as high as 475%. Proper adjustment should allow this value to be decreased to 80%. This would improve the boiler efficiency to 75%. At an estimated mazout consumption of 6500 ton/year, annual mazout savings are estimated to be approximately 1820 ton. Depending upon capacity utilization of the old

boilers after the #4 boiler is on line, annual savings for both boilers are estimated to be:

Equivalent Full Load Hours	5%	10%	15%	20%
Mazout Savings	91 ton	182 ton	273 ton	364 ton
Annual Savings	$10,200	$20,384	$30,600	$40,768

Capital investment is estimated at about $12,000 per boiler, giving a 9-month payback for 15% equivalent usage on one reconditioned reboiler. The work effort required to implement this option will include rehabilitating the FD and ID fan dampers as necessary; adding a flue gas O_2 monitor, adding furnace draft instrumentation, and repairing the inspection doors/furnace shell to cut down infiltration. The dampers should be pulled and inspected to ascertain the extent of repairs before this recommendation is implemented.

The economics of Recommendation 6.7 are summarized below for 15% equivalent usage:

Annual energy savings: 1.1×10^{10} KJ/yr (264 TOE)
Capital cost: $24,000
Annual savings: $30,600
Simply payback: 0.8 years
Internal rate of return: 127%

The bill of materials for the required equipment is shown in Appendix B; capital cost estimates are also broken down in Appendix B.

Appendix A

PEOPLE CONTACTED AT EL NASR

Chairman	Dr. Osama Kebir
Head of Planning	Dr. Hamdy
Prime Engineer	Eng Hussein Ramaden
First Engineer of Maintenance/Workshop	Eng Mohamed Kamel
First Engineer of Power	Eng Samir Nessem
Power Engineer	Eng Wadie Girgis
Engineer	Eng Lotfy Abd Ella
Block 1	Eng Scalah Abou El Enien Eng Moyd Mohamed Darwish
Block 2	Dr. Abdel Razek
Block 3	Dr. Mostafel
Block 4	Dr. Abdel Reheim
Block 5	Dr. Gamel, Dr. Alfonso
Block 6	Dr. Mohamed Nassar
Block 9	Dr. Hosneih
Block 16	Eng Maged
Block 21	Aly Sallah
Block 23	Eng Mohamed Nanbieh

APPENDIX B

TABLE B-1

BILL OF MATERIALS

Plant: El Nasr

Recommendation: 5.1 - Block 23 Instrumentation	Quantity
Mazot flow meter, 0-1 ton/hr, 100°C service, mechanical	(1)
Orifice flanges, 150 lb, carbon steel	(2)
Orifice plate	
Steam flow meters	
Pneumatic d/p cell transmitter, CS body, 316 SS diaphragm, 0-100" WC, 25 bar static	(2)
Pressure recorder, pneumatic, local mount	(2)
(Boiler feedwater flow meters, 100°C/20 bar service, 0-15 ton/hr)	(2)
Calibrate existing mazot meter	(2)

Recommendation: 5.1 - Block 1 Instrumentation	
D/P cell and pneumatic transmitter	(1)
Pressure recorder, pneumatic, local	(1)
Miscellaneous materials (pneumatic tubing, fittings, supports, etc.)	1 lot

Recommendation: 5.1 - Block 3 Instrumentation	
Pneumatic d/p cell transmitter(*), C.S. body, 316 SS element, 0-100" W.C., 25 bar static.	(1)
Pressure recorder, pneumatic, local mount	(1)
Miscellaneous materials (pneumatic tubing, fittings, supports, etc.)	lot

(*) As a cheaper alternative, a direct connect flow recorder could be used.

APPENDIX B

TABLE B-1 (Continued)

BILL OF MATERIALS

Recommendation: 5.1 - Block 4 Instrumentation

Pneumatic d/p cell transmitter(*), C.S. body, 316 SS element, 0-100" W.C., 25 bar static.	(1)
Pressure recorder, pneumatic, local mount	(1)
Miscellaneous materials (pneumatic tubing, fittings, supports, etc.)	lot

Recommendation: 6.5 - Block 5 Dryers

Steam trap - inverted bucket, c.s. body, 10-bar back pressure 100 lb/min maximum flow	(1)
Pneumatic temperature controller, direct connected, indicating, SS bulb, 0-150°C, air filter-regulator set, mounting yoke	(1)
Pneumatic control valve, 125 lb flange, cast iron, 1" control valve, positioner, airset.	(1)

