ROBERT EVAPORATORS

The Good, the Bad and the Ugly

By

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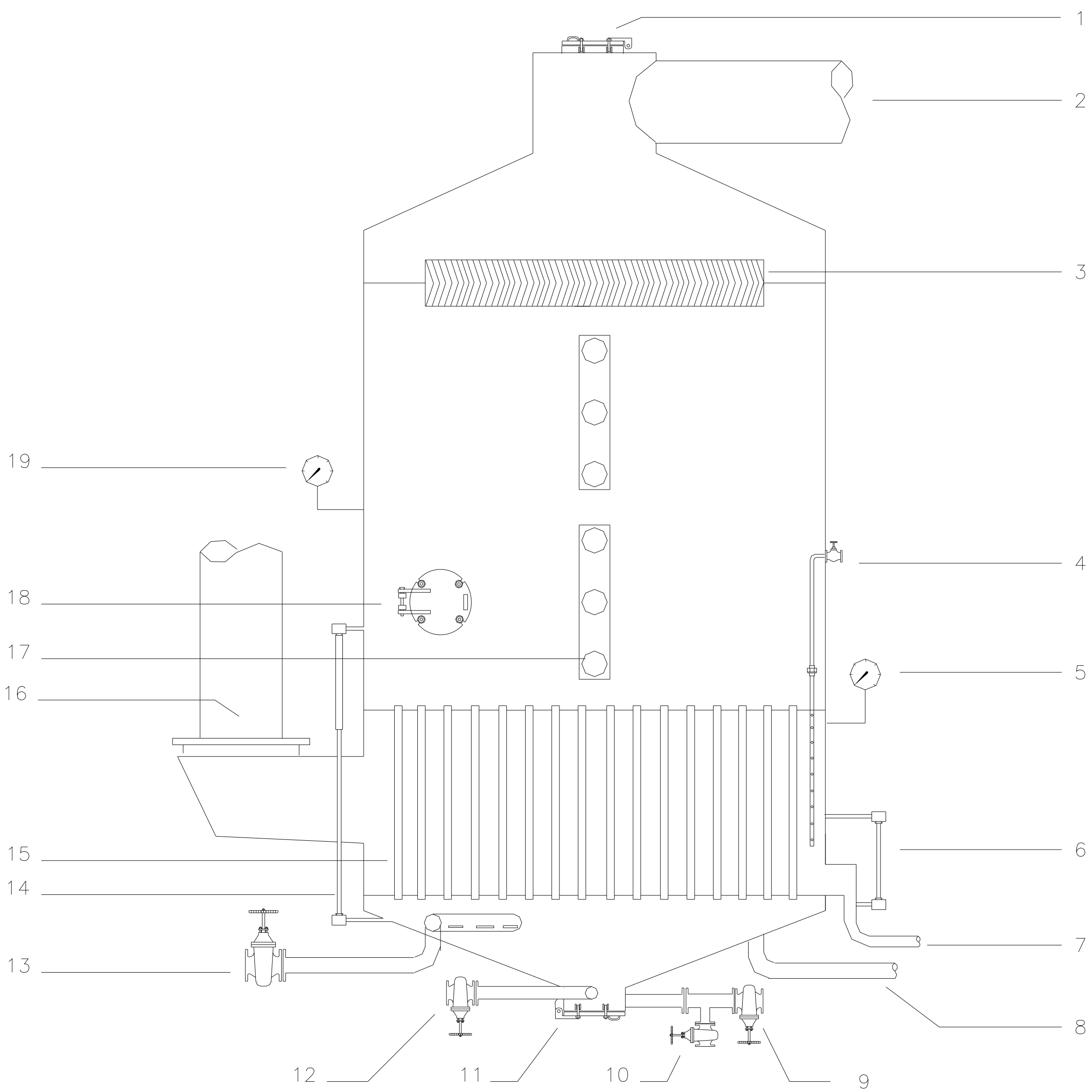
Robert rising film tube evaporator



1 Top Access Door
2 Vapour Pipe
3 Entrainment Baffle
4 Noxious Gas Outlet
5 Calandria Pressure Gauge
6 Condensate Level Gauge
7 Condensate Outlet Pipe
8 Juice Outlet
9 Water Service
10 Drain
11 Bottom Access Door
12 Caustic Service
13 Juice Inlet
14 Static Juice Level Gauge Glass
15 Calandria
16 Steam/Vapour Inlet
17 Sight Glasses
18 Evaporator Body Access Door
19 Body Pressure/Vacuum Gauge

