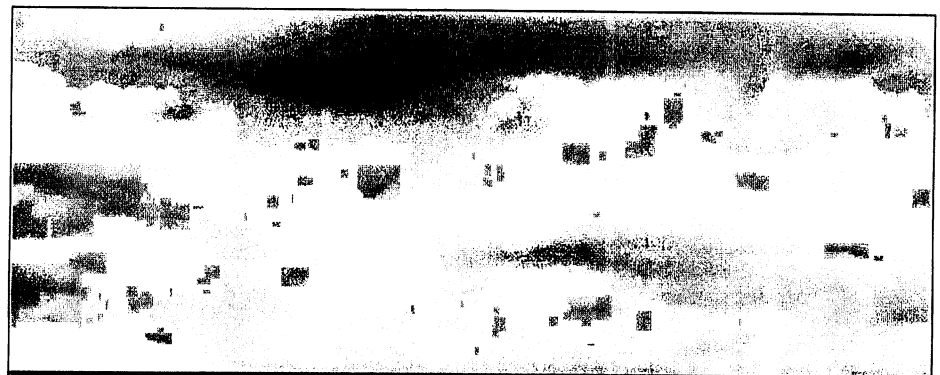
Outotec
More out of ore



Efficiency in sulphuric acid plants

COBRAS 2011
VII Congresso Brasileiro de Ácido Sulfúrico

Outotec
More out of ore

Efficiency

Efficiency is widely understood as time or effort required to reach a certain task or performance. Hereby understanding varies, e.g. in thermodynamics efficiency refers to the second thermodynamic law while the term **economic efficiency** refers to the use of resources so as to maximize the production of goods and services.

Carnot's theorem:

$$\eta = 1 - \frac{T_{Cold}}{T_{hot}}$$

"Do we all have the same understanding on efficiency???"

Outotec
More out of ore

Outotec
More out of ore

Agenda

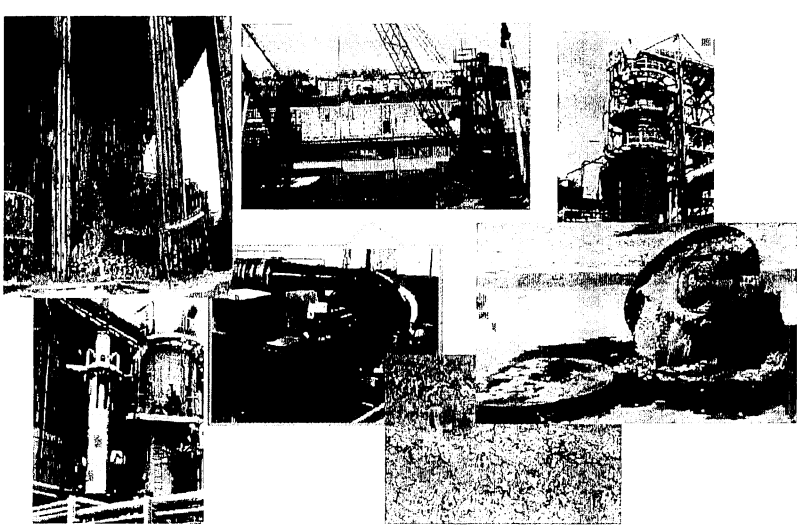
Efficiency - Definition and Considerations

Case Study: 750 tpd S-Burner Acid Plant

- Sulphur Melting and Filtration
- Combustion Area
- Converter Area
- Drying and Absorption Area
- Infrastructure

Outotec
More out of ore

Efficiency in sulphuric acid plants...?



Outotec
More out of ore

Outotec
More out of ore

Efficiency in sulphuric acid plants

is defined on performance of certain equipment, process units or overall plant performance, considering operation and/or maintenance etc.

