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MARMARA RESEARCH CENTRE

TRAINING IN IDENTIFICATION & EVALUATION OF ENERGY CONSERVATION MEASURES

Final Report

ENERGY SYSTEMS DEPARTMENT

UNIDO Project No: XP/TUR/93/081

January 1994

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PREFACE

This report was prepared as an input for the "Workshop on Technical, Economic and Financial Analysis of Energy Saving Projects" to be held in METU-Ankara, Turkey, from January 17 to 22, 1994.

The first chapter contains industrial energy auditing fundamentals. The topics covered can be summarized as energy conservation, energy auditing, instrumentation and measurement, electricity conservation, compressed air systems, water systems, steam generators, steam and condensate systems, thermal insulation, furnaces, kilns, dryers. Checklists are also provided for practical purposes.

Case studies are presented in the second chapter. Two detailed on site case studies were carried out at SEKA No.4 Paper Mill and Ankara Sugar Factory. The VCM Plant at PETKIM and ETİBANK Seydişehir Aluminium Plant were evaluated based on previous reports prepared by different institutions.

List of the staff who contributed to the preparation of the above mentioned chapters is given at the back of the report.

We sincerely acknowledge the support of UNIDO and the fruitful cooperation of all involved parties, namely, SEKA, Ankara Sugar Factory, PETKİM, ETIBANK Seydişehir Aluminum Plant, METU and TÜBİTAK.

CONTENTS

CHAPTER 1

INDUSTRIAL ENERGY AUDITING BASICS

These notes are prepared to present basic concepts of **energy auditing** in industrial plants. The main aim of auditing is to obtain an energy balance of the operation and to find and evaluate potential energy conservation opportunities, (ECO's). Economic analysis that will follow the technical preparation will be considered at the second part of the course.

TOPICS:

1. ENERGY CONSERVATION
2. ENERGY AUDITING
3. INSTRUMENTATION AND MEASUREMENT
4. ELECTRICITY CONSERVATION
5. COMPRESSED AIR SYSTEMS
6. WATER SYSTEMS
7. STEAM GENERATORS
8. STEAM AND CONDENSATE SYSTEM
9. THERMAL INSULATION
10. FURNACES, DRYERS, KILNS
11. CHECK LISTS

ACKNOWLEDMENT

These notes are based substantially, especially on ECO lists, to a " Training Manual" prepared by ENCONET INTERNATIONAL for UNIDO.

INTRODUCTION TO ENERGY CONSERVATION

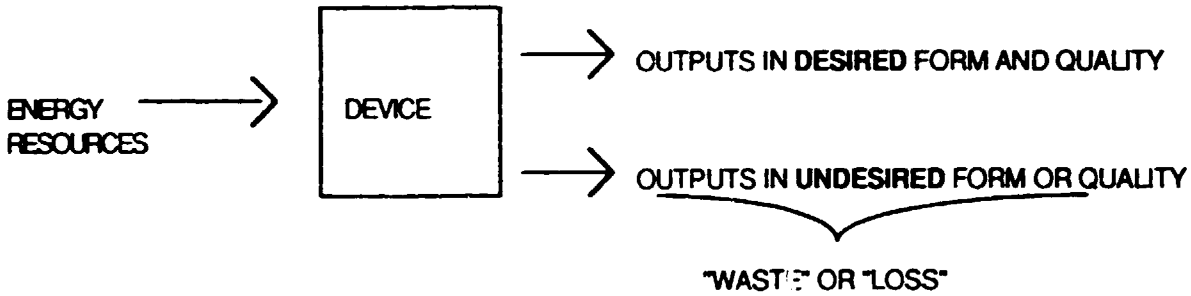
*** DEMAND FOR ENERGY INCREASES - because we want :**

- TO PRODUCE MORE PRODUCTS
- TO BE MORE CONFORTABLE
- TO TRAVEL AND TRANSPORT MORE AND FASTER

*** THERMODYNAMICS :**

- 1.LAW : ENERGY IS CONSERVED IN QUANTITY.
- 2.LAW : DIFFERENT FORMS OF ENERGY HAVE DIFFERENT QUALITY.

*** ENERGY UTILIZATION/CONVERSION MEANS :**



*** EFFICIENCY (1. LAW) :**

$$\eta = \frac{\text{DESIRED OUTPUTS}}{\text{REQUIRED (COSTLY) INPUTS}} = 1 - \frac{\text{LOSSES}}{\text{INPUTS}}$$

*** ENERGY (RESOURCES) MUST BE CONSERVED - because :**

- MOST RESOURCES ARE DEPLETABLE.
  - SAVING ENERGY COULD BE MORE ECONOMIC THAN :
    . GETTING (BUYING) NEW RESOURCES (person/company) .
    . DEVELOPING NEW RESOURCES (country/world)
- ENVIRONMENTAL EFFECTS :
  . Air pollution . acid rain/smog . greenhouse effect.
- EXPECTED TIGHTENING OF ENERGY MARKETS COULD BE DELEYED AND ITS IMPACT LESSENED
- RESULTS CAN BE OBTAINED IN SMALLER INCREMENTS AND IN SHORTER TIME(FLEXIBILITY UNDER UNCERTAIN OUTLOOK)
- THAT IS THE MODERN ATTITUDE.

ENERGY CONSERVATION MEANS :

- INCREASING ECONOMIC BENEFITS - unlike curtails !
- TO DO A SPECIFIED TASK WITH LESS ENERGY
- TO USE ENERGY MORE EFFICIENTLY (WISELY) BY
    - **MODIFIED BEHAVIOR**
    - **IMPROVED MANAGEMENT**
    - **INTRODUCTION OF NEW TECHNOLOGY**
    - **FUEL DIVERSIFICATION OR SUBSTITUTION** --

DECISION-MAKING : FACTORS/INCENTIVES/BARRIERS

internal vs. external to the plant

- products demand
- capital cost
- fuel cost and availability
- equipment age
- distruption during installation
- tax incentives
- government/local rules and regulations

REVIEW AND CLASSIFICATION OF
ENERGY CONSERVATION OPPORTUNITIES - ECO's

APPLICATION TYPE:
- INDUSTRY
- BUILDINGS
- TRANSPORTATION
- AGRICULTURE

ENERGY END-USE :
- PROCESS HEAT
- SPACE HEATING/COOLING
- MECHANICAL DRIVE
- ELECTRICAL PROCESSES

POTENTIAL AREAS :

1. HOUSEKEEPING AND IMPROVED OPERATION.
Little or no cost, short time, routine basis
Ex.: *Turn-off stand-by furnaces. Calibrate instruments.*

2. WASTE HEAT RECOVERY AND REUSE.
Right temperature ? quantity ? time ?
Ex.: *Air or water heating by refrigeration condensers.*

3. COMBUSTION AND STEAM SYSTEMS.
Improved combustion and heat recovery:
Ex.: *Adjust excess air. Recuperate heat from blowdown.*

4. ELECTRICAL SYSTEMS.
Lighting. Motor efficiency. Peak demand. Reactive power
Ex .: *Install capacitors at substations.*

5. PROCESS MODIFICATION.
Depends on specific cases.
Ex .: *Fluidized-bed drying of sugar*

6. COGENERATION.
Joint production of thermal energy and power (electricity)
Ex .: *Topping or bottoming cycles.*

SCOPE / COST :
1. HOUSEKEEPING OPPORTUNITIES
2. LOW-COST "
3. RETROFIT "

Potential Energy Savings and Typical Energy-Saving Measures in Selected Energy-Intensive Industries, All Developing Countries

Industry	Process or product	Potential savings rate percent Group A	Potential savings rate percent Group B	Examples of major energy-saving measures Group A	Examples of major energy-saving measures Group B
Steel	Raw steel finishing	5-7	5-13	Improve combustion controls and insulation, use iron ore pellets	Recover waste heat, replace inefficient equipment
Aluminum	Hall-Heroult smelting	2-4	10-15	Improve combustion controls in remelting furnaces, insulation, and power factor	Install process controls, increase waste heat recovery and aluminum recycling
Petroleum	Refining	7-12	15-25	Improve combustion controls, increase steam condensate return	Recover waste heat, replace inefficient equipment
Fertilizer	Ammonia (steam-reforming	2-5	20-25	Insulate primary reformer, do various housekeeping measures	Recover waste heat in reformer, recover hydrogen and carbon monoxide, hydrogen and replace compressors
Glass	Flat and containers	10-12	15-20	Improve combustion controls and insulation	Install efficient recuperators and waste heat boilers, increase boosting
Construction materials	Brick	10-15	15-20	Improve flue gas recirculation, combustion controls, and kiln insulation	Increase stack gas recuperation, rebuild kiln
Cement	Dry and wet	10-20	10-30	Replace burner Improve combustion, insulation etc.	Convert from wet to dry process Install high-efficiency heat exchanger systems and process controls
Pulp and paper	Integrated chemical	12-14	14-16	Improve boiler and steam system, recondition insulation	Increase use of waste fuels, black liquor, cogeneration, and waste-heat recovery from dryers
	Other	10-15	10-15		
Food	Raw cane sugar	16-18	up to 85	Improve boiler combustion efficiency, steam systems and insulation, and evaporator management	Increase use of waste fuels (e.g. bagasse), waste-heat recovery, and add-up effects on evaporators
	Cane sugar refining	16-18	15-30		
	Edible oil	8-10	12-15		
Textile	Finishing	12-15	15-17	Improve boiler combustion and steam distribution efficiency	Install waste-heat recovery devices, replace old, inefficient boilers, improve water and liquor systems
Other	Metalworking, mining, chemical products, wood products	5-10	10-15	Improve combustion, insulation, operation scheduling, maintenance	Increase waste-heat recovery, replace energy-inefficient equipment, lower temperature, correct power factors

A Housekeeping Needs Checklist for Industrial Plants

Fuel, gas, or oil leaks
Steam Leaks
Compressed air leaks
Condensate leaks
Water leaks
Damaged or missing insulation
Excessive heating or cooling
Leaks of (or excess in) heating, ventilation, and air conditioning system
Burners out of adjustment
Faulty steam trap operation (each trap is to be tagged with date of inspection)
Dirty heating surfaces such as coolers, exchangers, and so forth
Dirty motors
Worn belts
Improper viscosity of lubricating oils for large electric drives and hydraulic pumps (proper viscosity minimizes pump drive slippage)
Dirty lamps
Excess or accumulated additives in fuel
Improper operating pressure and temperature

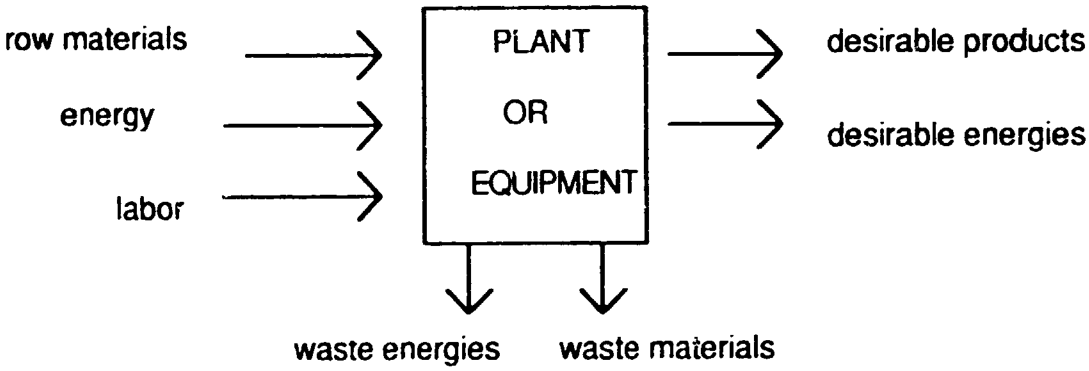
ENERGY AUDITING

Energy audits do not save energy by themselves. But they are important initial steps of energy conservation and management. Such a systematic procedure gained impetus after oil embargos and with greater awareness about :

. Energy conservation
. Economic compatition
. Environmental protection.

* scope and aim of an energy audit :

1. To determine where and how energy is used or converted.
2. To determine efficiencies of parts or whole of a plant.
3. To compare above results with quide values or standards.
4. To identify opportunities to reduce energy usage.
5. To evaluate the economics and techical feasibility of above.
6. To determine priorities of implementation.



***Efficiency**$=\dfrac{\textbf{desirable energy outputs}}{\textbf{required energy inputs}}$

***Figure of Merit**$=\dfrac{\textbf{desirable products}}{\textbf{required(energy)input}}$

*** Savings are expected, especially if there is a lack of :**

. skilled personnel
. adequate instruments
. maintanence programs
. preventive maintanence measures.

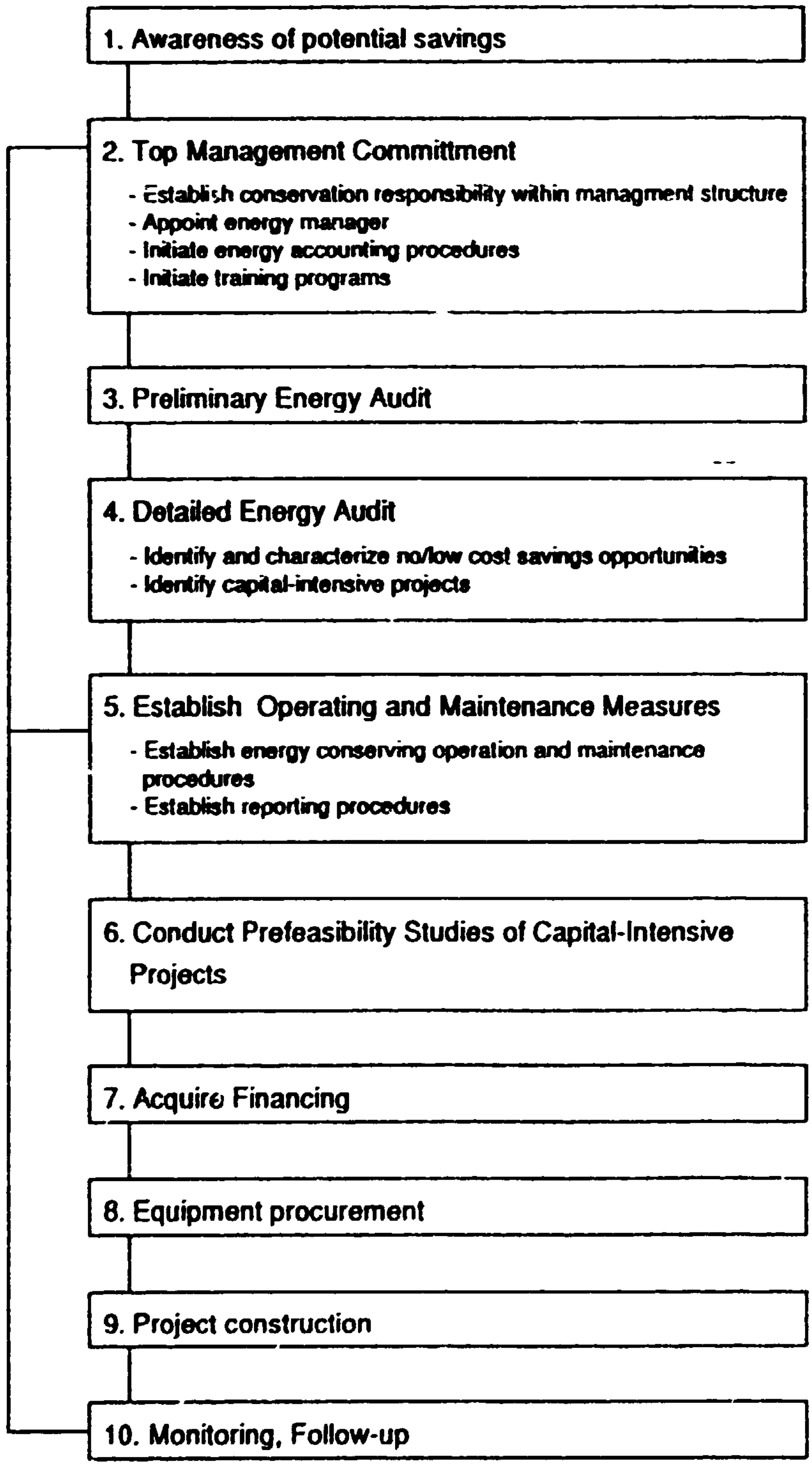


Figure: The Overall Energy Management Process

Table : Key objectives for the energy manager

1. Develop and maintain an energy accounting or audit system.
2. Co ordinate the efforts of all energy users in the organisation helping them from a source of sound information to set tough but realistic targets.
3. Provide sound technical and specialist advice to all departments within the organisation on energy-saving equipment and techniques to promote the efficient use of energy.
4. Liaise with committees and working groups within the industry/sector and maintain contact with appropriate research organisations, professional bodies and government organisations to monitor, assess and apply all significant developments in the field of energy conservation.
5. Appraise and advise upon government funding and other schemes applicable to the organisation.
6. Examine, appraise and advise upon any political, legislative and regulatory measures relating to energy and assess the possible impact on the organisation's products and activities.
7. Remain up-to-date on the changing world and national developments on energy matters and advise senior management of the possible effects on the organisation.

ENERGY MANAGEMENT PROGRAM

1. INITIATION PHASE :

- . Commitment by top management
- . Forming an "Energy Management Committee"
- . Naming an "Energy Management Coordinator"

2. AUDIT (AND ANALYSIS) PHASE:

- . Review energy use pattern.
- . Walk-through survey.
- . Preliminary analyses using drawings, data sheets, name plates, specifications, energy bills.
- . Plan the energy audit.
- . Conduct the audit(of process, facility or equipment).
- . Analysis and simulation
- . Identification and evaluation of ECO's
- . Determining priorities and procedures for implementation.

AUDIT TYPES :

- . SIMPLE WALK-THROUGH AUDIT
- . MINI AUDIT
- . DETAILED AUDIT

NUMBER AND VALUE OF ECO'S FOUND ⇔ SCOPE OF AUDIT AND ANALYSIS ⇔ TIME AND COST ALLOCATED

3. IMPLEMENTATION :

- . Finalizing the required engineering project for each ECO
- . Financing the projects
- . Doing actual engineering

4. FALLOW - UP :

- . Promote continuing awareness, if needed
- . Establish monitoring, recording, reporting procedures
- . Determine and evaluate the energy saving realised

***DATA COLLECTION:**

SOURCES:
- Equipment name plates
- Bills for fuel, electricity, water
- Readings of meters within the plant
- Production information

ANALYSIS:
- Energy use quantities
- Total cost
- Where, how much energy is used
- Peak electricity demand
- Trends
- Effects of weather, etc.

*** MEASUREMENTS :**

Additional metering may be needed to get:
- Energy use per department or production line
- Improved energy accounting
- Data for comparison with standards

More frequent metering may show:
- Meter misreadings, errors
- Load changes due to production changes
- Efficiency of different shifts
- Need for maintanence

*** FINAL REPORT:**

- Breakdown of energy use
- Trends
- Energy balance: tables, charts, sankey diagram
- Specific energy per unit production
- ECO's
- Economic analysis and priority list

INSTRUMENTATION AND MEASUREMENT

Measurement is a basic process of obtaining required information. Data gathering could be done manually, automatically or semiautomatically.

