Final Report to

Organization for Energy Planning
Cairo, Egypt

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Industrial Energy Audit Report Edfina Food Company Alexandria, Egypt

Arthur D. Little *Reference 59643*

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REPORT SUMMARY

EDFINA FOOD COMPANY
ALEXANDRIA, 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 Edfina Food Company facility located in Alexandria, Egypt. The field audit was conducted in January, 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, a variety of tests and analyses were performed using both plant and portable instrumentation.

PLANT DESCRIPTION

The Edfina Food Plant in Alexandria processes fruit juices, tomato paste, frozen foods, jams, and beans. The plant employs about 4,000 people and has been running since the early 1950's. It operates on a highly seasonal schedule ranging from 2 shifts/day, 6 days/week, to 3 shifts/day, 7 days/week. In 1986/1987, the plant used 3480 tons mazout, 476 tons sular, and 4166 MWH of electricity. This is equivalent to 4827 tons oil equivalent (TOE) of total energy. The plant has total direct energy costs of about $ 134,800/year. There is an active energy engineering staff of about 5 engineers.

The plant operations basically consist of a series of batch operations strung together in different sequences for different products. The operations are basically simple technology, relying on low temperature/pressure steam to heat food products and subsequent cooling. Examples of these operations are:

- Autoclaving
- Pasteurizing
- Continuous Vacuum Evaporation
- Batch Vacuum Evaporation
- Pan Evaporation
- Blanching
- Freezing
- Refrigeration
- Can making

The production schedule is highly seasonal so that during any given period only some of the operations are run, and the resulting energy requirements fluctuate during the year.

ESTABLISHING AUDIT PRIORITIES AT EDFINA

At Edfina Food, the initial survey revealed that:

- Mazout-generated, low-pressure steam was the dominant plant energy source.
- General housekeeping controls could have a major impact on energy savings.
- The boilers were in fairly good shape, but the combustion air damper needed to be fixed, and an 0_2 monitor could be useful.
- The stack gases generated by the diesel electric generators and lacquer ovens were hot enough that waste heat recovery might be appropriate. The lacquer ovens might also benefit from an 0_2 monitor.
- Enough energy was used in refrigeration and freezing compressors that a careful examination of compressor operations might result in justifiable savings.
- Energy monitoring instrumentation was minimal to non-existent.
- Electrical power factor was already partially controlled. The plant had a low power factor penalty and had already trimmed one substation.

Accordingly, our primary focus in the audit was in examining how low pressure steam was used, examining maintenance procedures, studying compressor operations, and studying boiler and furnace operations.

FINDINGS

Process Instrumentation. The plant in general suffers from a lack of instruments. The original instrumentation was scant, and only instrumentation absolutely essential to running the plant has been maintained. Instruments here refer to pressure, temperature, flow, and analytical devices on the equipment; to signal transmitters and controllers; and to control valves and actuators. This situation is attributed to (1) a low priority in energy monitoring instrumentation by the original designers, and (2) a present lack of foreign currency to buy replacements or parts.

Energy Consumption. The principal consumers of purchased energy in the plant are:

- Two Mazout (#6 fuel oil) fired, fire tube boilers rated to produce 10 bar steam at a capacity of 12 tons per hour. The boilers operate about 20 hours per day, 310 days per year.

- Five diesel (sular) electric generator sets with a total capacity of 2 megawatts are available for standby power in the event of a power failure. Because the plant annual average electrical demand is about 800 kW normally only 2 to 3 generators are run under partial load at any one time. However, during peak processing season, all of the units are needed during power outages.

- Sular is used to fire two lacquer drying ovens for tin can production. The ovens operate about 10 hours per day, 300 days per year and consume a total of about 80 kg/hr of fuel.

- Most of the electric energy in the plant is consumed in running low voltage (230 volt) motors under 75 kW in size. Most of the thermal energy in the plant is consumed as low pressure steam in a variety of intermittent process operations. The plant may be characterized as using energy in a diverse range of batch operations.

- The power factor at the plant for the main (trimmed) substation was .945; for the other two substations, which are used to a lesser extent, power factor (untrimmed) was .82 and .723. Given the low penalty associated with these two substations and given their lower level of use, it is not currently economic to add trimming capacitors.

Because there is no instrumentation at the plant, a plant steam balance was estimated based on measurements, plant data, and engineering calculations. An average yearly steam balance was made. At any one time, the actual steam balance may vary significantly from this due to daily variation in the production scheduling. The major energy consuming operations include:

Estimated steam uses:

• Plant A pasteurizers	30%
• Tomato evaporation	19%
• Blanching	8%
• Jam cooking plant A	6%
• Jam cooking plant B	4%
• Autoclaving	5%
• Tomato juice and puree heat up	3%
• Losses due to lack of insulation	10%
• Steam leaks and faulty steam traps	15%

Estimated electric power uses:

• Refrigerated storage	17%
• Frozen food freezing	13%
• Air compressors	8%
• Tin melting	3%
• Electric motors	59%

Estimated sular uses:

- Lacquer furnaces 51%
- Operating diesel electric generators 49%

For the purpose of estimating specific energy consumption, we have categorized the plant's products as frozen and non-frozen. Frozen products consume principally electricity with small smounts of steam for blanching. Non-frozen products require significant amounts of both steam and electricity. Estimated specific energy consumption for both major products are shown in Figure S-1.

Management and Organization. Another problem that was observed is a basic lack of department textbooks and technical information. Even the most competent of engineers cannot perform at his best capabilities without technical references. We recommend that some selected general purpose and energy specific handbooks be purchased for general use by the engineering staff.

Finally, one other aspect of management that would probably prove beneficial would be to undertake some job rotation among the engineering staff. At the present time, most of the engineering staff are fairly specialized and have relatively narrowly defined responsibilities. Although this approach can work well in keeping process equipment operating at peak efficiency, after a period of time it tends to make the engineering personnel stale in general skills. The successful energy conservationist must have a fairly integrated outlook of the plant in order to accomplish his job well; overspecialization in an energy professional can result in conservation opportunities being missed. By periodically rotating the positions, the staff can develop a better rounded background and a more comprehensive and integrated outlook on the plant.

RECOMMENDATIONS

Based on the plant audit, a series of potential energy conservation opportunities (ECO's) were identified. Three basic types of recommendations are made: general management recommendations, which are primarily organizational or procedural modifications; housekeeping projects involving a capital investment (this includes projects which although they may be large in investment, require only domestic materials and labor); capital projects involving the importing of materials and/or labor. Engineering and economic analyses of these options were performed, and economically favorable options identified by use of payback period and internal rate of return. The improvements we suggest are summarized in Table S-2 and discussed below.

Energy Monitoring Instrumentation - Recommendation 5.1. Present instrumentation at the plant should be repaired, particularly automatic steam controls, and steam and electric flow meters installed, particularly steam. Instrumentation maintenance programs should be begun. It is also important that the plant have the necessary skills to repair and maintain the instrumentation. By metering steam flow in the

Figure S-1: Estimated Specific Energy Consumption Edfina Food

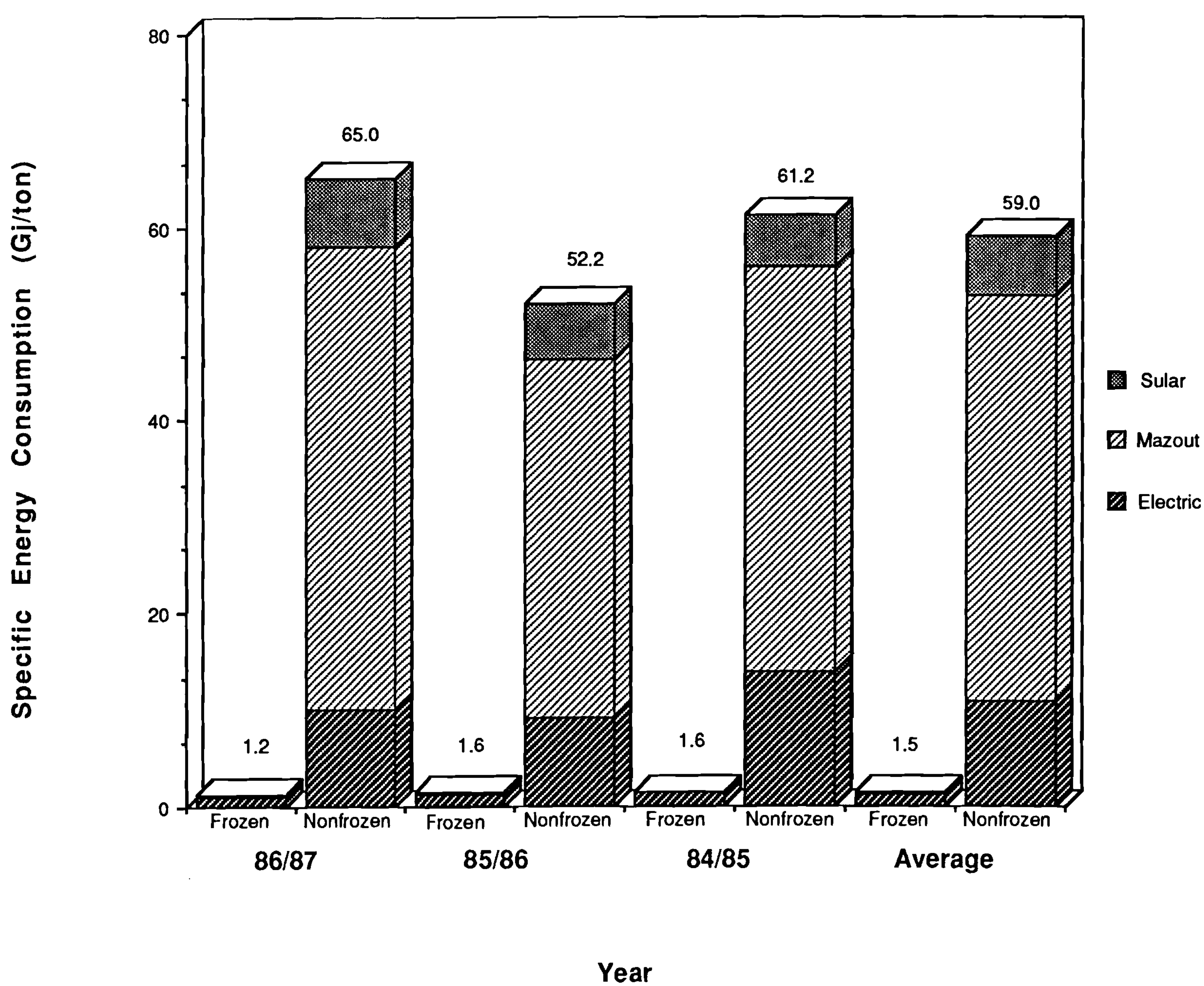


TABLE S-2
AUDIT RESULTS SUMMARY
EDFINA FOOD COMPANY

RECOMMENDATION	ANNUAL FUEL SAVINGS (1) (units/yr)	ANNUAL ENERGY SAVINGS (1) (kj/yr)	(TOE/yr)	International Prices: ANNUAL VALUE OF SAVINGS (2) ($/yr)	ANNUAL OPERATING COST ($/yr)	CAPITAL COST ($)	PAYBACK (Years)	LIFETIME (Years)	IRR (%)	Local Prices: ANNUAL VALUE OF SAVINGS (2) (L.E./yr)	CAPITAL COST (3) (L.E.)	PAYBACK (Years)
ENERGY MONITORING												
5.1 Energy Monitoring Instrumentation	N/A	N/A	N/A	N/A	N/A	$10,000	N/A	N/A	N/A			
SUBTOTAL	N/A	N/A	N/A	N/A	N/A	$10,000	N/A	N/A	N/A			
HOUSEKEEPING												
6.1 Traditional Housekeeping												
Air Leak Maint.	34 MWH (4)	3.4E+08	8	$1,557	neg	$0	0.0	5	>1000%	880	0	0.0
Steam Trap Maint.	509 ton mazout	1.8E+10	492	$60,259	neg	$1,200	0.0	5	5022%	21,482	2,640	0.1
Ref Door Maint	555 MWH (4)	5.6E+09	128	$25,530	neg	$1,000	0.0	5	2553%	14,430	2,200	0.2
Electric Motor Management	196 MWH (4)	2.0E+09	45	$9,016	neg	$0	0.0	5	>1000%	5,096	0	0.0
6.2 Pasteurizer Flaps	108 ton mazout	3.9E+09	105	$12,844	neg	$1,000	0.1	5	1284%	4,579	2,200	0.5
6.3 Condenser Shading	117 MWH (4)	1.2E+09	27	$5,382	neg	$6,900	1.3	5	73%	3,042	15,180	5.0
6.4 Insulate Steam Lines	270 ton mazout	9.6E+09	261	$31,968	neg	$21,700	0.7	5	146%	11,397	21,560	1.9
6.5 Recover Condensate	N/A (5)	N/A (5)	N/A	$4,320	neg	$10,100	2.3	5	32%	9,504	22,220	2.3
SUBTOTAL		4.1E+10	1,066	$150,876	neg	$41,900	0.3	N/A	360%	70,410	66,000	0.9
CAPITAL IMPROVEMENTS												
6.6 Evap Turbines	142 ton mazout	5.0E+09	137	$15,860	neg	$13,200	0.8	10	120%			
6.7 Blancher Controls	272 ton mazout	9.7E+09	263	$32,251	neg	$9,000	0.3	10	358%			
6.8 Boiler O2 Analyzer	108 ton mazout	4.5E+09	104	$12,089	neg	$5,000	0.4	10	242%			
6.9 Lacquer Oven O2 Anal	22 ton sular	9.6E+08	22	$3,273	neg	$4,000	1.2	10	82%			
6.10 Waste heat Boiler	N/A	1.1E+10	254	$87,200	$20,000	$69,000	1.0	10	97%			
SUBTOTAL		3.1E+10	781	$150,673	$20,000	$100,200	0.8	N/A	130%			
TOTAL		7.2E+10	1,847	$301,550	$20,000	$152,100	0.5	N/A	213%			

Note: 1) Energy savings for steam must be adjusted for boiler efficiency to get equivalent mazout and TOE.
2) For non-returned condensate based systems, water treatment cost of L.E. 1.1/ton steam ($6.5/ton mazout) is added to fuel cost.
3) Assumes that local labor supplied by plant at no incremental cost.
4) Electric conversion at 10,000 kj/kwh, incorporates a central power station efficiency of about 36%.
5) Value of returned condensate, based on water treatment costs.

Assumptions:
- Energy Conversion 4.33E+07 kj/TOE
- Currency conversion 2.20 LE/$
- Boiler Efficiency 85%

main distribution headers, and working with the batch scheduling, the plant should be able to eventually measure and control the steam consumption of individual processes con. The recommended instrumentation cost is estimated at U.S. $10,000.

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

- Recommendation 6.1 - Traditional Housekeeping

Traditional housekeeping management was identified as an important way Edfina could save energy, specifically active programs to monitor and prevent motors being left on, compressed air leaks, steam leaks and refrigerated air losses were all identified as having the potential to save significant amounts of energy.

Annual energy savings
(steam plus electricity): 2.6×10^{10} KJ/yr (673 TOE)
Capital cost: $2,200
Annual savings (international): $96,000/yr
Simple payback: immediate
Internal rate of return: >1000%

- Recommendation 6.2 - Pasteurizer Flaps

Evaporative losses from hot water pasteurizers can be reduced by the use of flexible flaps. At present there are 4 steam and hot water pasteurizers which develop significant energy losses from steam and hot water vapors carried off by convection currents. Flexible flaps have been recommended to block these currents.