So many variations in design (1)

- Steam entry
  - Single or dual entry onto tube bundle at periphery
  - Single or dual entry onto outer annulus
  - Into centre of calandria
  - With or without steam lanes
- Condensate removal
  - At periphery
  - At centre
- Incondensible gas removal
  - Several off takes around calandria
  - At end of defined steam path
  - Through top tube plate; through side wall

So many variations in design (2)

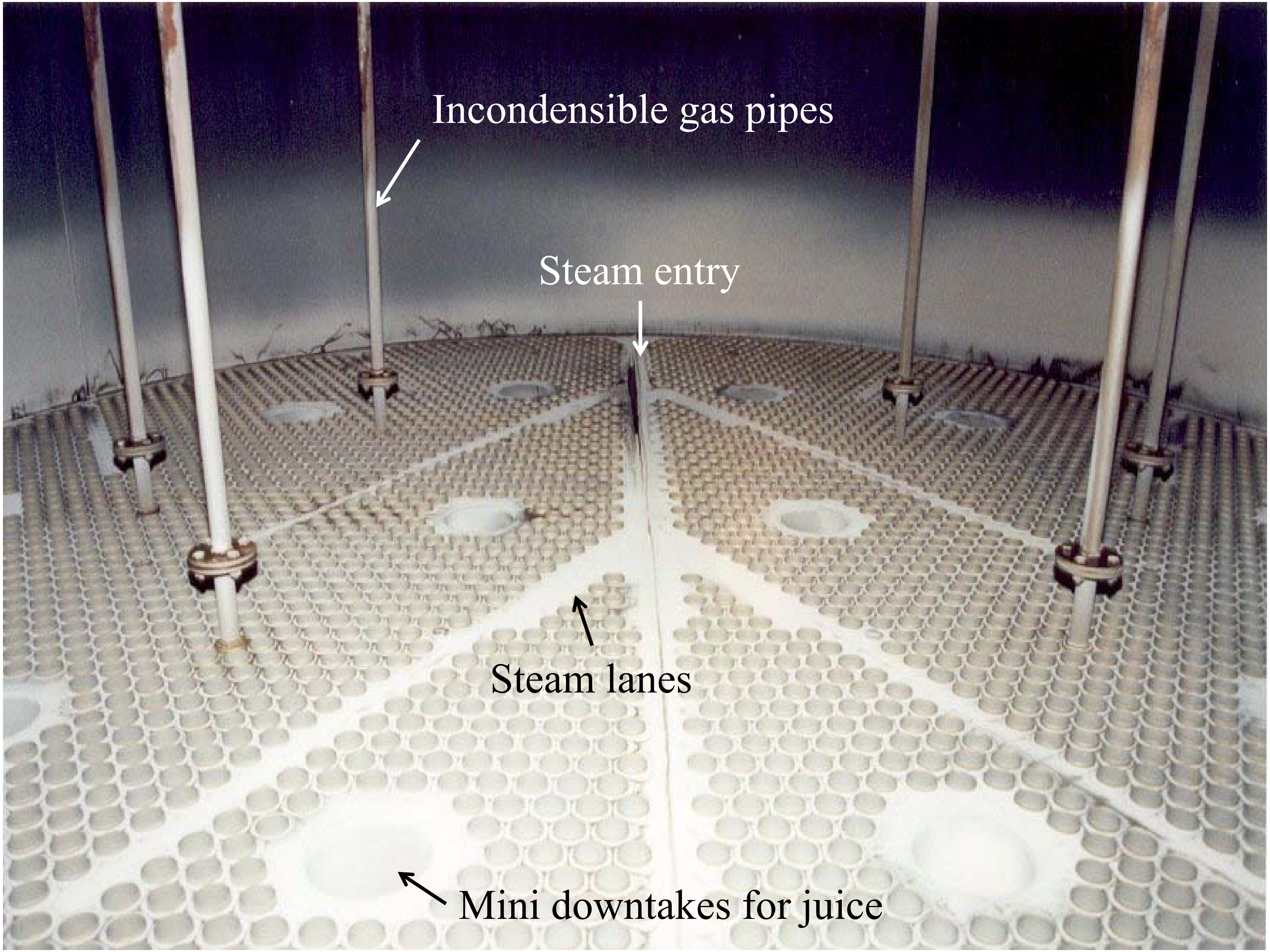
- Juice entry
  - All underneath (rising film)
  - Single entry (capped)
  - Multiple entry (tubes with holes)
- Juice flow within the vessel
  - Full basket calandria (all downflow of juice is via the heating tubes)
  - Use mini downtakes