Recommendation: 6.1 - Block 2 Condensate Recovery

Condensate return piping, c.s., 1" Ø, welded	1000 m
Condensate pump, 20 gpm, 100' head, centrifugal, carbon steel 1 Hp electric drive	1 lot (1)
Condensate tank - 3 kg/cm^2 design pressure, carbon steel, 2.5 m^3 vertical	(1)
Piping and valves - local	
Instrumentation - level controller, top mounted displacement-type, SP/DT relay	(1)

(*) As a cheaper alternative, a direct connect flow recorder could be used.

APPENDIX B

TABLE B-1 (Continued)

BILL OF MATERIALS

Plant: El Nasr

Recommendation: 6.2 - Block 5 Hot Water Loop

Pneumatic temperature controller, direct connected, indicating, SS bulb, 0-150°C, air filter, regulator set, mounting yoke.	(1)
Pneumatic control valve, 150 lb flange, cast iron, 1" control valve, positioner, airset.	(1)
Vessel 2.5 m^3, atm, carbon steel, with pressure relief valve, vertical.	(1)
Pump, centrifugal, carbon steel, 100 gpm, 200' head, electric.	(3)
Level controller, top mounted displacement type, mechanical connection to Spring operated globe valve	(1)

Recommendation: 6.4 - Block 11 - Low Pressure Air

Diaphragm-type pressure switch, SS diaphragm, dual setting, 10-A microswitch	(1)
Motor control relay, 440 VAC, 3Ø	(1)
Controller, pneumatic pressure, 0-10 bar psi, 2 bar set point	(1)
Transmitter, pneumatic, SS diaphragm, C.S. body, 2 bar static.	(1)

Recommendation: 6.6 - Pipe Insulation

Calcium silicate insulation, aluminum jacket various diameters, 1 meter lengths

APPENDIX B

TABLE B-1 (Continued)

BILL OF MATERIALS

Recommendation: 6.7 - Air Infiltration/Excess Air Control

Rehabilitate, as necessary, ID and FD fan dampers (pull dampers, clean, repair positioner)	(2)
Pressure indicator, -10" - +10" W.C., direct connected, manometer-type	(2)
Flue gas O_2 monitor, installed electronic, local readout, zirconia or fuel cell, sampling train.	(1)
Miscellaneous materials to repair inspection ports/furnace shell (refractory brick, steel sheet, etc.)	lot

Appendix B

Table B-2
Summary of Capital Cost Estimates
Plant: El Nasr Pharmaceuticals

Recommendation	Major Equipment Local	Major Equipment Foreign	Materials Local	Materials Foreign	Installation Labor Local	Installation Labor Foreign	Total Local	Total Foreign
5.1 Block 1, Instrumentation	--	$ 1,600	$ 1,400	--	*	--	$ 1,400	$ 1,600
5.1 Block 3, Instrumentation	--	$ 1,600	$ 1,400	--	*	--	$ 1,400	$ 1,600
5.1 Block 4, Instrumentation	--	$ 1,600	$ 1,400	--	*	--	$ 1,400	$ 1,600
5.1 Block 23, Instrumentation	$3,300	$ 3,200	$ 2,800	--	*	$ 2,000[1]	$ 5,800	$ 5,200
6.1 Block 2, Cond. Recovery	$1,500	--	$ 5,600	--	*	--	$ 7,100	--
6.2 Block 5, Hot Water Loop	$6,000	$ 2,700	$ 4,100	--	$ 2,700	--	$12,800	$ 2,700
6.4 Block 11, Low Pressure Air-Controller	--	$ 2,000	$ 1,500	--	*	--	$ 2,000	$ 1,500
6.5 Block 5, Dryers	--	$ 2,800	$ 500	--	*	--	$ 500	$ 2,800
6.6 Pipe Insulation	--	--	$ 1,000	$ 8,600	$11,900	--	$ 8,600	$12,900
6.7 Excess Air Control	--	$15,000	$ 4,000	--	$ 5,000	--	$ 9,000	$15,000

Note:

*Assumed can be done by plant

[1]Calibration only

Arthur D. Little, Inc.