Annual energy (steam) savings: 3.9×10^{9} KJ/yr (105 TOE)
Capital cost: $1,000
Annual savings (international): $12,800/yr
Simple payback: 0.1 year
Internal rate of return: 1284%

- Recommendation 6.3 - Condenser Shading

Energy efficiency in refrigeration systems can be improved by shading condensers. The condenser temperature can be lowered, with a corresponding increase in energy efficiency, if sular energy is prevented from striking the coils with shading.

Annual energy savings: 1.2×10^{9} KJ/yr (27 TOE)
Capital cost: $6,900
Annual savings (international): $5,400
Simple payback: 1.3 years
Internal rate of return: 73%

- Recommendation 6.4 - Insulate Steam Lines

Reduction in energy losses through insulation of steam lines will have significant savings. Estimated are based on calcium silicate insulation. The plant indicates that it could install local insulation at a savings in material cost, thus increasing the economic attractiveness of this measure.

Energy (steam) savings: $.96 \times 10^{10}$ KJ/yr (261 TOE)
Capital cost: $21,700
Annual savings: $32,200
Simple payback: 0.7 year
Internal rate of return: 146%

- Recommendation 6.5 - Recover Condensate

Steam costs can be reduced by the installation of additional condensate recovery. Currently, about 20% of the condensate is returned. An additional 16% was found to be economically justified in recovery. In general, even intermittent batch process could be justified as long as equipment could be limited to simple collection tanks, pumps and steel lines.

Energy savings: N/A
Capital cost: $10,100
Annual savings (international): $4,320/yr
Simple payback: 2.3 year
Internal rate of return: 32%

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

- Recommendation 6.6 - Evaporator Turbines

Steam losses in the evaporators can be reduced by making modifications to allow the 3 effect evaporator to be used rather than the 2 effect evaporator presently used. A high capacity, high efficiency 3 effect evaporator was available, but not being used because of plant problems when it ran. By replacing low efficiency turbines with electric motors or high efficiency units, it should be possible to operate the 3 effect unit.

Energy savings: 5.0×10^{9} KJ/yr (137 TOE)
Capital cost: $13,200
Annual savings: $15,900
Simple payback: 0.8 year
Internal rate of return: 120%

- Recommendation 6.7 - Blancher Controls

Blanching steam can be reduced by installing new blancher control systems. Automatic control systems on the blanchers have fallen into disrepair. As a result, the equipment is run manually. The inefficiency of manual operation results in about a 4-fold increase in the amount of steam consumed by the blanchers.

Energy (steam) savings: 9.7×10^9 KJ/yr (263 TOE)
Capital cost: $9,000
Annual savings: $32,300
Simple payback: 0.3 year
Internal rate of return: 358%

- Recommendation 6.8 - Boiler Excess Air

Boiler efficiency can be reduced by the use of a continuous oxygen analyzer. By using a continuous O2 analyzer with manual combustion air damper adjustment, a lower excess O2 level can be used in the boiler, with an increase in energy efficiency.

Energy savings: 4.5×10^9 KJ/yr (104 TOE)
Capital cost: $5,000
Annual savings: $12,100
Simple payback: 0.4 year
Internal rate of return: 242%

- Recommendation 6.9 - Lacquer Ovens

Lacquer oven efficiency improvements can be made through the use of a portable oxygen analyzer. As in the boiler, excess O2 control through a portable meter and damper adjustment allows an increase in energy efficiency.

Energy savings: 9.6×10^8 KJ/yr (22 TOE)
Capital cost: $4,000
Annual savings: $3,270
Simple payback: 1.2 year
Internal rate of return: 82%

- Recommendation 6.10 - Waste Heat Boiler

We recommend the use of diesel generators to generate all electric power for the plant and installation of a stack gas waste heat boiler (this option is not currently feasible under Egyptian law). Because there is a large capacity diesel electric generator system at Edfina used for standby power, the possible savings was calculated based on the assumption of generating all Edfina electric power with the generator, then using waste heat boilers on the stack gases (cogeneration). The results were economically favorable.

Energy savings: 11.0×10^9 KJ/yr (254 TOE)
Capital Cost: $69,000
Annual savings: $67,200
Simple payback: 1.0 year
Internal rate of return: 97%

Section 1
Plant Description

The Edfina Food Plant in Alexandria processes fruit juices, tomato paste, frozen foods, jams, and beans. The plant employs about 4000 people and has been running since the early 1950's. It operates on a highly seasonal schedule ranging from 2 shifts/day, 6 days/week, to 3 shifts/day, 7 days/week. The plant uses 4827 ton oil equivalent (TOE)/year of total energy and has total direct energy costs of about $134,800/year. There is an active energy engineering staff of about 5 engineers.

The plant was in generally good shape and efforts to maintain equipment and modify processes and utilities to conserve energy were evident. For example, power factor trimming capacitors had been installed on one of the three plant substations, a condensate return system had been installed for the tomato juice evaporator system, and the boiler system, auxiliary diesel electric generators, and air compressors are well-maintained.

The plant operations basically consist of a series of batch operations, strung together in different sequences for different products. The operations are basically simple technology, relying on low temperature/pressure steam to heat food products, and subsequent cooling. Examples of these operations are:

- Autoclaving
- Pasteurizing
- Continuous Vacuum Evaporation
- Batch Vacuum Evaporation
- Pan Evaporation
- Blanching
- Freezing
- Refrigeration

The production schedule is highly seasonal, so that during any given period, only some of the operations are run, and the resulting energy requirements fluctuate during the year. The production history is shown in Table 1-1:

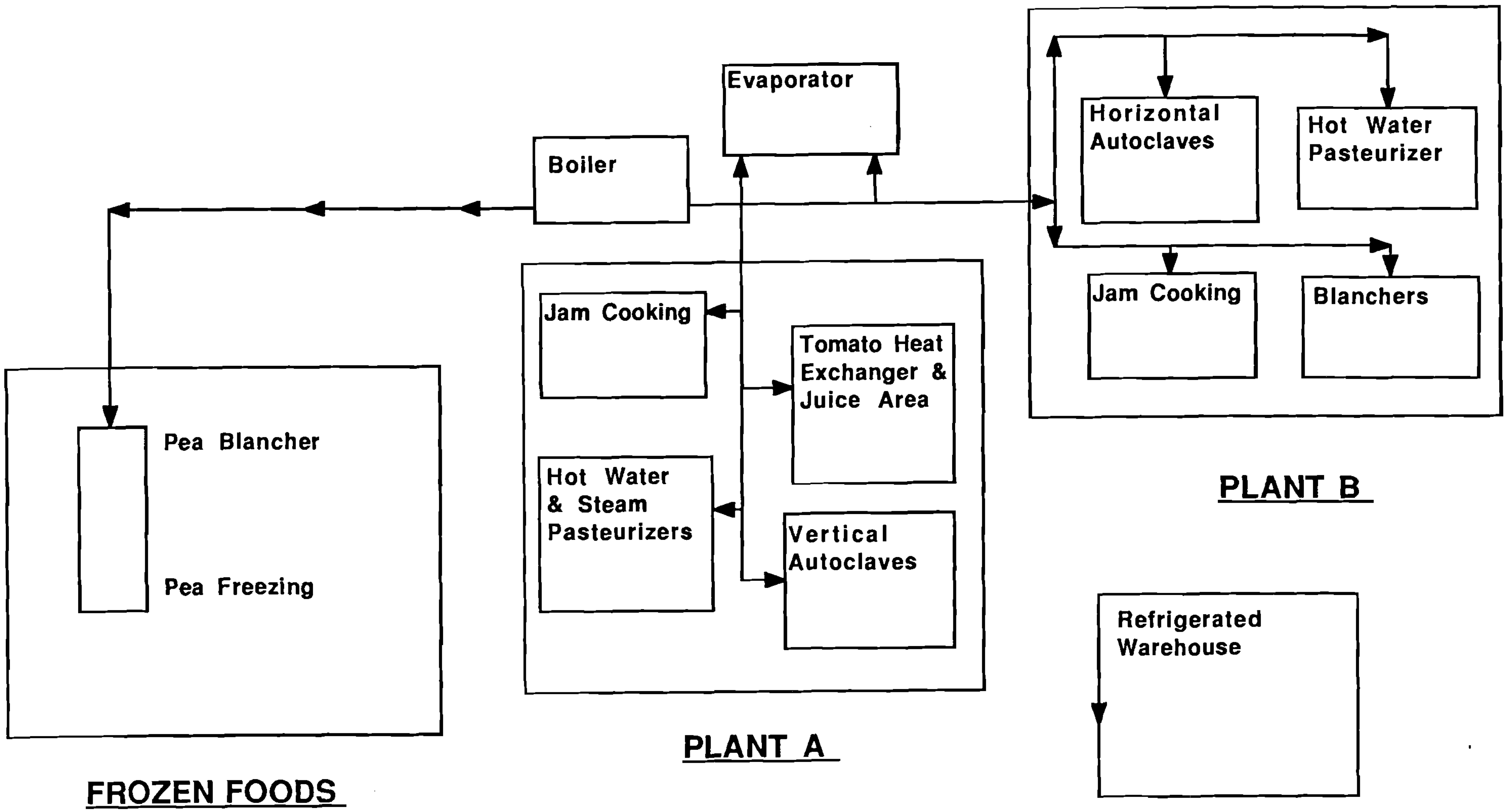
Table 1-1
Historical Production at Edfina
(Tons of Product/Year)

	Years		
	86/87	85/86	84/85
Tomato Paste	2489	3098	2131
Frozen Foods	12265	12769	13692
Jams/Canning (inc. Juices)	490	1158	1121

The plant has three main food processing areas (see Figure 1-1):

- Plant A, which processes fruit juices, tomato juice, tomato paste, and fruit jams,

Figure 1-1: General Plant Layout



- Plant B, which processes fruit jams, beans, and honey, and
- Frozen Foods, which processes frozen vegetables and meats.

In addition to the food processing areas, a can making and printing area, frozen foods warehouse, and maintenance area are medium-sized users of energy. The plant also has a non-refrigerated storage area, and office and laboratory areas, which are relatively small users of energy.

Section 2
Audit Approach and Philosophy

2.1 Introduction

The field survey was conducted at the Edfina Food factory in Alexandria, ARE, in January 1988. Analysis of the information gathered in the field and preparation of this report continued in the offices of OEP (Cairo).

The survey consisted of a review of the process and plant's performance by interviewing various managers and by reviewing drawings, design information, and selected operating records. Based on this review, major sections of the plant were inspected, and a field survey of 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 audits began with a plant inspection and preliminary identification of energy conservation opportunities (ECO's). 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 were 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 were 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 Establishing Audit Priorities at Edfina

At Edfina Food, the initial survey revealed that:

- Mazout generated low pressure steam was the dominant plant energy source.
- General housekeeping controls could be important to energy savings. These included maintenance and proper use of steam traps, use of insulation, control of compressed air leaks, and refrigeration maintenance.

- The boilers were in fairly good shape, but the combustion air damper needed to be fixed, and an 0_2 monitor could be useful.

- The stack gases generated by the diesel electric generators and lacquer ovens were hot enough that waste heat recovery might be appropriate. The lacquer ovens might also benefit from an 0_2 monitor.

- Enough energy was used in refrigeration and freezing compressors that a careful examination of compressor operations might result in justifiable savings.

- Energy monitoring instrumentation was minimal to non-existent.

- The plant had a low power factor penalty and had already trimmed one substation. Electrical power use outside of refrigeration was widely distributed in many small motors. Furthermore, idle lines appeared generally to be shut off. Electric power represents a minor percentage of total consumed power. Thus, it appeared doubtful significant energy savings could be developed by studying electric motor use.

Accordingly, our primary focus in the audit was in examining how low pressure steam was used, examining maintenance procedures, studying compressor operations, and studying boiler and furnace operations.

Section 3
Plant Material/Energy Profile

The principal consumers of purchased energy in the plant are:

- Two Mazout (#6 fuel oil) fired, fire tube boilers rated to produce 10 bar steam at a capacity of 12 tons per hour. The boilers operate about 20 hours per day, 310 days per year.

- Electricity is supplied through three 1 megawatt substations. One station has been capacitor trimmed to a power factor of 0.95. The other two stations are not used for primary power and are untrimmed. Their power factors were 0.72 and 0.82. These values are consistent with power factor measurements taken during the audit (see appendix E). Electricity costs decreased in 1986 and 1987 after the installation of power factor correcting capacitors on the one substation.

- Five diesel (sular) electric generator sets with a total capacity of 2 megawatts are available for standby power in the event of a power failure. Because the plant annual average electrical demand is about 800 kW, normally 2 to 3 generators are run under partial load at any one time. (However, during peak processing season, all of the units are needed during power outages.) Each of the 5 engines is used about 400 hours a year to generate electricity and consumes a total of about 120 kg/hr of fuel.

- Sular is used to fire two lacquer drying ovens for tin can production. The ovens operate about 10 hours per day, 300 days per year and consume a total of about 80 kg/hr of fuel.

- A small amount of propane, about 200 tons per year, is used to melt tin alloy for can making.