So many variations in design (3)

- Juice outflow
  - From underside of calandria (single or multiple)
  - Via a central downtake (mostly semi-sealed)
  - Via peripheral offtake gutter(s) above the top tube plate

Robert evaporators are basically ‘home’ designed

VERY ROBUST DESIGN

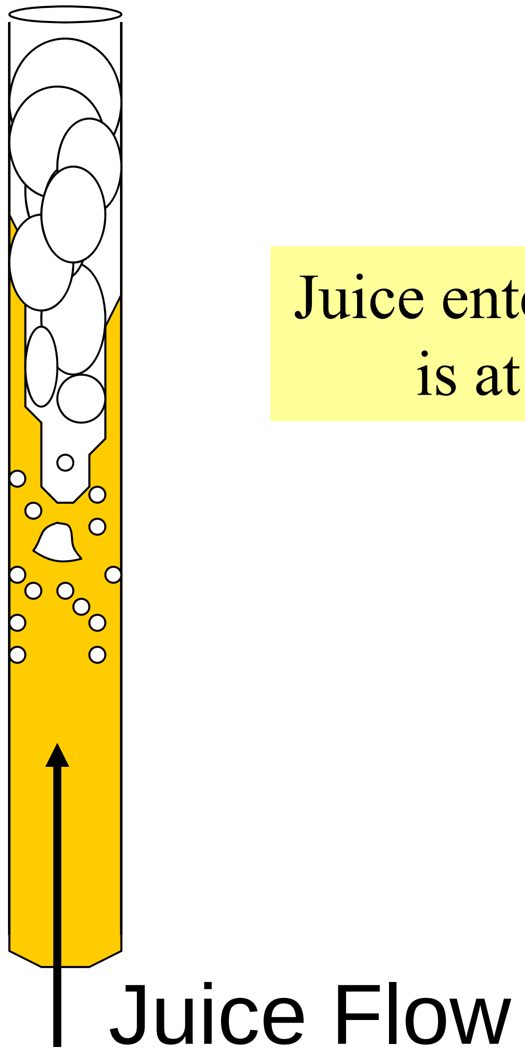


Incondensible gas pipes
Steam entry
Steam lanes
Mini downtakes for juice

Boiling action in a tube

ΔT = Vapour temperature
- Juice boiling temperature

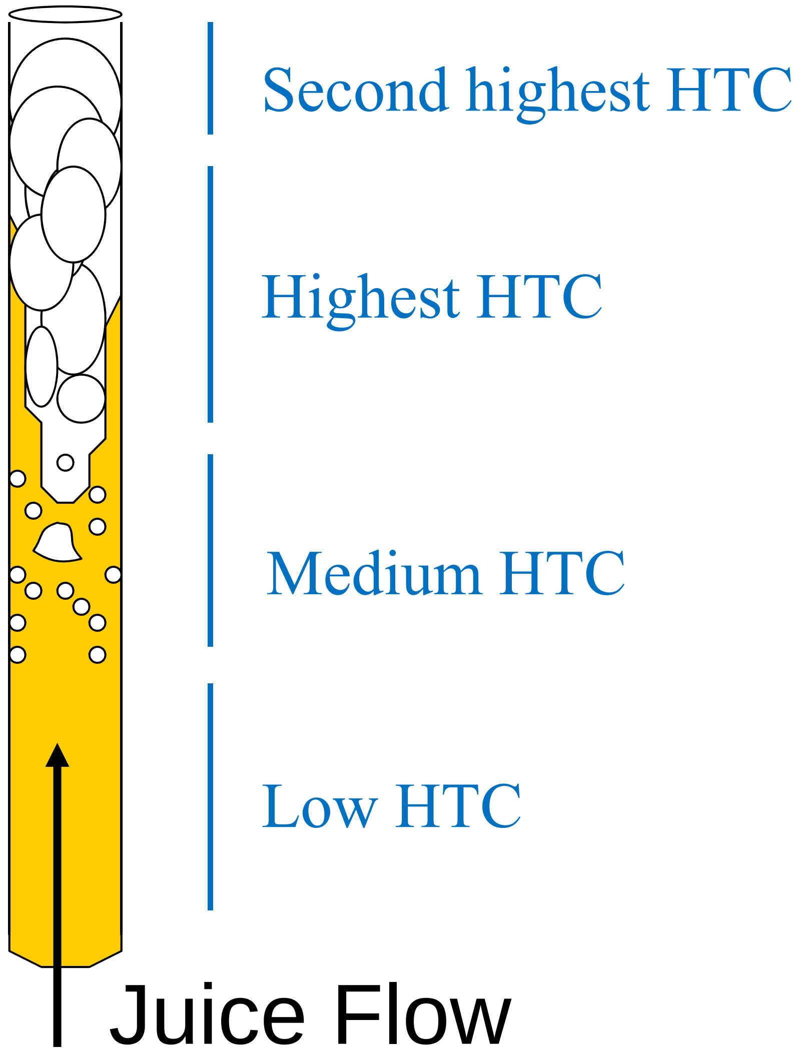
Juice boiling temp =
Head space
saturation temp + BPE +
Temp rise due to
hydrostatic head