For example:

- Removal or conversion efficiency (conversion rate, yield)

$$Y = \frac{c_{i,in} - c_{i,out}}{c_{i,out}}$$

- Operational efficiency, e.g. $\eta = 1 - \frac{t_{op.,scheduled} - t_{op,unscheduled}}{t_{op,scheduled}} * 100\%$

- Plant efficiency, e.g. kWh/t acid, US $/t acid

Outotec
More out of ore

Aspects

impacting the efficiency in acid plants

Process:
- Design basis
- Heat recovery
  - Steam cond. HP
  - LP steam prod.
- Processing of high SO2 content
- Feedstock control (Venturi vs. RFS)
- Integration in infrastructure, e.g. cooling concept
- etc.

Equipment:
- Energy efficient equipment (reduction of Δp; increased electr. efficiency)
- Performance eff. equipment (lifetime, performance, maintainability)

Other aspects:
- Operation („will design basis meet the later operation?")
- Maintenance (preventive vs. reactive; RCM analyses)
- Plant integrity (sensitivity of individual plant sections)
- HSE
- R&D

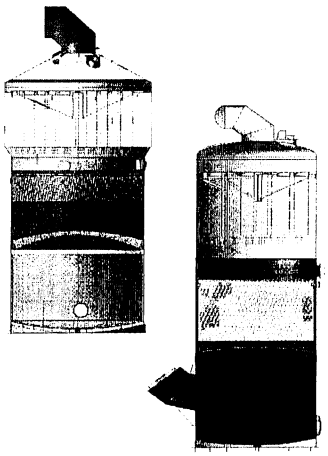
Outotec
More out of ore

Outotec
More out of ore

Efficiency in equipment design: Towers

Conventional Tower

- Multi layer bricklining
- Self supporting dome (or grid)
- Distribution system; SX or cast iron
- Adequate acid mist and droplet removal with shell of 316L



Stainless Steel Tower

- Stainless steel (e.g. SX)
- With or without one-layer bricklining up to dome
- Self-supporting dome (or grid)
- Distribution system of SX
- adequate acid mist and droplet removal with shell of 316L

Outotec
More out of ore

New design = higher efficiency?

Tower design has changed:

- Bricklined tower to SS tower
- More efficient (Δp) packing and irrigation systems (material, type)
- Design parameters (higher gas velocity, irrigation density = smaller tower diameter)
  - → Reduced installation time (revamp)
  - → Not relying on brickwork quality (new, revamp)
  - → Reduced energy consumption, increased capacity (new, revamp)

However.....

„Is a reduced operational flexibility/operating window to be considered?"

„Are potential implications on downstream equipment considered?"

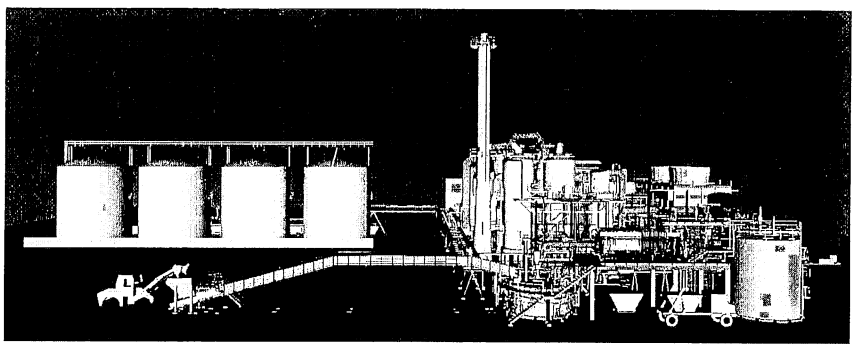
„Can you utilize this effect if you don't consider the full operational system?"