The historical energy consumption in the plant is summarized in Tables 3-1 through 3-4:

Table 3-1
Historical Energy Use at Edfina - Alexandria
Raw Unit Basis

Energy Source	Years 86/87	85/86	84/85	Average
Mazout (ton/yr)	3480	3859	3339	3559
Sular (ton/yr)	475.6	571.8	395.7	481
Power Elec. (MWH/yr)	3745.	5214.	5829	4929
Light Elec. (MWH/yr)	420.5	425.8	559.8	468.7

Table 3-2
Historical Energy Use at Edfina - Alexandria
KJ/yr Basis[1]

Energy Source	Years 86/87	85/86	84/85	Average
Mazout	14.6×10^{10}	16.2×10^{10}	14.0×10^{10}	15.0×10^{10}
Sular	2.10×10^{10}	2.53×10^{10}	1.74×10^{10}	2.12×10^{10}
Power Elec.	3.74×10^{10}	5.21×10^{10}	5.83×10^{10}	4.93×10^{10}
Light Elec.	0.420×10^{10}	0.425×10^{10}	0.560×10^{10}	0.489×10^{10}
Total	20.9×10^{10}	24.4×10^{10}	22.1×10^{10}	22.5×10^{10}
(TOE/yr)[2]	(4827)	(5635)	(5104)	(5196)

(1) Based on energy conversion factors given in Section 4.1.
(2) 4.33×10^{7} KJ/TOE

Table 3-3
Historical Energy Use at Edfina - Alexandria
KJ/yr on Percent Basis

Energy Source	Years 86/87	85/86	84/85	Average
Mazout	69.9%	66.5%	63.3%	66.6%
Sular	10.0	10.4	7.9	9.4
Power Elec.	17.9	21.4	26.3	21.9
Light Elec.	2.1	1.7	2.5	2.2

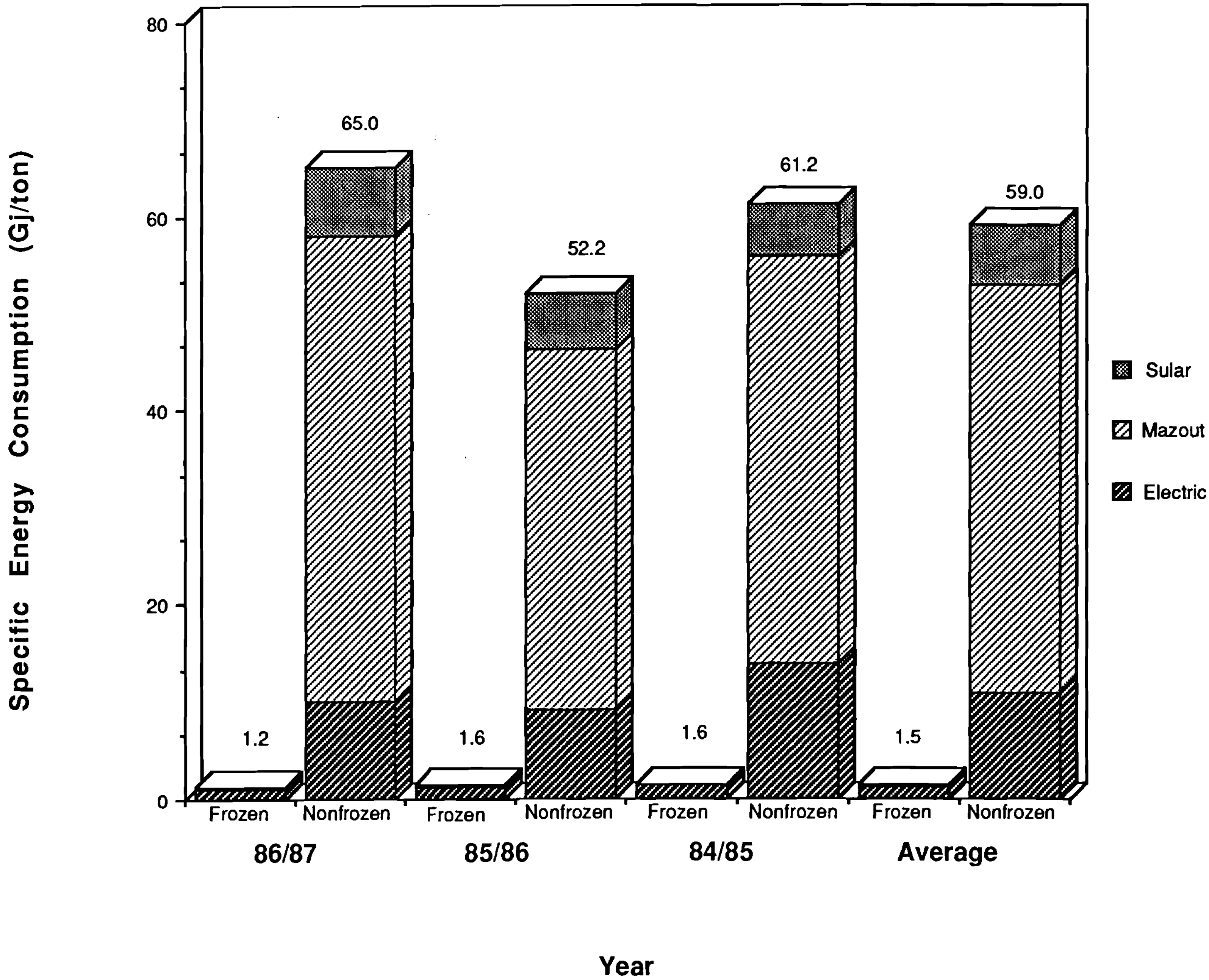
Table 3-4
Historical Energy Costs at Edfina - Alexandria
Based on local energy prices

Energy Source	Years 86/87	85/86	84/85	Average
Mazout ($ US/yr)	44300	49100	42500	45300
Sular ($ US/yr)	16900	20300	14000	17000
Power Elec. ($ US/yr)	38200	53200	59400	50300
Light. Elec. ($ US/yr)	15600	15800	20800	17400
Total	115,000[1]	138,400	136,800	130,000

(1) Actual Edfina Costs are reported as $80,600 for 86/87. The difference is due to different local cost assumptions used to develop these prices in order to keep this report consistent with other plants audited. Actual prices used are given in Section 4-1.

Most of the electric energy in the plant is consumed in running low voltage (230 volt) motors under 75 kW in size. Most of the thermal energy in the plant is consumed as low pressure steam in a variety of intermittent process operations. The plant may be characterized as using energy in a diverse range of batch operations. Specific energy consumption of the main products at the plant (frozen foods and nonfrozen foods) are shown in Figure 3-1 by energy form.

Figure 3-1: Estimated Specific Energy Consumption
Edfina Food



Section 4
Main Engineering and Economic Data

4.1 Energy Prices and Capital 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
Electricity[(1)]	10.0/MWH	L.E.26/MWH	$46/MWH

Throughout this report, the term ton is used to indicate metric tons of 100 KJ. To convert from kilojoules (KJ) to tons oil equivalent, divide by 43.3×10^6 KJ/TOE.

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 Energy Distribution and Uses (Basis for Recommendation 5.1)

Because there is no flow instrumentation at the plant, a plant steam balance was estimated based on measurements, plant data, and engineering calculations. An average yearly steam balance was made. The basic steam balance is shown in Figure 4-1. At any one time the actual steam balance may vary significantly from this due to daily variation in production scheduling. The major energy consuming operations include:

Estimated steam uses:

• Plant A pasteurizers	30%
• Tomato evaporation	19%
• Blanching	8%
• Jam cooking plant A	6%
• Jam cooking plant B	4%
• Autoclaving	5%
• Tomato juice and puree heat up	3%
• Losses due to lack of insulation	10%
• Steam leaks and faulty steam traps	15%

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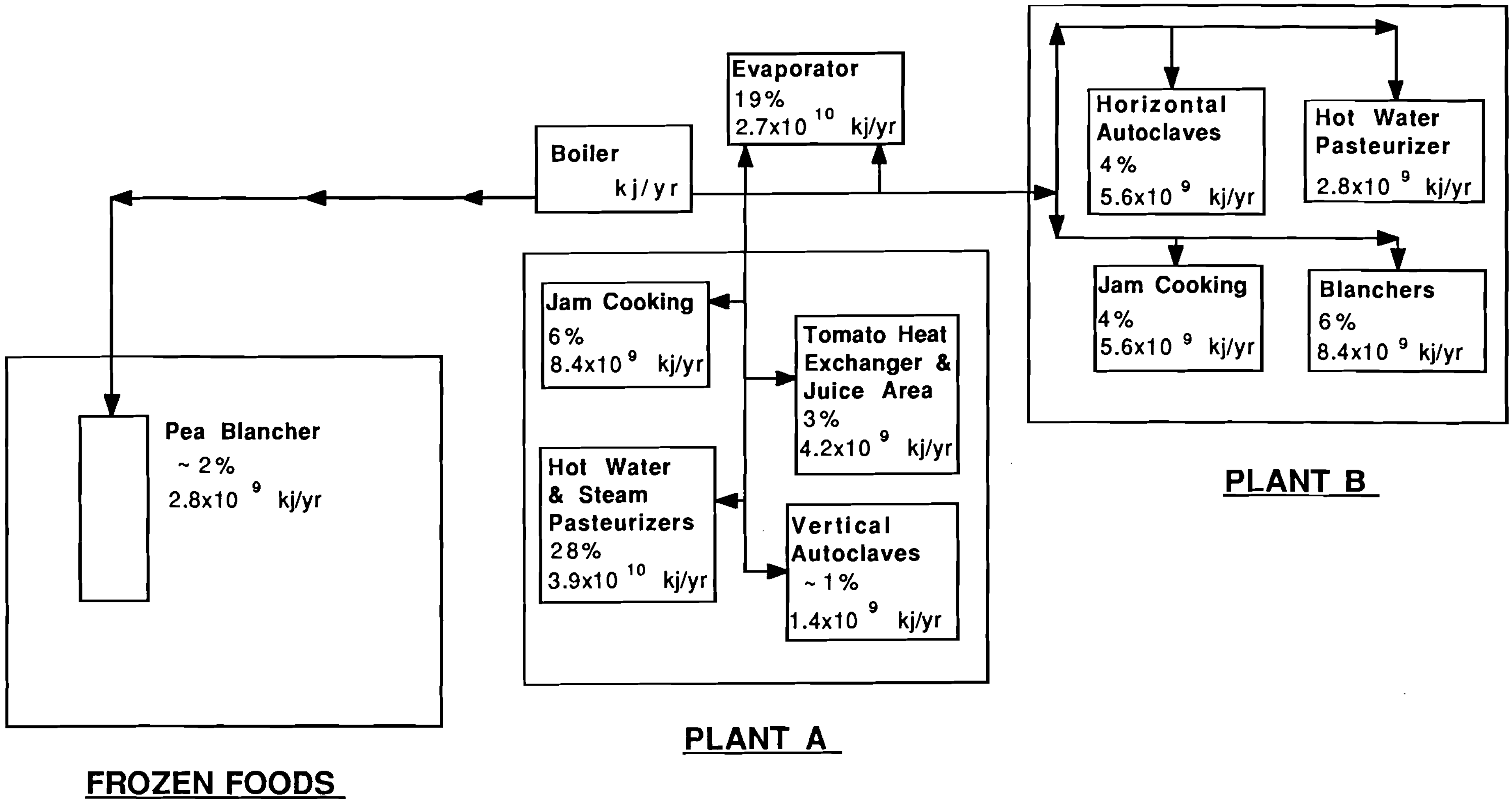
(1) Note that electricity is converted at its approximate heat input value, not at its theoretical equivalent. Assumed central power station efficiency is 36%.

Figure 4-1: Edfina Steam Use
Unmodified Plant



Estimated electric power uses:

- Refrigerated storage 17%
- Frozen food freezing 13%
- Air compressors 8%
- Tin melting 3%
- Electric motors 59%

Estimated sular uses:

- Lacquer furnaces 51%
- Operating diesel elec. 49%

Because of the key role energy monitoring plays in overall energy conservation, we suggest that Edfina implement an instrumentation/energy monitoring program. This recommendation is discussed in Section 5.1.

4.3 Plant A Pasteurizers (Basis for Recommendation 6.2)

One of the major process operations at Edfina is pasteurizing tomato and jam containers. There are two types of pasteurizers used: hot water heated by steam injection and direct steam heating. Each hot water pasteurizer uses direct steam injection to heat a flow of 25 to 30 m3/hr of water in a bath recycle loop from 70°C to 90°C. The two steam pasteurizers and one hot water pasteurizer are used 5 months a year, 15 hours/day. One hot water pasteurizer bath is used 10 hours/day, 4 months per year. The pasteurizers are observed to generate large clouds of steam. The pasteurizers process about 200 cans/minute at 170 grams/can (See Figure 4-2).

This information can be used in the following manner to calculate steam consumption:

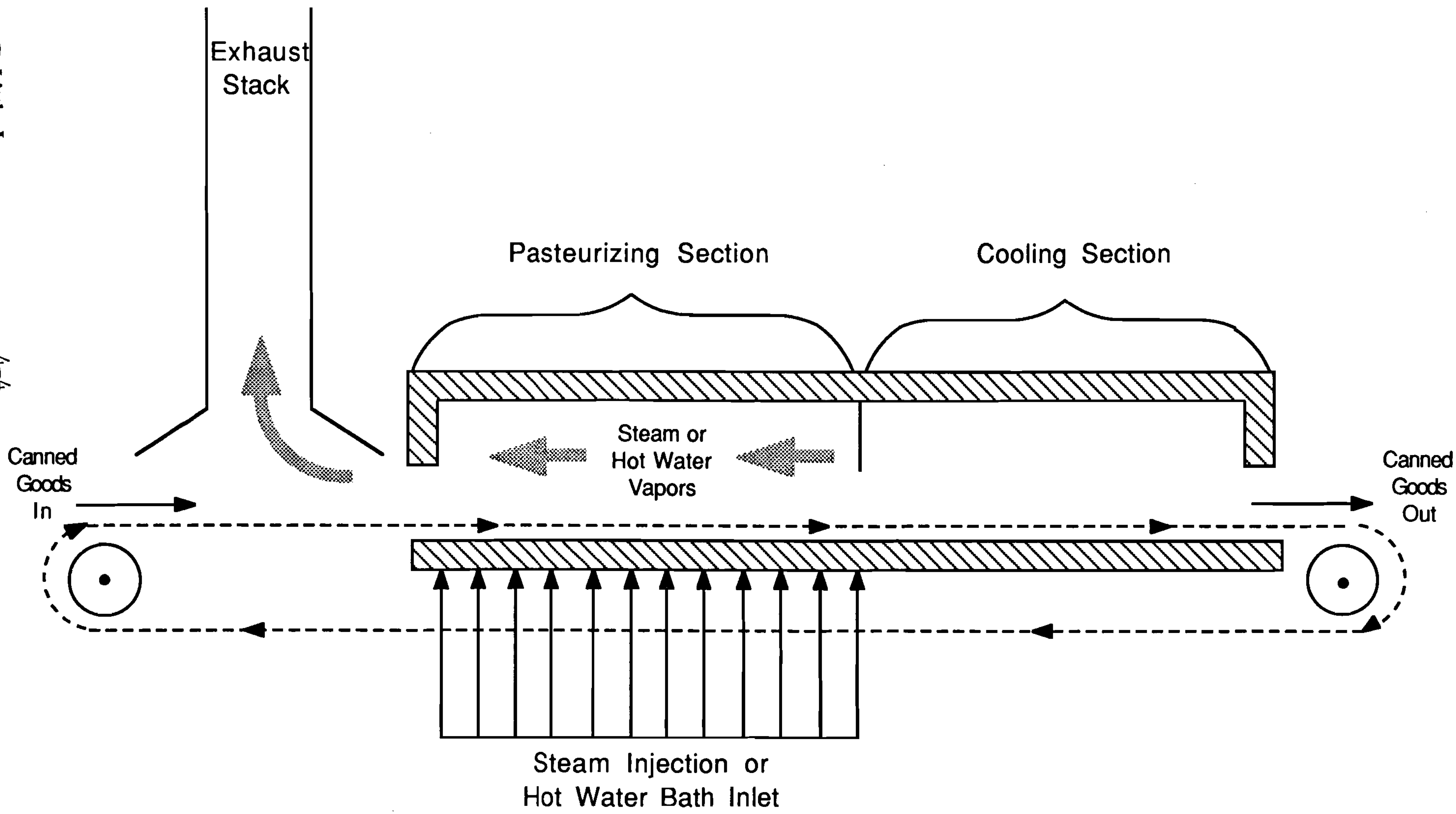
- Since 25 to 30 m3/hour of water is heated to 20°C, the average steam use per pasteurizer is 1040 kg/hr of steam. At 1 pasteurizer and 1950 hours per year, and 1 pasteurizer and 1040 hours per year, the total annual steam use is $3x10^6$ kg/year.

- At 200 cans/minute and 170 grams/can, and heating the cans from 30 to 90°C, the average heat load from can heating is 231 kg/hr of steam.

- The heat losses from metal surfaces of the hot baths by convection will generate about 76 kg/hr of steam loss for a 10m x 3m x 1m bath.

- An exposed agitated hot water surface at 90°C would lose about 25 kg/hr/m2 of heating steam (pg. 126 of the North American Combustion Handbook). Significantly more would be lost if agitation caused the formation of water spray or mist. This

Figure 4-2: Generalized Cross Section of Pasteurizer



mechanism of loss, hot spray and water surface evaporation and convection, accounts for a loss of about 730 kg/hr of steam.