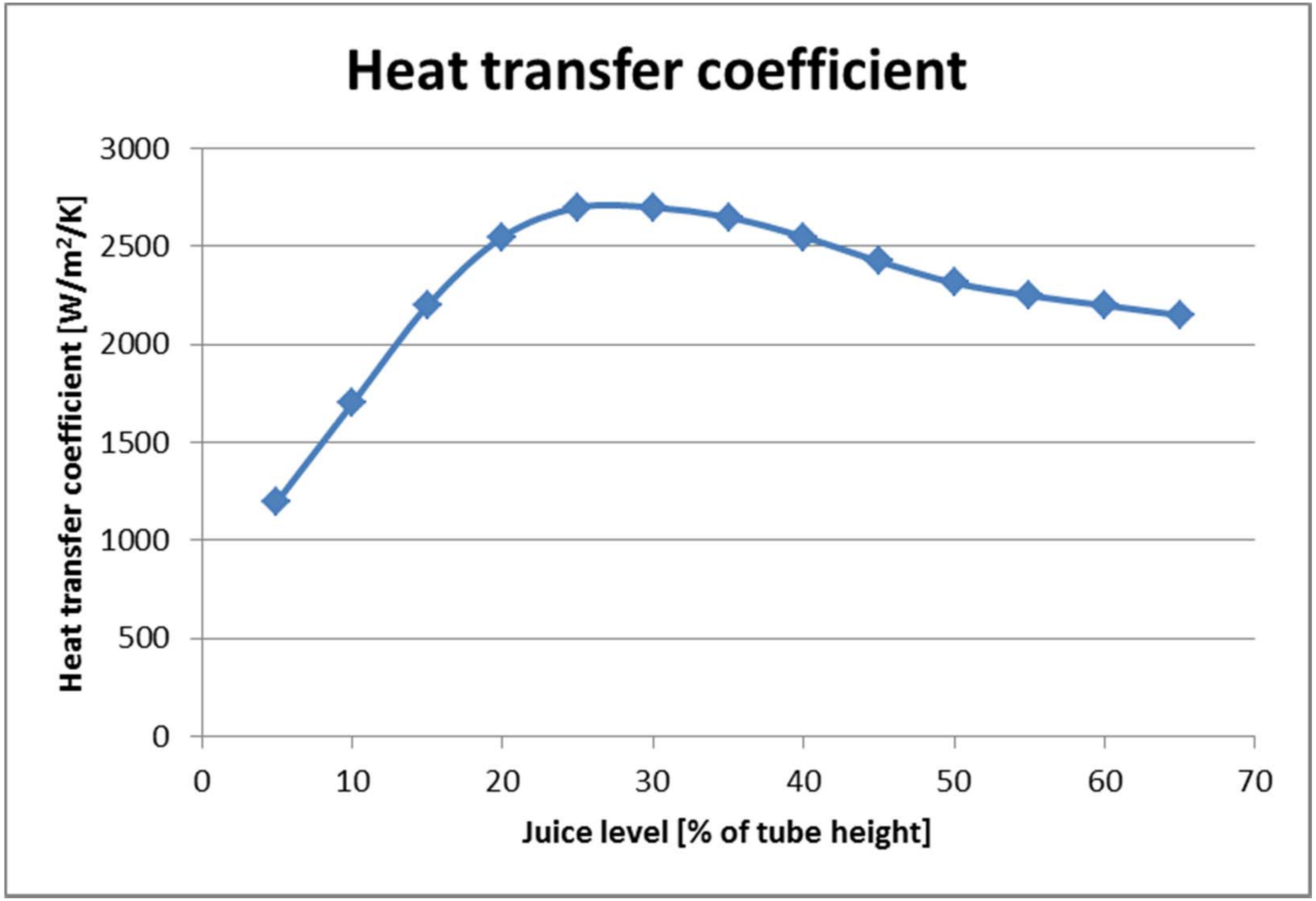
Juice entering base of tubes
is at the outlet brix