*** INSTRUMENT TYPES :**

- DIRECT	: Result obtained by direct observation Ex .: *temperature by a thermometer.*
- INDIRECT	: Result is deduced from measurement by using some known functional relationships. Ex .: *flowrate by an anemometer.*
- INDICATING	: Ex.: *pressure gage*
- CONTROLLING	: Ex.: *thermostat*
- RECORDING	: Ex.: *chart-recorder*
- ANALOGUE	: Deflection of a pointer . Ex.: *voltmeter*
- DIGITAL	: Series of digits Ex.: *digital multimeter*
- STATIONARY	: Ex.: *boiler pressure gage.*
- PORTABLE	: Ex.:*Orsat apparatus.*

*** PARTS OF AN INSTRUMENT:**

-SENSING ELEMENT (TRANSDUCER) Ex: *thermometer bulb*

Generates an output signal proportional to the input value.
Output could be motion, pressure, electrical signal,etc.

-TRANSMITTING ELEMENT Ex: *thermometer stem*

Modifies, controls, amplifies the output signal.
Mechanical linkage, tubes, wiring, etc.

-OUTPUT ELEMENT (DISPLAY) Ex: *divisions on the stem*

Allows accurate reading or recording of the output.

*** SELECTING AN INSTRUMENT**

performance	: range, accuracy, precision, sensitivity, size
cost	: initial cost, operational (maintenance) cost.
environment	: corrosive, vibrating

ERROR IN MEASUREMENTS

***TERMINOLOGY:**

ERROR : Difference between measurement and "true value".
In % : error- [(measured value-true value)/true value] x100%

TYPES : . RANDOM (corrected by statistical analysis)
. SYSTEMATIC (" " calibration)
. MISTAKES (" " being careful)

ACCURACY : Ability to give close results to the true value.
Sometimes given as based on full-scale deflection
[(measured value-true value) / maximum scale value] x 100%

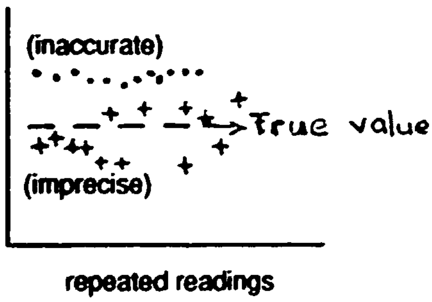
PRECISION (REPEATABILITY) : Ability to reproduce the same reading.

RANGE : Lowest and heighest values of calibrated reading.

SENSITIVITY: Ratio of change in output to the change in input.

DISCRIMINATION (RESOLUTION) : Ability to react to small changes in input.

CALIBRATION : Comparison of the output with a standard value.



***DYNAMIC RESPONSE:**

LAG: Delay in response to changes in input (dead time)

MODELS :

ZERO-ORDER : No effect

FIRST - ORDER : Time constant. (τ)

For a step change. response reaches 63% of final change in $t=\tau$,

and 99 % in $t=5\tau$. (Ex.: $\tau \approx 1$ *sec. for thermometers)*

SECOND-ORDER: Natural frequency,
Damping ratio (coefficient or factor)

ECO'S RELATED TO MEASUREMENT

A) HOUSEKEEPING :

1. CALIBRATION:Periodically; More often for portable devices.
2. RECORDS : To determine a shift in calibration or change in a process. Both require corrective actions.

B) LOW COST :

1. INSTRUMENT SELECTION : Insufficient as well as excess accuracy is undesirable and affects operation.
2. INSTALLATION : Improper installation should be corrected. This could increase accuracy and in turn affect operation.
3. FILTERS : Add differential pressure gages to determine time for filter cleaning in air or fluid supply lines.
4. GAS ANALYSIS: Combustion efficiency must be monitored by using gas analyzers.
5. MONITORING SPACE HEATING/COOLING: Space temperature ventilation and equipment operation should be controlled.
6. WARNING: Various modes of warning devices are available.

C) RETROFIT :

Opportunities depend on specific plants. In general:

1. METERING: Sufficient metering could be installed to check the operation and energy utilization.

ELECTRICITY

***POWER :**

Power= Voltage * Total current * Cos θ

θ = phase angle between voltage and current
$\theta = 0$ in a purely resistive circuit
$\theta > 0$ in inductive circuit, current lags voltage

-Usuful Power, Real Power, Active Power	(in W)
-Total Power, Apparent Power	(in VA)
-Reactive Power, Magnetizing Power	(in VAr)

For 3-phase circuit :

Usuful Power (W)= $\sqrt{3}$ V I cos θ

Total Power (VA)= $\sqrt{3}$ V I

$$\text{Power factor} = \cos\theta = \frac{\text{useful power}}{\text{total power}} = \frac{W}{VA}$$

***BILLING :**

- Maximum demand charges (per kW)
- Over peak charge (per kW)
- Power (per kWh)
- Reactive power (per kVArh)
- Miscellaneous charges

***DEMAND MANAGEMENT :**

Manual or automatic control of operation of devices such as:

- water heaters
- air conditioners
- furnaces or ovens
- battery chargers
- grinders
- pumps (to storage)

REACTIVE POWER COMPENSATION

. Motors, transformers use reactive power for magnetization
. Less reactive power is consumed, i.e higher cos α, better it is.
. Capacitors are used to supply reactive power.

kVAr (required) = (Load in kW) ($\tan \theta_1 - \tan \theta_2$)

θ_1= existing phase angle
θ_2= desired phase angle

. Equipment causing poor power factor :

%80 or more	: Air conditioners, pumps, fans, blowers
%60-%80	: induction furnaces, stamping and weaving machines
%60 or less	: presses, grinders, welders

-INDIVIDUAL COMPENSATION

. Large loads with constant power requirement and high duty factor

-GROUP COMPENSATION

-CENTRALIZED COMPENSATION

. large number of small loads with varying power requirements and different duty factors are connected.

• HARMONIC SUPPRESSION

Use filters on 3- phase systems with converters.

LIGHTING

AIM: - sufficient and suitable lighting, without glare, etc.
- minimum energy

SOURCES:	**Efficacy (Lm/W)**
- INCANDESCENT	(20)
- FLUORESCENT	(80)
- MERCURY	(63)
- METAL HALIDE	(125)
- HIGH-P SODIUM	(140)
- LOW-P SODIUM	(183)

CONTROL:

- MANUAL
- PHOTO ELECTRIC
- TIME
- MIXED

ECONOMIC LIFE ENDS, IF :

- DOES NOT OPERATE *(INCANDESCENT)*
- EFFICIENCY DROPPED ENOUGH TO REPLACE *(OTHERS)*

LUMINAIRE

RECOMMENDED ILLUMINANCE:

	lux
Exterior areas, carparks, stockyards	20 - 50
Rooms, Stores	100 - 150
Machine work, assembly rooms	300 - 500
Fine bench work, critical drawing	1000 - 1500
Instrument repair, watch making	2000 -

COMRESSED AIR SYSTEMS

* Requires about 10% of all electrical power used in industry.
* Used in: pneumatic tools, cleaning, combustion,..
* Air for instruments should be purer and at lower humidity than general plant air used by tools.
* System is consisted of:
  - Compressor
  - distribution network

*** SAVING POTENTIAL:**

- Detect and eliminate leaks (at joints, valves, hoses,...)
  * to save compressed air
  * to maintain required pressure

- Reduce pressure drops, caused by
  * small size pipes, (speed < 6 m/s if 1 > 10 m)
  * coked filters

- Reduce pressure to the lowest acceptable level
- Avoid water in air (To control corrosion. May use chilled driers to separate water. But do not over chill, could cause freezing upon expansion.

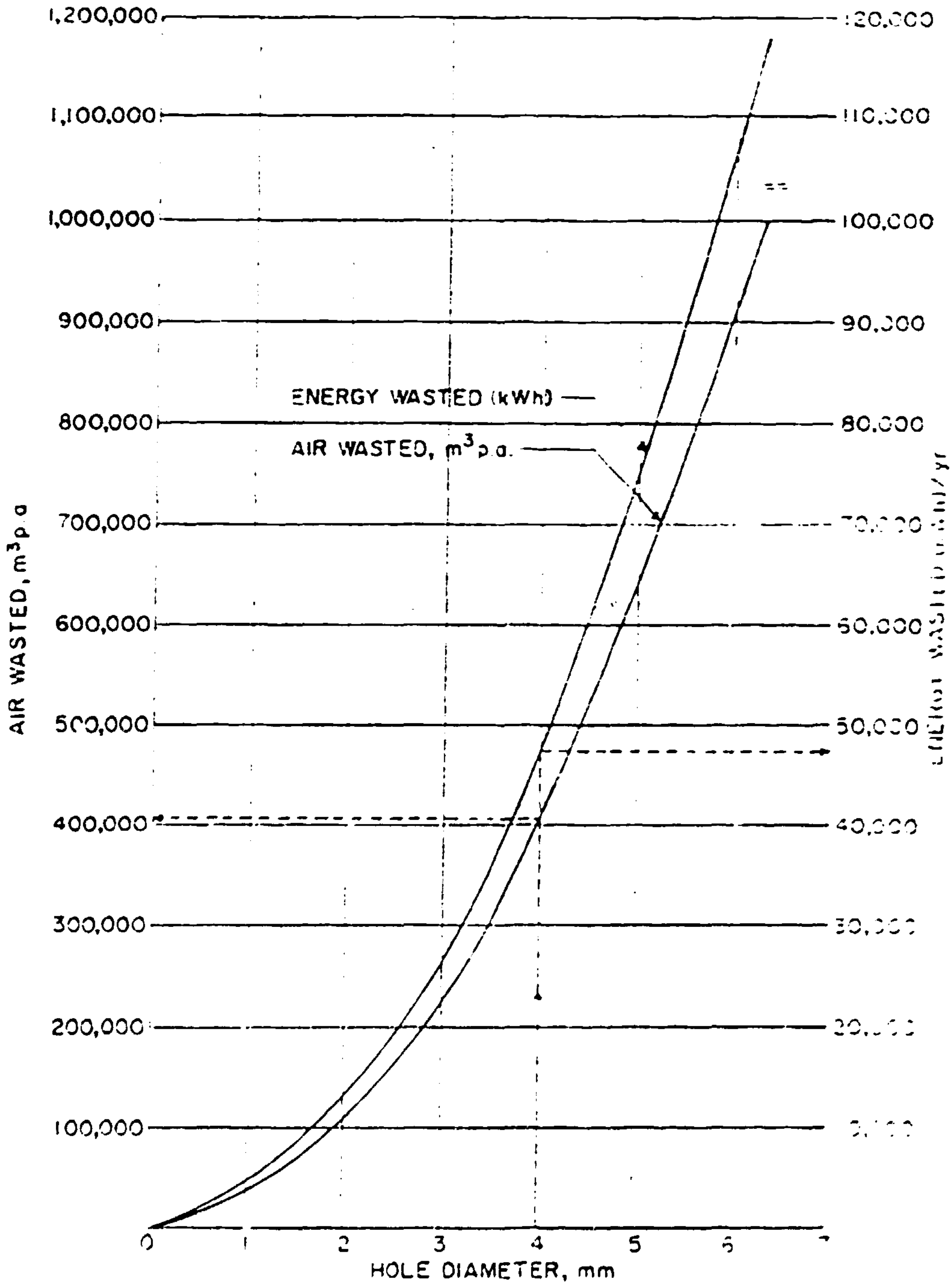
*** TESTING:**

- Pump-up test
- Leak test.

  (1 mm hole ⇒ 3500 kwh/year)

APPENDIX B

NOMOGRAPHS FOR QUICK ESTIMATION OF AIR AND ENERGY WASTED vs. EQUVALENT HOLE



NOTE: THE CURVES ARE BASED ON THE FOLLOWING ASSUMPTIONS
DISCHARGE PRESSURE : 700 kPa
1 kWh : 8.5 m^3 AIR DELIVERED
800 HRS/ANNUM OPERATION

COMPRESSORS

***TYPES:**

-POSITIVE DISPLACEMENT
. RECIPROCATING (Trunk, sliding, diaphram)
. ROTARY (Screw, lobe, sliding vane, liquid ring)

-DYNAMIC
. CENTRIFUGAL
. AXIAL

*** CAPACITY CONTROL METHODS :**

-CONSTANT SPEED WITH UNLOADING SYSTEMS
. Suction valve unloading
. Clearance pocket unloading
. Inlet throttling unloading
. By-pass unloading

- ON/OFF

-DUAL CONTROL
Combination of the above.

*** ENERGY RECOVERY :**

- INTERCOOLERS

. Save energy in subsequent compression stages.

- AFTERCOOLERS

. Reduce moisture
. Reduce specific volume.
Thus reducc storage size or pipe size.

WATER SYSTEMS

- pumps
- distribution network
- expansion tank
- treatment

*** CONSERVATION :**

- DETECT AND ELIMINATE ALL LEAKS
- REDUSE PRESSURE LOSSES
- REDUCE HEAT TRANSFER (HOT/CHILLED WATER)
  (This implies correct insulation)
- ADEQUATE TREATMENT

WATER TREATMENT

INPURITIES :
- DISSOLVED GASES, SALTS, ORGANICS
- SUSPENDED SOLIDS
- LIVING ORGANISM

EFFECTS :
- SCALE FORMATION
  * Reduced flow rate
  * Increased heat transfer resistance
- CORROSION
- WEAR ON MOVING PARTS

METHODS :
- FILTERS
- CHEMICAL TREATMENT
* EXTERNAL
  Ex.: *Removal of dissolved O_2 in a deaerator*
* INTERNAL
  Ex.: *Removal of dissolved O_2 by adding hydrazine . Adding corrosion inhibitors that form a protective film on metals.*

STEAM GENERATORS

*** FUELS AND COMBUSTION EQUIPMENT (BURNER) TYPES:**

GAS : 1.NATURALLY ASPIRATED BURNERS
2. PREMIX BURNERS
3. NOZZLE MIX BURNERS

OIL : 1. STEAM/AIR ATOMIZATION
2. MECHANICAL ATOMIZATION
3. ROTARY-CUP BURNERS

COAL : 1. STOKERS : Traveling grate stoker
Reciprocating grate stoker
Spreader stoker
Underfeed stoker

2. CYCLONE Burners
3. PULVERIZED Burners
4. FLUIDIZED-BED Burners

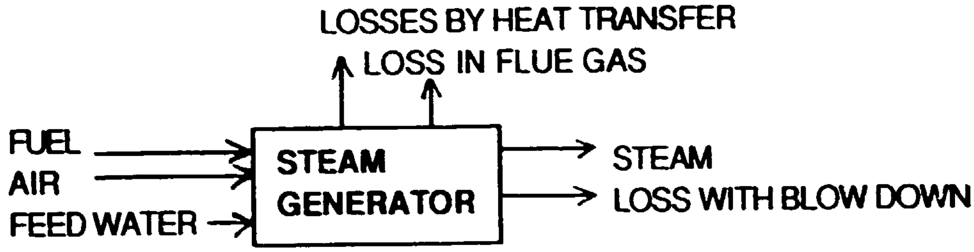
*** BOILER TYPES:**

Many parameters could be used for classification. Main types:

1.FIRE TUBE BOILERS:
- Horizantal Return Tubular
- Scotch

2.WATER TUBE BOILERS:
- Straight tube
- Bent - tube : - natural circulation (2 or more drums)
  - forced circulation
  - once through
  - supercritical

* THERMAL EFFICIENCY



EFFICIENCY $= \eta = \dfrac{\text{Useful heating of water}}{\text{Energy of fuel}}$

$$= \frac{\Sigma\, \dot{m}\, \Delta h}{\dot{m}_f\, HHV_f} \qquad \textbf{[direct method]}$$

$$= 1 - \frac{\text{Losses}}{\text{fuel input}} \qquad \textbf{[indirect method]}$$

[PREFERRED]

* LOSSES

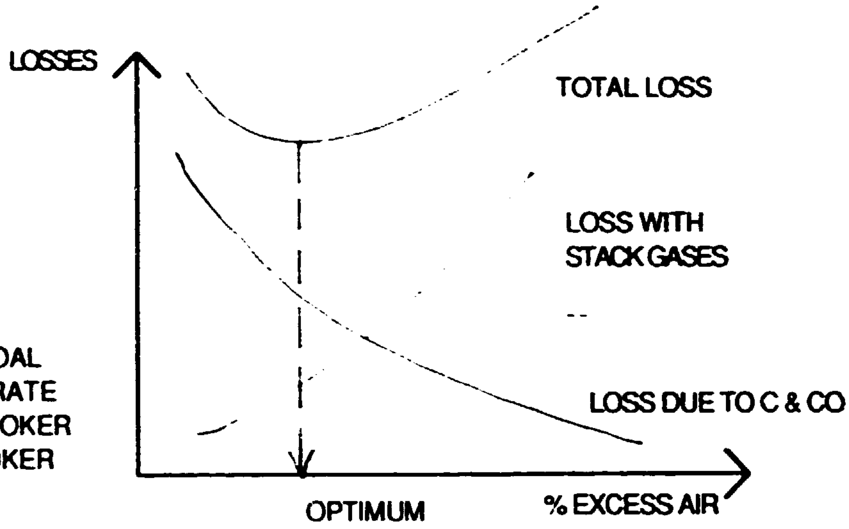
1. Sensible energy lost by dry portion of exhaust gas.
2. Sensible and latent loss by moisture in the exhaust gas.
3. Incomplete combustion loss due to CO in exhaust gas, and unburned fuel in ash.
4. Heat loss (radiation) through walls and other misc. losses.
5. Blowndown loss.

* FACTORS AFFECTING EFFICIENCY

1. Excess air
2. Stack gas temperature
3. Burners and fuel type
4. Firing rate
5. Fouling on heat transfer surfaces
6. Steam Pressure
7. Blowdown
8. Feedwater and combustion air temperatures
9. Condensate recovery
10. Exterior surfaces

RECOMMENDED EXCESS AIR LEVELS

%	
5-10	NATURAL GAS
5-7	BLACK LIQUOR
10-20	FUEL OIL
20-25	WOOD
15-20	PULVERIZED COAL
15-50	TRAVELLING GRATE
20-50	UNDERFEED STOKER
30-60	SPREADER STOKER



STACK GAS ANALYSIS

MEASURE/MONITOR:

1. GAS TEMPERATURE
2. GAS COMPOSITION: -%CO, %CO_2, %O_2

   % CO_2 or % O_2 give % excess air.

   %CO_2 is more dependent on fuel, %O_2 is preferred.

   (Typical values: 4 %CO_2 $\Rightarrow$ 20 % EXCESS AIR)

   %CO, if high indicates incomplete combustion (<100- 400ppm)

   If both %O_2 and %CO is high: defective burner or operation

Measuring devices:

- ORSAT APPARATUS
- PORTABLE ANALYZERS
- STATIONARY METERS

MEASUREMENTS NEEDED FUR DETERMINING BOILER EFFICIENCY :

• BY DIRECT METHOD:

- FLOWRATE OF FEEDWATER AND ALSO STEAM THROUGH REHEATER
- P AND T OF : FEEDWATER
  : STEAM THROUGH REHEATER (S)
  : MAIN STEAM OUTPUT
- FLOWRATE OF FUEL (S)
- HEATING VALUE OF FUEL(S)

• BY INDIRECT METHOD:

- T AND COMPOSITION OF STACK GAS
- T AND ω OF COMBUSTION AIR
- HEATING VALUE AND ULTIMATE ANALYSIS OF FUEL
- QUANTITY AND HEATING VALUE OF SOLID REFUSE

• OTHER MEASUREMENTS AND ACCESSORIES

- WATER LEVEL GAGES
- FEEDWATER REGULATORS
- BLOWDOWN VALVES
- SOOT BLOWERS
- SAFETY VALVES

METHODS FOR AIR/FUEL RATIO CONTROL

- FIXED POSITIONING

Responds to steam pressure. A cam and linkage mechanism adjust the fuel valve setting and air damper. Cannot compansate variations in fuel or air conditions or wear and other mulfunctions of mechanical system.

