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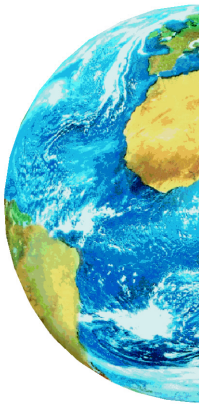
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Maximizing cogeneration
Minimizing steam consumption
System design

Factory energy balances

Steffen Kaufmann, Hans Cramer
BMA - Germany



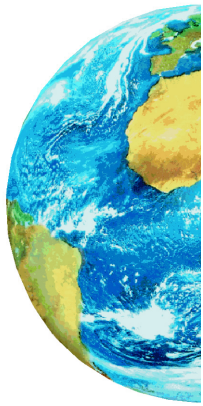
ISSCT factory workshop 2011

Gold Coast - Australia

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Total steam consumption in not optimized cane sugar mills:

- ***Total steam consumption includes evaporation station, vacuum pans and juice heating***
- ***In most cases total steam consumption lies between 40 and 60 %o.c.***
- ***Minimum process steam usage using present technology of 30 to 35 %o.c. can be reached***
- ***Minimizing process steam consumption leads to a surplus of bagasse, that can be sold as a byproduct or burned for more electrical power production***

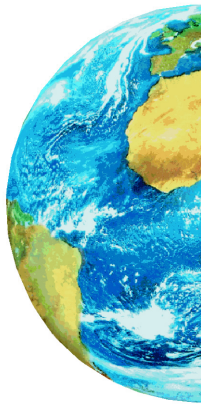


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Example of a cane sugar mill in Central America:

- ***Operational parameters:***

  Crashing rate = 6.000 TCD
  Sucrose in cane = 12 %
  Fiber in cane = 12,6 %
  Mill tandem including 5 x mills
  5 x effect evaporation station including Robert evaporators
  Syrup Bx = 62 %
  No vapor bleeding from the evaporation effects 4 and 5
  Crystallization in batch pans (plantation white sugar)
  Only VP 1 for sugar house



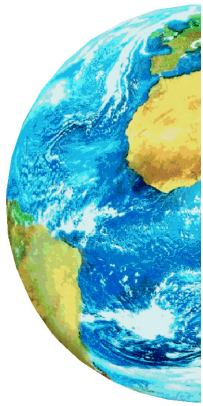
- ***Process steam consumption:***

  Process steam consumption = 51 %o.c.

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Ways to reduce process steam consumption:

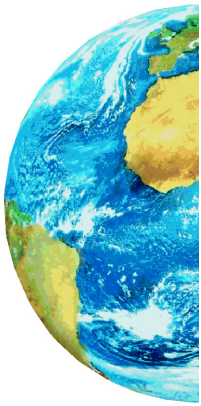
- ***Diffuser technology + recycling of clarifier underflow to diffuser***
- ***Multiple effect evaporation with falling film evaporators ➔ 5 x effects instead of 4 x effects***
- ***Maximum juice concentration in multiple effect evaporation ➔ Syrup Bx = 72 % instead of 65 %***
- ***Crystallization in continuous pans and upgrading of batch pans for crystal seed with installation of agitators improve circulation of massecuite***
- ***Increase bleed vapor temperatures to switch vapor consumers to final evaporator effects***