APPENDIX C

PRODUCTION DATA

TABLE C-1
PRODUCTION BLOCK 1
1987 CALENDER
(in TONs)

	TETRA HCL	OXY TETRA HCL	PENCILLIN	KEMILASE	LADINASE
JAN	2.717	-	-	1.8	1.6
FEB	4.561	-	-	0.6	0.6
MAR	7.149	-	-	1.8	1
APR	3.065	-	2.0	3.0	1.2
MAY	-	-	2.512	1.8	1.6
JUNE	1.19	-	1.5	3.0	1.2
JULY	-	-	1.922	1.8	0.6
AUG	-	-	1.074	-	1.35
SEPT	-	1.854	0.7	-	1.0
OCT	-	3.285	2.56	3.0	1.2
NOV	5.113	0.346	2.576	1.8	0.8
DEC	6.56	-	3.864	-	-
TOTAL	30.355	5.485	18.708	18.6	12.15
STEAM/ DAY	1.64	0.29		2.6	1.7

STEAM FOR DISTILLED WATER/DAY 2.4

TOTAL STEAM TON/DAY 8.63

TABLE C-2
PRODUCTION BLOCK 3
1987 CALENDER
(in Tonnes)

	SULFAGUANIDINE	SULFADIMIDINE NA	SULFADIMIDINE	METFORMIN HCL	TOLBUTAMIDE
JAN	10.0	-	-	-	-
FEB	10.0	-	-	-	-
MAR	0.56	-	-	-	-
APR	5.08	4.5	-	-	2.88
MAY	5.0	4.5	-	-	1.84
JUNE	0.36	5.24	5.15	0.4	0.58
JULY	-	2.84	4.9	-	-
AUG	-	-	4.375	-	-
SEPT	-	-	-	2.715	-
OCT	-	-	-	3.725	0.6
NOV	-	-	-	2.12	4.6
DEC	-	-	4.0	5.68	-
TOTAL	31.0	17.08	18.425	14.64	10.5
STEAM/ DAY	0.15	0.28	N/A	N/A	N/A

STEAM FOR DISTILLED WATER/DAY 2.1

TOTAL STEAM TON/DAY 2.53
note does not include steam ejector use

TABLE C-3
PRODUCTION BLOCK 5
1987 CALENDER
(in TONs)

	THIAM CHLORAM TONS	PALMITATE STEARATE TONS	AMPICILLINE TONS	PARACETAMOL TONS
JAN	4.12	3.0	3.13	21.22
FEB	5.075	1.325	2.385	16.2
MAR	5.099	3.025	1.61	16.06
APR	2.325	3.0	-	16.02
MAY	4.039	4.0	-	13.12
JUNE	4.886	1.71	0.98	1.6
JULY	-	-	4.09	4.32
AUG	4.081	0.43	4.86	15.92
SEPT	5.146	-	4.8765	15.52
OCT	7.992	-	3.27	6.04
NOV	2.722	-	5.34	14.3
DEC	0.715	-	2.731	16.22
TOTAL	46.1997	16.49	33.2725	156.54
STEAM/ DAY	1.8	0.3	0.25	8.0
STEAM FOR DISTILLED WATER/DAY			5.3	
TOTAL STEAM PER BLOCK, TON/DAY			15.65	

TABLE C-4
PRODUCTION BLOCK 6
1987 CALENDER
(in TONs)

	ASPIRIN	ACID ACETIC	METHYL SALICYLATE	ALUMINA ASPIRIN
JAN	59.64	14.6	13.72	-
FEB	-	0.6	13.44	-
MAR	-	-	12.88	-
APR	-	-	8	-
MAY	-	-	8.12	-
JUNE	5.	1.2	9.48	0.133
JULY	47.52	7.2	11.76	0.386
AUG	68.04	9.6	3.66	-
SEPT	47.8	4.2	5.96	-
OCT	15.4	10.8		0.39
NOV	55.08	14.0		0.15
DEC	54.62	6.6		2.156
TOTAL	353.1	68.8	83.82	3.215
STEAM/ DAY	4.2	0.33	0.58	0.26

STEAM FOR DISTILLED WATER/DAY 1.86

TOTAL STEAM TON/DAY 7.23
(note does not include steam ejector use)

APPENDIX D

POWER FACTOR/BOILER FLOW TESTS

Power factor tests were made on a variety of motors at El Nasr to verify the plant's power factor. In addition an ultrasonic flowmeter was used to measure selected liquid flowrates in the boilerhouse.