Reduction of this excessive steam use is covered in Recommendation 6.2, discussed in Section 6.1.2.

4.4 Refrigeration System (Basis for Recommendation 6.3)

Edfina presently has four sets of refrigeration units and a new system under construction. Three of the 4 units are estimated to consume 98% of the refrigeration power in the plant. The refrigeration system is ammonia with air-cooled, roof-top mounted condensers. The present condensers are about 1 m by 2 m in cross section.

The present system is well maintained and, with the exception of door housekeeping (see Section 6.1) no major shortcomings could be seen in present operation. Thus improvement will come by increasing basic efficiency (COP). The easiest way to do this is by lowering condenser temperature. For the refrigerated storage warehouse the measured pressures across the compressors indicated the condenser was operating at about 301°K, which at the time was about 8°C higher than the outside air temperature.

The COP is the ratio of refrigeration power/effective power put into the compression of the refrigerant. It is defined as:

$$COP = Tc/(Tc-Te)$$

where Tc = the condenser temperature, absolute, and Te = the evaporator temperature, absolute. The saturation temperature at the compressor outlet pressure is the condenser temperature, and the saturation temperature of the compressor inlet pressure is the evaporator temperature. The temperatures and COP's for refrigeration are shown in Table 4-1:

Table 4-1
Performance Data for Unmodified Edfina Refrigeration

System	Condenser Temp. °K	Evaporator Temp. °K	COP
Warehouse Hall Thermotank Compressors	301	240	4.0
Warehouse Gramm Compressor	301	243	4.2
Pea Freezer	325	245	3.1

The Hall Thermotank units are 75 kW motors reported to be running continuously for 14 hours a day, 300 days per year, with two units running all the time. The Hall compressors are 70% efficient. The Gramm units are also 75 kW units and run for the same amount of time, with only one running. The Gramm units are 60% efficient.

The condensers already have water sprays (a standard ECO in dry climates) which have a big effect on improving system efficiency. Additionally, the efficiency can be increased by shading the condensers. This is covered by Recommendation 6.3, discussed in Section 6.1.3.

4.5 Insulation of Steam Lines (Basis of Recommendation 6.4)

One potential cost saving measure at Edfina is insulating steam lines. Because energy losses and insulation costs for a given diameter and insulation thickness and type are constant per foot of pipe, the economic profitability of insulating the piping network can be studied on a per foot basis.

Insulation prices used were for calcium silicate insulation with an aluminum jacket. Alternatives are glass wool and asbestos. Calcium silicate is somewhat more expensive; it has higher initial cost and is offset by a longer life. Glass wool may be locally less expensive but its cheaper initial cost is usually offset by a shorter life. Asbestos is expensive and dangerous to handle, and a high worker health hazard because free inhaled asbestos fibers cause lung cancer in man. Therefore we recommend calcium silicate insulation. The prices used are summarized in Table 4-2.

Table 4-2

Estimated Installed 1988
Insulation prices for Steam Piping
($ US/m)

Pipe Size (Inches)	Insulation Thickness (Inches)		
	1.0	1.5	2.0
0.5	22.14	25.59	30.21
1.0	23.55	27.00	33.82
1.5	25.56	30.21	35.43
2.0	26.96	32.61	39.46
2.5	30.15	35.17	42.06
4.0	36.45	44.71	52.98

If fiberglass insulation is available locally, installed prices are estimated to be $7.55/M for one-inch thick and $9.25/M for two-inch thick. The estimated overall heat losses for uninsulated and insulated pipe are given in Table 4-3:

Table 4-3

Heat losses for Steam pipe in (kj/hr/m)

Pipe Size (inches)	Insulation Thickness (inches) 0.0	1.0	1.5	2.0
0.5	560	69	59	52
1.0	879	104	90	83
1.5	1111	145	125	111
2.0	1588	173	138	121
2.5	1924	208	159	131
4.0	2173	311	242	208

The resulting savings in kj/hr/m are given in table 4-4.

Table 4-4

Heat Savings for Insulated Steam Pipe (kj/hr/m)

Pipe Size (inches)	Insulation Thickness (inches) 1.0	1.5	2.0
0.5	491	502	509
1.0	775	789	796
1.5	965	986	1000
2.0	1415	1450	1467
2.5	1717	1765	1793
4.0	1862	1931	1966

The resulting savings per meter of pipe were then calculated in $US/yr based on 6200 hours of operation per year, the current market price for mazout, the world market price for mazout, and with and without water costs of $0.5/m3 of water. The water costs should be included if no condensate return system is present and not included if a condensate return system is present. The water costs were obtained from plant interview and are the sum of city water plus water treatment costs. For local energy prices, the operating losses are $\$4.43 \times 10^{-7}$/KJ with condensate return, and $\$6.74 \times 10^{-7}$/KJ without condensate return. For world market prices, the operating losses are $\$3.90 \times 10^{-6}$/KJ with condensate return, and $\$4.16 \times 10^{-6}$/KJ without condensate return.

The steam lines in the Edfina plant range from 1/2 inch to 4 inches in diameter. During the audit, the pressure was measured in the distribution lines at 5 to 7 bar. The line temperature was also measured underneath surface insulation in several places at about 160°C, corresponding to the saturation temperature of 5.2 bar gauge steam, a pressure noted by gauge to be available in all steam lines. Therefore, for the purposes of this analysis it is assumed that steam lines are normally about 160°C throughout the plant.

Specific recommendations for insulating the Edfina steam distribution system are covered by Recommendation 6.4, discussed in Section 6.1.4.

4.6 Condensate Recovery (Basis for Recommendation 6.5)

At the present time, Edfina has condensate recovery installed only for the tomato evaporators. Thus only about 19% of the steam generated is returned as condensate. The current cost for boiler feed water is $0.5/3: $.43 for water treatment, and $0.07 for city water. Because the Mazout price is currently low, the total steam cost turns out to be significantly affected by water treatment costs; the total steam cost is 1.5 times higher if there is no condensate return versus returning the condensate, just from water costs alone. Thus if condensate return is attractive, a significant reduction in steam costs can be realized.

The economic attractiveness of a condensate recovery system at Edfina is hampered by the use of direct injection steam heating in steam pasteurizers and blanchers. Installation of a condensate recovery system must include the added cost of indirect heating systems for these units. In addition, the analysis is complicated by the presence of a large number of disperse steam sources in several different locations at widely different steam loads. Further, if two of the proposed modifications of this report are implemented, the steam consumption of the hot water pasteurizers and blanchers, two major users, will be significantly reduced. The analysis could be misleading if the steam consumption from these units was inaccurately accounted for.

The analysis was therefore carried out assuming the blanchers and pasteurizers ran at the modified process rates. The return system was broken down into several lines and the economic attractiveness of the lines were calculated individually. If any line or return system for a particular process was not economical, it was left out of the design. The economic attractiveness of insulating the lines was also determined.

The installation costs of condensate recovery piping goes up significantly if insulation is added. In order to properly cost out the Edfina system the first step was to determine if the lines should be insulated. The analysis is carried out per foot of pipe. According to the North American Combustion Handbook, 1" and 2" steam lines at 77°C (the expected return temperature for insulated lines), will lose 283 and 488 kj/hr/m of pipe, respectively. At local Mazout prices and 6200/hr/yr of operation, this corresponds to a loss of $.75/m for 1-inch pipe and $1.3/m for 2-inch pipe. For international market prices, the loss is $6.62 for 1-inch pipe and $11.91 for 2-inch pipe.

The cost to insulate the pipe is $23.55/m for 1-inch pipe and $26.96 for 2-inch pipe based on calcium silicate insulation with an aluminum jacket. A different type of local insulation may be available, but calcium silicate is preferred due to life expectancy and insulating value. The installed prices for calcium silicate (1-inch dia. pipe) are: for 1-inch thick $23.55/m; for 1.5-inch thick $27.00/m; for 2-inch thick $33.82/m. If fiberglass insulation is available locally, installed prices are estimated to be: for 1-inch thick $7.55/m; for 2-inch $9.25/m. With this data the payback periods in Table 4-5 can be calculated.

Table 4-5

Payback Periods for Condensate Return Insulation

Line Size (inches)	Local Energy Price	World Energy Price
1	31	6.5
2	21	4.3

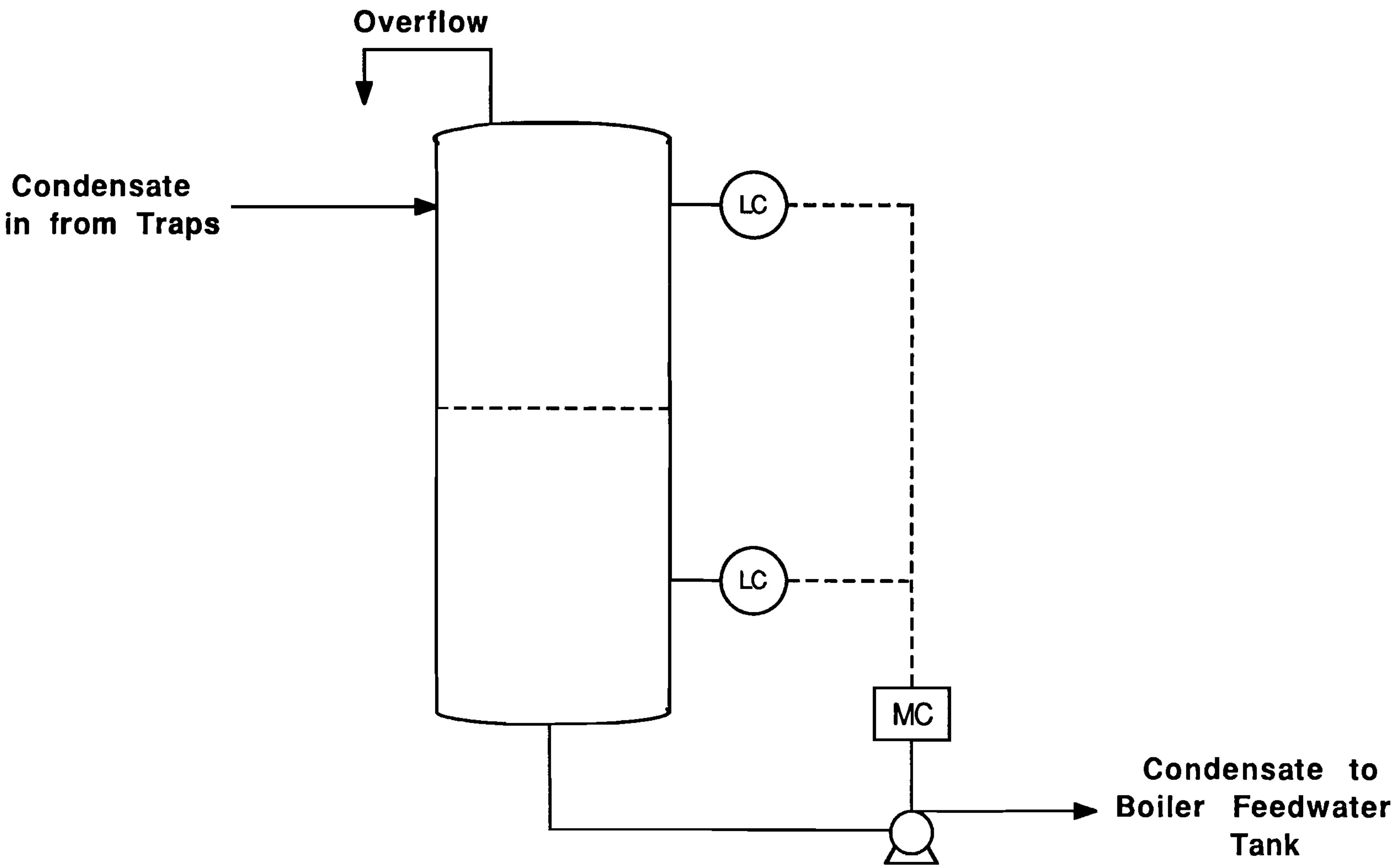
Thus, the investment is unattractive at local prices and marginal at world market prices. Therefore the condensate return system will be analyzed with uninsulated pipe.

The proposed condensate return system requires several basic groups of equipment depending on the particular process. The blanchers and hot water pasteurizers require the installation of a temperature control system and heat exchanger plus recirculating pump so condensate may be kept separate from process water. The vertical autoclaves require steam traps and relief valves. Condensate collection vessels with transfer pumps and drain overflows are required near all of the process areas (see Figure 4-3). The costs of these assemblies are summarized in Table 4-6:

Table 4-6
Equipment Costs for Condensate Return Assemblies

Equipment Assembly	Cost
4.6 m2 heat exchanger with 2.3 m3/hr circ. pump	$ 3000
Temperature controller and valve	$ 3000
0.62 m2 vessel with 2.3 m3/hr circ. pump and float switch level control	$ 1600
1 meter of 1 inch pipe plus valves and fittings installed	$ 11.6

Figure 4-3 : Typical Condensate Recovery Assembly
(Vessel Assembly)



1 meter of 2 inch pipe plus valves and fittings installed	$ 16.5
1 installed steam trap	$ 310

These assembly costs were used with the condensate flow rates and return distances to define the condensate recovery system covered by Recommendation 6.5, discussed in Section 6.1.5.

4.7 Tomato Evaporation 2 and 3 Effect Evaporator (Basis for Recommendation 6.6)

Edfina has 2 tomato juice/paste evaporators: a 2 effect evaporator which evaporates 8,000 kg/hr of water, and a 3 effect evaporator which evaporates 12,000 to 20,000 kg/hr of water. Presently, Edfina uses the 2 effect evaporator as its primary evaporator, and only uses the 3 effect high capacity unit when the production schedule is unusually heavy. The 3 effect evaporator is only operated at the lower rate of 12,000 kg/hr. Both evaporators are hooked up to a condensate return system. The reason for using the 2 effect evaporator is the Edfina staff believe that the 3 effect evaporator starves the plant for steam when operated. The Edfina staff believe the main cause of the excessive steam consumption is the two single-stage, single-valve impulse turbines used to power the evaporator recirculation pumps. They would like to switch to variable speed electric motors as a source of pump power so they can use the 3 effect evaporator as a principal evaporator. The 3 effect evaporator should be about 1.5 times more efficient than the double effect evaporator.

During the Edfina audit, only the 2 effect evaporator was running. Because the condensate return empties into an atmospheric horizontal cylindrical tank before being fed into the boiler feed water tank, dipstick measurements could be used to measure the condensate return flow. Based on these measurements, the rate of steam consumption for the 2 effect evaporator is 4610 kg/hr. The 2 effect evaporates about 1.74 kg of tomato juice water for every kg of steam. The evaporator operates about 10 hrs/day, 5 months a year (1300 hrs/yr). Thus tomato juice and paste evaporation use about $6.0x10^6$ kg/yr of steam.

Because the 3 effect evaporator was not operating during the audit, it was impossible to measure its steam consumption. However the 3 effect design is similar to the two effect, and operates at similar temperatures and pressures, and evaporates the same material over the same percent solids range. Thus the degree of inefficiency per stage should be similar, and the 3 effect would evaporate about 2.5 kg water for every kg of steam. The two effect uses (1/1.74) = 0.57 kg steam/kg water; the three effect uses (1/2.5) = 0.4 kg steam/kg water.