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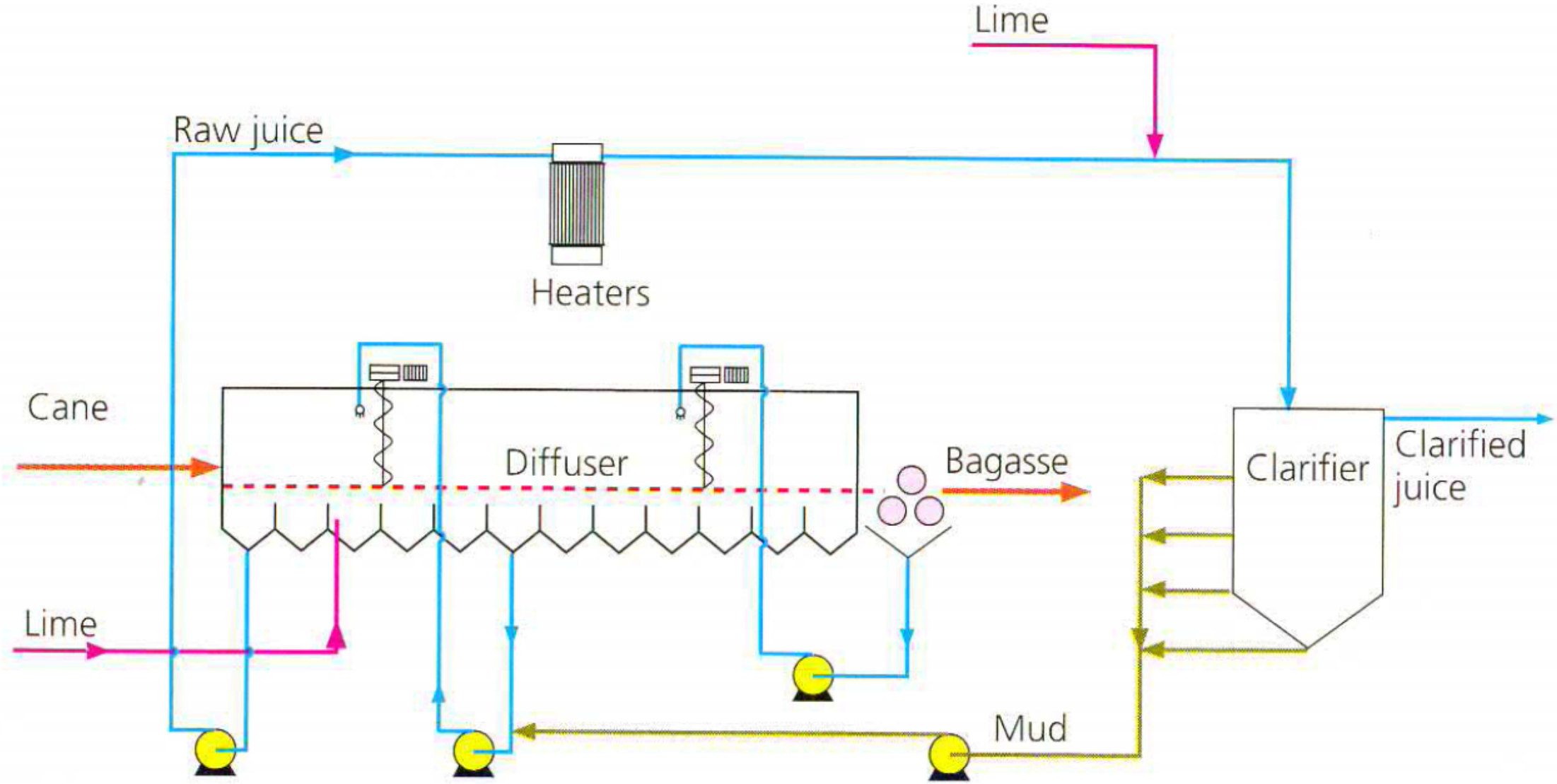
Ways to reduce process steam consumption:

- ***Bleeding of vapor 3 and vapor 2 for pans and heaters instead of vapor 1 and exhaust steam***
- ***Stepwise heating of juices***
- ***Utilization of heat from condensate and low-pressure vapor for raw juice heating***
- ***Stepwise flashing of condensate and reuse of flash vapors***
- ***Fully electrified drives for knives, shredders and mills (no steam turbines – lower efficiency)***



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Diffuser + recycling of clarifier underflow:



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Diffuser + recycling of clarifier underflow:

- ***The return of mud to the diffuser has significant advantages:***

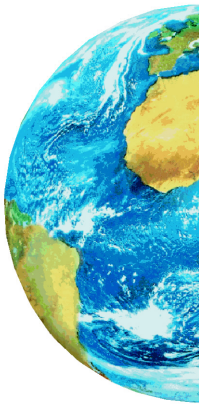
  Filter station is no longer necessary

  Loss of sugar in cake is eliminated

  Water washing of cake is obviated, reducing evaporation requirements

  Equipment for bagacillo and cake conveying is not required

  The bagasse supply to the boiler is increased (approx. 2 %o.c.) ➔ more steam production (approx. 4,5 %o.c.)