Boiling action in a tube

Optimum juice level exists



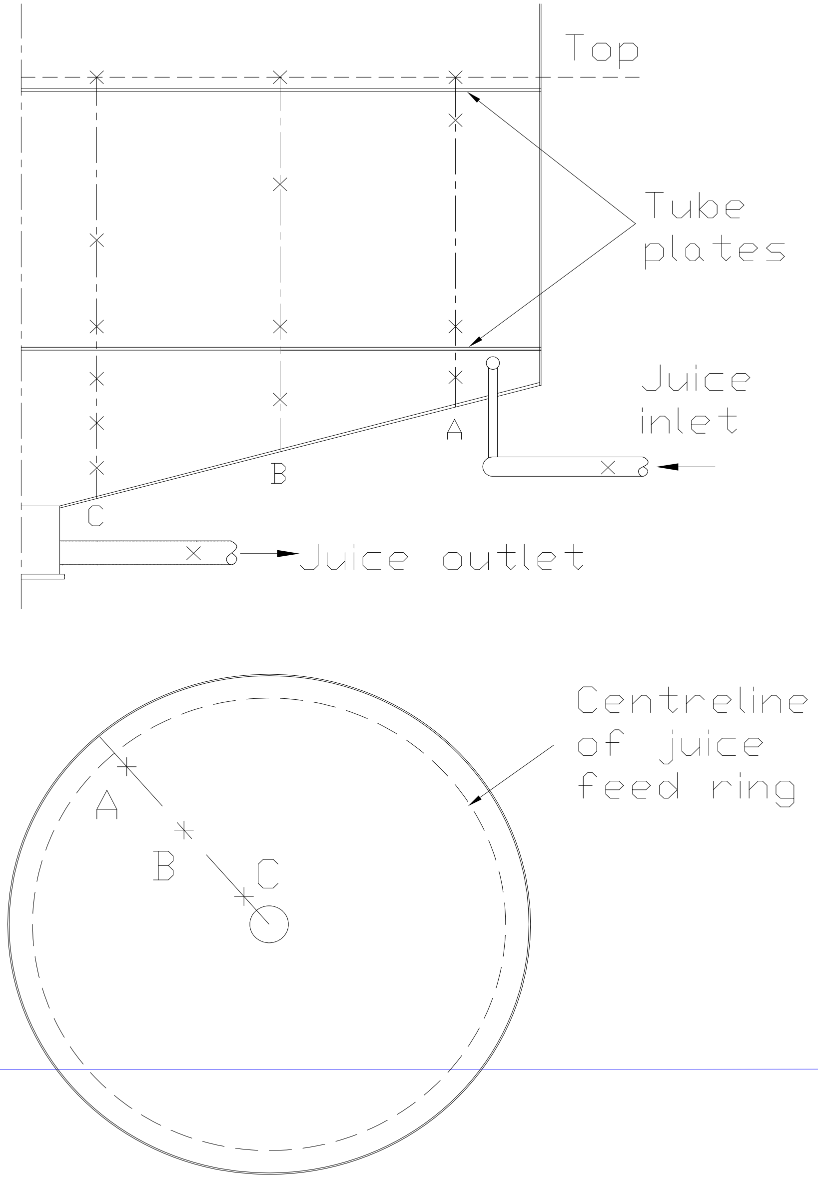
Optimum juice level exists
Example for first effect