It may be possible to run the 3 effect evaporator without changing to electric motors for recirculation pump motors. A typical small single stage turbine has an energy efficiency of about 30 to 50%. The steam turbine is supposed to have a rated horsepower of 60 HP. With about 6 bar steam coming in on the average, being let down to 1.5 bar isentropically, the steam turbines exhaust should exit at 93% quality, and have a net consumption of 480 kg/hr to 800 kg/hr of steam, which is not enough to starve the plant. Therefore if the turbine is operating appropriately, it will not starve the plant for steam.

One reason the turbines consume excessively large quantities of steam is because they are operating at about 60 % capacity. A single stage turbine like those in the evaporator rapidly falls off in efficiency as operating rate is decreased from the design capacity. If the reduced throughput causes a large drop in turbine efficiency, this would consume large quantities of steam. Because the unit was not running, it was difficult to tell exactly how the system performs.

Our suggestions for resolving the multiple effect evaporator problem are covered in Recommendation 6.6, discussed in Section 6.2.1.

4.8 Blancher Steam Consumption (Basis for Recommendation 6.7)

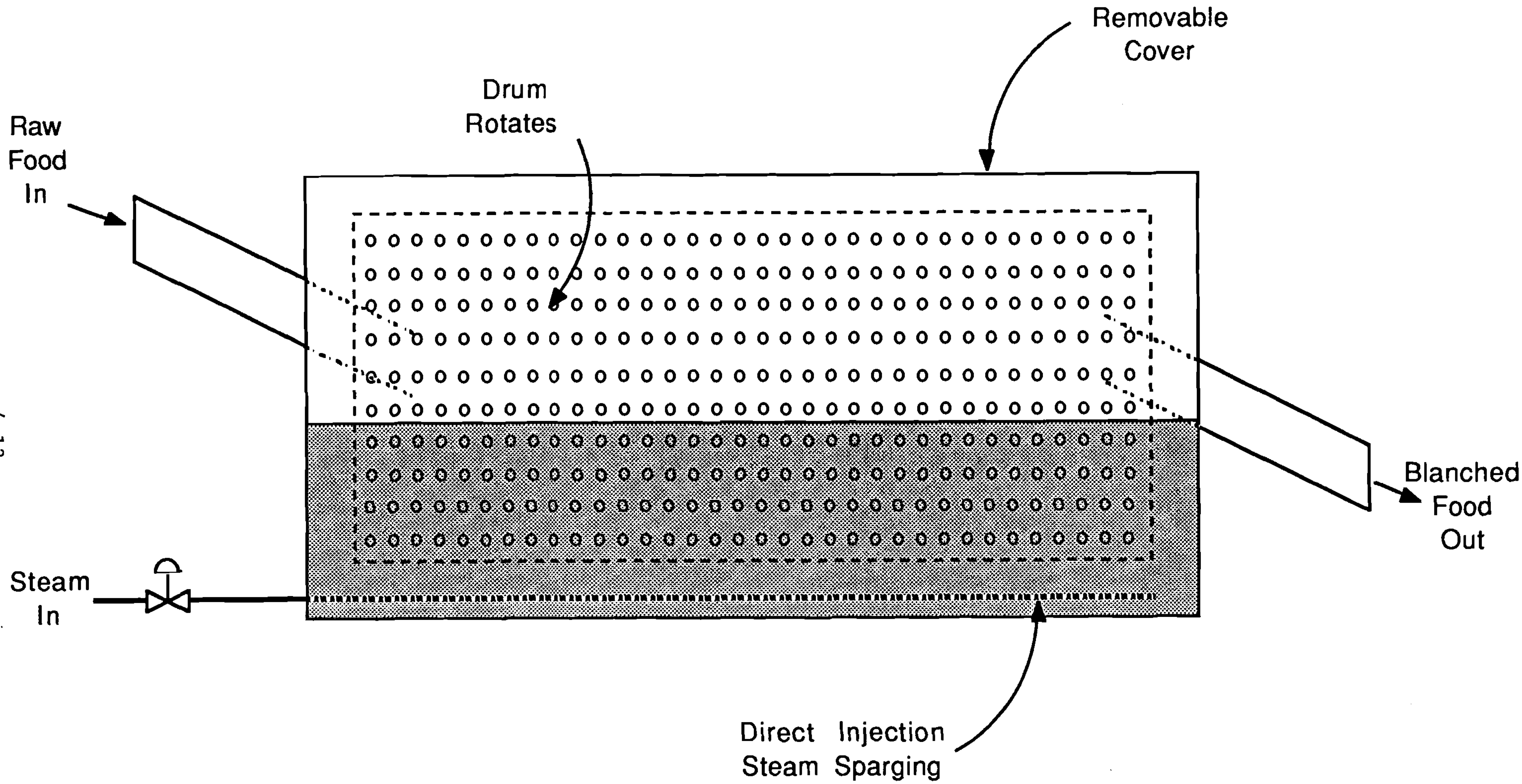
The blanchers at the Edfina Plant consist of cylinders through which food is fed in a rotating cage from one end to the other. The blancher water is heated by direct steam injection. The steam flow rate is adjusted manually; when originally installed the blanchers had automatic temperature control, but they no longer operate (see Figure 4-4).

The blanchers in Plant B are larger than the pea blancher used in the frozen food section. The blanchers in Plant B process about 1000 kg/hr of food, the pea blancher processes about 500 kg/hr. Steam consumption rates in one of the Plant B Blanchers and in the pea blancher were measured by filling the blanchers up to the drain weirs with cold water of a known mass, having the operator turn the steam on to the normal operating position, and then measuring the rate of temperature rise. In both cases no visible steam was emitted from the water surface during testing; all steam was absorbed by the cold water. The results of the tests demonstrate the Plant B blancher uses about 1160 kg/hr of steam and the pea blancher uses about 420 kg/hr of steam.

The heat load from the incoming food may also be determined. Since fresh beans and peas are about 50 % water, the average food heat capacity would be 0.75 kcal/kg/°C. Knowing the food is heated up from 25 to 90°C, it can be concluded that food based heat demand for the plant B blancher is about 92 kg/hr of steam, and for the pea blancher about 46 kg/hr. Additional losses of steam are expected from convection losses and evaporation losses from the water through the openings in the ends of the blanchers where food passes in and out (about 1 foot diameter holes). A reasonable but conservative estimate of these losses is about 100 kg/hr, if the bath temperature was at 90-95°C.

It is concluded that over-opened, manually controlled valves result in about 1000 kg/hr of wasted steam in Plant B blanchers, and about 275 kg/hr of extra steam in the pea blancher. The pea blancher is operated about 6 months a year for 12 hours a day (1880 hours/yr). The Plant B blanchers are operated with one on, one on standby, for 10 hours/day, 300 days per year (3000 hours/yr). Thus reducing the excess steam used in the pea blancher would save $5.2x10^5$ kg/yr of steam, and reducing the excess steam used in the Plant B blanchers would save $3x10^6$ kg/yr of steam.

Figure 4-4: Typical Food Blancher
Edfina Foods



Reducing blancher steam consumption is covered by Recommendation 6.7, discussed in Section 6.2.2.

4.9 Steam Boiler Performance and Efficiency (Basis for Recommendation 6.8)

The Edfina Plant has 2 fire-tube mazout fired boilers each rated to produce 10 bar steam at 12,000 kg/hr. Atomization is a standard pressure atomization system. The boilers are routinely maintained and overhauled. One boiler normally operates and one is on standby. At present there is a solenoid operated hi/lo fire damper control but no combustion gas instrumentation of any type.

The performance of the Edfina boiler was calculated by a combination of dipstick readings of the mazout feed tank, a Fyrite portable combustion gas analyzer, and measurement of FD fan airflow. The calculations were confirmed by comparing the calculated air flow rate with the measured air velocity of the combustion air fan. Air flows agreed within the experimental error of the measurement techniques used. During the tests we determined that the damper adjustment cam was not working, resulting in extremely high O_2 levels at low fire. The plant intends to repair this. However, at normal operating rates, the boiler performance could be measured. The boiler performance is summarized below:

Boiler Performance for Edfina Boiler System

% O_2	8.1%
% CO_2	7.2%
Stack Gas Temp	226°C
Excess Air	59%
Calculated Boiler Eff	88%
Estimated Steam Generation Eff	85%
Fuel Consumption	588 kg/hr
Air Flow in	13400 kg/hr
Kg steam per Kg Mazout	12.93

Increasing boiler efficiency through excess air control is covered by Recommendation 6.8, discussed in Section 6.2.3.

4.10 Lacquer Furnaces (Basis for Recommendation 6.9)

Edfina has two sular fired lacquer drying ovens which are used to dry the lacquer coating for tin can production. The furnaces operate as tunnel kilns. Burners indirectly heat circulating air, which is moved by a fan between the tunnel (direct heat exchange with the tin sheets) and the air heater (indirect heat exchange with the burner flue gases). The furnaces operate with process air at 200°C. The burners operate with a FD fan and/or an ID fan. One lacquer furnace is an induced draft system made by Ballard of the U.K. that burns approximately 34.0 kg/hr of sular. The other furnace is a forced draft system made by LKG of Germany that burns 46.8 kg/hr of sular. Both Furnaces operate 10 hours/day, 300 days/year.

The flue gas oxygen and CO_2 levels and temperature were measured and stack gas flow rates and burner efficiencies calculated. The results are shown in Table 4-7:

Table 4-7

Oven Performances for Lacquer Furnaces

Parameter	Ballard (average)	LKG
O_2%	10.9%	8.6%
CO_2%	5.5	6.4%
Stack gas Temp.°C	347°C	374°C
Stack gas Flow, Kg/hr	806 kg/hr	1131 kg/hr

As can be seen from the above table the stack gases are fairly hot.

There are two options to improve lacquer furnace efficiency; excess air control via O_2 monitoring; and waste heat recovery. Both options are covered by Recommendation 6.9, discussed in Section 6.2.4.

4.11 SKL 550 KVA Diesel Electric Generators (Basis for Analysis in 6.2.5)

Edfina presently has 5 diesel electric generators capable of generating a total of 2000 kW of electricity. Edfina's current annual average load requires only about 800 kW (although during peak processing season all the units are required during power outages). Two of their generators, SKL 550 KVA units, are located adjacent to each other. These units could be run at about 86% load, with a third on standby, and generate 800 kW. Although the present laws do not allow Edfina to generate their own power routinely, OEP is interested in determining options under different situations. One cost savings option at Edfina, if there were a change in the law, would be for Edfina to generate their own primary power routinely and recoup stack gas heat from the grouped SKL diesels with a waste heat boiler.

According to the manufacturer, at 800 kW load the 2 SKL's will consume 187 kg/hr of sular, and generate 5160 kg/hr of waste gas at a temperature of about 425°C. Exhaust gas typically would be is cooled down to about 175°C in a waste heat boiler.

Installation of a waste heat boiler is discussed in Section 6.2.5.

Section 5
Energy Management Improvements

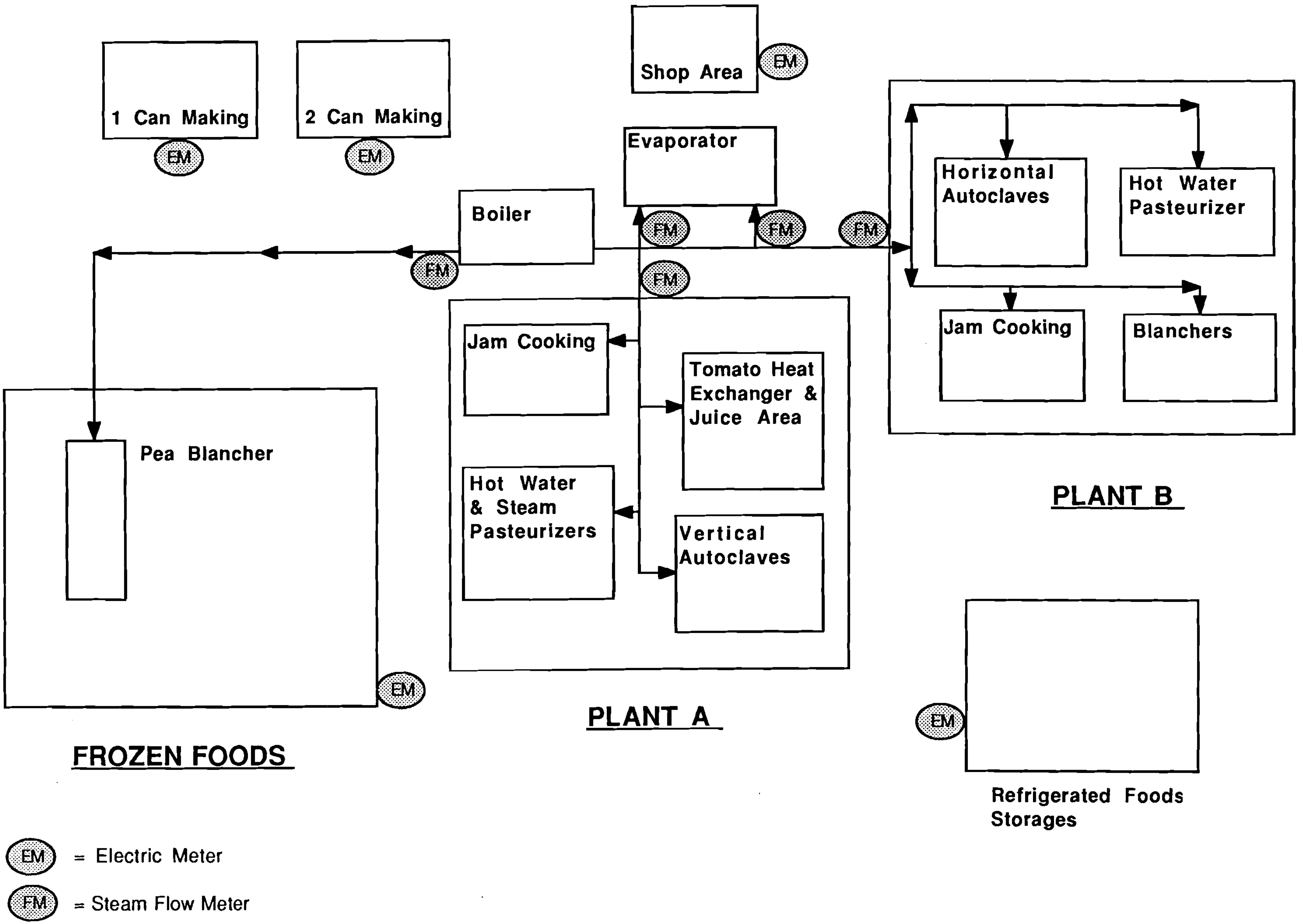
5.1 Recommendation 5.1 - Energy Monitoring Instrumentation

There is presently very little on-line instrumentation for energy monitoring functioning at Edfina. There are two significant energy costs at Edfina which could both benefit from regular monitoring: local steam and local electric consumption. Proposed energy monitoring instrumentation is shown in Figure 5-1.

Local steam by various processes could be monitored at the steam line entrances to the evaporator, Plant A, and Plant B. An orifice plate, flanges, and pressure gauge with local recording readout can be set up for about $2,500. At a minimum, an orifice plate, flanges and pressure taps can be set up for $1,000. Thus, for $3,000 to $7,500, steam use by various processes can be monitored.

Electric meters in Manufacturing Buildings can also be used to monitor electric power. There are several areas where this could be beneficial; the 2 can manufacturing buildings, the pea-freezing area, and the refrigerated storage warehouse. Electric meters with power factor can be purchased for about $1,000. An ammeter is much less. By monitoring power in these areas regularly, leaks and inefficiency in refrigeration could be located, and electrical use could be related to various manufacturing machines.