„Carefully evaluate your operational scenario"

Outotec
More out of ore

Outotec
More out of ore

Efficiency in acid plants – 750 tpd S-burner plant



Outotec
More out of ore

Consumption and production figures

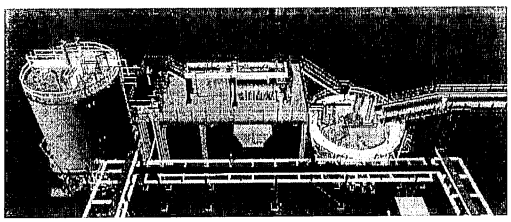
	Amount	Conditions	Remarks
Power	1300 kW		Clean Plant
Sulphur	10.3 t/h		2.5 % humidity
LP-Steam	8.5 t/h	sat.,8 bar (g)	max. value, during S-melting
Process Water	6 m³/h	20 ° C	For process use
Boiler Feed Water	40 t/h	105 ° C	
Cooling Water	1,900 m³/h	33 ° C	For main & product acid cooler
Sulphuric Acid	750 tpd		
HP-steam	37 t/h	50 bar (g), 510 ° C	Export to produce electrical power (approx. 8 MW, net)

+ Optional reat recovery from absorption area feasible

Outotec
More out of ore

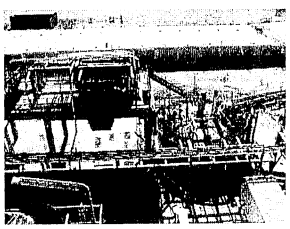
Outotec
More out of ore

Sulphur melting and filtration



Above ground S-melter

- Capacity: 32 t/h (design 2 % humidity in sulfur prills)
- Integrated pre-coating compartment
- Heating coils removable
- Easy access for maintenance and cleaning of tank

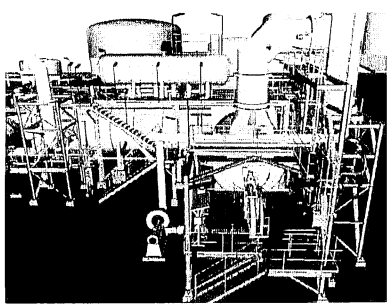


Sulphur filter and storage

- Main „leaf-type" filter: Filtration capacity: 32 t/h (filtration cycle: 8 h; filter area: 44 m²)
- Additional polishing filter
- Capacity sulfur storage tank: 500 t (2 days of production)

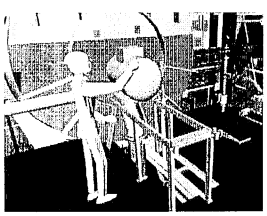
Outotec
More out of ore

Sulphur combustion



Features

- Sulfur (10.3 t/h) will be burned at 11.5 vol.-% SO_2
- Combustion by a single **LURO2** burner, latest generation
- SO_2 gases will be cooled in fire tube boiler (steam conditions: 50 bar (g), 510 ° C)

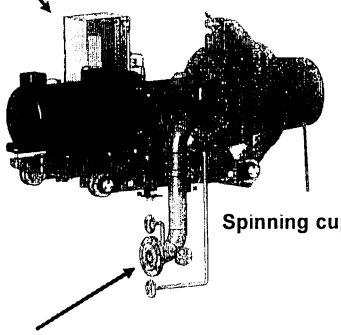


Outotec
More out of ore

Outotec
More out of ore

Sulfur combustion: LURO2 burner

Automatic greasing system



Features

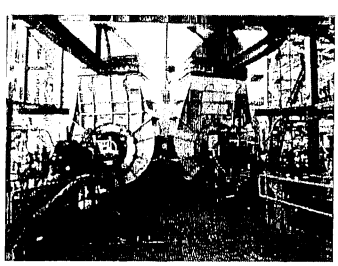
Improvement of the successful LURO burner

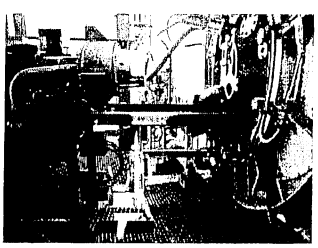
- Spinning cup with variable drive, magnetic coupled
- Excellent sulfur atomisation over the complete range (15 – 110 %)
- connected to small, baffle free combustion furnace (2 x 106 [kcal/m³])
- Efficient operation:
  - Easy removal of burner
  - Sulfur pressure below 1 [bar (g)]
  - Same equipment for preheating and sulfur burning
  - No risk of burner steam leaks
  - Nominal risk of unburned sulfur in downstream equipment (e.g. boiler, etc.)