-PARALLEL POSITIONING WITH OPERATOR TRIM

Separate control of air fuel flow rates, using pneumatic or electronic devices. Allows manual bias by the operator.

- OXYGEN TRIM

Air flow is controlled to achieve a constant O_2 percentage in stack gases.

HEAT RECOVERY FROM BOILERS

1. **FROM STACK GASES.** (Limit on Tgas $\approx 150^0$ -180^0 C)

-ECONOMISER: Heats feed water (upto T sat- 30^0 C)
Cross flow heat exchanger, water in tubes, fins on gas side
($\Delta T \approx$ 6-7 K $\Rightarrow$ $\Delta\eta \approx 1\%$)

-AIR (PRE)HEATER: heat combustion air.
Upto 150^0 C for stokers, 300^0 C for pulvarized.
($\Delta T \approx 30$ K $\Rightarrow$ $\Delta\eta \approx 1\%$)

TYPES:

1. Regenerative
2. Recuperative (plate or tubular)

2. **FROM BOILER BLOWDOWN**
- may preheat boiler make-up water.

NOTES ON BLOWDOWN

Excess blowdown $\Rightarrow$ waste of water and energy
Insufficient blowdown $\Rightarrow$ Scale formation on boiler tube surfaces. Foaming and carry-over to steam.
Recommended Total dissolved solids in water$\approx$1000-3000 ppm

TYPES:

. Intermittent: Removes settled sludge from the bottom
. Continuous : Removal near the water level.
This controls TDS. (better when over 40 kg/h)

AIM:

1. DO NOT EXCEED THE MINIMUM AMOUNT
2. RECOVER HEAT: basic method is to recover steam that forms when pressure is reduced through the valve.

COGENERATION

Let us compare a conventional system producing separately heat energy and electric power with a combined system based on Diesel engine. Let us also assume that each of these two systems will produce 40 equivalent units of heat energy and 40.2 equivalent units of electric power (Figure 1). If the efficiencies of individual energy transformation technologies corresponding to the current level of development are taken into account, it can be easily concluded that energy inputs required for these two energy systems with equal outputs are quite different, i.e. 154.3 equivalent energy units will be consumed in case of the conventional energy system while the cogeneration one would required only 100 units.

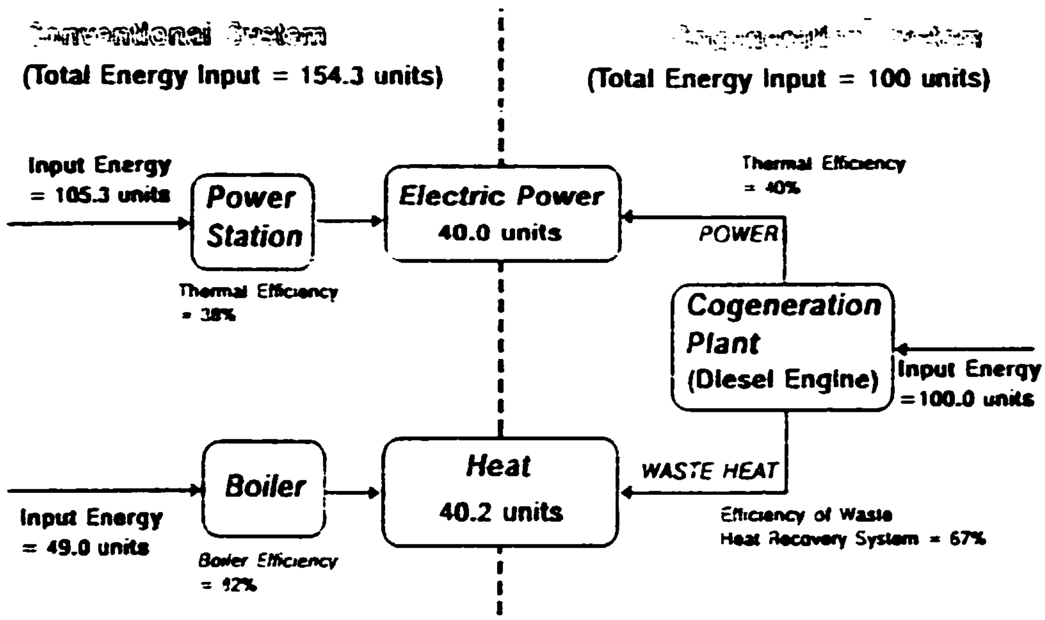


Figure 1: Comparison of conventional and cogeneration heat and power systems

Table 1: Costs and Efficiency of Cogeneration Technology

TECHNOLOGY	Total System		Power-to-Heat Generation Ratio
	Capital Cost*	Efficiency (percent)	
Cogeneration			
o Boiler/steam turbine	1,500 - 3,000	65 - 80	0.05 - 0.20
o Combustion turbine/ heat recovery boiler	400 - 1,500	65 - 80	0.50 - 0.80
o Diesel engine/heat recovery boiler	400 - 1,000	50 - 75	1.00 - 3.00
Convential			
o Central steam power plant	600 - 2,000	32 - 35	–

* In 1983 dollars per kilowatt

– Not applicable

STEAM AND CONDENSATE SYSTEM

ONE OF THE MOST REASONABLE AND EFFECTIVE HEAT TRANSFER MEDIA

*** SYSTEM COMPONENTS :**

- BOILER
- MAINS
- CONTROL VALVES....
- TRAPS
- THROTLING VALVES
- CONSUMING UNITS
- CONDENSATE RETURN

*** OVERALL SYSTEM EFFICIENCY :**

$$\eta_{SYSTEM} = \eta_{BOILER} \cdot \eta_{MAINS} \cdot \eta_{CONDENSATE} \cdot \eta_{USER} \approx 0.50$$

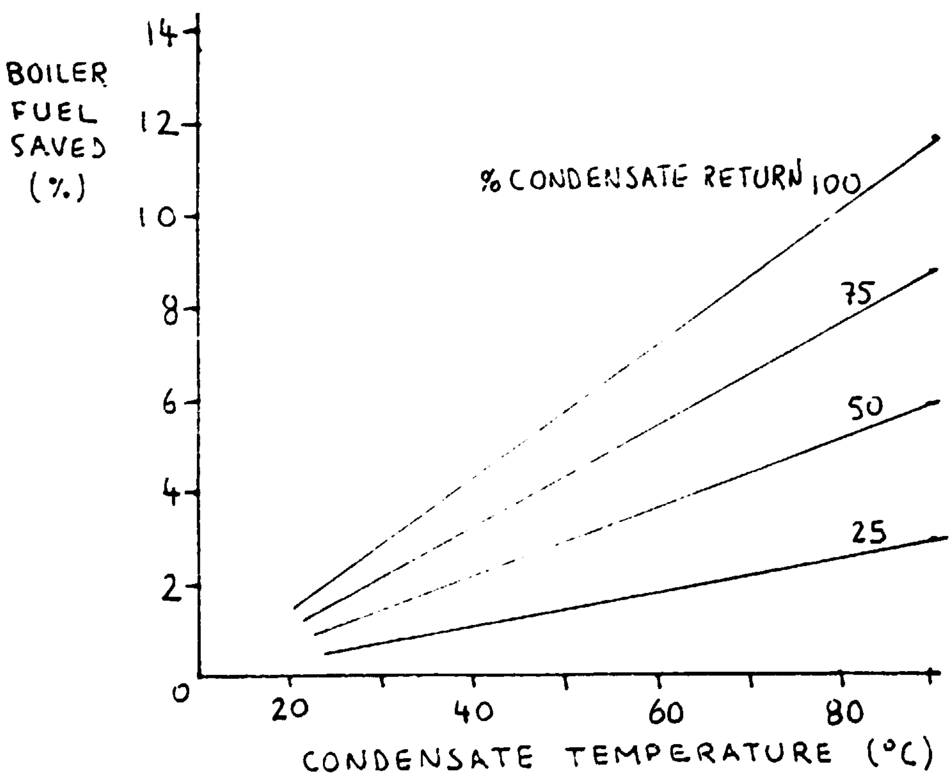
***LOSSES :**

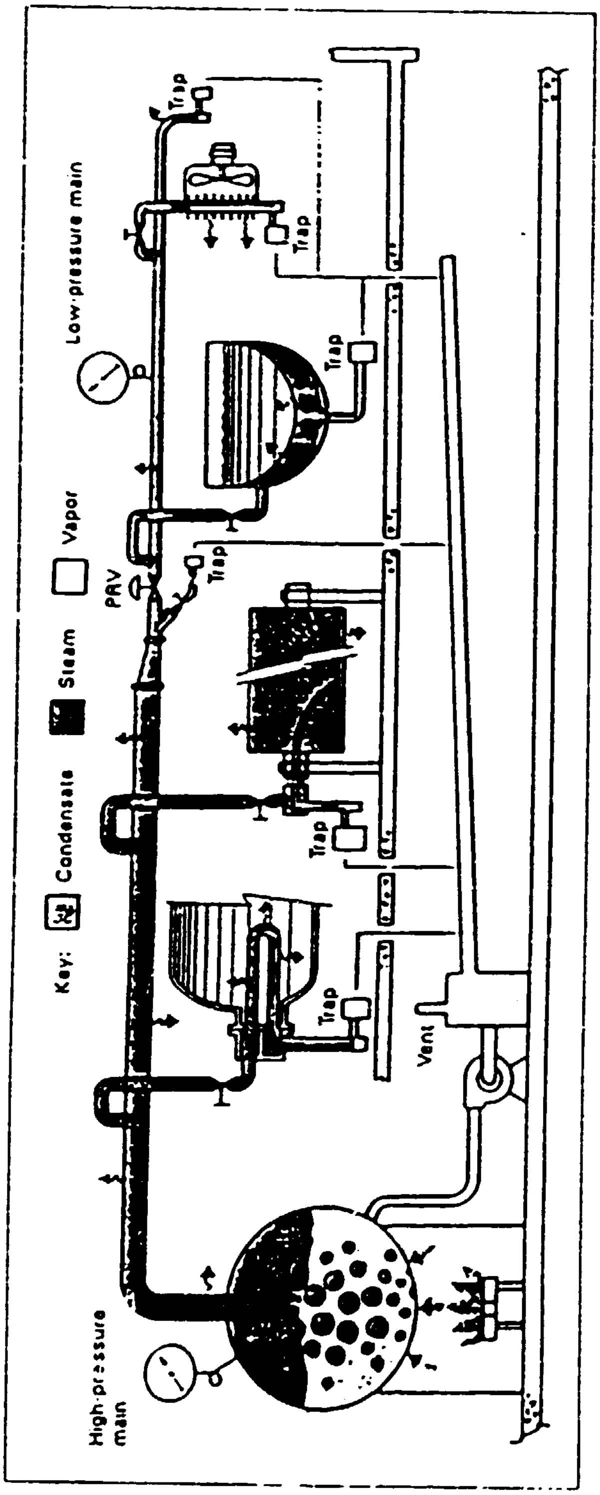
BOILER : STACK GASES, RADIATION, BLOWDOWN

MAINS : LEAKS, HEAT LOSS

CONDENSATE : IF NO RETURN, $\eta_{COND} \approx \dfrac{h_{st} - h_{co}}{h_{st}} \approx 0.75$

USER : LEAKS, HEAT LOSS





Typical steam and condensate system

***STEAM TRAPS :**

- REMOVE CONDENSATE
- REMOVE AIR, CO_2 AND OTHER GASES
- PREVENT STEAM LOSS

TYPES :

- **THERMOSTATIC (TEMPERATURE DIFFERENCE)**

Condensate, slightly subcooled, cools the sensor, valve opens

. Liquid expansion . balanced pressure . bimetalic

- **MECHANICAL (DENSITY DIFFERENCE)**

Float or bucket rises when liquid is present.

. Ball float . inverted bucket

- **THERMODYNAMIC (CHANGE OF STATE)**

Most common, uses flashed steam.

*** CONDENSATE RECOVERY**

- PROPER LAYOUT OF PIPING
- CORROSION
- HEAT RECOVERY
- FLASH TANKS TO BENEFIT FROM FLASHED STEAM
- PUMPING
  - by trap pressure. 11 kPa → 1m height.
  - by pumps.

    Avoid cavitation by subcooling or providing sufficient net positive suction head.

THERMAL INSULATION

*** PURPOSE :**

- REDUCE HEAT LOSS OR GAIN
- PROTECT PERSONNEL OR MATERIALS

*** IMPORTANT PARAMETERS OF INSULATION MATERIALS :**

- THERMAL CONDUCTIVITY AT OPERATING TEMPERATURE
- MECHANICAL PROPERTIES (STRENGTH)
- COST
- CHEMICAL RESISTANCE
- FIRE RESISTANCE
- WEIGHT

*** COMMON MATERIALS**

ORGANIC	INORGANIC	SYNTHETIC
CORK	VERMICULATE	POLYSTYRENE
FELT	PERLITE	POLYURETHANE
	GLASS WOOL	ELASTOMERS
	ROCK WOOL	
	ASBESTOS (BANNED DUE TO HEALT HAZARD)	

*** FINISHES (COVERS)**

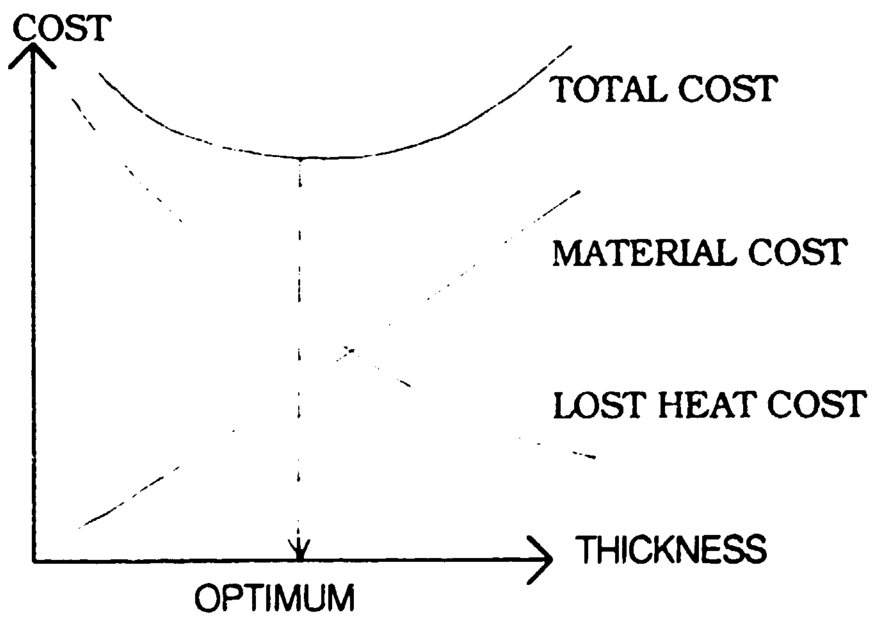
IN DOOR	OUTDOOR
CEMENT AND MASTICS	ALUMINUM
TEXTILES	GALVANIZED STEEL
PLASTIC SHEETS	PLASTIC SHEETS
METAL SHEETS	

*** GOOD PRACTICE :**

- INSULATE ALL HOT SURFACES, ESPECIALLY IF ABOVE 50 °C
- PROCECT AGAINST IMPACT, WEAR, WEATHER
- INSULATE EVEN IF FREQUENT ACCESS IS NEEDED
- INSULATE PIPE SUPPORTS
- PROPER MAINTANENCE, ESPECIALLY FOR WATER PROTECTION

*** ECONOMIC THICKNESS :**

- COST OF INSULATION INCLUDING INSTALLATION
- ENERGY SAVED
- COST OF HEAT (FUEL, FURNACE EFF.)
- OPERATING HOURS IN A YEAR



PROCESS FURNACES, DRYERS, KILNS

Example Usage:

- heating metals or glass for heat treatment or forging
- melting metals for casting
- evaporating water or solvents
- manufacturing lime by heating limestone
- manufacturing bricks and ceramics

TYPES:

. Batch . Direct fired

. Continues . Indirect fired

. Electrical heating

- direct units have lower efficiency due to product limitations
- losses related to movement of product in and out
- losses due to air leakage through access doors or ports.

* ECO'S:

- IMPROVING COMBUSTION EFFICIENCY
  . BURNER MAINTENANCE
  . EXCESS AIR CONTROL
  . REDUCTION OF OPENINGS AND LEAKS
  . INSULATION
- HEAT RECOVERY
  . RECUPERATIVE BURNER.
  . AIR PREHEATING FOR FURNACE.
  . AIR OR WATER HEATING FOR ANOTHER SYSTEM.
- OPERATION
  . REDUCTION OF LOSSES DURING CYCLING OF BATCH UNITS
  . IDLE EQUIPMENT SHUTDOWN
  . CONTINUOUS EFFICIENCY MONITORING

POTENTIAL ECO'S (ELECTRIC)

1. USE DEMAND LIMITERS
2. REPLACE OLD/OVERSIZED MOTORS
3. IMPROVE POWER FACTOR
4. USE 2-OR 3-SPEED MOTORS ON PUMPS OR FANS
5. IMPROVE MAINTANENCE
6. REDUCE LIGHTING LEVEL, TURN IT OFF
7. USE MORE EFFICIENT LIGHT SOURCE
8. CONTROL WARM-UP, TURN-OFF TIMES
9. SPREAD OUT ELECTRICAL LOADS
10. CONSIDER SMALL LOCAL HEATERS
11. USE SUBMETERING
12. USE VARIABLE SPEED DRIVES
13. USE ELECTRICAL-PEAK-SHAVING GENERATORS

POTENTIAL ECO'S (COMPRESSED AIR)

A) HOUSE KEEPING :

1. REPAIR ALL LEAKS
2. KEEP SYSTEM UNDER CONTROL
3. SHUT DOWN UNUSED SYSTEMS
4. CLEAN FILTERS
5. CHECK MONITORING AND CONTROL EQUIPMENT
6. ELIMINATE UNNECESSARY HOSES, COUPLINGS
7. USE PROPER LUBRICATORS

B) LOW-COST :

1. INSTALL FLOW REGULATORS, PRESSURE REDUCING VALVES, HAND VALVES TO SUPPLY AIR AT MINIMUM

C) RETROFIT :

1. ELIMINATE REDUNDANT OR EXCESS FLOWS
2. USE DRYERS TO ELIMINATE MOISTURE
3. USE PIPE MATERIAL WITH LOW PRESSURE LOSS
4. USE FILTERS WITH LOW PRESSURE DROP
5. USE LOCAL AIR RECEIVERS NEAR HIGH DEMAND
6. REPLACE OLD COMPRESSORS
7. REPLACE HIGH PRESSURE DROP VALVES, FITTINGS

POTENTIAL ECO'S (WATER)

A) HOUSEKEEPING :

1. REPAIR ALL LEAKS
2. KEPP SYSTEM UNDER CONTROL
3. REDUCE HOT WATER TEMPERATURE
4. SHUT DOWN SYSTEMS WHEN NOT IN USE
5. TREAT WATER TO MAINTAIN CORRECT FLOWRATES

B) LOW COST :

1. COVER OPEN SURFACES OF HEATED LIQUIDS
2. INSTALL REGULATORS, VALVES TO CONTROL FLOWRATE
3. CHECK / REPLACE PUMPS

C) RETROFIT :

1. DECREASE ENERGY LOSS WITH WASTE STREAMS
2. ELIMINATE EXCESS OR REDUNDANT FLOWS
3. MIST ELIMINATORS ON COOLING TOWERS
4. USE LOW FRICTION PIPES
5. INSULATE HOT AND COLD WATER PIPES
6. CONVERT ONCE THROUGH TO CLOSED LOOP COOLING
7. BOOSTER PUMPS FOR ISOLATED DEMANDS
8. TREATMENT TO REDUCE WASTE STREAMS
9. EXPANSION TANKS
10. REPLACE HIGH PRESSURE DROP VALVES, FITTINGS