Figure 5-1: Energy Monitoring Instrumentation



Section 6
Energy Conservation Opportunities (ECO's)

6.1 Housekeeping and Low Cost/No Cost Recommendations

6.1.1 Recommendation 6.1 - Traditional Housekeeping

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 Edfina in keeping its energy costs down:

- About 60% of the electrical power consumed at Edfina is by motors used to drive manufacturing machinery, and by small sized induction motors throughout the plant. If just 10% of the motors are running unnecessarily and could be turned off, the resulting savings would be $2,300/yr by local prices and $9,000 by world prices. Developing habits in workers of turning off unnecessary equipment is important.

- Compressed air is used in many of the manufacturing and food processing areas. A survey of these areas located 7 air leaks in pressurized equipment. The survey was done while the plant was under pressure, but no equipment was running, therefore, the number is probably higher, since not all parts of the plant were pressurized. If seven leaks 2 mm in diameter are present in Edfina at any one time, the resulting costs are about $400/yr at local costs, and $1,560 at international prices. Periodically surveying and identifying leaks, and eliminating them can be cost-effective.

- Steam leaks can be costly. There were many places in Edfina where steam leaks could be observed, particularly around valve stems. There were also various places where steam was being run, but no process was operating, particularly steam lines at can filling stations. Maintaining steam traps is also very cost effective. There were several places in the plant where the auditors observed traps bypassed during operation. Assuming a total leak cross sectional area for the plant of just 500 mm2, Edfina would lose about 15% of their steam per year. The dollar value of this would be about $9,800/yr at local prices, and $60,000 at world prices. Capital costs are $300/trap.

- Good housekeeping in refrigeration areas is also important. Edfina's frozen food storage warehouse consumes 7 times more power than recommended by ASHRAE for a well-designed food warehouse of its size. The warehouse is well-insulated with .2 m of cork. The principal reason for the high consumption can be attributed to air infiltration. In particular, the Edfina warehouse has non-spring-loaded doors in a double air lock. When personnel enter the warehouse, they leave the doors open during their stay inside. There are rubber double doors inside, but they do not seal well. Keeping the doors closed, or adding self-closing, spring loaded doors, should do much to reduce air infiltration. There is also a possibility of air leaks through the walls. These can be reduced by adding a plastic vapor barrier on wall surfaces. Getting air infiltration down to good design levels should save Edfina about 5.55 x 10^9 KJ/yr, or $6,500/yr at local prices and $25,530/yr at world prices. Capital costs are $1,000.

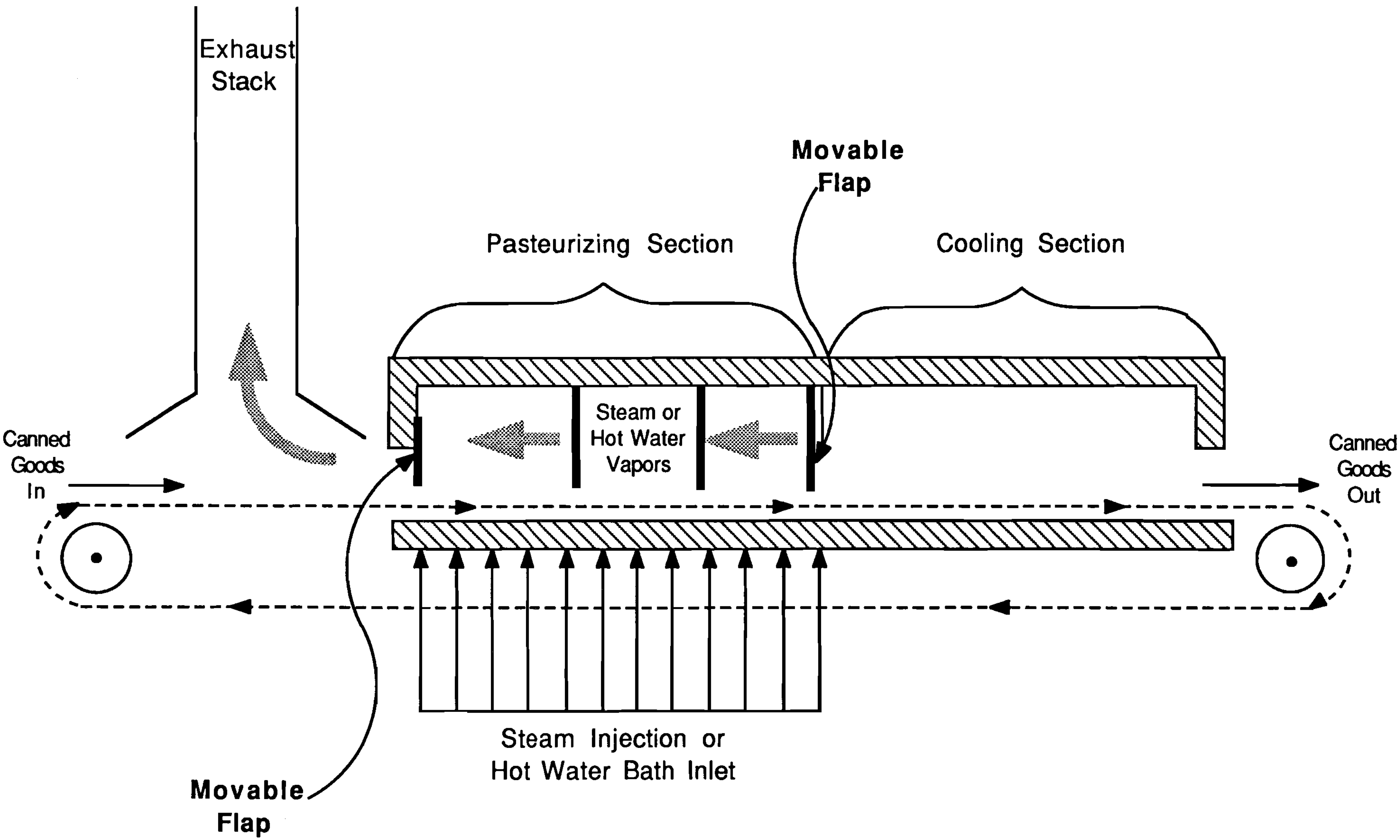
6.1.2 Recommendation 6.2 - Reduce Steam Use with Flexible Flaps in Plant A Pasteurizers

It was demonstrated in Section 4-3 that a significant amount of the energy used by the pasteurizers is for unnecessary evaporation and convection losses. Reducing these losses would eliminate a significant portion of the steam used by the baths. It can be concluded that all but 250 kg/hr (convection losses plus about 100 kg/hr of loss out the ends) of the steam presently lost by evaporation could be saved if air above the hot water could be trapped. In particular, in the hot water pasteurizers the savings would be 733 kg/hr present consumption less the 250 kg/hr estimated load if the system operated efficiently, or 483 kg/hr. A bath of this design is presently used in Plant B and steam losses are minimal. Although the Plant A hot water bath pasteurizers have a cover, they are open on the ends, and one end comes in direct contact with cold water spray. This sets up a convection current from one end of the bath to the other and carries off large quantities of steam (see Figure 6-1). Therefore, if the bath ends in the hot water area were covered with several flexible baffles down to the water and can levels so strong air currents and convection through the evaporator is eliminated, steam use would be greatly reduced.

We have determined that covering the open bath hot water pasteurizers could save about 733-250 or 483 kg/hr of steam from each bath, or save 1.4 x10^6 kg/yr of steam. Similarly, the steam pasteurizers are open between the hot steam side and cold water side, which will cause quenching of the steam by cold water spray, consuming extra steam. Unfortunately the equipment set up made it impossible to estimate this particular steam loss. However, based on the hot water pasteurizers the cost savings with the baffles is $2,100/yr at local Mazout costs, and $12,800/yr at estimated international market costs. The production supervisor also noted that during bath operation, steam delivery pressure at the evaporators is only about 4 bar from which it may be concluded that the pasteurizers can starve the evaporators and the rest of the plant for steam. Reducing the steam use at the pasteurizers could significantly increase the available steam at the evaporators and the rest of the plant.

Constructing the flaps from heavy plastic or canvas, and riveted or screwed into place, the total installed cost would be less than $1,000 to modify all units. The engineering description of the required equipment is contained in Appendix B. Capital Cost estimates are also broken down in Appendix C. The resulting payback would be 0.5 years for local market prices, and 0.08 years at world market prices. The economics of Recommendation 6.2 are summarized below.

Figure 6-1: Generalized Cross Section of Pasteurizer



Energy (steam) savings: 3.9×10^9 KG/yr (105 TOE)
Capital cost: $1,000
Annual Savings: $12,800
Simple payback: 0.5 years
Internal rate of return[(1)]: 1280%

We recommend that Edfina install the above described flaps on the hot water and steam pasteurizers to reduce evaporated water and quenched steam loss.

6.1.3 Recommendation 6.3 - Increase Refrigeration Efficiency by Shading Condensers

If the outside air temperature around the roof top units can be cooled down economically, refrigeration costs can be lowered. If an overhead, open sided roof is installed so the condenser and the surrounding roof top is shaded from the sun, the air temperature is lowered and a lower condenser pressure and temperature is required, saving compressor energy.

The present condensers are about 1 m x 2 m in cross-section. Erecting a 5 m x 5 m roof overhead can reduce the average air temperature by about 5°C. Because the required temperature difference across the exchanger remains constant for a given refrigeration load, the resulting decrease in required energy costs may be calculated by comparing the change in theoretical coefficients of performance (COP) for the original temperatures, and temperatures correspondingly lowered by the drop in outside air temperature. The temperatures and COP's for the unmodified system are shown in Table 6-1:

Table 6-1

Performance Data for Unmodified Edfina Refrigeration

System	Condenser Temp. °K	Evaporator Temp. °K	COP
Warehouse Hall Thermotank Compressors	301	240	4.0
Warehouse Gramm Compressor	301	243	4.2
Pea Freezer	325	245	3.1

Transferring the 5°C air drop to a 5°C condenser temperature drop, the resulting new COP's and corresponding drops in required refrigeration power are shown in Table 6-2:

[(1)]The relationship between simple payback and internal rate of return is described in Appendix F.

Table 6-2

Performance Data for Edfina Refrigeration with Shading and Dry Condenser

System	Condenser Temp. °K	Evaporator Temp. °K	COP	Decrease in Power Demand
Warehouse Hall Thermotank Compressors	296	240	4.3	7%
Warehouse Gramm Compressor	296	243	4.6	9%
Pea Freezer	320	245	3.3	6%

The following yearly electric costs may be calculated:

Frozen Food Warehouse unmodified:

(150 kW + 75 kW) x 14 hrs/day x 300 days/year x $.0118/kWh = $11,150/yr at local prices

Frozen Food Warehouse with roof:

$10,245/yr, cost savings of $906/year at current prices and $3,526 at international prices

The Pea Freezer is a 200 kW unit reported to operate 16 hrs/day, 209 days/year. The following yearly electric costs may be calculated:

Pea Freezer Unmodified:

200 kW x 16 hours/day x 209 days/year x $.0118/kWh = $7,892/yr at local prices

Pea Freezer with roof:

$7,416/yr, cost savings of $476/yr at local market prices. The corresponding cost savings at international prices would be $1856/yr.

According to personnel at El Nasr Pharmaceutical, the cost to erect a 5m x 5m roof would be no more than $2,300. Two roofs are needed for the refrigerated warehouse and one for the Pea Freezer. The engineering description of the required equipment is contained in Appendix B. Capital cost estimates are also broken down in Appendix C.

The economics of Recommendation 6.3 are summarized below:

Energy savings:	1.2×10^9 KJ/yr (27 TOE)	
Capital cost:	Pea freezer:	$2,300
	Refrigerated Warehouse:	$4,600
	Total	$6,900
Annual Savings:	Refrigerated Warehouse	$3,526/yr
	Pea Freezer	$1,856/yr
Simple Payback:	Refrigerated Warehouse	1.3 year
	Pea Freezer	1.2 year

Internal Rate of Return: 73%

According to this analysis, shading the condensers is a good investment at world market prices. The cost estimate for the roof was reported as a maximum and is probably less at Edfina.

6.1.4 Recommendation 6.4 - Insulation of Steam Lines

One potential cost saving measure at Edfina is insulating steam lines. Because energy losses and insulation costs for a given diameter and insulation thickness and type are constant per foot of pipe, the economic attractiveness of insulating the piping network was done on a unit length basis (see Section 4.5). In all cases, the highest payback occurred for 1-inch thick insulation. The results are summarized in Table 6-3. The total operating savings for Edfina are shown in Table 6-4.

Table 6-3

Summary of Steam Line insulation Paybacks

Pipe Dia.	Local Market		World Market	
Inches	Cond.	No cond.	Cond.	No. Cond.
0.5	16.4	11.	1.9	1.8
7.3	11.1	7.3	1.3	1.2
1.5	9.6	6.4	1.1	1.04
2.0	7.0	4.6	0.8	0.7
2.5	6.5	4.3	0.7	0.7
4.0	7.2	4.7	0.8	0.7

Table 6-4

Summary of Steam Line Insulation Savings, $/year

Pipe Dia	Pipe	Energy Saved	Local Market		World Market	
Inches	Length m	10^8 KJ/yr	Cond.	No Cond.	Cond.	No Cond.
0.5	82.	3.6	110	167	991	1036
1.0	18.	1.3	38	72	336	447
1.5	61.	5.2	161	244	1424	1514
2.0	550.	70.1	2129	3229	18831	20039
2.5	60.	9.3	281	425	2486	2637
4.0	140.	23.5	712	1079	6297	6699
Total		113	3431	5216	30365	32372

It can be seen from the above table that for local market conditions, insulating the steam lines is moderately attractive for no condensate return, and probably not economically attractive for lines with condensate return. As can be seen in the table, under world market prices, it is very attractive economically to insulate; if locally available insulation is significantly cheaper installed than world costs, the option may be more attractive.