Power Factor

The overall power factor at El Nasr is about 0.85 as previously indicated. The specific power factor measurements taken included:

Low pressure air compressor #5 — 235 KW

Normal operation	- continuously on
No load amps	- 120 amps
Voltage	- 370 VAC, 3Ø
pf	- 0.75
Normal load amps	- 252 amps (avg of two tests)
Voltage	- 370 VAC, 3Ø
pf	- 0.92

Block 38 water treatment pump #2, #M564F-2 — 90 KW

Normal operation	- continuous
No load amps	- 65A
Voltage	- 370 VAC, 3Ø
pf	- 0.82
Normal load amps	- 140A (avg of two tests)
Voltage	- 380 VC, 3Ø
pf	- 0.91

Block 11, Brine Pump #2

Normal operation	- continuous
No load amps	- 65 amps
Voltage	- 380 VAC
pf	- 0.88
Normal load amps	- 119A (avg of two tests)
Voltage	- 375 VAC
pf	- 0.91

Cooling Water Pump #7 — #546231 — 75 KW

Normal operation	- continuous
No load amps	- 32
Voltage	- 355 VAC
pf	- 0.44
Normal load amps	- 122 (avg of two tests)
Voltage	- 350
pf	- 0.9

Cooling Tower Fan #1

Normal operation	- continuous
No load amps	- Not applicable
Voltage	- Not applicable
pf	- Not applicable
Normal load amps	- 78 (avg of two tests)
Voltage	- 357
pf	- 0.9

Ultrasonic Flowmeter

3/29/88 - #3 boiler operating; #1,2 down

Drum is on manual control.

Attached to boiler feedwater inlet to economizer. Water temperature 22°C (initially) - 41°C (end).

	Time	BFW Velocity (ft/sec)	Drum Level
	11:03	2.0	+85 mm
	11:09	0[1]	+50
	11:15	0	+15
	11:20	0	-20 mm
	11:25	1.8	+00
	11:31	2.0	+25
	11:35	0	+75
	11:41	0.8	+60
	11:45	0	+40
	11:50	2.0	+25
	11:54	2.0	+20
	Avg	0.964 ft/sec	
Mazot	10:41	480430	
	11:11	480650	
	11:27	480800	
	11:42	480920	
	11:56	481010	
	1.25 hr	580 ℓ	

Pipe id = 0.67 mm

[1] Not detectable

$A = (6.7/2)\ \pi = 35.25$ cm

(0.964 ft/s) (3600 s/hr) (12 in/ft) (2.54 cm/in) (35.25 cm) (1 kg/ℓ)/1000/1000

= 3.73 ton/hr x 2204 lb/ton x 1220 kj/lb
= 10.0×10^6 kj/hr

(580/1.25) x 0.90 kg/ℓ x 41,875 kj/kg

= 17.49×10^6 kj/hr
= 57% boiler n (HHV)

3.73 x 2.24 = 180 tons steam/day approximately.

Both the boiler efficiency values calculated and the daily steam production support the original conclusions in the audit report.

1) Total steam production is probably 175-200 ton/day

2) Boiler efficiency is about 55-60%.

APPENDIX E

SUMMARY OF MEASUREMENTS ON BOILER #2,3
EL NASR PHARMACEUTICALS

		#2	#3
26 Jan	- avg mazout	- 540 ℓ/hr	416
	- avg header press	- 9.45 bar	--
	- avg O_2	- 15.1 bar	15.3 bar
	- avg flue gas	- 196°C	212°C
	- avg econo inlet	- 41.5°C	38°C
	- mazot temp	----------69°C----------	
	- FD fan air flow	5560 m^3/hr	6713 m^3/hr

APPENDIX F

SUMMARY CALCULATIONS

Rec 6.1 - Cond Recovery

Initial Condensate Temp	140°C
Heat Loss/Meter Return	627 kj/m-hr
Return Piping	540 m

540 x 627 = 338,000 kj/hr loss
Return temp = [140 - (338,000/833 x 4.168)] = 44°C