POTENTIAL ECO'S (PUMPS)

A) HOUSEKEEPING :

1. ADJUST PACKING GLANDS
2. TOLERANCES AT IMPELLERS AND SEALS --
3. BELT TENSION, COUPLING ALIGNMENT
4. REPAIR AND CONTROL UNITS
5. CHECK CONTROL UNITS
6. SHUT DOWN IF NOT NEEDED
7. PREVENTIVE MAINTENANCE

B) LOW COST :

1. REPLACE PACKING WITH MECHANICAL SEALS
2. TRIM PUMP IMPELLERS

C) RETROFIT :

1. INSTALL VARIABLE SPEED CONTROL
2. REPLACE OLD UNITS
3. REPLACE OVERSIZED MOTORS
4. MICROPROCESSOR CONTROL

POTENTIAL ECO'S (BOILERS)

A) HOUSEKEEPING :

1. REPAIR LEAKS, DEFECTS
2. INSPECT DOOR GASKETS
3. REPAIR BOILER INSULATION, WATER LINES
4. CLEAN HEATER COILS
5. CLEAN FIRESIDE OF FURNACE
6. DURING SHUTDOWN CLEAN WATER-SIDE
7. CHECK BURNER BY WATCHING SMOKE
8. INSPECT LINKAGES, BLOWER BELTS
9. CHECK BOILER STACK TEMPERATURE
10. NOTE FIRING RATE
11. INSPECT CONDENSATE TANK
12. DAILY LOGS OF PRESSURE, TEMPERATURE,...
13. INSPECT COAL STOKERS
14. CLEAN STRAINERS AND FILTERS
15. CHECK OIL LEAKS
16. CHECK OIL BURNERS
17. CHECK OIL PREHEATING LEVEL
18. CHECK UNBURNED COAL IN ASH
19. CLEAN GAS BURNERS

B) LOW COST :

1. IMPROVE WATER TREATMENT
2. MONITOR BLOWDOWN WATER
3. INSULATE ALL HOT AND COLD LINES
4. INSULATE OIL STORAGE TANKS
5. CLOSING DAMPER FOR NON-OPERATING STACKS
6. REPLACE PACKED JOINTS WITH BELLOW JOINS
7. REMOWE SELDOM-USED VESSELS
8. ULTRASONIC LEAK SNIFFER
9. COMPRESSED AIR VS. STEAM FOR AUTOMIZATION
10. REPLACE GATE VALVES WITH BALL VALVES
11. UTILIZE WASTE OIL IN BOILERS
12. RETURN ALL CONDENSATE

C) RETROFIT :

1. USE ENGINE EXHAUST TO MAKE STEAM
2. RECOVER HEAT FROM STACK GASES, ETC.
3. USE CONDENSATE FLASH STEAM
4. HEAT BOILER MAKE-UP BY COMPRESSOR AFTERCOOLERS, ETC.
5. TURBULATOR IN BOILER TUBES
6. INSTALL SOOT BLOWERS
7. REPLACE OLD BOILER CONTROL
8. AUTOMATIC OIL VISCOSITY CONTROL
9. CONTINUOUS EXCESS OXYGEN CONTROL
10. INJECT UNBURNED DUST TO FURNACE

POTENTIAL ECO'S (FURNACES)

A) HOUSEKEEPING :

1. MAINTAIN BURNER ADJUSTMENTS
2. CHECK EXCESS AIR AND COMBUSTIBLES IN WASTE
3. KEEP HEAT EXCHANGERS CLEAN
4. REPAIR OR REPLACE INSULATION
5. REINSTALL DOORS OR COVERS
6. CHECK FURNACE PRESSURE
7. OPERATE NEAR MAXIMUM OUTPUT

B) LOW COST:

1. REPLACE DAMAGED DOORS OR COVERS
2. INSTALL MONITORING INSTRUMENTS
3. RECOVER ENERGY FROM COOLING WATER
4. RELOCATE COMBUSTION AIR INTAKE

C) RETROFIT:

1. HEAT EXCHANGER FOR EXHAUST GAS
2. REINSULATE ENCLOSURE
3. REPLACE BURNER
4. INSTALL NEW CONTROL SYSTEM

POTENTIAL ECO'S (REFRIGERATORS)

A) HOUSEKEEPING :

1. CLEAN HEAT TRANSFER SURFACES
2. REPAIR SUCTION AND LIQUID LINE INSULATIONS
3. CALIBRATE CONTROLS
4. MAINTAIN CORRECT REFRIGERATION CHARGE
5. EASE AIR FLOW AROUND CONDENSERS OR TOWERS
6. MINIMIZE SIMULTANEOUS HEATING AND COOLING

B) LOW COST :

1. INCREASE EVAPORATORT
   - RESET THE TEMPERATURE AT PART LOAD
   - RELOCATE HEAT PUMP OUTDOOR COIL
2. REDUCE CONDENSINGT
   - RELOCATE AIR COOLED CONDENSERS
   - REDUCE COOLING WATER T BY TOWER CONTROL
   - WATER TREATMENT TO KEEP SURFACES CLEAN
3. RESCHEDULE PRODUCTION TO REDUCE PEAK DEMAND
4. UPGRADE AUTOMATIC CONTROLS
5. REPLACE CENTRIFUGAL COMPRESSORS.
6. UPGRADE INSULATION
7. USE MULTI-SPEED MOTORS
8. USE EVAPORATIVE COOLERS AND CONDENSERS
9. USE HEAT PUMPS
10. USE COVERS ON CONTROLS TO PREVENT TAMPERING

C) RETROFIT :

1. USE ABSORPTION REFRIGERATION
2. USE HEAT PUMP
3. PROVIDE THERMAL STORAGE
4. PROVIDE DECENTRALIZED SYSTEM
5. RECLAIM REJECTED HEAT
   - HEATING CITY WATER, MELTING SNOW ALSO LOWERS CONDENSER T
6. DESUPERHEAT COMPRESSOR EXIT
7. USE WATER CONDENSERS, OR EVAPORATIVE CONDENSERS
8. USE REFRIGERATION FOR HUMIDITY CONTROL

POTENTIAL ECO'S (HVAC)

A) HOUSEKEEPING :

1. TIGHTEN DAMPER LINKAGES
2. ADJUST MOTOR BELT TENSION, COUPLING
3. CLEAN, REPLACE AIR FILTERS
4. SHUT OFF EXHAUST AND MAKE-UP WHEN NOT NEEDED
5. SHUT OFF LIGHTS, EQUIPMENT WHEN NOT NEEDED
6. RECALIBRATE CONTROL UNITS
7. REPAIR PIPE AND DUCT INSULATION
8. REPAIR DUCTS
9. CLEAN HEAT EXCHANGER SURFACES
10. DESIGNATE AREAS FOR SMOKING, ETC
11. RESTATE MINIMUM/MAXIMUM TEMPERATURES FOR HEATING/COOLING OCCUPIED/ UNOCCUPIED TIMES
12. ADJUST AIR FLOW RATES
13. IMPLEMENT MAINTENANCE PROGRAM

B) LOW COST :

1. INSALL TIME CLOCKS TO SHUT SYSTEM OR TO SWICH 100% RECIRCULATION
2. CONTROL CIRCULATION PUMPS
3. USE OUTSIDE AIR CONTROL
4. INSTALL ZONE THERMOSTATS
6. INSTALL EDGE SEALS ON AIR DAMPERS
7. ADD VALVE CONTROL ON FAN-COIL UNITS
8. PREVENTING SIMULTANEOUS HEATING AND COOLING
9. CONTROLS TO MINIMIZE REHEAT LOADS

10. REDUCE OUTDOOR AIR INTAKE TO MINIMUM
11. BARRIERS AROUND HEAT PRODUCING EQUIPMENT
12. DESTRATIFICATION FANS IN HIGH CEILLINGS
13. REDUCE PRESSURE DROPS

C) **RETROFIT**:

1. HEAT RECOVERY FROM EXHAUST
2. AIR TREATMENT TO REDUCE VENTILATION
3. REDUCE AIR FLOW TO HIGH QUALITY AREAS
4. SEPARATE SYSTEMS FOR DIFFERENT TYPE LOADS
5. CONVERT CONSTANT VOLUME TO VARIABLE VOLUME CONTROL
6. ADDITIONAL INSULATION ON PIPES AND DUCTS
7. RECOVER CONDENSER HEAT
8. EXTEND HEAT RECOVERY TO 12 MONTHS
9. MICROPROCESSOR ENERGY MANAGEMENT SYSTEM
    - OPTIMIZE START/STOP TIMES
    - ENTHALPY-BASED CONTROL ON ECONOMISER CYCLE
    - RESETS AIR/ WATER TEMPERATURES
    - MONITOR VARIOUS SYSTEMS TO CHECK TRENDS
    - LIMIT PEAK ELECTRIC DEMANDS
    - MONITOR AGAINST MULFUNCTIONING
10. WATER SPRAYS ON LARGE ROOFS

CHAPTER 2

CASE STUDIES

2.1 SEKA Paper Plant

SEKA is a state-owned company which has nine paper and cellulose production plants. The annual total production capacity is reported to be 577,500 tonnes of paper and cardboard, 356,000 tonnes of cellulose and 214,000 tonnes of mechanical pulp as of 1992.

SEKA-İzmit Plant -the oldest plant of SEKA- was founded in 1936. Currently, SEKA-İzmit (Figure 1) has a variety of products such as writing paper, board and covers, news print, onion skin, Kraft wrapping, grey board, straw fluting and cigarette paper. Annually around 175,00 tonnes of paper products are produced at SEKA-İzmit Plant and recently, on site cellulose production has been stopped. Right now, only mechanical and semi-mechanical pulp production is realized in İzmit. This case study only deals with the Paper Mill No.4.

Case Study: SEKA Paper Mill No.4

INTRODUCTION

The production of paper at the SEKA-İzmit Paper Plant No.4 can be divided into three distinct phases:

Phase 1. Preparation of groundwood pulp from wood logs,

Phase 2. Proper blending of specialty chemicals and chemical pulp (cellulose) with the mechanical pulp,

Phase 3. Mechanical water removal, sizing and felt drying.

The resulting product, finished paper, from felt drying is wound on reels prior to entering the cutting/wrapping section. A simplified drawing of the above mentioned phases is provided in Figure 2.

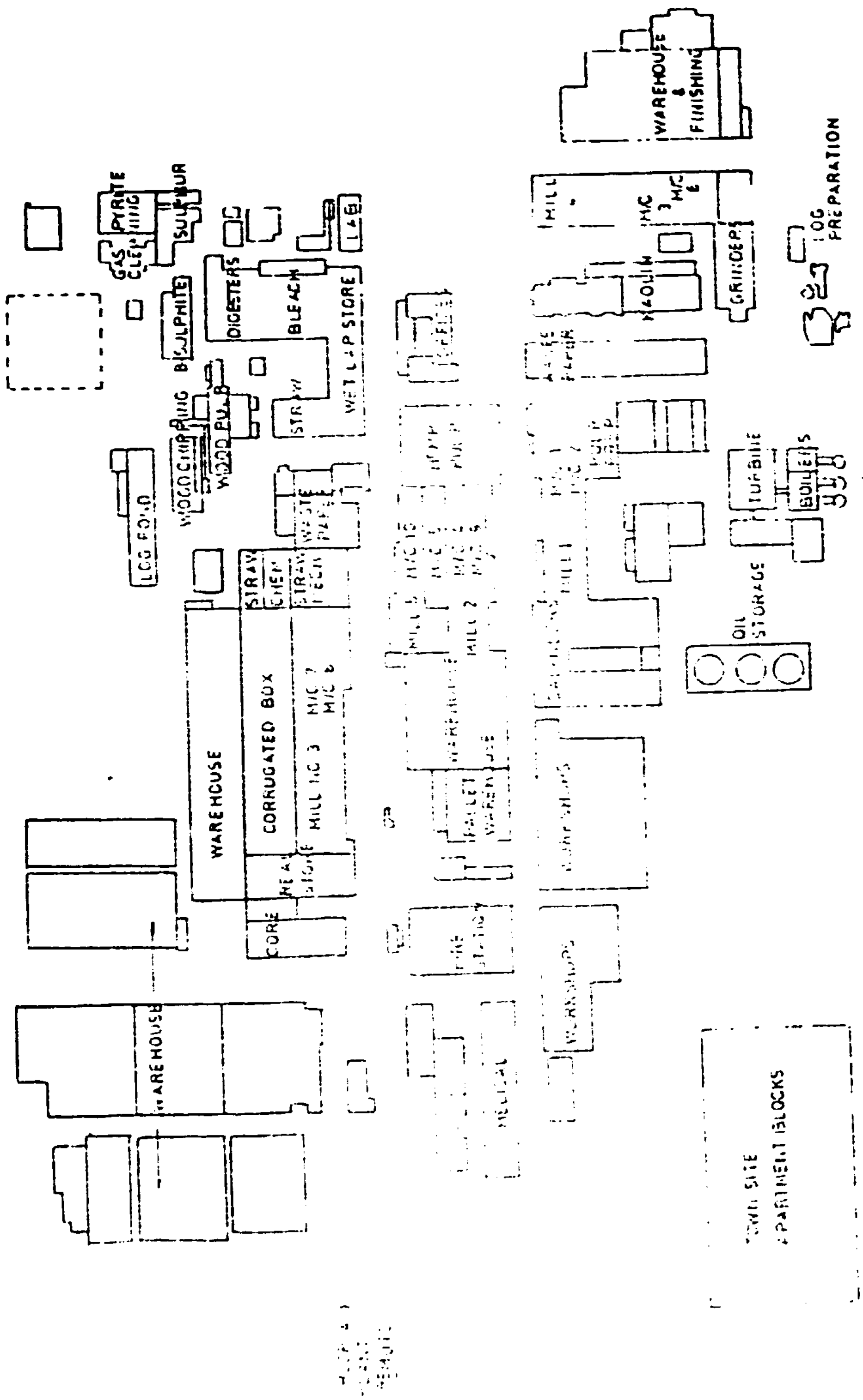


Figure 1. Lay-out of the SEKA-Izmit Plant

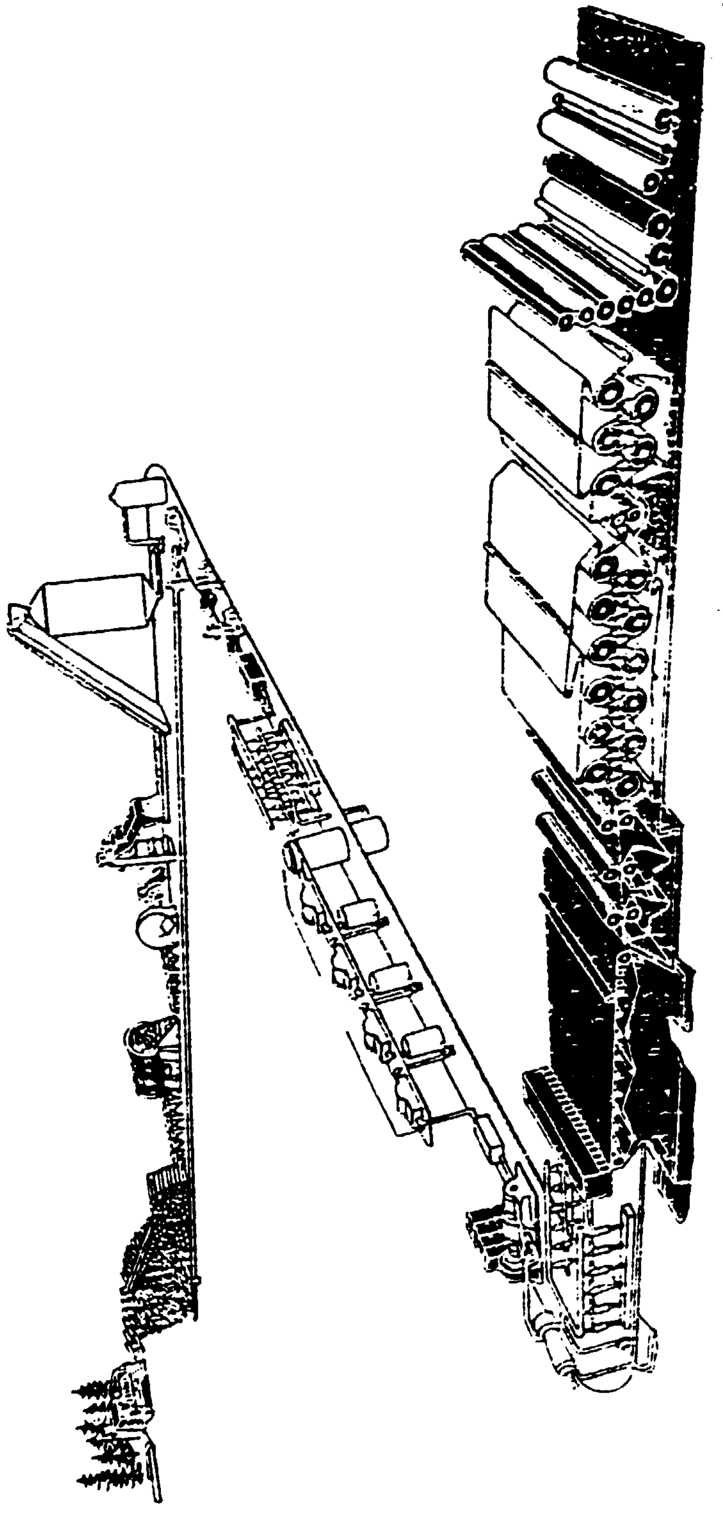


Figure 2. Phases of Paper Production at SEKA

PHASE 1

Wood is the principal raw material of groundwood pulp. The preparation of groundwood pulp begins with bark removal treatment of logs. A rotary drum is used at Paper Plant No.4 for debarking purposes. The logs are fed into the drum even if they have been purchased with barks removed. However, generally, only a small percentage of purchased logs require bark removal treatment at SEKA. The logs are fed into a rotating drum immensed in a tank with water. During tumbling, the bark is rubbed-off and the debarked logs are discharged from the drum. The rotary drum for bark removal at SEKA uses about 10 kWh per tonne of timber processed. Hence, there is a potential for electrical energy saving at the bark removal operation (ECO-1). The wood residue from the rotary drum could also be used either on site or sold to prospective customers (ECO-2).

Debarked logs are transferred to the grinders via a water through. The nominal total capacity of the grinders at the P'‥nt No.4 is 126 tonnes per day. The following grinders are available:

- 3 Tamperalla pocket grinders: 1500 kW, 22 tonnes per day each,
- 2 Chain grinders: 2100 kW, 30 tonnes per day each.

Figure 3 illustrates the groundwood pulp preparation section of the Plant No.4. The debarked wood is ground in water. Water removes the heat of friction and it also floats the fibers away. The pulp and water mixture from the grinders is later on handled by the auxiliary equipments consisting of cleaners, selectifiers, refiners, centrifugers and polydisc to separate the larger materials from the fines. The fines are concentrated and stored. The majority of power is consumed for grinding. Hence, major consideration must be given to the possible reduction of power consumption by grinders (ECO-3). The storage tower agitator rated at 55 kW could also benefit from installation of a power saver.