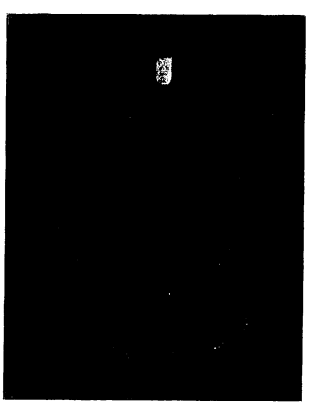
Outotec
More out of ore

LURO2 burner

Burner arrangment for Ma'aden (5,000 tpd)





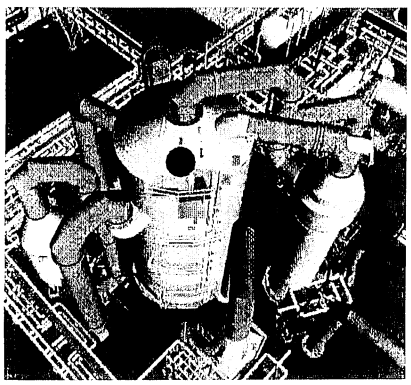


LURO burner with 870 tpd production (VIDEO)

Outotec
More out of ore

Outotec
More out of ore

Converter area

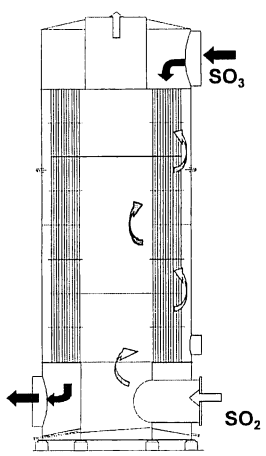


Features

- Fully welded stainless steel design from 304H/321 delivered in 5 segments (converter diameter: approx. 7 m)
- Four passes, first pass on top
- Fourth pass gas inlet from central tube (radial gas distribution)
- Conversion rate: 99,8 %
  Emissions < 800 mg SO_2/Nm^3
  Specific catalyst load 185 ltr/t
- Proprietary Re-Heat Exchanger 3

Outotec
More out of ore

Gas/Gas heat exchanger

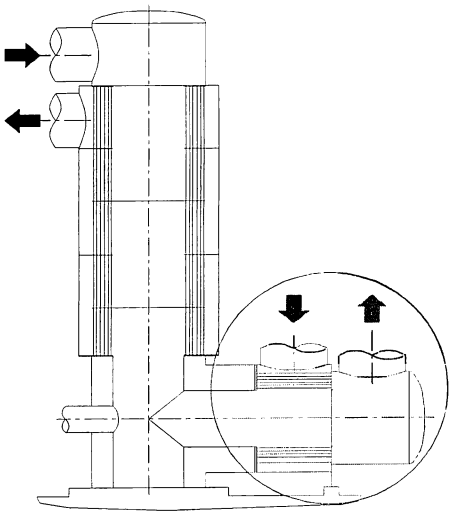


- Today gas/gas heat exchangers are generally of radial flow design:
  - Minimized gas flow dead zones
  - Lower shell side pressure drop
  - Uniform radial temperature profile
  - Simple, reliable support of tube bundle
  - Universal nozzle positioning
- Cold re-heat exchanger most exposed to potential condensation and sulphate build up/corrosion
  → Maintenance intensive