Condensate rate	20 ton/day = 833 kg/hr
BFW Reference	18°C

Energy Savings
(333 days) (20,000) (44-18) (1) (4.1868)
$= 7.25 \times 10^8$ kj steam/yr

$$\frac{7.25\times10^8}{0.60\ (41.9\times10^6)} = 29 \text{ ton mazout}$$

Rec 6.2 - Hot Water Loop $H_{vap} = 2688$ kj/kg

Water flow to Block 5 reactors: at 10 bar
2.35 ton/day steam

Actual utilized - 15%
2.35 x (1-15%) = 2.00 ton/day wasted

Fraction recoverable - 75%
2.00 x (75%) - 1.5 ton/day saved

Energy savings
(1.5 ton) (1000) (333 days) (2688kj/kg) $= 1.34 \times 10^9$ kj/yr steam

$$\frac{1.34 \times 10^9}{(.60)\ (41.9\times10^6)} = 53 \text{ ton/yr mazout}$$

Rec 6.4 - Low Pressure Compressed Air

Current Operation	- continuous
Measured power draw	- 145 KW (no-load)
Fermenter in use	- 40 hr/wk

If compressor shutdown, minimum savings equal no-load power

(52 weeks) (7x24 -40) (145kw) $= 0.965\times10^6$ kwh/yr

Rec 6.5 - Dryers

Paracetamol - 1 tons steam/hr	156.5 tons produced/yr
30% H_2O Cake 300 kg/batch	5 hrs/batch drying

(156.5)(1000/300) = 522 batch/yr x (5) = 2609 drying hr/yr

2609 hours x 1 tons steam/hr = 2609 ton steam/yr

(156.5) (30% H_2O) = 47 ton/yr H_2O evap

(47/2609) = 1.7% dryer n

Dryer n can be improved to a minimum of 10% by using temperature controller and steam trap.

46.9 ton/(10% n) = 470 ton/yr steam use

(2609 -470) = 2130 ton/yr steam saved

21320 x 1000 x 2688 = 5.7×10^9 kj/yr steam

5.7×10^9/(60% n) (41.9×10^6)

Rec 6.6 - Insulation

Pipe - 923 m x 2.5 cm diameter
Insulation - 2.5 cm - saves 775 kj/hr-m

923 x 775 x 8000 = 5.7×10^9 kj/yr steam

5.7×10^9/(60%) (41.9×10^6) = 227 ton/yr mazout

EL NASR
APPENDIX G

RELATIONSHIP BETWEEN PAYBACK AND IRR

A large number of energy efficiency improvement projects involve relatively simple one time investments which require periodic maintenance and repair to keep in operating order and realize the benefits. After all equipment is delivered, implementation time for a large number of energy conservation projects is often on the order of a few weeks or months to half a year. Once implemented, the net cost savings accrue over the economic life of the equipment which is typically 5 to 15 years, depending on the type of equipment.

The company decision to make investments involves a large number of parameters including financial/economic criteria, availability of trained personnel, infrastructural support and so on. Focusing on the financial/economic criteria, the most appropriate criteria would consider the time value of money (used in investments and savings obtained) and the life of the investment. Tools developed for such analyses include net present value (NPV), internal rate of return (IRR), levelized life-cycle cost analyses, etc. However, within the course of the study, we found that most initial feasibility analyses undertaken at the plant level used a simple payback analysis which did not consider the life of the investments. If hurdle rate criteria were not met, then the project was not considered sufficiently viable to bring to the attention of higher levels in plant management.

Because of this, two economic tests were used: payback time (years) and internal rate of return (IRR) in %. We assume an initial investment (INV) at time t-0 with annual net savings (S) accumulating at the end of each year for the life of a project of n years. The time value of money is set at i.

The payout period (P) is equal to investments divided by annual savings: (eq 1)

$$P = INV/S$$

The relationship for internal rate of return is developed from the cash flow C.F. over each year for a project of life n years, involving an initial investment of INV.

$$CF = -INV + S(1+i)^{-1} + S(1+i)^{-2} + \ldots S(1+i)^{-n} \qquad \text{(eq 2)}$$

To derive the internal rate of return we set the cash flow equal to zero in equation 2 and solve for i. The internal rate of return, i, is the rate that equates the present value of an expected future series of even or uneven cash flows to the initial investment.