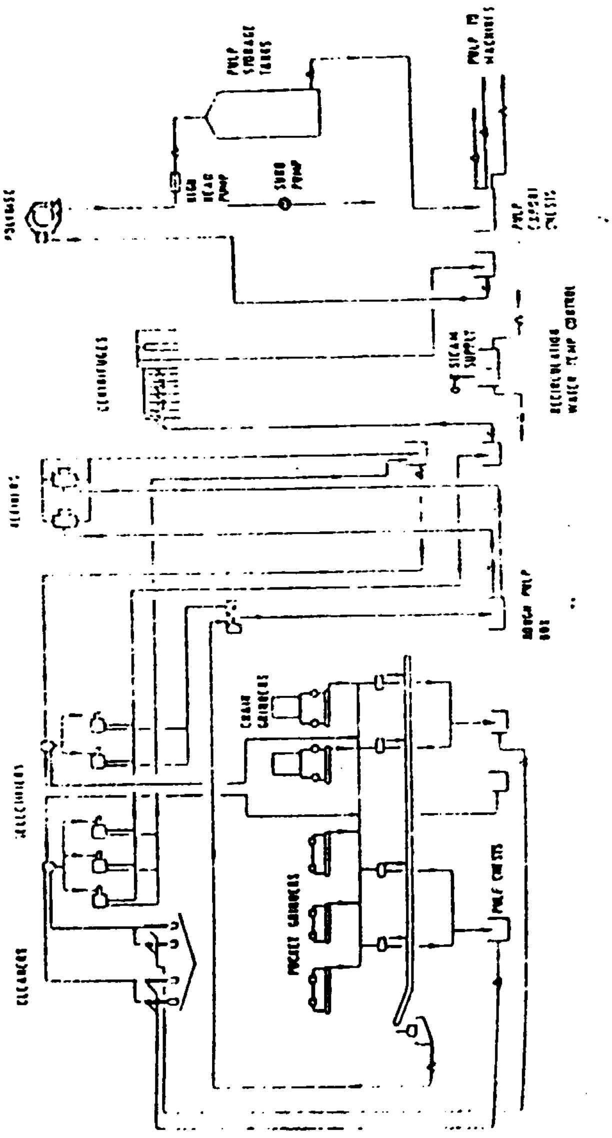


Figure 3. Groundwood Pulp Preparation Section of the Paper Mill No.4

During groundwood pulp production the aim is to get fibers as long as possible. This aim is usually achieved via proper angle cutting of the logs in the grinder system. The only chemical change occurring in mechanical pumping is slight hydration of the cellulose due to long contact with water, since this process does not involve any chemical treatment at this stage. According to the SEKA-Plant No.4 design conditions, the enormous amount of water to be fed to the grinders has to be around 60-68 °C, resulting in outlet temperatures around 80 °C from the grinder. Although the actual operation temperatures are slightly lower (58 °C and 72 °C, respectively) and the major part of the water is warm recirculation water, the thermal energy needed is calculated to be about 2.5 times higher than the supplied data. Both make-up water and the warm recirculation water are brought to the desired temperature level via steam injection (4.5 at, 200 °C) into the water supply tank of the grinders. Careful consideration should be given to thermal energy saving possibilities in the grinder/groundwood pulp preparation section. However, an up-to point detailed study of this partially open (life steam injection into water) system cannot be realistically examined within the framework of this case-study.

PHASE 2

The groundwood pulp contains the noncellulosic portions of the wood. Hence, the paper made from groundwood pulp eventually undergoes deterioration due to the chemical decompositions of the noncellulosic parts. To improve the paper quality, mechanical pulp is mixed with chemical pulp in the blending section, in other words, the pulp's cellulosic material content is increased. Also, recycled newspapers can be used as a substitute for wood fiber and cellulose (ECO-4). The paper must also have a "filler" added. The fillers, in SEKA case are certain clays, they occupy the spaces between the fibers so that the paper surface becomes smoother. The smoother the paper surface, the better it is for printability. Sizing is added to the paper to impart resistance to penetration by liquids in the pulp blending section. The sizing agent, a resin at SEKA, is precipitated with papermaker's alum, $Al_2(SO_4)_3 \cdot 18\ H_2O$. The sizing treatment produces a hardened paper surface. At SEKA, the blending operation is followed by dilution of the prepared stock to about 0.7% dry matter (≈0.6% fiber) via water addition. The diluted stuck undergoes a cleaning operation prior to entering the drying section. During the cleaning phase, some water and dry matter are lost. However, no major change is observed in the composition of the stock.

PHASE 3

The cleaned stock with a fiber content of about 0.6% (dry matter approx. 0.7%) is supplied to a Fourdrinier type paper machine at SEKA (Machine No.8, Figure 4). The stock is first sent through screens where a great portion of the water drains through while the pulp fibers remain on the screen. As the screen moves along, the pulp fibers are slightly shaken sidewise on the screen to orient the fibers and give better felting action and strength to the sheet. While still on the screen, the paper passes over suction boxes to remove additional water. Simultaneously, dandy rolls smooth the top sheet and edges of the paper are formed by straps travelling along the screen sides. From the screen, the paper is transferred to the first felt blanket which carries it through a series of press rolls to remove more water. The water content of the paper decreases from about 99.3% to 60% during the above mentioned mechanical operations. New equipment is available (extended nip press systems) for reaching of at least 50% dryness level (ECO-5).

The paper leaving the felt with about 40% dry matter content is smoothed via passing it through steel rolls. Leaving the steel rolls, paper is picked up by another felt which carries it through a series of drying rolls heated internally by steam (Figure 5). The steam drying section of the No.8 machine at SEKA has 40 cylinders of 1500 mm diameter plus felt drying and cooling cylinders. The paper leaves the drying cylinders 97% dry at SEKA. This dryness level is quite high compared to 6-7% moisture levels encountered in general elsewhere (ECO-6). The dried paper enters the roll calendars and is wound on reels. This operation is followed by supercalender by slitting facilities and warehouse section.

It is clear that enormous quantities of water are used during paper production. Hence, It is necessary to recirculate it as much as possible. Moreover, a considerable amount of steam is consumed to get rid of this water in the finished product. Hence, both water economics and steam economics are a must in the paper industry.

A typical mass balance to produce finished paper of the below mentioned quality at SEKA on a daily basis by utilizing Machine No.8 only has been provided in Figure 6. All the recommendations are based on the average daily production of 76.3 tons of paper composed of:

	% composition (weight)
cellulose	27.3
wood fiber	64.5
clay	5.2
water	3.0.

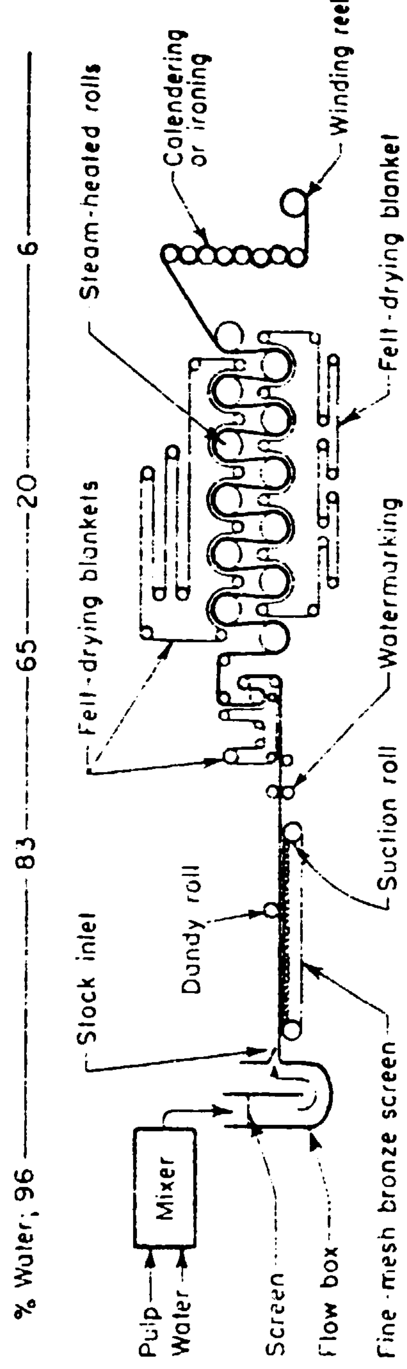


Figure 4. Schematic Illustration of the Fourdrinier Machine

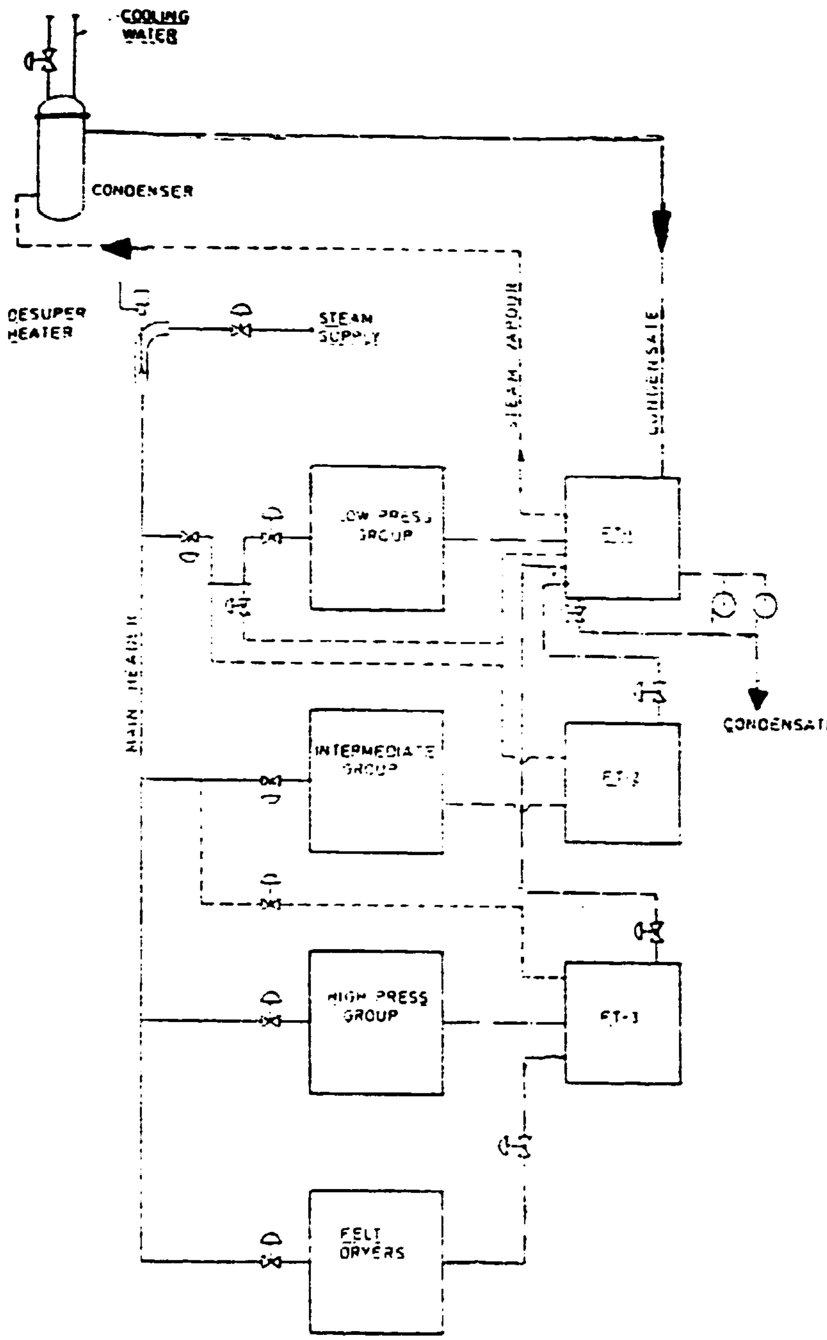
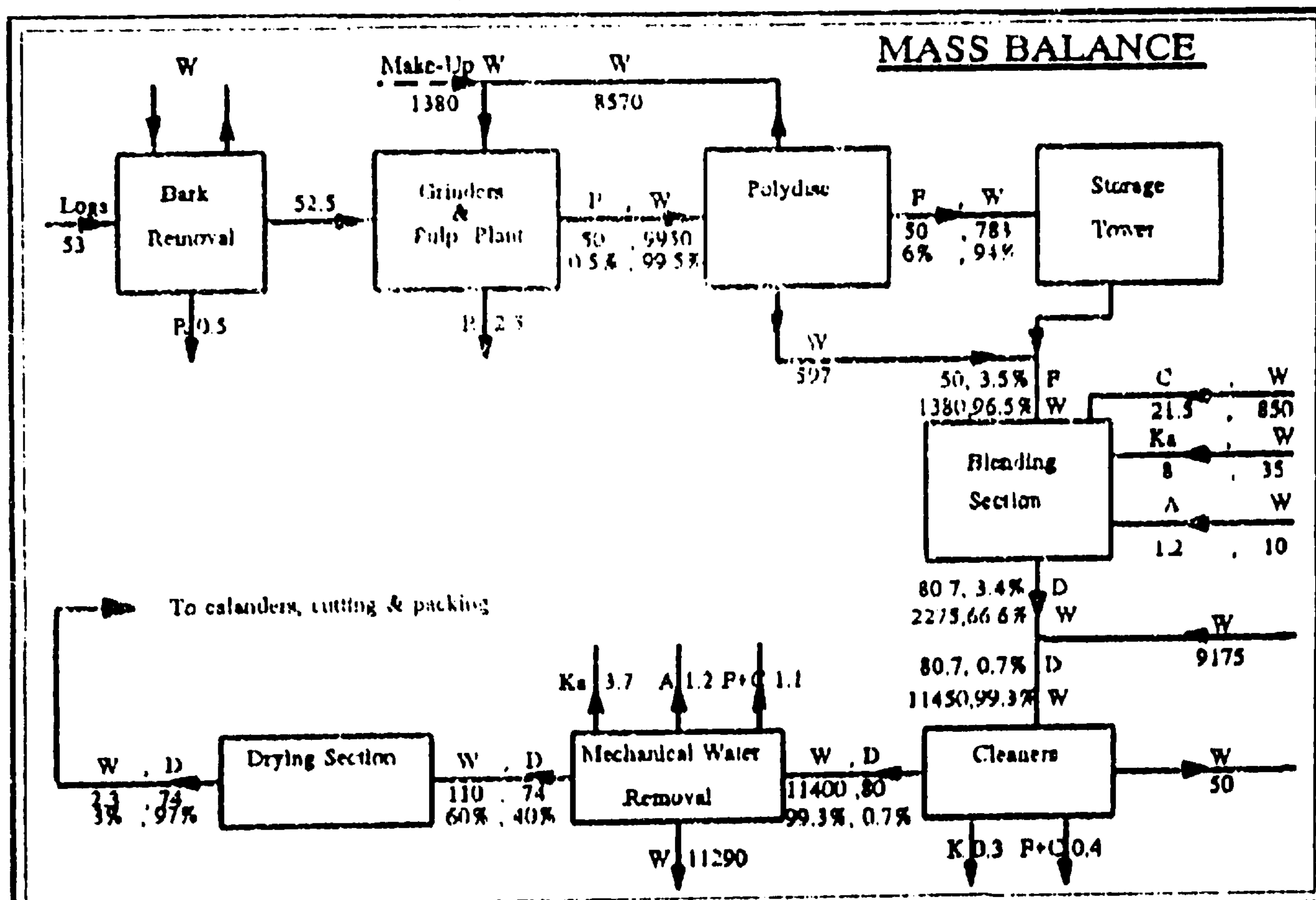


Figure 5. Paper Machine Steam System

All the numbers without units are given in tonnes/day.



(R): Residue, (W): Water, (Ka): Clay, (F): Fiber, (C): Cellulose, (D): Dry matter

Figure 6. A Simplified Mass Flow Diagram for the Paper Mill No.4

Energy Use

Energy is supplied to the Paper Plant No.4 as

- electrical energy and
- steam.

Power Demand

The total power demand average for the plant has been measured at 5.3 MW. This demand is allocated as shown in Table 1.

Table 1. Power Demand Allocation at Paper Plant No.4.

Consumers	Demand (kW)
Illumination	320
Bark Removal	90
Grinder	2285
Blender	760
Paper Machine	1585
Cutting & Packaging	260
Total	5300

Several of the above consumers, e.g. grinders, calendars and a part of the machine consumption for drive power is used at 3.15 kV. The remaining portion passes through 1500 kVA transformers to a nominal 525 V to serve the other consumers. The specific power consumption for individual machines is not accurately available.

Steam Demand

Steam is cogenerated at SEKA (back-pressure turbine system) at two different pressures (13.5 at and 4.5 at). The steam supply to the Plant No.4 is based on 4.5 at, 200° C steam. It is claimed that the steam consumption per tonne of paper produced is 2.5 tonnes; 0.5 tonnes being consumed at the grinding section for water heating and the remainder for felt drying. These numbers appear to be lower than the actual ones according to our data based calculations.

Description of ECOs

ECO No.1: Reduction of Power Consumption at the Bark Removal Section

TECHNICAL ASPECTS

For 53 tonnes of timber debarked on a daily basis, about 530 kWh are used in the rotary drum. Logs purchased debarked could be sorted out from the logs which require the treatment of debarking. Hence, it is estimated that this would save about 70% of the power consumed by the rotary drum.

ECONOMICAL ASPECTS

Via sorting out the debarked logs, on the average 122,430 kWh can be saved on an annual basis.

Annual Additional Labor Cost (US$)	=	4,000
Energy Use (before, kWh/yr)	=	174,900
Energy Use (after, kWh/yr)	=	52,470
Energy Savings (kWh/yr)	=	122,430
Power Cost (US $/kWh)	=	0.074
Annual Savings (US$)	=	9,060

ECO No.2: Wood Residue Utilisation

<u>TECHNICAL ASPECTS</u>

Annually about 165 tonnes (dry basis) of wood is deposited from the bark removal section as residue. This residue could be sold for 40 to 50 US$ per tonne (on dry basis). The residue has an average moisture content of 45%, resulting in a HHV of 14.5 MJ/kg on dry basis and can be utilized either as on site fuel or sold.

<u>ECONOMICAL ASPECTS</u>

The expected annual profit is about US$ 7,500.

ECO No.3: Reduction of Power Consumption at the Groundwood Production and the Pulp Storage Sections

TECHNICAL ASPECTS

A major consideration must be given to the reduction of power consumption in the No.4 Mill section of SEKA. Even a preliminary assessment indicates that the following recommendation are worth to be considered.

a) Power reduction may be achieved via installing variable frequency electronic control devices, in other words, variable speed inverters for equipment such as mill water pumps, vacuum pumps, discharge pumps to and from storage tower etc.

These control units are particularly applicable to units which operate for long periods at low load levels. However, their application to large size motors appears to be restricted at the first sight due to high capital costs. We still recommend that contact must be taken with manufacturers of the above mentioned control devices. In general, about 1000 kW with potential savings of 30-40% appears to be available.

b) Power reduction can also be achieved via power saver control units. These units serve the load to which motors are being subjected, and act immediately to vary the voltage and current applied to service the load demand. They appear to be suitable for those applications on which the previously mentioned frequency control is not acceptable, e.g. certain agitators such as the tower agitator in the storage tank, grinder motors, air compressors etc. With power savers, the power demand at 1000 kW can be reduced on the average at 5%.