Outotec
More out of ore

Outotec
More out of ore

OT CORD™ - Cold Gas/Gas heat exchanger



Features

- Horizontal part made of SS316L
- Condensate can be drained
- Longer lifetime due to less corrosion (due to operation in temperature corrosion resistant conditions)
- Temperature increase in sacrificial part by approx. 20 ° C
- Horizontal part easy to replace/clean

patented by OT

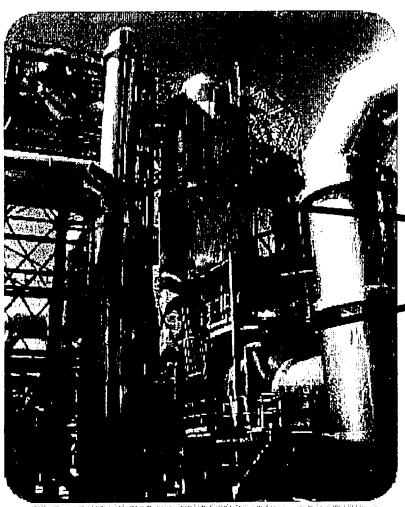
CORD = Cost Optimized Reliable Design

"Both HX types have same thermal efficiency, however the production efficiency (maintenance downtime) is different"

17

Outotec
More out of ore

OT CORD™ - Cold Gas/Gas heat exchanger



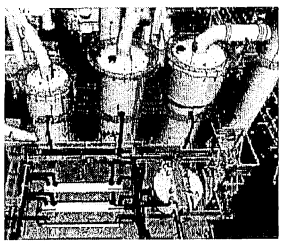
Main heat exchanger

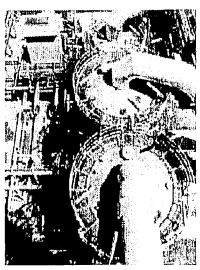
"Horizontal" part

Outotec
More out of ore

Outotec
More out of ore

Drying and absorption section





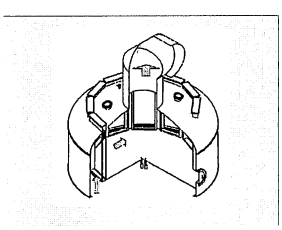
Features

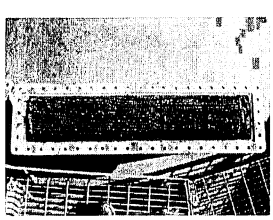
- Conservative packing design (> 3.5 m)
- Tower diameter approx. 3.8 m
- SX piping
- Common acid system

  → *Reduced equipment, instrumentation*
- Drying tower equipped with „vertical" demister
- Acid distribution by FIDI system

Outotec
More out of ore

Drying tower - vertical wire mesh





Features

- Excellent removal efficiency

  99.99 % > 5 µm

  95 % > 3 µm

  Δp: approx 100 mm WC
- Easy access for maintenance and inspection (HSE)

Safety + maintainability

= Efficiency

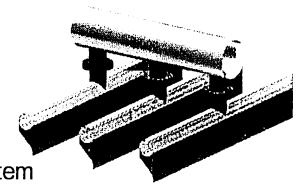
Outotec
More out of ore

Outotec
More out of ore

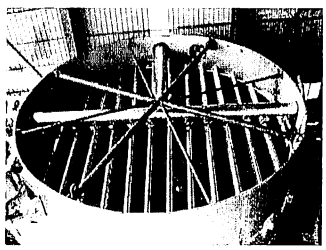
FIDI™ acid irrigation system

Features

- Simple design manufactured from SX® ALLOY
- Low investment costs
- Minimization of carry over of sulfuric acid
- Optimized acid distribution by fluid dynamic analysis
- Improved free gas flow area with new FIDI Irrigation System (from 45-60 % with common systems (trough, pipe) up to 65 to 75 %)



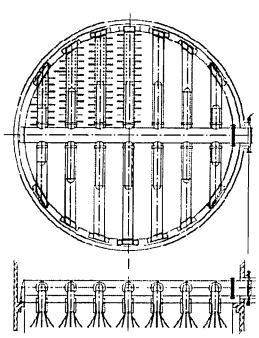
- References:
  - Evonik Marl (IAT)
  - Kayalekera
  - Cajamarquilla (IAT)
  - Ravensdown (FAT)
  - Noracid
  - Pequiven