The economics of Recommendation 6.4 are summarized below, assuming 20% condensate recovery:

Energy savings: 9.6×10^9 KJ/yr (261 TOE)
Capital cost: $21,700
Annual Savings: $32,000
Simple Payback: 0.7 year
Internal rate of return: 146%

6.1.5 Recommendation 6.5 - Installation of a Condensate Recovery System

One option which may be considered at Edfina is the addition of more condensate recovery. At present, Edfina only recovers about 19% of the generated steam as condensate. Based on the annual condensate generation rates for the individual processes, the equipment, total cost, and savings per year for various condensate sections are summarized in Table 6-5:

Table 6-5

Required Equipment and Installed Cost
for Various Condensate Return Options

Pea Blancher to Boiler:
80 m of 1 inch pipe, 1 heat exchanger assembly, 1- .62 m^3 tank assembly, 1 temperature control assembly, 1 steam trap — $8,830

Savings/year: $123 — Payback: 72 yr

Vertical Autoclaves to Pasteurizer Area, Plant A:
22 m of 1 inch pipe, 4 relief valves, 1- .62 m^3 vessel assembly (estimated cost for relief valves $200 total) — $3,390

Savings/year: $153 — Payback: 22 yr

Plant A Pasteurizers:
86 m of 2" pipe, 3 heat exchanger assemblies, 1- 3.1 m^3 transfer tank at $1700, 3 temperature control assemblies — $21,200

Savings/year: $950 — Payback: 22 yr

Plant A Jam Cooker Area:
34 m of 1 inch pipe, 1- .62 m^3 vessel assembly $1,995

Savings/year: $1,460 Payback: 1.37 yr

Tomato Juice and Puree Heat exchanger area:
39 m of 1 inch pipe 20 m of 2 inch pipe, 2- .62 m^3 vessel assemblies $3,983

Savings/year: $781 Payback: 5.0 yr

Plant B blanchers to Plant B Jam cookers:
40 m of 1 inch pipe, 1 heat exchanger assembly, 1- .62 m^3 vessel assembly, 1 steam trap $5,380

Savings/year: $240 Payback: 22.4 yr

From Plant B Jam Cookers and Horizontal Autoclaves to Outside:
60 m of 1 inch pipe, 1- .62 m^3 tank assembly, 1 steam trap $2,609

Savings/year: $2,075 Payback: 1.26 yr

From Plant B Hot water Pasteurizer to Horizontal Autoclaves:
36 m of 1 inch pipe, 9 m of 2 inch pipe, 1 heat exchanger assembly, 0.62 m3 vessel assembly, 1 steam trap, 1 temperature control assembly $8,480

Savings/year $476 Payback: 17.8 yr

Costs of Additional Piping Hook-ups:

Run from Plant B outside to Boiler:
86 m of 2 inch pipe $1,500

Piping from Plant A Pasteurizers and Vertical Autoclaves to Plant A Vacuum Jam Cookers:
18 m of/1 inch pipe $300

Thus, only the Plant A Jam Cooker area and the Plant B Jam Cooker and Horizontal Autoclaves are economically attractive for condensate recovery. The Tomato Juice and Puree areas are marginally attractive. All other process areas are not.

Total Condensate returned :

Plant A Jam Cookers:	2.9x106 kg/yr
Plant B Jam Cookers and Horizontal Autoclaves	4.1x106 kg/yr
Tomato Juice and Puree Heat Exchangers	1.6x106 kg/yr
Total	8.5x106 kg/yr

(22 % of total recoverable condensate)

The economics of Recommendation 6.5 are summarized below:

Energy savings: N/A
Capital cost for condensate return
From Plant A jam cookers and tomato heat exchangers,
plus plant B jam cookers and horizontal autoclaves: $10,100
Annual savings: $4,320/yr
Simple payback: 2.3 years
Internal rate of return: 32%

The final payback for condensate return must include the addition of the appropriate extra transfer lines. The engineering description of the required equipment is contained in Appendix B; capital cost estimates are also broken down in Appendix C.

Note that world price and local price savings and payback are the same, because operating savings are based on water costs alone. It is recommended the Edfina condensate return system be extended to include the above three areas.

6.2 Capital Equipment Recommendations

All capital equipment costs are calculated with international prices only.

6.2.1 Recommendation 6.6 - Reduction in Tomato Evaporation Steam Consumption by Use of 3 Effect Evaporator

It is shown in Section 4.7 that the two effect evaporator uses 0.57 kg of steam/kg of evaporated water, and the three effect uses 0.4 kg of steam/kg of water evaporated. Using the 3 effect instead of the 2 effect would result in a steam savings of 1.8×10^6 kg/yr. At world market prices, the savings would be $15,860/year. There are three possible options for accomplishing this:

1) Study the evaporator turbines' energy consumption and solve the operating problems.

   We believe that based on our turbine performance analysis discussed in Section 4 Edfina should study the steam turbine operation carefully to determine if the turbines starve the system when steam exhaust feed to the evaporator is used, particularly after initiating some of the steam consumption reducing steps mentioned elsewhere in the report. If the system can be run at the 12000 kg/hr evaporation rate with the steam turbines using energy efficiently, the evaporator should use only about 5000 to 6000 kg/hr of steam, and generate a significant cost savings.

2) Use electric motors to operate the evaporator recirculation pumps

If the steam turbines are replaced with a 50 Hp electric motor and an adjustable speed drive, the cost of a motor and drive assembly would run over $12,000 each, resulting in a payback period of 13 years at local prices and 2.9 years at world market prices. If a fixed speed drive is used however, so only steam pressure is used to control flow rate, the motor and drive combination would cost about $6,600. This would result in a payback of 0.8 years at world prices. Thus, the economic attractiveness of the electric motor replacement is marginally attractive with a variable speed drive. However, with a fixed speed drive the electric motor is an attractive option.

3) Replace the present turbines with higher efficiency turbines

Another alternative would be to replace the turbine with a higher efficiency unit. A well-selected 30-50 Hp replacement turbine costs about $6,500 to $8,500, assuming the plant can perform the installation at negligible cost. Using an average $7,500 for each turbine (total $15,000) the payback would be 1.0 years at international market prices. Thus the steam turbine replacement may be more economical than a variable speed motor drive, but would be less economical than a fixed electric motor drive. However, the most economical alternative of all would be to use the present system if possible.

The economics of Recommendation 6.6 are summarized below for the second (electric motor) option:

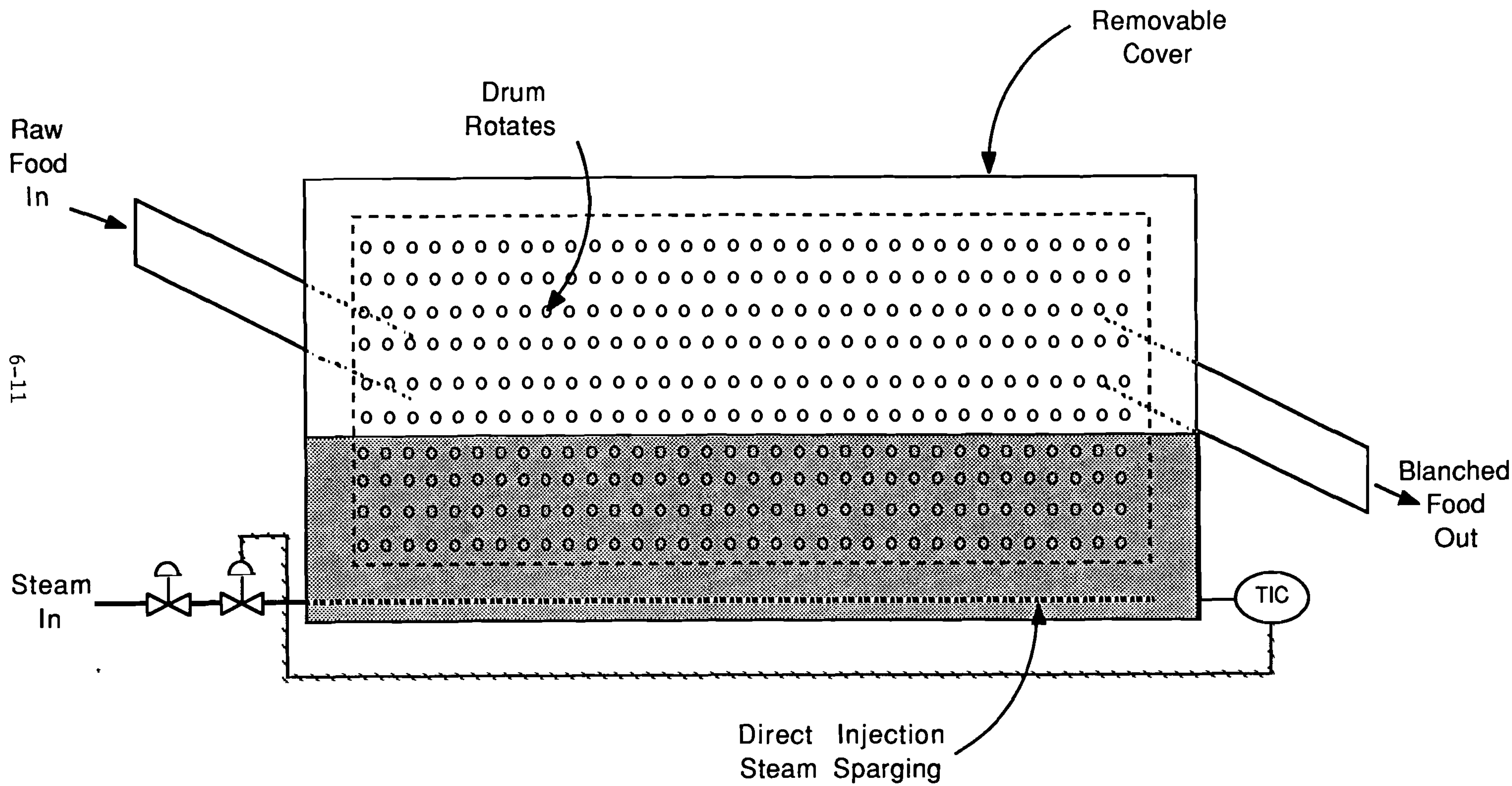
Energy savings: 5.0×10^9 KJ/yr (137 TOE)
Capital cost: $13,200
Annual savings: $15,900
Simple payback: 0.8
Internal rate of return: 120%

It is recommended that Edfina study the performance of the turbine carefully, and try to work the 3 effect evaporator closer to design capacity. If this does not allow the evaporator to be used, the motor with a fixed drive is an attractive investment under local prices. If variable speed operation is desired it can be justified only under world market pricing.

6.2.2 Recommendation 6.7 - Reduction of Blancher Steam Consumption With New Blancher Control System

It is demonstrated in Section 4.8 that over-opened, manually-controlled valves result in about 1000 kg/hr of wasted steam in Plant B blanchers and about 275 kg/hr of extra steam in the pea blancher. The pea blancher is operated about 6 months a year for 12 hours a day (1880 hours). The Plant B blanchers are operated with one on, one on standby for 10 hours/day 300 days per year (3000 hours). Thus reducing the extra steam from the pea blancher would save 5.2×10^5 kg/yr of steam and reducing the extra steam from the Plant B blanchers would save 3×10^6 kg/yr of steam. This can be done by installing a simple temperature control loop (see Figure 6-2).

Figure 6-2 : Blancher Temperature Control Edfina Foods



At international market prices, the savings would be $4,750/yr in the pea blancher and $27,500/yr in the Plant B blanchers.

The cost of a temperature control system installed is estimated to be $3,000. One should be installed on each blancher. The economics of Recommendation 6.7 are summarized below:

Energy savings: $.97 \times 10^{10}$ KJ/yr (263 TOE)

Pea Blancher:
Capital cost: $3,000
Annual savings: $4,750
Simple payback: 0.6 years

Plant B Blanchers:
Capital cost: $6,000
Annual savings: $27,500
Simple payback: 0.2 years

Internal rate of return: 358%

The engineering description of the required equipment is contained in Appendix B. Capital cost estimates are also broken down in Appendix C.

Therefore, putting new control systems in and maintaining them is economically attractive for both blanchers and is clearly recommended at Edfina. At the very least some immediate savings could be realized by having the operators adjust the temperature of the baths carefully with the steam valves to keep them below 95°C.

6.2.3 Recommendation 6.8 - Improvement in Boiler Efficiency with a Continuous Oxygen Analyzer

If excess air can be controlled in the boiler, a higher burner efficiency will result. Although the Edfina boiler presently has a hi/lo fire damper adjustment, it needs to be fixed and tuned. They also do not have a combustion gas analyzer. If the damper was repaired, and an oxygen analyzer installed and used to manually adjust the air fan damper, the flue gas 0_2 could be brought down to 2 to 3% with a corresponding efficiency increase of 3%. This corresponds to a decrease in current Mazout use of 108,000 kg/yr or about $12,100/yr at international market prices. An on-line combustion gas analyzer costs about $5,000. The economics of Recommendation 6.7 are are summarized below:

Energy savings: 4.5×10^9 KJ/yr (104 TOE)
Capital Cost: $5,000
Annual Savings: $12,100
Simple Payback: 0.4 years
Internal rate of return: 242%

The engineering description of the required equipment is contained in Appendix B. Capital cost estimates are also broken down in Appendix C.

The installation of an online combustion gas analyzer and manual adjustment of the damper is economically attractive to Edfina under all circumstances and is strongly recommended.

6.2.4 Recommendation 6.9 - Increase in Energy Efficiency in Lacquer Furnaces Through the Use of Stack Gas Waste Heat Recovery

One possible method of saving energy is to install crossflow heat exchangers in the flue gas stream that are used to heat recirculated oven air via insulated duct work and a blower. The current yearly fuel costs are shown in Table 6-6:

Table 6-6

Yearly Fuels Costs for Lacquer Furnaces

Furnace	Yearly Cost
LKG	$ 18,300/yr
Ballard	$ 13,300/yr

It is estimated each furnace requires the following equipment in order to recover this heat:

One QDOT[(1)] heat pipe assisted crossflow heat exchanger assembly consisting of 4 SP 21(H) x 36(L) units in series, total installed cost is	$15,000
30 feet of of insulated duct at $ 21/linear foot	$630
One process gas air blower, installed cost	$900
Total installed cost	$16,530

Assuming a 20°C approach temperature in the heat exchanger the amount of heat that can be recovered, corresponding operating savings, and corresponding payback periods are shown in Table 6-7:

Table 6-7

Estimated Heat Recovery,Operating Savings, and Payback for Lacquer Furnaces

Furnace	Heat Recovery KJ/hr	Operating Savings (International)	Payback
Ballard	190,000	$2,952/yr	5.6 yr
LKG	112,000	$1,766/yr	9.4 yr

---

(1) QDOT - manufactured by Q-Dot Corp., Garland, Texas, USA

The conclusion is waste heat recovery is unattractive.

A second alternative is the introduction of damper control into lacquer furnaces. If a damper control system is added to the lacquer furnaces, with manual control, the flue gas O_2 may be brought down to 2-3%. The North American Combustion Handbook was used to estimate efficiencies. The efficiency improvements for the two furnaces, and the corresponding operating savings may be estimated as shown in Table 6-8:

Table 6-8

Efficiencies and Operating Improvements
for Burner Fan Control

Furnace	Present Eff. %	Eff. at 2.5 %	Oper. Savings $/yr International Energy Prices
Ballard	70 %	78 %	$1,580
LKG	69 %	75 %	$1,693

Although a permanently mounted O_2 analyzer costs $5,000 (see the boiler control discussion), the cost for a portable unit, which would be adequate for a constant load burner, like the ovens, is only $2,500. Three manual damper controls need to be installed at $500 each. The total cost for O_2 control would therefore be $4,000. The corresponding payback period would be 1.2 yrs. Damper control therefore is very attractive under world market prices. It is recommended that Edfina install this option.

The economics for Recommendation 6.9 are summarized below:

Option 1: Stack Gas Waste heat recovery

Energy savings: 2.4×10^9 KJ/yr (56 TOE)
Capital costs:
Ballard: $16,530
LKG: $16,530
Annual savings:
Ballard: $2,952/yr
LKG: $1,766/yr
Simple payback:
Ballard: 5.6 yrs
LKG: 9.4 yrs

Option 2: Damper Control

Energy savings: 0.96×10^9 KJ/yr (22 TOE)
Capital costs: $4,000
Annual savings:
Ballard: $1,580/yr
LKG: $1,693/yr
Total: $3,273/yr
Simple payback: 1.2 yrs
Internal rate of return: 82%

6.2.5 <u>Recommendation 6.10 - Installation of A Waste Heat Boiler on SKL 550 KVA Diesel Electric Generators</u>

It was shown in Section 4.11 that 5160 kg/hr of 425°C waste gas is generated at the average plant power demand of 800 kW. Cooling the gas to 175°C, a typical waste heat boiler temperature would recover 1.4×10^6 KJ/hr, or generate 630 kg/hr of steam with an appropriate size boiler.