ECONOMICAL ASPECTS

a) Power reduction via installing variable frequency electronic control devices

Total Equipment Cost (US $)	=	220,000
Energy Use (before, kWh/yr)	=	5,280,000
Energy Use (after, kWh/yr)	=	3,700,000
Energy Savings (kWh/yr)	=	1,580,000
Power Cost (US $/kWh)	=	0.074
Annual Savings (US $)	=	117,000

b) Power reduction via power saver control units

Total Equipment Cost (US $)	=	36,000
Energy Use (before, kWh/yr)	=	5,280,000
Energy Use (after, kWh/yr)	=	5,020,000
Energy Savings (kWh/yr)	=	260,000
Power Cost (US $/kWh)	=	0.074
Annual Savings (US $)	=	19,240

ECO No.4: Waste Newspaper Utilization in the Preparation of the Pulp Blend

TECHNICAL ASPECTS

On a daily basis about 21 tons of cellulose and 50 tons of wood fiber are consumed to produce about 76 tons of paper. Research has shown that the substitution of a quarter of the pulp blend with waste newspaper pulp still results in paper production of sellable quality. Only the paper color slightly changes since prior to the blending no ink removal is applied to the newspaper wastes. Even without to the newspaper wastes. Even without installing new equipment such as hydropulpers and cleaning systems, this process change has turned out to be technically and economically feasible.

ECONOMICAL ASPECTS

Without waste newspaper pulp substitution, the production cost of the paper blend is about US$ 385.7 per tonne. The cost of the blend in which about a quarter of its (cellulose + wood fiber) content is replaced by newspaper pulp comes to about US$ 322.6 per tonne.

Annual Production Cost (before, US$)	=	9,040,000
Annual Production Cost (after, US$)	=	7,560,000
Annual Savings (US$)	=	1,480,000

A portion of these savings is due to better energy use:

Steam consumption decrease (t/yr)	=	3406
Steam cost (US$/t)	=	15.5
Steam related savings (US$/yr)	=	52,800
Electrical energy consumption decrease (kWh)	=	1,300,000
Power cost (US$/kWh)	=	0.074
Power related savings (US$/yr)	=	96,200.

The remaining portion of the savings are mainly due to the cuts of cellulose and wood fiber consumption, as well as, due to the decrease of water usage and labor hours.

ECO No.5: Improvement of the Mechanical Water Removal Section

TECHNICAL ASPECTS

Under current conditions, the pulp blend enters the mechanical water removal section with a water content of 99.3%. The exit water content is about 60%. Via installing an extended nip press to the end of the mechanical water removal section, the dry matter content can be increased from 40% to at least 50%. Hence, less job is left to the thermal drying section.

ECONOMICAL ASPECTS

Total Equipment Cost (1993, US $)	=	1,200,000
Annual Steam Consumption (before, t/yr)	=	50,358
Annual Steam Consumption (after, t/yr)	=	41,514
Annual Steam Savings (t/yr)	=	8,844
Unit Steam Cost (US$/t)	=	15.5
Annual Monetary Savings (US$)	=	137,000

ECO No.6: Control Equipment Installation at the Thermal Drying Section

TECHNICAL ASPECTS

The finished paper product at SEKA contains only about 3% moisture. In general, the paper industry produces similar types of paper with around 6 to 7% moisture content. Hence, the finished product is over-dried in SEKA resulting in energy loss.

The lack of appropriate controls of parameters such as moisture content and paper weight across and along the drying route necessitates the unnecessarily high levels of dryness. Only such a low moisture content can protect the product from being damaged at the calendars section and becoming less appropriate for printing purposes. To achieve homogeneous drying at the acceptable level of 6% final moisture content, the following control equipment package must be installed.

The package includes measuring equipments and a computer system. Measurements are made with a high performance scanner, an air-gap temperature sensor, a basis weight digitector (Krypton/Strontium), an infrared moisture sensor and a caliper sensor. The computer system is equipped with a central computer/printer/software. The system supervisory software is developed to control basis weigth, decoupled moisture, dryer shutdown and dry stock flow. Even profile section is possible.

ECONOMICAL ASPECTS

Control Unit Cost (US$)	=	300,000*
Annual Steam Consumption (before, t/yr)	=	50,358
Annual Steam Consumption (after, t/yr)	=	47,718
Annual Steam Savings (t/yr)	=	2,640
Unit Steam Cost (US$/t)	=	15.5
Annual Monetary Savings (US$)	=	40,920

* In contrast to previous years, SEKA is facing strong competition due to the market penetration of private sector and foreign paper producers. Hence, homogenity and printability are of utmost importance. To achieve these standarts even longer pay-back periods than the ones usually acceptable by industry appear to be worth considering. The above mentioned controls are a typical example within this frame.

2.2 PETKİM PETROCHEMICAL COMPANY

Petkim Petrochemical Company was founded on April 3, 1965 for the purpose of establishing and developing the petrochemical industry in Turkey. Petkim produces a variety of petrochemical intermediates and end products including plastics, detergents, fiber intermediates starting from naphtha (a total of 2.5 mtpa). The company's first investment Yarımca Petrochemical Complex is located in the vicinity of İzmit. Petrochemicals that are being produced at Yarımca Complex are polyethylene (LDPE), polyvinylchloride (PVC), polystrene (PS), carbon black (CB), linear alkylbenzene (LAB), caprolactam, styrene-butadiene rubber (SBR), cis-butadiene rubber (CBR). The company's second complex is Aliağa which is located near İzmir. Aliağa Complex with twelve production plants based on 350,000 mtpa ethylene together with the related auxiliary and common plant facilities, represents one of the largest industrial projects undertaken in Turkey.

Case Study: PETKIM - VCM Plant

INTRODUCTION

Petkim Yarımca VCM plant has two identical units producing 48,000 mtpa VCM totally. Petkim Yarımca VCM process can be separated into three sections;

i) Direct chlorination,
ii) EDC fractionation and VC purification,
iii) Oxychlorination.

Direct chlorination of ethylene to ethylene dichloride (EDC), is conducted by mixing ethylene and chlorine in liquid EDC. The product EDC is line-mixed with an equal quantity of caustic and then is fed to the NaOH/EDC separator. Crude EDC from the separator is transferred into the crude EDC storage tank. By-products contained in EDC from direct chlorination, and oxychlorination and recovered EDC from the tracking section is removed in the purification section. In the EDC cracking section, EDC is vaporized and superheated to ensure that no liquid EDC is carried forward into cracker. The superheated EDC is fed to the EDC cracker. The cracker product consists of EDC, VCM and HCl. Then, VCM is purified and pumped into the VCM storage drums. In the oxychlorination section, ethylene reacts with dry hydrogen chloride and compressed air to produce EDC and water.

Two major ECOs have been found in the 1st and 2nd sections. The applicable process flow diagrams, mass balances and operation parameters for the actual and proposed cases are provided in the Figures 1-3.*

Energy Use

The actual consumption of the utilities at the VCM-1 plant is given in Table 1 on an hourly basis.

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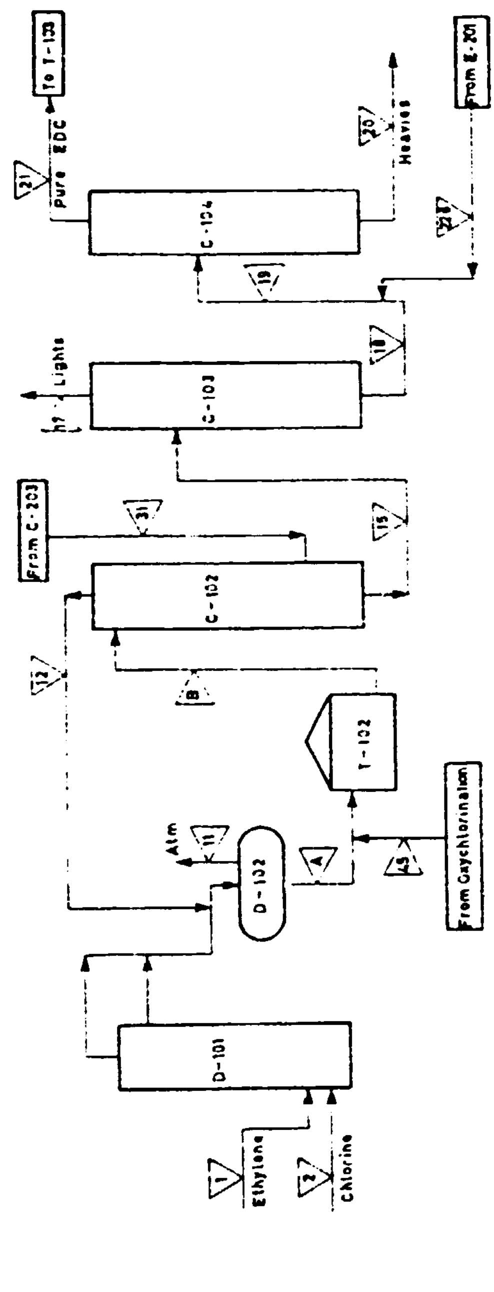
* Please, note that all the numbers without units in the following Figures No.1 to 6 are "flow-rates", the units being "kg per hour".

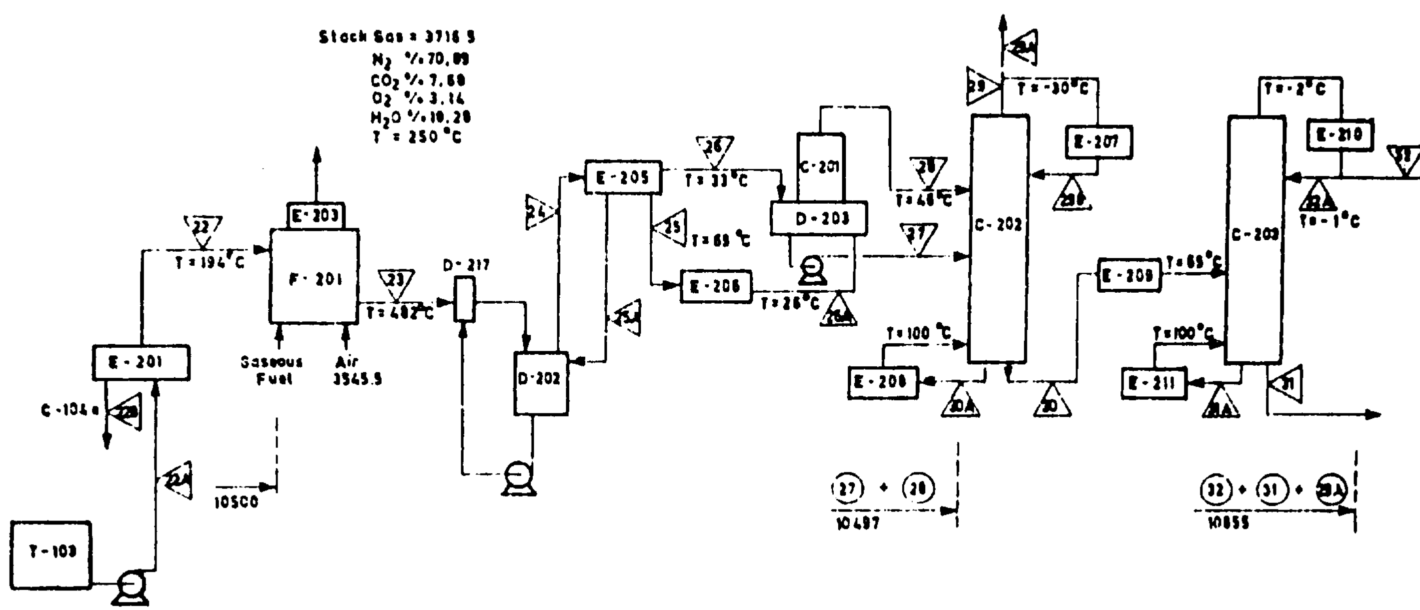
Table 1. Hourly consumption of utilities by the VCM-1 plant.

Utility	Amount (kg/hr)
Low Pressure Steam	41
High Pressure Steam	3642
Condensate	11985
Cooling Water	982531
Cooling Water (return)	404240
Process Water	778.4
Boiler Feed Water (for E-203)	742.4
Gaseous Fuel	254.4
Boiler Feed Water (for D-406)	3716
Low Pressure Steam Production (D-903)	2760
Electrical Energy	36900 kWh



	1 Ethylene-in	2 Chlorine-in	A from D-102 to T-102	B C-102 Feed	16 C-102 Bottom Product	17 C-103 Top Product	18 C 103 Bottom Product	20 C-104 Bottom Product	21 C-104 Top Product	22 B from E-201 to C-104	31 from C-203 to C-102 Feed	45 From oxychlorination to T-102
Ethylene	963.6											
Chlorine		2115										
EDC			3115	8353	11779	6	11773	41	13153	1802	5507	1960
Others	0.4		195	198	358	19	339	167	203	28	63	40
TOTAL	964	2115	3310	8551	12137	25	12112	208	13356	1830	5570	2000

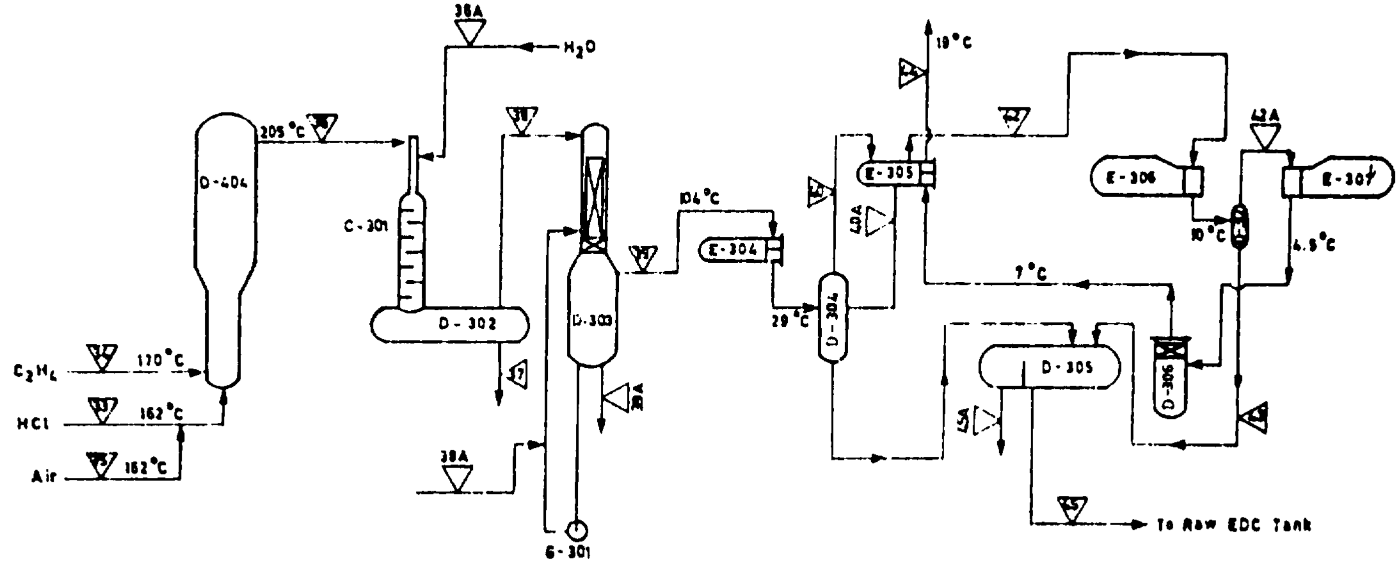
Figure 1. Mass Balance for the Direct Chlorination Unit



	22A	22B	22	23	24*	25*	25A	26	27
HCl				1098.3*	2568.4	472.9	741.76	1454	
VC				3250.6*	7157.05	2496.5	3915.9	775	
CP									
DCEE'S									
EDC	12134.6	1801	10299	5148.4	12887.1	4996.3	7838.1	54.7	
1,1 DCE									
$CHCl_3/CCl_4$									
TRI	54,25	8.1	48.2				286.6		
BTRI									
Others	141.15	20.9	154.8	202.2	675.45	250.63	109.64		
Total	12330	1830	10500	10500	23388	8216.33	12886	2283.7	7300

	28	29*	29A	29B	30	30A*	31*	31A*	32	32A
HCl			1834							
VC					3453.05				3450.8	
CP										
DCEE'S									0.17	
EDC					5506.3		5506.3		0.17	
1,1 DCE										
$CHCl_3/CCl_4$										
TRI					49.56		49.56			
BTRI					4.29		4.29			
Others					10.00		9.85			
Total	12597	3773	1834	1756	9024	3675.3	5569.8	4481.8	3454.2	1361

Figure 2. Mass Balance for the EDC Fractination and VC Purification Unit



	33	34	35	36	36A	37	38	38A	39	39A	40	40A	41	42	42A	43	44	45	45A
C_2H_4	–	704	–	11.2	–	–	11.2	–	11.2	–	11.2	–	–	11.2	11.2	–	11.2	–	–
EDC	–	–	–	2290	–	–	2290	–	2290	–	1029.6	26	1288.4	1003.8	350	653.6	350	1940	–
H_2O	–	–	–	459.5	1524	1254.5	729	163.8	715.3	177.5	31.4	13	698.9	18.4	–	18.4	–	–	715.3
HCl	1834	–	–	61.1	–	60.5	0.8	–	–	–	–	–	–	–	–	–	–	–	–
O_2	–	–	557	99.4	–	–	99.4	–	99.4	–	99.4	–	–	99.4	99.4	–	99.4	–	–
N_2	–	–	1834	1834	–	–	1834	–	1834	–	1834	–	–	1834	1834	–	1834	–	–
NaOH	–	–	–	–	–	–	–	18.2	–	–	–	–	–	–	–	–	–	–	–
CO_2	–	–	–	35.2	–	–	35.2	–	35.2	–	35.2	–	–	35.2	35.2	–	35.2	–	–
CO	–	–	–	22.4	–	–	22.4	–	22.4	–	22.4	–	–	22.4	22.4	–	22.4	–	–
β-TRI	–	–	–	53.4	–	–	53.4	–	53.4	–	–	–	–	–	–	–	–	19.8	–
Chloral	–	–	–	28.3	–	–	28.3	–	–	–	–	–	–	–	–	–	–	–	–
Others	–	–	–	34.5	–	–	34.5	–	34.5	47.1	–	–	82.9	–	–	–	–	40.2	27.9
Total	1834	704	2391	4929	1524	1315	5138	182	5085.4	224.6	3063.2	39	2071.2	3024.2	2352.2	672	2352.2	2000	743.2

Figure 3. Mass Balance for the Oxychlorination Unit

Description of ECOs

ECO No.1: Better Use of Energy in the EDC Fractionation and VC Purification Section

TECHNICAL ASPECTS

Proposed changes for energy conservation in the EDC fractionation and VC purification section are indicated in Figure 4. The additional units to be purchased are a preheater (E-201 A), a reboiler (E-208 A) and a separation tank (D-202 A). The preheater (E-201 A) is used to preheat the liquid EDC flow (10,960 kg/hr) from 298 K to 398 K. The heating medium is half of the filtered gas flow from the D-202 separation tank (24,086 kg/hr); i.e. 12,043 kg/hr at 423 K. It leaves the preheater partially condensed at 393 K. The other half of the filtered gas flow is utilized in the additional reboiler (E-208 A) of the HCl column. The new separation tank (D-202 A) is necessary to separate the two phase flows from the exit of the EDC preheater (E-201 A) and the HCl-column reboiler (E-208 A) into the vapor and liquid phases. The thermal energy saving potential of the proposed system is calculated to be 745,000 kcal/hr.

ECONOMICAL ASPECTS

Via purchasing a new EDC preheater (E-201 A), a HCl-column reboiler (E-208 A) and the additional separation tank (D-202 A), about 745,000 kcal/hr can be saved.