Outotec
More out of ore

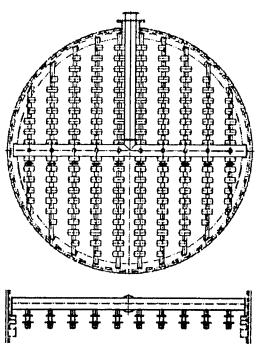
Comparison of acid irrigation systems

Trough System



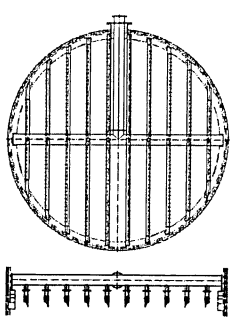
Free Gas Flow Area through Irrigation System
45 to 55 %

LURGI System



Free Gas Flow Area through Irrigation System
55 to 60 %

Outotec FiDi™ System

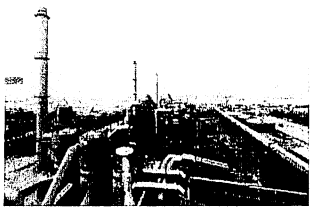


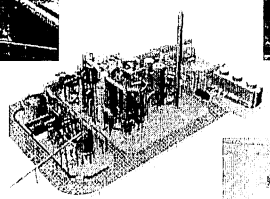
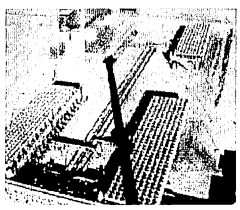
Free Gas Flow Area through Irrigation System
65 to 75 %

Outotec
More out of ore

Outotec
More out of ore

Infrastructure



- Sulfur storage area
- Desalination, demineralization
- Offices/buildings
- Cooling area

Outotec
More out of ore

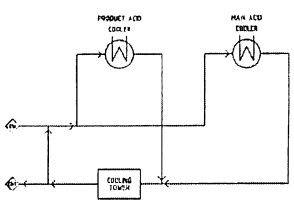
Cooling area concepts

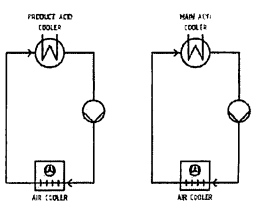
- Cooling tower
  - + Investment & operation cost, low temperature level
  - - Make-up water requirement, cooling water quality

  Operation Cost: depending on make-up water
- Sea/river water
  - + Availability, low temperature level,
  - - Potential environmental impact, water quality (chlorine, bio fouling, etc.),

  Operating cost: depending on local conditions
- Air Cooler (Fin Fan Coolers)
  - + No environmental impact, good operability, no fouling on water side, no make-up water, flexibility to temperature fluctuations
  - - High temperature level, operation cost

  Operating cost: depending on required temperature





Outotec
More out of ore

Outotec
More out of ore

Heat recovery from intermediate absorber

Approx. 40 % of the total chemical energy is evolved in drying and absorption operation, approx. 25 % in intermediate absorption tower (IAT)

Heat available in IAT (and normally sent to the cooling system)

1,900 MJ/tonne acid (~500,000 kcal/t)

Typical acid temperature level 70 ... 120 ° C

Waste heat can be used for:

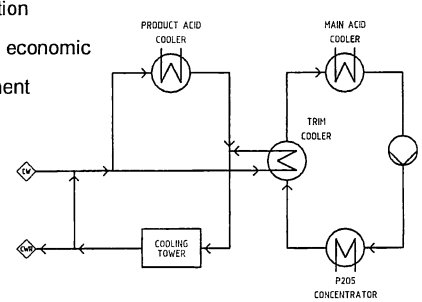
Hot Water Preparation or LP Steam Production

Outotec
More out of ore

Hot water preparation

General Considerations

+ decent acid temperatures, minor modification of process flow diagram simple operation, economic
- required: back-up cooling system, permanent consumption of hot water, max. 100 ° C water temperature