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Evaporation plant with falling film evaporators:

- ***The number of effects in an evaporator station is limited through the given pressure and temperature difference between exhaust steam and vapor of the last effect and from the necessary pressure difference in each effect.***

- ***4 x effects***
  vacuum evaporation
  (Robert Evaporators)

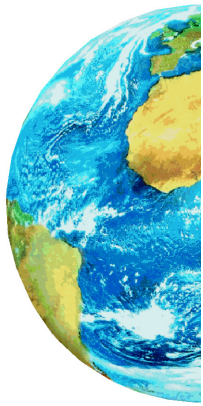
  Exhaust steam: 2,0 bar

  Effect 1: 1,5 bar(a)
  Effect 2: 1,1 bar(a)
  Effect 3: 0,8 bar(a)
  Effect 4: 0,3 bar(a)

  5 x effects
  vacuum/pressure evaporation
  (Falling-Film Evaporators)

  Exhaust steam: 2,4 bar

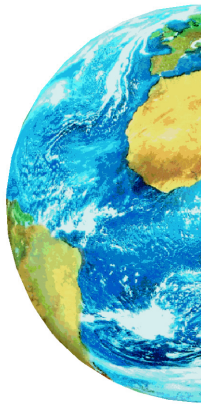
  Effect 1: 2,0 bar(a)
  Effect 2: 1,6 bar(a)
  Effect 3: 1,3 bar(a)
  Effect 4: 1,0 bar(a)
  Effect 5: 0,6 bar(a)



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Evaporation plant with falling film evaporators:

- ***Independence of hydrodynamic and heat transfer***
- ***High heat transfer coefficients ➔ small temperature and pressure drops in each evaporation effect***
- ***Low retention time ➔ limited color formation and sucrose hydrolysis***
- ***Temperature difference in a evaporation plant can be changed form 120 - 70 °C to 125 – 90 °C ➔ possible bleeding of vapor from the last effects***

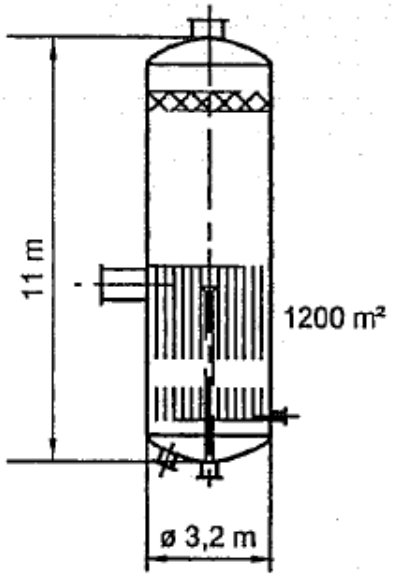


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Roberts evaporators vs. Falling film evaporators:

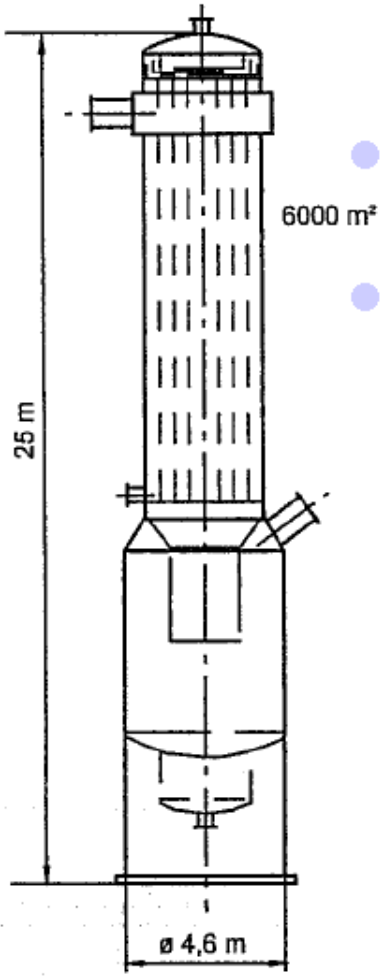
Roberts evaporator

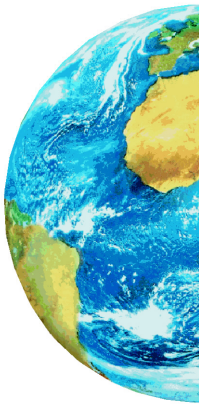
- max. heating surface area approx. 2000 m² per unit
- high juice volume
- minimum temperature difference required



Falling film evaporator

- heating surface area up to 8000 m² possible per unit
- low juice volume
- heat transfer coefficient independent from temperature difference





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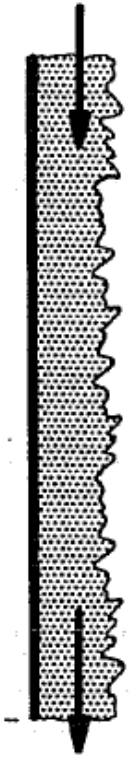
Roberts evaporators vs. Falling film evaporators:

Evaporation tube at Roberts evaporator

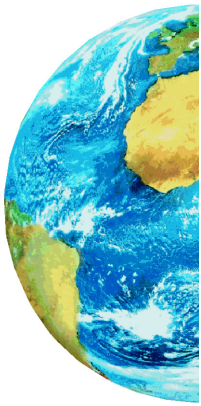


- upper part: bubble column
- at entrance (lower part): laminar flow
- upper part with bubbles: turbulence
- high efficiency only at high production rate of bubbles
  high temperature difference necessary (> 10 K)
- bad k-value at elevated juice concentration

Evaporation tube at falling film evaporator



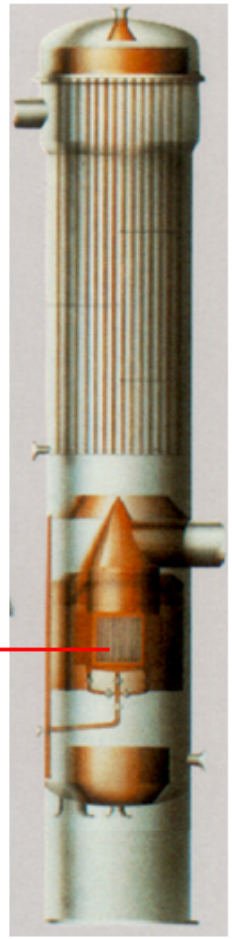
- thin layer of juice on heating surface
- turbulent flow of juice
- high efficiency of heat transfer (k-value) also at low temperature differences (3 - 5 K)
- high k-value also at high juice concentration



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Tubular Falling-Film Evaporator:

- ***Top dome with juice distributor***
- ***Heating chamber***
- ***Vapour chest***
- ***Entrainment separator***
- ***Juice chamber***
- ***Support section***



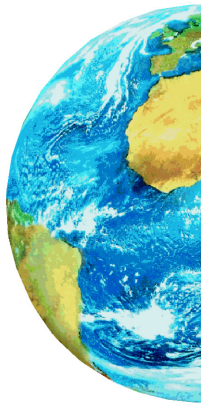
- ***Nozzles***
  - circulation in
  - steam in
  - condensate out
  - vapour out
  - juice feed
  - circulation out
  - concentrate out

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Example of an optimized cane sugar mill in Asia:

- ***Operational parameters:***

  Crashing rate = 7.000 TCD
  Sucrose in cane = 15 %
  Fiber in cane = 14,2 %
  Mill tandem including 4 x mills
  5 x effect evaporation station including Falling film evaporators
  Syrup Bx = 72 %
  Vapor bleeding from evaporator 5 for raw juice heating
  Crystallization in continuous pans (plantation white sugar)
  VP 2 and VP 3 for sugar house



- ***Process steam consumption:***

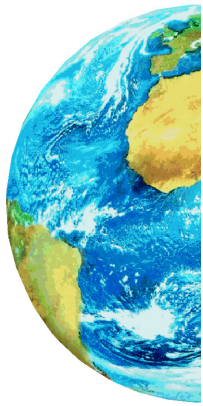
  Process steam consumption = 33 %o.c.

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Minimizing process steam consumption:

- ***Minimizing process steam consumption by using present technology is possible***

- ***New investments are usually necessary:***
  - Diffuser
  - Falling film evaporators
  - Wide gap Plate heat exchangers
  - High automation standard



- ***Process steam consumption in cane sugar mills of 30 to 35 %o.c. is nowadays a realistic target***

- ***Decreasing process steam consumption enables more electrical power production***

- ***The surplus an electrical power produced depends from boiler pressure and specific steam consumption of the turbine***

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Influence of process steam consumption on cogeneration:

- ***Example:***

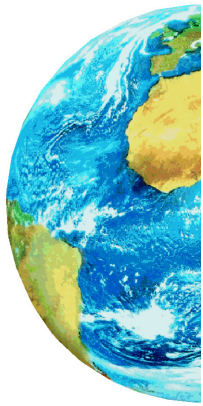
  High pressure boiler (65 bar, 510 °C)

  Condensation turbine with a specific steam consumption of 4 kg/kWh

- ***Decreasing process steam consumption by 1 %o.c. ➔ Increasing electrical power production by 2,5 kWh/t cane***

  Crashing capacity = 6.000 TCD

  Decreasing process steam production by 15 %o.c. (from 50 %o.c. to 35 %o.c.)



- ***Surplus electrical power of 6,25 MW***

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