Total Equipment Cost	$= EC_{E\text{-}201A} + EC_{E\text{-}208A} + EC_{D\text{-}202A}$
Total Equipment Cost (1993, US $)	= 28,600 + 27,400 + 9,200 = 65,200
Erection Costs (1993, US $)	= (0.4)(65,200) = 26,000
Piping & Instrumentation (1993, US $)	= (0.85)(65,200) = 55,400
Total Cost (1993, US $)	= 146,600
Energy Saving Potential (kcal/hr)	= 745,000
Equivalent Fuel-Oil Savings (kg/yr)	= 702,429
Fuel-Oil Cost (US $/kg)	= 0.114
Annual Fuel-Oil Savings (US $)	= 80,000

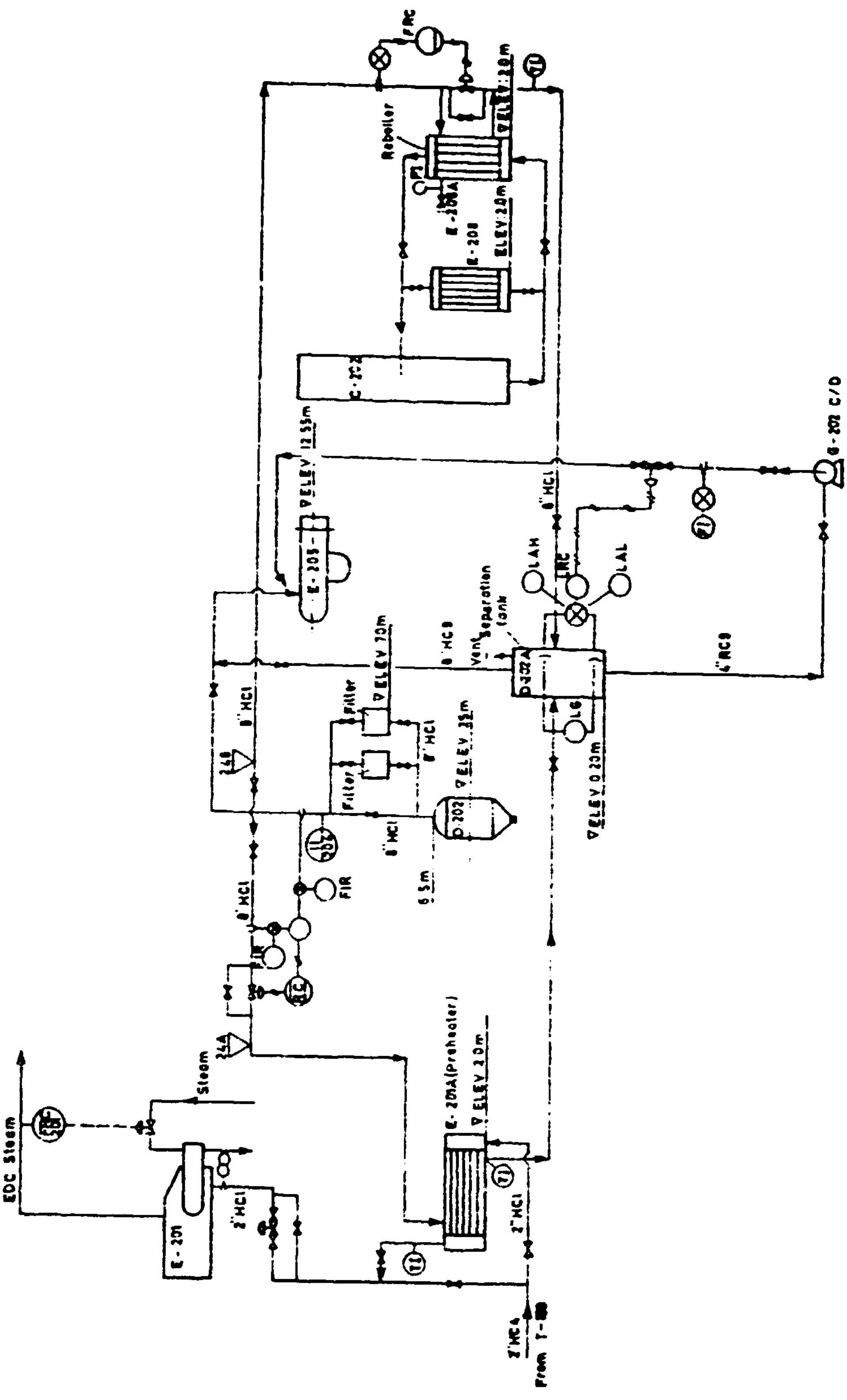


Figure 4. Proposed Process Changes in the EDC Fractionation and VC Purification Section

ECO No.2: Direct Chlorination Section Energy Conservation Opportunity

TECHNICAL ASPECTS

A considerably high exergy loss is observed at the condenser (E-112) of the heavy fraction column (C-104) in the direct chlorination section of the VCM-plant (Table 2 and Figure 5).

Table 2. Exergy losses in the direct chlorination section.

Equipment No.	Exergy Losses (kW)
E-101	148
E-102	1.5
E-104	0.1
E-106	39
E-109	152.9
E-111	22.6
E-112	397
E-115	22

The losses are associated with irreversibilities in the heat-exchanger (E-112) where about 26,500 kg EDC vapor coming from the top of C-104 column is condensed on an hourly basis. A solution is sought which will decrease the overall energy needs of the EDC-separation system (C-103, C-104) via better utilization of the top EDC vapor without compromising the overall system performance. The proposed changes are shown in Figure 6. The original EDC vapor flow from the top of the heavy fraction column is divided into two streams. Only 39% of the EDC vapor is condensed and sent to the reflux drum of the C-104 column. The remaining portion of the EDC vapor (16,200 kg/hr) is compressed to 3.5 atm via a centrifugal turbo-compressor system (148.6 kW). EDC vapor at around 403 K is utilized as heating medium in the new reboiler (E-110 A) of the C-103 column instead of the original one coded E-110. The thermal energy saving potential of the proposed design is calculated to be 1,134,000 kcal/hr.

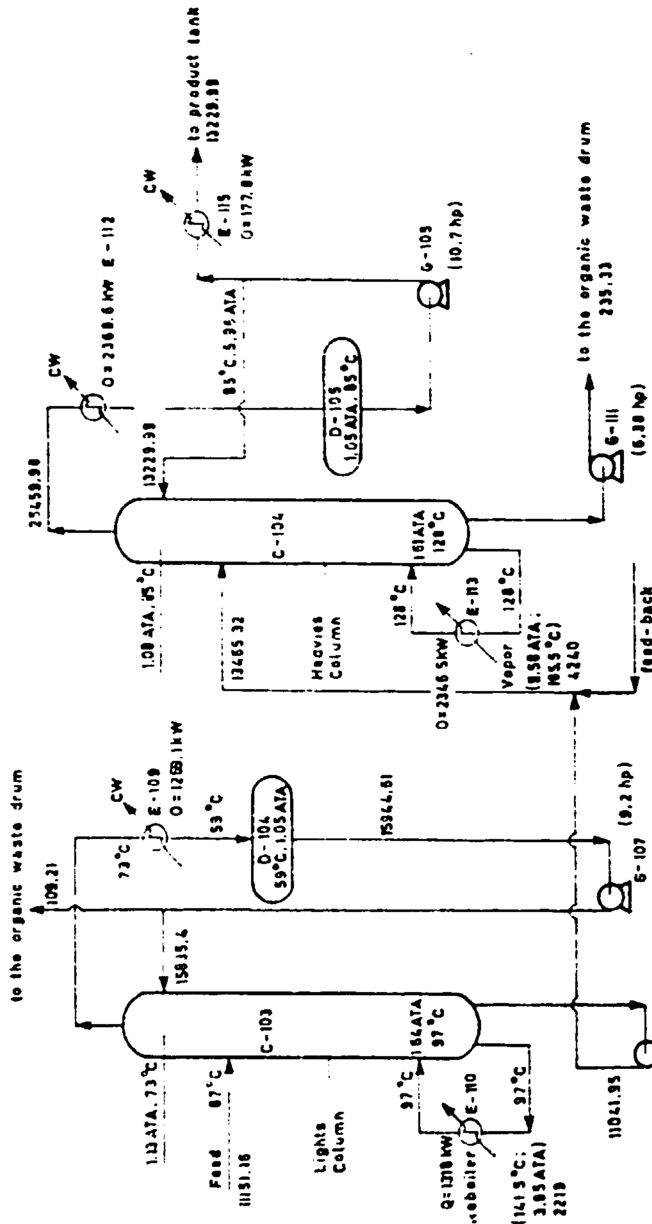


Figure 5. Conventional Flow-Chart for the Separation of the Light and Heavy Fractions from the EDC

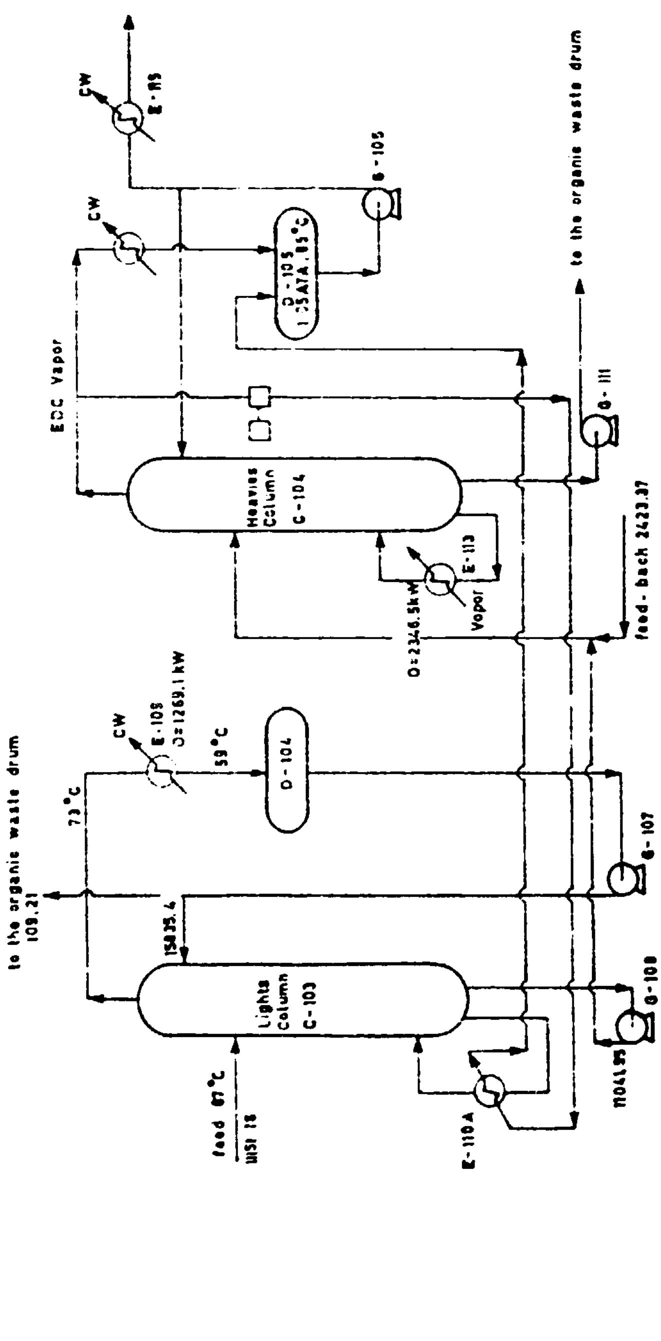


Figure 6. Proposed Changes for the Separation of the Light a[illegible]actions from the EDC

ECONOMICAL ASPECTS

Via purchasing a new compressor system and a new reboiler system (E-110 A), about 1,134,000 kcal/hr can be saved in the EDC separation system of the direct chlorination section.

Total Equipment Cost	=	$EC_{E\text{-}110A} + EC_{compressor}$
Total Equipment Cost (1993, US $)	=	121,820
Erection Costs (1993, US $)	=	(0.4)(121,820) = 48,728
Piping & Instrumentation (1993, US $)	=	(0.85)(121,820) = 103,547
Total Cost (1993, US$)	=	274,095

Energy Use (before, kcal/hr)	=	2,370,000
Energy Use (after, kcal/hr)	=	1,236,000
Energy Savings (kcal/hr)	=	1,134,000
Equivalent Fuel-Oil Savings (kg/yr)	=	1,070,000
Fuel-Oil Cost (US $/kg)	=	0.114
Annual Fuel-Oil Savings (US $)	=	122,000

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PETKIM

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2.3 ANKARA SUGAR FACTORY

Ankara Sugar Factory can lower its energy cost substantially by the implementation of an energy conservation program, in order to be able to determine the possibilities of energy savings and energy recoveries.

Since sugar production consists of complex interrelated multistage processes, and procejt team has only one staff to do all audit jobs all processes of plant are not examined, as a separate units instead whole factory is taken as a single unit, and measurement and calculations are done on it. Here the aim is just to illustrate the methodology of making an energy audit.

At the begining of the audit project staff went to the factory to learn the chemical and mechanical processes and take a first look to the factory. At that visit flow charts of the factory were taken from the plant staff. Before the second visit these flow charts and processes were studied. In the next visit, flow of sugar beets were observed, while the first eco possibilities were checked. Also in that visit, some measurement values such as natural gas, steam,sugar beet, juice flow rates and their respective temperatures were asked to factory staff, and taking monitering reports which show all required information about the factory audit are available for 10 days period.

By using these detailed reports, all inputs can be checked or calculated easily .However, these reports are not sufficient for detailed calculations, because they give information only about factory, not for production line steps. Using these reports, factory performance can be compared with the other factories, but does not give detaiiled idea about the quality of various production lines, etc.

For a detailed audit; factory could be divided into 3 parts:

1- steam production unit,

2- raw juice factory,

3- refinery.

1-Steam Production Unit

It consists of 3 furnaces. Two of the furnaces have almost 70 percent efficiency while the big capacity one has 85-90 percent efficiency. Less efficient furnaces which are a result of improper conversion of coal furnaces to natural gas cause some losses. For more information, energy audit and balance values of steam production unit are given in steam production process control volume and table.

2-Raw Juice Factory

This part which contains diffusion, purification, and evaparation processes obtains thick juice from sugar beets.

3-Refinery

In this part, white sugar is produced from thick juice. Again detailed informations are shown on related control volumes and tables.

In the factory there are two more parts that might be considered;

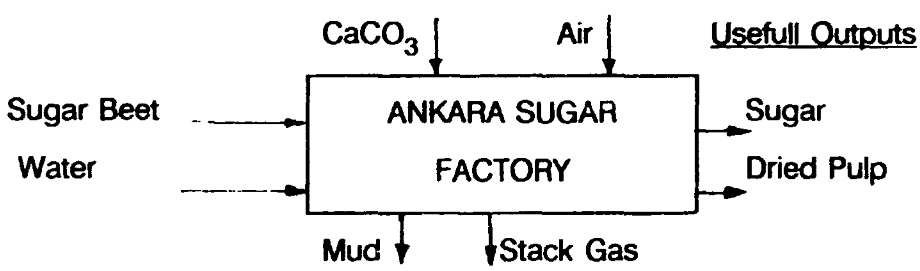
i) Obtaining $Ca(OH)_2$ from $CaCO_3$,

ii) Drying pulp.

But, these parts are not so significant in terms of energy audit. Consequently they are ignored in this report.

FACTORY

* Established in 1962 with a capacity 1200 tonnes/day (sugar beet),
* Capacity increased in 1983 to 3000 tonnes/day,
* Recenty, instead of coal, natural gas is used as fuel,
* natural gas with heating value = 8200 kcal/m^3; cost = 1717 TL/m^3 (in 1993)
* electricity is produced within the factory



Inlets	Mass (kg)	Energy (kJ)	Outputs	Mass (kg)	Energy (kJ)
Sugar Beet	36.3	2737	Sugar	4.82	154.2
Water	21.8	1830	Dried pulp	4.72	637.2
NGas (m^3)	1,076	35000	TOTAL		791.4
TOTAL		39567	LOSS		12599.1

Note:

Air, $CaCO_3$ have so litte energy input to the system then, they are neglected in energy balance.

Energy efficieny, η $= \frac{791.4}{39567} = 0,3$

Figure of merit $= \frac{4,82}{36,3} = 0,13$ kg sugar/kg beet.

Figure of merit $= \frac{4,82}{1,076} = 4,48$ kg sugar/m3 fuel.

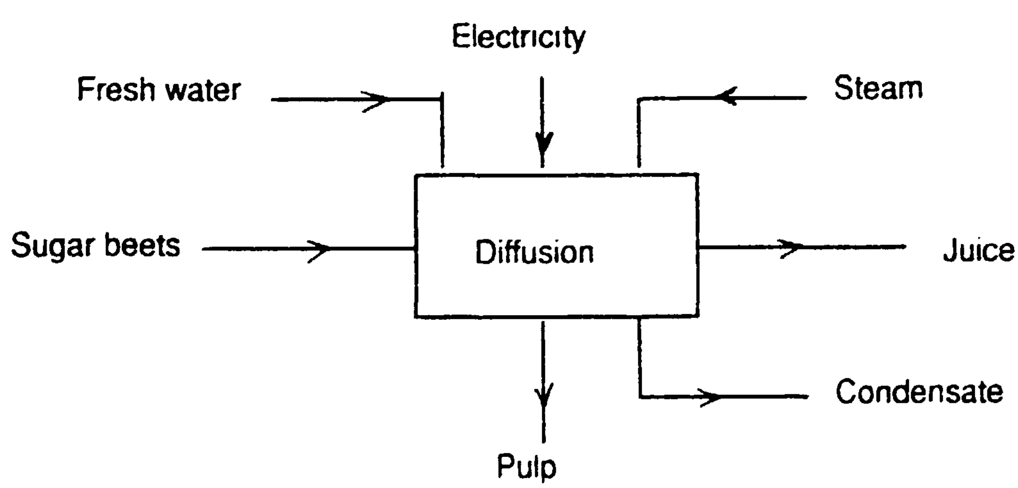
ENERGY BALANCE ON SUGAR PRODUCTION PROCESS

1- RAW JUICE FACTORY

I)-DIFFUSION= PRODUCTION OF JUICE

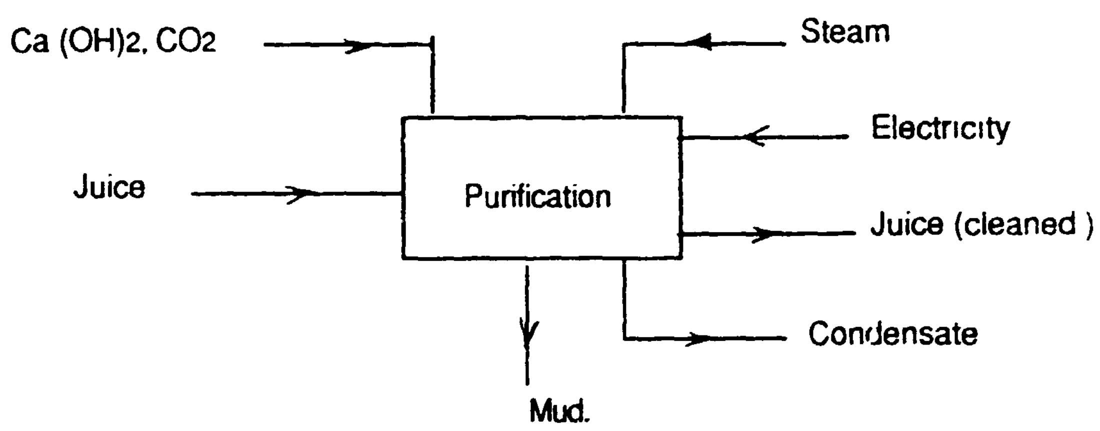
PROCESSES: STORAGE, CLEANING, WASHING, CUTTING INTO SMALL PIECES OF SUGAR BEET, ADDITION OF HOT WATER AT 70-80^0