Application (typical):

- P_2O_5-concentration, solvent heating
- Boiler feed water pre-heating
- Potable water production (multiple stage distillation of sea water)

Outotec
More out of ore

Outotec
More out of ore

LP steam production

Considerations:

- Temperature: Requires acid temperatures beyond 200 ° C
- LP Steam Use: Requires continuous LP-steam demand (back-up system)
- Corrosion: Has potential for rapid material loss, esp in presence of impurities
- Safety: Operation with concentrated acid and boiling water !
- Availability: Failure of hot circuit must not lead to plant shutdown !
- Operators: Skilled operators required
- Maintenance: Instrumentation is vital

Production figures:

- LP steam production ~ 0.4 t/t acid (5...10 bar saturated)
- Can boost HP steam production in sulphur burning plants up to ~1.45 t/t acid, using proprietary patented process

Target: balancing operational risk and heat recovery options!

Outotec
More out of ore

Revised figures – Hot water preparation

	Amount	Conditions	Remarks
Power	1300 kW		Clean Plant
Sulphur	10.3 t/h		2.5 % humidity
LP-Steam	8.5 t/h	sat.,8 bar (g)	For S-melting unit
Process Water	6 m^3/h	20 ° C	For process use
Boiler Feed Water	40 t/h	105 ° C	
Cooling Water	1,900 m^3/h	33 ° C	For main & product acid cooler
OPTION – HOT Water preparation:			
→ Cooling Water	80 m^3/h	33 ° C	For product acid cooler
Hot water	260 m^3/h	95 ° C	**21 MW for heating purposes**

Outotec
More out of ore

Outotec
More out of ore

Conclusion

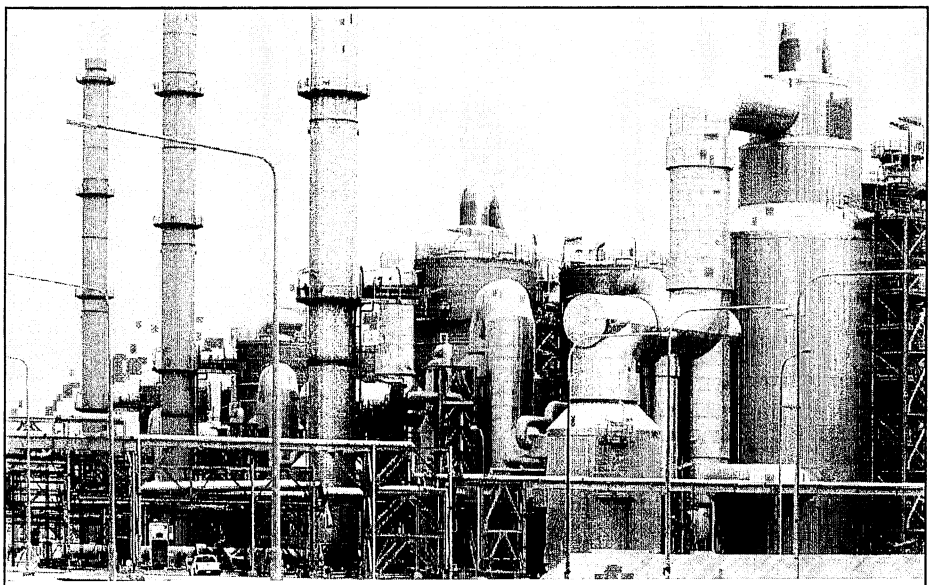
Efficiency of a plant component/(sub)system impacts your overall plant economics

Careful design/new development can improve the efficiency/ economics of the plant component/(sub)system, however not neccessarily the overall plant efficiency/economics

Don't isolate component performance from the efficiency of the (sub)system/overall plant

To achieve optimized plant efficiency you need to understand/analyze your entire process/operation

Outotec
More out of ore



Thank you for your attention ...

Outotec
More out of ore