A waste heat boiler capable of recouping 1.4 x 106 KJ/hr has a purchased equipment cost of about $21,300, and an installed cost of about $63,900. Since the SKL's operate 6200 hr/yr, they would burn 1.16×10^6 kg/yr of fuel, reduce the boiler mazout consumption by 3.02×10^5 kg of mazout per year, and generate 4.96×10^6 kWh of power. The maintenance cost of routinely operated diesel electric generators is typically 5%/yr of total installed cost. Thus, the maintenance cost is about $10,000/yr for each engine or $20,000/yr.

The operating savings per year of operating the diesels and waste heat boiler is:

$228,160 + $33,800 - $174,740 - $20,000 = $67,200/yr,
(electric) (mazout) (sular) maintenance)

The corresponding payback would be 1.0 years. Therefore, based on the currently selected international costs, the installation of a waste heat boiler would be economically attractive.

The economics for Recommendation 6.10 are summarized below:

Energy savings: 11.0×10^9 KJ/yr (254 TOE)
Capital cost: $69,000
Annual savings: $67,200
Simple payback: 1.0 year
Internal rate of return: 97%

Appendix A

Edfina Personnel Interviewed During Audit

GENERAL PROJECT AND ENGINEERING MANAGER		
[Ahmed Abo El Eneen]		
Eng. Sayed Amen (boilers)	Eng. Tahseen Zabaria Abed E. Halim (mechanical	Eng. Yosef Mahmoud (compressors)

GENERAL ELECTRIC AND ENERGY MANAGER			
[Amal Shoukry]			
Eng. Entessar Mahmoud (electric)	Eng. Ramadan Mohamed (power)	Eng. Aziza AdbAlla (electrican)	Eng Mohamed Taher (diesel generator)

Canning Plant
Engineer Hanafi Mahmoud (production)
Mahmoud Yakout (atoctlaves)

Tin Making and Varnishing Plant
Eng. Mahmoun Fauzi (ovens)

Appendix B

BILL OF MATERIALS

Plant: Edfina

Recommendation: 6.2 - Plant A Pasteurizers

Flaps	Heavy plastic (vinyl) or canvas; approximately 5m x .5m; 4 sets, locally manufactured, installed	(4)

Recommendation: 6.3 - Shade Refrigeration Condenser

Open Roof	5m x 5m, 2.5m above existing roof, simple pipe framework, nonflammable roof panels as locally available--resistent to NH_3 attack	(3)

Recommendation: 6.4 - Insulation

Insulation	Calcium silicate, aluminum jacket, various diameters 0.5-4", various thickness 1-2"	

Recommendation: 6.5 - Condensate Recovery

Vessel	0.62 m^2 vessel, carbon steel, 5 bar design pressure, with pressure relief valve, flanges	(4)
Steam Traps	Inverted bucket steam trap, or as locally available, various flows	(2)
Condensate Pump	Centrifugal pump, fluid-water, 100°C, 2.3m^3/hr flow, 5-bar design pressure	(4)
Piping	Condensate return piping, standard schedule 40 or equivalent, 151 m 1 inch, 106 m 2 inch.	
Miscellaneous	Fittings, valves, hangers, miscellaneous materials	

BILL OF MATERIALS (Continued)

Plant: Edfina

Recommendation: 6.6 - Effect Evaporator

Motor 50 hp, 440 VAC, 3Ø, totally enclosed induction motor (2)
Standard NEMA B, mechanical fixed drive.

Turbine Steam turbine, 50 hp, single stage, axial flow, mechanical drive, horizontal configuration, direct connect, with speed governor and positive overspeed trip, non-condensing, 10 bar inlet, 1 bar exhaust, 18" wheel, rated for continuous duty.

Footings existing

Miscellaneous material provided by plant.

Recommendation: 6.7 - Blancher Instrumentation

Controller
Pneumatic temperature controller, direct connected, Indicating, SS bulb, 0-120°C, air filter-regulator set, mounting yoke (3)

Control Valve
Pneumatic control valve for steam 125 lb flange, cast iron, 2" control value, positioner, airset (3)

Recommendation: 6.8 - Boiler Excess Air

Analyzer
O_2 analyzer, panel readout, heavy duty industrial, zirconia cell or fuel cell, 750°C rating, 0-21% O_2, in-situ cell or mount sampling equipment at stack (1)

Recommendation: 6.9 - Lacquer Furnace Damper Control

Analyzer
Flue gas O_2, 0-21% O_2, portable, fuel-cell based (1)

Damper
Manual adjustment duct dampers, approximately 0.33m Ø (2)
and .5m x .5m
sized for existing ducts, with position indicator

BILL OF MATERIALS (Continued)

Plant: Edfina

Recommendation: 6.10 - Diesel Exhaust Waste-Heat Boiler

Waste Heat Boiler

Instrumentation

Foundations

Valves/Piping

Miscellaneous

Appendix C

Summary of Capital Cost Estimates
Plant: Edfina Foods

Recommendation	Major Equipment Local	Major Equipment Foreign	Materials Local	Materials Foreign	Installation Labor Local	Installation Labor Foreign	Total Local	Total Foreign
6.2 Pasteurizer Flaps	--	--	$ 1,000	--	(1)	--	$ 1,000	--
6.3 Refrig. Cond.	--	--	$ 6,900	--	(3)	--	$ 6,900	--
6.4 Insulation	--	--	$ 1,000	$8,700	$11,900	--	$13,000	$ 8,700
6.5 Condensate Recovery	$6,700	--	$ 3,400	--	--	--	$10,100	--
6.6 Evaporator								
1. electric motors or		$13,200	(2)	--	(3)	--	--	$13,200
2. steam turbines	--	$15,000	(2)	--	(3)	--	--	$15,000
6.7 Blancher	--	$4,800	$ 4,200	--	--	--	$ 4,200	$ 4,800
6.8 Boiler O_2	--	$ 5,000	--	--	(1)	--	--	$ 5,000
6.9 Lacquer Furnaces-O_2	--	$ 2,500	$ 1,500	--	(1)	--	$ 1,500	$ 2,500
6.10 Cogeneration	--	$25,300	$20,100	$ 5,000	$13,400	--	$38,700	$30,300

Note:

(1)Done by plant personnel as part of maintenance budget.
(2)Uses existing pads.
(3)Installed by existing plant personnel.

Appendix D
Energy Measurements of Edfina

1) Lacquer Furnace Area Measurements

General Description: There are two furnaces, one LKG and one Ballard. The LKG has a single forced draft burner. The Ballard has 2 induced draft burners. Both furnaces are fed from a single oil feed system consisting of a large storage tank and a smaller horizontal, cylindrical non-dished head surge tank. The oil flow rate was measured by dip stick to each burner by measuring the flow to the Ballard furnace alone and measuring the flow to the two furnaces together. The measurements are:

Diameter of the tank: 0.81 m. Length of the tank: 4.04 m

Ballard only:

Initial oil depth 0.525 m. Final oil depth 0.510 m. Time: 71 min. Volume consumed: 0.0472 M3. At a density of 850 kg/m3, the consumption rate is 33.9 kg/hr.

LKG and Ballard both:

Initial oil depth 0.528 m. Final oil depth 0.485 m. Time 85 min. Volume consumed 0.136 M3. At a density of 850 kg/m3, the consumption rate is 80.7 kg/hr.

LKG only: By subtraction, the flow rate is 46.8 kg/hr.

Combustion Air Measurements:

Ballard:

Burner closest to oven outlet:

O_2 = 11.7%
CO_2 = 5.1%
Stack Gas Temp = 325°C

Burner furthest from oven outlet:

O_2 = 10.1%
CO_2 = 6.0%
Stack Gas Temp = 370°C

LKG:

O_2 = 8.6%
CO_2 = 6.9%
Temp = 374°C

2) Boiler Measurements:

One boiler is normally operated at a time. The boiler is fed from a horizontal cylindrical tank with a diameter of 1.293 m and a length of 3.02 m. The fuel use was measured by dipstick under normal operating conditions: Initial depth: 0.808 m. Final depth 0.65 m. Time 60 min. Volume consumed: 0.610 m. At 964 kg/m3 density, the fuel consumption rate is 588 kg/hr.

Combustion Air Conditions, fyrite measured:
(Under normal operating conditions)

O_2 = 8.1%
CO_2 = 7.2%
Stack Gas Temperature = 226°C
Excess Air by Fyrite: 59%

Combustion Air Fan Inlet Diameter = 14.6 m/sec
Combustion Air Fan Diameter = 0.5334 m
Steam Pressure in Steam Chest = 7.5 Bar

3) Condensate returned from 2 Effect Evaporator

Condensate is returned to a horizontal cylindrical tank with a hole in the top, then in turn pumped to the boiler feedwater tank. The condensate level was measured by shutting off the feed pump, then measuring the level in the horizontal tank, waiting for a period of time, then measuring the new level.

Tank diameter: .8072 m Tank level: 2.819 m. Initial depth: .478 m Final depth: .656 m. Time: 286 seconds Volume Filled: 0.366 m3 At a density of 1000 kg/m3, the fill rate is 4608 kg/hr.

4) Steam Use in Horizontal Autoclaves

The Steam use in the horizontal autoclaves were measured by trapping condensate from steam traps, and by measuring the steam velocity of dry, atmospheric pressure steam from the top vapor vent.

Large 10.2 cm inside diameter vapor vent: velocity at 2.3 m/s. The flow area was 0.0081 m2. At atmospheric density and 373°K, the resulting flow is 0.696 kg/min.

The main condensate drain for one autoclave was measured by stop watch and a collection bucket with a known volume during normal operation. Because a moderate amount of vapor was not trapped, the final flow was assumed to be 10% higher than the measured flow. The resulting flow was 1.56 kg/min.

A single steam trap at the end of the feed line was observed releasing condensate at a steady rate during operation. The condensate flow rate was measured by bucket and stop watch and determined to be 2.06 kg/min, including an increase of 30% over the condensate flow rate based on the amount of wet condensate vapor observed to be approximately lost from the bucket.

The normal operating schedule was determined by interviewing the lead operator and production supervisor. For each autoclave, the vapor line operates for 10 minutes and the main condensate drain operates for 4 hours. Average flow rate during operation is therefore is:

(1.56(60)(4) + 0.696(60)(.167)) / 4.167 = 91.5 kg/hr.

There are 6 autoclaves that operate 10 hours/day. Total flow in Kg/hr is therefore:

(91.5(10)(6) +2.06(60)(10))/10 = 673 kg/hr

(5) Measurement of Steam use in Plant B Food Blanchers

Only one Blancher was available for testing. There are two Blanchers, only one of which operates at a time. The steam flow rates to the two are similar, through identical sized pipes. Both blanchers process food at about 1 ton/hour. Because the control system is broken on both blanchers, they are controlled manually by setting the steam valve to a "typical" position.

The flow into the tank was measured by filling the blancher with water to the water outlet weir which controls blancher depth, then measuring the rate of temperature rise of the water with the steam valve set at a known position. Because the water volume remains constant in the tank, and the average heat capacity and steam enthalpy change can be quantified. The data is:

Water contained in blancher: 2.10 m3 or 2100 kg. Water heat up rate at normal operating valve position: 4.8°C per minute. (10,080 kcal/min). At 522 kcal.kg, the resulting steam flow is 19.3 kg/min.

A similar measurement was made in the smaller pea blancher located in the pea freezing area. The data and results are:

Water contained in pea blancher: Volume: 2.35 m3 or 2350 kg of water. At normal valve operating position, the water heats 1.6°C/min (3760 kcal/min). At 522 kcal/kg, the resulting steam flow is 7.2 kg/min.

6) Steam use in Vertical Autoclaves

The autoclaves heat empty tin cans. They consist of a 1.22 m diameter x 2.44 m deep cylindrical vessel with 0.3 m3 of steel in the walls and lid. There is a 3mm hole in the top that is always open. The surface area of the autoclave is 11.6 m2. Each autoclave is heated up cold once per day and then operates for 10 hours. The autoclave is pressurized to 10 bar and heated to about 373°C. outside temp.

Since the tin can weight is negligible, the heat demand consists of radiation convection losses from the autoclave surface, the steam leak form the unsealed hole, and the heat up of the autoclave mass.

From the North American Combustion Handbook, the heat loss from a 100°C steel surface is 700 kcal/hr/m2. This corresponds to a steam demand of 15 kg/hr. The steel in the autoclave is heated from 30 to 100°C (70°C rise). With 0.3 m3 of steel would require 24 kg of steam for the heat up. The steam leak through the 3 mm hole at 1.2 bar would be 8.3 kg/hr (choke flow through a sharp edged orifice). Total steam use:

24/10 + 15 + 8.3 = 25.6 kg/hr for each autoclave.

7) Tomato and tomato puree heat exchanger steam use

The tomato heat exchanger heats 5000 kg/hr of tomato juice for a 40°C rise. At 540 kcal/kg, this is equivalent to 370 kg/hr of steam. (The heat exchanger is insulated so surface heat losses are negligible.)

The tomato puree heat exchanger is also well-insulated and heats 7500 kg/hr of tomato puree 40°C. The equivalent heat load is 555 kg/hr of steam.

8) Heat losses from uninsulated steam lines

Heat losses from uninsulated steam lines can be determined from published tables if the surface temperature of the line is known. Several lines in the plant were jacketed with pieces of insulation over 1 inch thick. A thermocouple was slipped under the insulation at these points and temperature readings taken. The line temperature of the bare steel surface would be the same temperature. The readings were:

Line temperature at the evaporator: 160°C.

Line temperature inside the Plant B at the steam line entrance: 154°C.

Appendix E

On 2 April, 1988, additional power factor measurements were taken at the Edfina plant at the request of OEP. The results of these tests are summarized below:

Substation A Reported Power Factor - 0.82

<u>Transformer 1</u>			
Load	410 V	150 A	0.76 p.f.
Lighting A	410 V	110 A	0.90 p.f.
Lighting B	410 V	36 A	0.76 p.f.
Lighting C	410 V	< 1 A	0.62
Combined	410 V	255 A	0.91
<u>Transformer 2</u>			
Load	---	---	---
Lighting A	410 V	6 A	0.94 p.f.

Substation B Reported Power Factor - 0.723

<u>Transformer 3</u>			
Load	410 V	30 A	0.65 p.f.
Lighting A	450 V	30 A	0.88 p.f.
Combined	410 V	100 A	0.84 p.f.
<u>Transformer 4</u>			
Load	400 V	185 A	0.78 p.f.

Substation C (Capacitor trimmed) Reported Power Factor - 0.945

<u>Transformer 5</u>			
Combined	410 V	450 A	0.61 p.f. (before capacitor)
	410 V	375 A	0.95 p.m. (after capacitor)
<u>Transformer 6</u>			
Load	410 V	240 A	0.55 p.f. (before capacitor)
Lighting	410 V	29A	0.55 p.f. (before capacitor)
Combined	410 V	142 A	0.95 p.f. (after capacitor)

In addition, several individual motors were also tested at various places around the plant.

Electric welding circuit	400 V	36 A	<0.2 p.f.
Air compressor	390 V	175 A	0.85 p.f.
Vacuum pump	400 V	24 A	0.73 p.f.
Transfer pump	400 V	4 A	0.89 p.f.
Refrigeration compressor	390 V	46 A	<0.2 p.f.

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APPENDIX F

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.