(Inputs)	Mass(kg)	Total Energy (kj)	Outputs	Mass(kg)	TotalEnergy (kJ)
Sugar beet	25	1885	Juice	30	5401
Fresh water	12,5	3589,25	Dried pulp	7.25	1363
Steam	1	2500	Condensate	1	385.5
Electricity		409	TOTAL		7149.5
TOTAL		8500	LOSS		1350



ii) JUICE PURIFICATION: REMOVAL OF MUD FROM JUICE BY LIMING

Inputs	Mass (kg)	Total Energy (kJ)	Outputs	Mass (kg)	Total Energy (kJ)
Juice	30	5401	Juice	31.25	14843.75
Steam	4.58	12291.8	Condensate	4.58	1991.75
Electricity		702	Total	--	16835
TOTAL		18394.75	Loss		1559.75

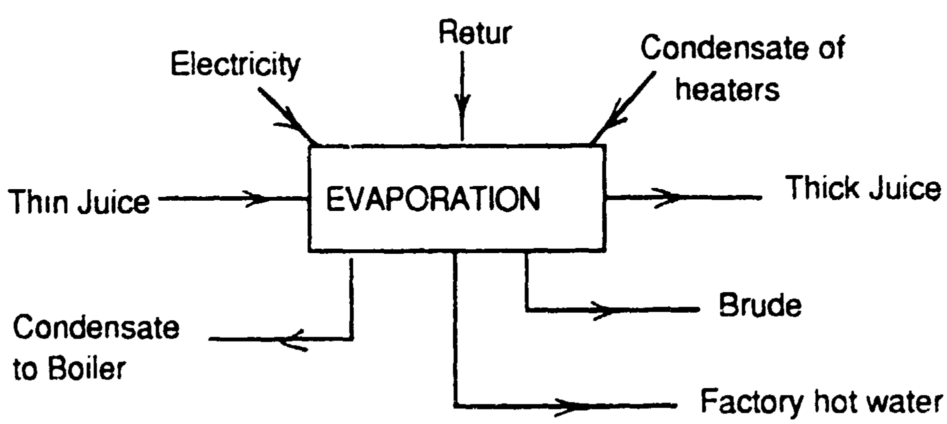


NOTE: CA (OH)2, CO2 AND MUD ENERGY CONTENT ARE IGNORED; DUE TO THEIR ORDER OF MAGNITUDE.

iii) EVAPORATION:

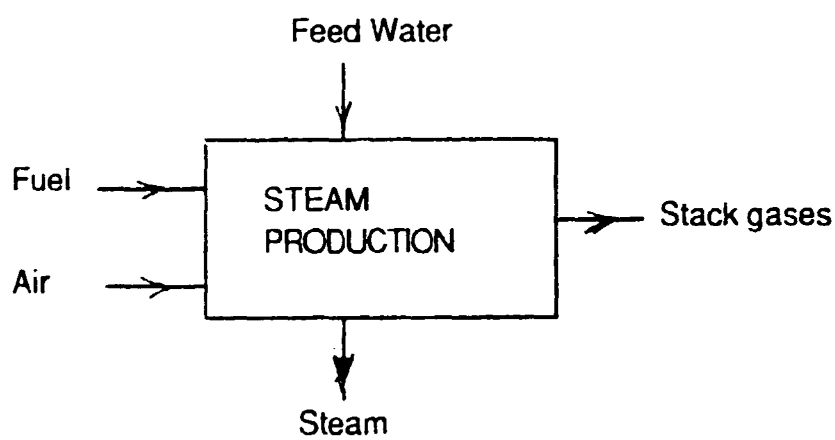
•THIN JUICE ⇒ THICK JUICE (AT EVAPORATORS)
•USING⇒ MULTIPLE EFFECT EVAPORATORS
•SOLID PERCANTAGE INCRESED TO 50-65% from 15%

Inlets	Mass(kg)	Energy (kj)	Outputs	Mass (kg)	Energy (kJ)
Thin juice	31.25	14843.75	Thick Juice	7.25	1818
Retur	11.25	30674.25	Brude (*)	12.64	34038.25
Condensate of Heaters (*)	11.66	5159.75	Condensate to Boiler	11.55	4986.25
Electricity		168.75	Factory Hot Water	22.73	8568
TOTAL		50846.5	TOTAL		49411.75
			LOSS		1434.75



2- STEAM PRODUCTION: STEAM AND ELECTIRICITY IS GENERATED AT A COGENERATION UNIT TO PROVIDE HEAT AND POWER REQUIREMENT OF FACTORY.

Inputs	Mass (kg)	Energy (kJ)	Outputs	Mass (kg)	Energy (kJ)
Feed Water	11.6	5000	Steam	11.25	25610
Fuel (m3)	0.75	25731.6	TOTAL		25610
TOTAL		30731.6	LOSS		5122

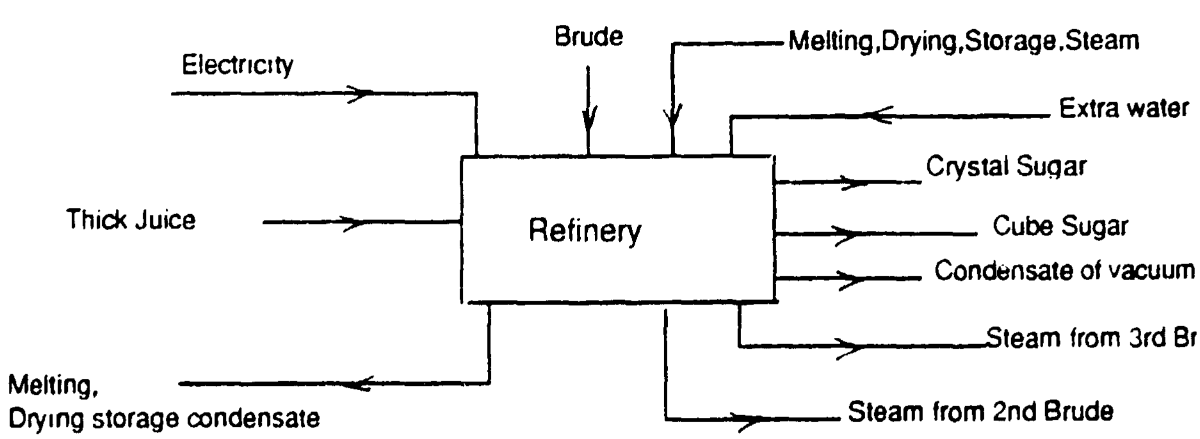


* AIR HAS NEGLIGIBLE ENERGY IF IT IS COMPARED WITH OTHERS VALUE AND STACK GASES GIVE DIRECTLY AS A LOSS BECAUSE OF THIS REASON IT IS NOT MENTIONED IN OUTPUT ITEMS.

3- REFINARY:

- BOILING OF THICK JUICE UNDER LOW TEMPERATURE AND PRESSURE
- OCCUR AT ⇒ VACUUM PRESSURE
- MULTIPLE STAGE PROCESS:
- OUTPUT IS DRIED ⇒ WHITE SUGAR

Inputs	Mass(kg)	Energy (kj)	Outputs	Mass (kg)	Energy (kj)
Thick juice	7.25	1818	Cube Sugar	0.8	23.5
Brude	6.25	16792.25	Crystal Sugar	3.06	98
Extra Water	2	3915	Vacum Condensate	6.25	2689.75
Melting drying storage steam	0.85	2306	Melting, drying stroge conden.	0.85	439
Electricity		1080	Steam ;2nd brude	4.13	10870
TOTAL		22627.5	Steam:3rd brude	1.275	3406
			TOTAL		17276
			LOSS		5351.5



2.3 ANKARA SUGAR FACTORY

Ankara Sugar Factory was established in 1962 with a capacity of 1200 tons sugar beet per day and then this capacity was increased to 3000 tons/day in 1983. Some modifications on the production line were done. Recantly all three main cogeneration furnaces are converted to use natural gas instead of lignite.

In this factory, for each 13-15 tons of sugar production, 100 tons of sugar beet is required, and 25 tons of steam is consumed. If these values are compared with newer factories, they indicate some potential for improvements. Some of the causes of this relatively low efficiency can be imperfect conversion of small size boilers, inadequate insulation, insufficient automation.

ENERGY CONVERSION OPPORTUNITES:

ECO NO : 1
Title : Insulation of Valves.
Description : There are 1000-1200 valves of different sizes in the factory. All of them are not insulated. Especially valves at feeding line where temperature and pressure are 70-150 ^{o}C and 1,5-2 atm respectively cause huge amount of heat loss.

To insulate the valve a box will be prepared according to known valve size and, space between valve and box will be filled with insutation material. To clean and check the valve,box will be opened required work will be done then box will be closed again easily.

By using a rackwool as a insulation material, 80 percent reduction in the heat loss from valve will be achieved. Moreover, insulation prevents high temperature on the surface of valve SO some accident, and burning will be prevented.

2.4 ETIBANK ALUMINUM PLANT

The Etibank Aluminum Works at Seydişehir is started up in 1971 as an integrated facility with yearly production capacity of 200000 tons alumina and 60000 tons aluminum. The only modification on the original Russion design is addition of an aluminim sulphate unit. Bauxite mine is nearby, alumina is not used in the plant, finished aluminum is marketed within Turkiye.

An energy study on the plant was done in 1986 by Bechtel/Kaiser group. ECO's are idintified and evaluated some of which is implemented by now. Actual 1985 production is 113303 tons alumuna and 60337 tons aluminim. The major energy input is electricity and costed $ 30.000.000. in 1985. The remaining energy input is no. 5 and no. 6 fuel oils. In general plant performance compares favorably with design. and international norms:

	RANGE		AVERAGE
SEYDİŞEHIR			
<u>Alumina</u>			
Power (kwh/ton alumina):	200-300	275	205
Steam generation (in 10^6 Btu/ton)	4.4-11.3	7.3	8.9
Alumina Calcination(in 10^6 Btu/ton)	2.8-5.0	4.0	4.8
<u>Aluminum</u>			
Power(kwh/ton aluminum):	-	15600	14420

The plant has abundant supply of spare parts and equipment and is well maintained.

Following is a summary of values assumed during costing in 1985.

1$= 650 TL
Turkish engineeering = $ 20/hr
U.S. engineering = $ 70/hr
Electricity cost=$ 0.0371 /kWh
No.6 Fuel oil cost = $ 207.7 / tons

APPENDIX

ENERCOST INPUT DATA SHEETS

ENERGY CONSEVATION OPPORTUNITIES

ECO No: 1

Title : Energy information system

Description: Previously the plant staff were maintaining detailed production statistics which could be used to determine overall energy consuption. When "the energy information System" is implemented. 8 to 12 measurements of process variables are to be recorded and reported daily. These variables are selected to give an indication of energy use for the entire plant and are independent of previous measurements. The values will be obtained by new or carefully recalibrated insturements. When a measured variable will indicate positive trend, it will be discontinued from the daily report. Following will be evaluated at first: tons steam/tons paste, kg oil/ton metal melted, kwh/m^3 air compressed, m^3water lost, kg oil/ ton steam produced, ton of blowdown/ ton of steam, water quality, thermal load on cooling circuit.

ECO No: 2

Title : Revamp Control System For Boilers

Description: There are 4 boilers, each rated at 75 tons/hr producing steam at 40 atm, 440'C. They burn mazout, roughly a light grade of No.6 fuel oil. There are electronically controlled electric motors for value operators. There is no way to measure the flow of fuel oil.

With this ECO, boiler control system will be revised, including automated control of fuel and air flow. Steam pressure will be used to determine firing rate. An O_2 analyzer will trim the air/fuel ratio. About 3% improvement in boiler efficiency is expected. Other benefits will be safety of boiler, reduction in NO_x discharge. Part of the engineering will be training the personnel.

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 1**

Title: Reduction of Power Consumption at the Bark Removal Section

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before	174,900	kWh/yr	0.074 US$/kWh	12.942 US$
Energy consumption after	52,470	kWh/yr	0.074 US$/kWh	3,882 US$
Annual energy savings	122,430	kWh/yr	0.074 US$/kWh	9,060 US$
Better using				
Environmental impact assessment				
Labor cost	4,000 US$/yr			4,000 US$
Engineering cost				
Equipment cost-local				
Equipment cost-imported				
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 2**
Title: Wood Residue Utilization

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before				
Energy consumption after				
Annual energy savings				
Better using	165	t/yr	45.5 US$/t	7,500 US$/yr
Environmental impact assessment				
Labor cost	1,000 US$/yr			1,000 US$/yr
Engineering cost-foreign				
Equipment cost-local				
Equipment cost-imported				
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 3a**
Title: Power Reduction at the Groundwood Production and Pulp Storage

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before	5,280,000	kWh/yr	0.074 US$/kWh	391,000 US$/yr
Energy consumption after	3,700,000	kWh/yr	0.074 US$/kWh	274,000 US$/yr
Annual energy savings	1,580,000	kWh/yr	0.074 US$/kWh	117,000 US$/yr
Better using				
Environmental impact assessment				
Engineering cost-domestic				
Engineering cost-foreign				
Equipment cost-local				
Equipment cost-imported	220,000 US$			220,000 US$
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 3b**

Title: Power Reduction at the Groundwood Production and Pulp Storage

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before	5,280,000	kWh/yr	0.074 US$/kWh	390,720 US$
Energy consumption after	5,020,000	kWh/yr	0.074 US$/kWh	371,480 US$
Annual energy savings	260,000	kWh/yr	0.074 US$/kWh	19,240 US$
Better using				
Environmental impact assessment				
Engineering cost-domestic				
Engineering cost-foreign				
Equipment cost-local				
Equipment cost imported	36,000 US$			36,000 US$
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 4**

Title: Waste Newspaper Utilization in the Pulp Blend Preparation

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before				
Energy consumption after				
Annual energy savings				
Better using	3,406 1,300,000	tonnes steam/yr kWh/yr	15.5 US$/t 0.074 US$/kWh	52,800 US$/yr 96,200 US$/yr
Environmental impact assessment				
Engineering cost domestic				
Engineering cost foreign				
Equipment cost local				
Equipment cost imported				
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 5**
Title: Improvement of the Mechanical Water Removal Section

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before	50,358	t/yr	15.5 US$/yr	780,000 US$/yr
Energy consumption after	41,514	t/yr	15.5 US$/yr	643,000 US$/yr
Annual energy savings	8,844	t/yr	15.5 US$/yr	137,000 US$/yr
Better using				
Environmental impact assessment				
Engineering cost-domestic				
Engineering cost-foreign				
Equipment cost-local	200,000 US$			200,000 US$
Equipment cost-imported	1,000,000 US$			1,000,000 US$
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: SEKA Paper Mill No.4 **ECO Number: 6**
Title: Control Equipment Installation at the Thermal Drying Section

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before	50,358	t/yr	15.5 US$/t	780,549 US$/yr
Energy consumption after	47,718	t/yr	15.5 US$/t	739,629 US$/yr
Annual energy savings	2,640	t/yr	15.5 US$/t	40,920 US$/yr
Better using				
Environmental impact assessment				
Engineering cost-domestic				
Engineering cost-foreign				
Equipment cost-local	50,000 US$			50,000 US$
Equipment cost-imported	250,000 US$			250,000 US$
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: PETKİM - VCM Plant **ECO Number: 1**

Title: Better Use of Energy in the EDC Fractionation and VC Purification Section

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before				
Energy consumption after				
Annual energy savings				
Better using	702,429	kg/yr	0.114 US$/kg	80,000 US$/yr
Environmental impact assessment				
Engineering cost-domestic				
Engineering cost-foreign				
Equipment cost-local	146,600 US$			146,600 US$
Equipment cost-imported				
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: PETKİM - VCM Plant **ECO Number: 2**
Title: Direct Chlorination Section Energy Conservation Opportunity

ITEM	Quantity	Unit	Price	TOTAL
Energy consumption before	2,236,243	kg/yr	0.114 US$/kg	254,900 US$/yr
Energy consumption after	1,166,243	kg/yr	0.114 US$/kg	132,900 US$/yr
Annual energy savings	1,070,000	kg/yr	0.114 US$/kg	122,000 US$/yr
Better using				
Environmental impact assessment				
Engineering cost domestic				
Engineering cost foreign				
Equipment cost local	274,095 US$			274,095 US$
Equipment cost-imported				
Other				
Price contingency				
Physical contingency				
Installation period (year)				
O and main. cost-yearly				
Other operating costs				
Depreciation rate %				
Corporate tax rate %				
Government incentives				
ETC, ITC				
Owners equity				
Loan amount				
Int. value				
Grace period				
Lender period				

ENERCOST INPUT DATA SHEET

Plant Name: ANKARA SUGAR FACTORY
ECO Number: .1.. Title: INSULATION OF VALVES

Item		TOTAL
Energy Consumption before		
Energy Consumpιion after		
Annual Energy Savings		$ 29.125.-
Better Using		
Environmental Impact Assess.		
Engineering Cost-Domestic	200 Eng.hr.	$ 4.000
Engineering Cost-Foreign	-	
Equipment Cost-Local	1200 piece	$ 8.889
Equipment Cost-Imported		-
Other		-
Price Contingcy		5 %
Physical Contingency		0 %
Installation period (y)		1
O and Main, Cost-yarly		2 %
Other operating costs		-
Life Cycle		4
Depreciatın rate %		0
Corparate tax rate %		40
Goverment incentives		NO
ETC, ITC		NO
Owner's Equity		30 %
Loan: Amount		70 %
Int Value		60 %
Grase period		1 year
lender period		3 year

ENERCOST INPUT DATA SHEET

Plant Name: ETİBANK SEYDİŞEHİR ALUMINUM WORKS
ECO Number: .1.. Title: ENERGY INFORMATION SYSTEM

Item		TOTAL
Energy Consumption before		
Energy Consumption after		
Annual Energy Savings		$ 300.000.-
Better Using		--
Environmental Impact Assess.		
Engineering Cost-Domestic	320 Eng.hr.	$ 64.000
Engineering Cost-Foreign	80 Eng.hr.	$ 5600
Equipment Cost-Local	(80.000.000.-TL)	$ 5.00?
Equipment Cost-Imported		$ 20.000
Other		-
Price Contingcy		5 %
Physical Contingency		0 %
Installation period (y)		1
O and Main, Cost-yarly		2 %
Other operating costs		-
Life Cycle		4
Depreciatın rate %		0
Corparate tax rate %		40
Goverment incentives		NO
ETC, ITC		NO
Owner's Equity		30 %
Loan: Amount		70 %
Int Value		60 %
Grase period		1 year
lender period		3 year

ENERCOST INPUT DATA SHEET

Plant Name: ETİBANK SEYDİŞEHİR ALUMINUM WORKS
ECO Number: ..2.. Title: .REVAMP CONTROL SYSTEM

Item		TOTAL
Energy Consumption before		
Energy Consumption after		
Annual Energy Savings		$ 1.000.000.-
Better Using		
Environmental Impact Assess.		
Engineering Cost-Domestic	800 Eng.hr.	$ 16.000
Engineering Cost-Foreign	160 Eng.hr.	$ 8000
Equipment Cost-Local	(800.000.000.-TL)	$ 50.000
Equipment Cost-imported		$ 420.000
Other		-
Price Contingcy		5 %
Physical Contingency		0 %
Installation period (y)		1
O and Main, Cost-yarly		2 %
Other operating costs		-
Life Cycle		4
Depreciatın rate %		0
Corparate tax rate %		40
Goverment incentives		NO
ETC, ITC		NO
Owner's Equity		30 %
Loan: Amount		70 %
Int Value		60 %
Grase period		1 year
lender period		3 year

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