Typical ideal juice levels for good heat transfer efficiency

Vessel number	Typical static operating levels
1	30-35%
2	30-35%
3	35-40%
4	35-40%
5	45%

Juice sampling trials in Robert evaporators



Tully #4 vessel

Full basket calandria

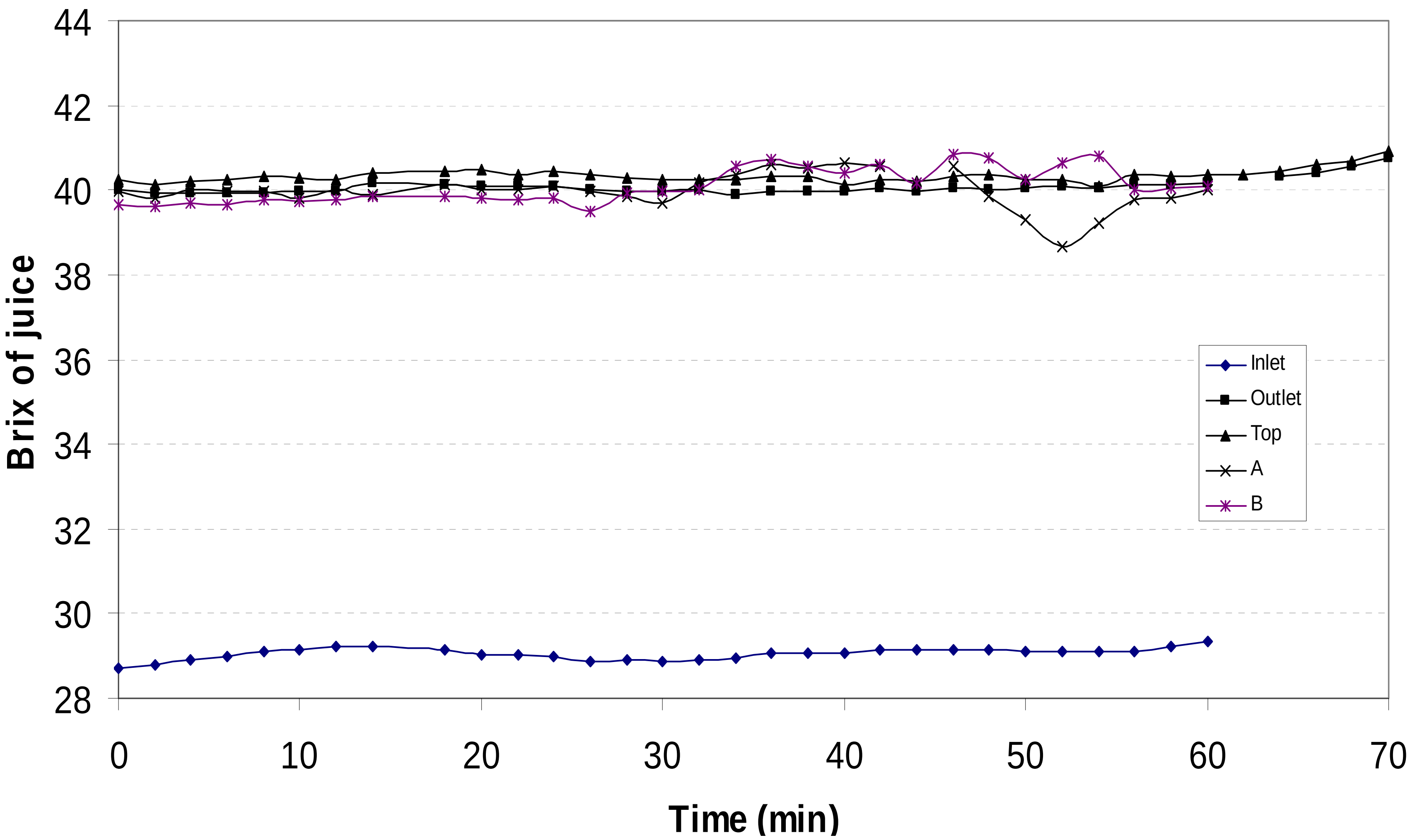
Five sampling pumps

Cool extracted juice

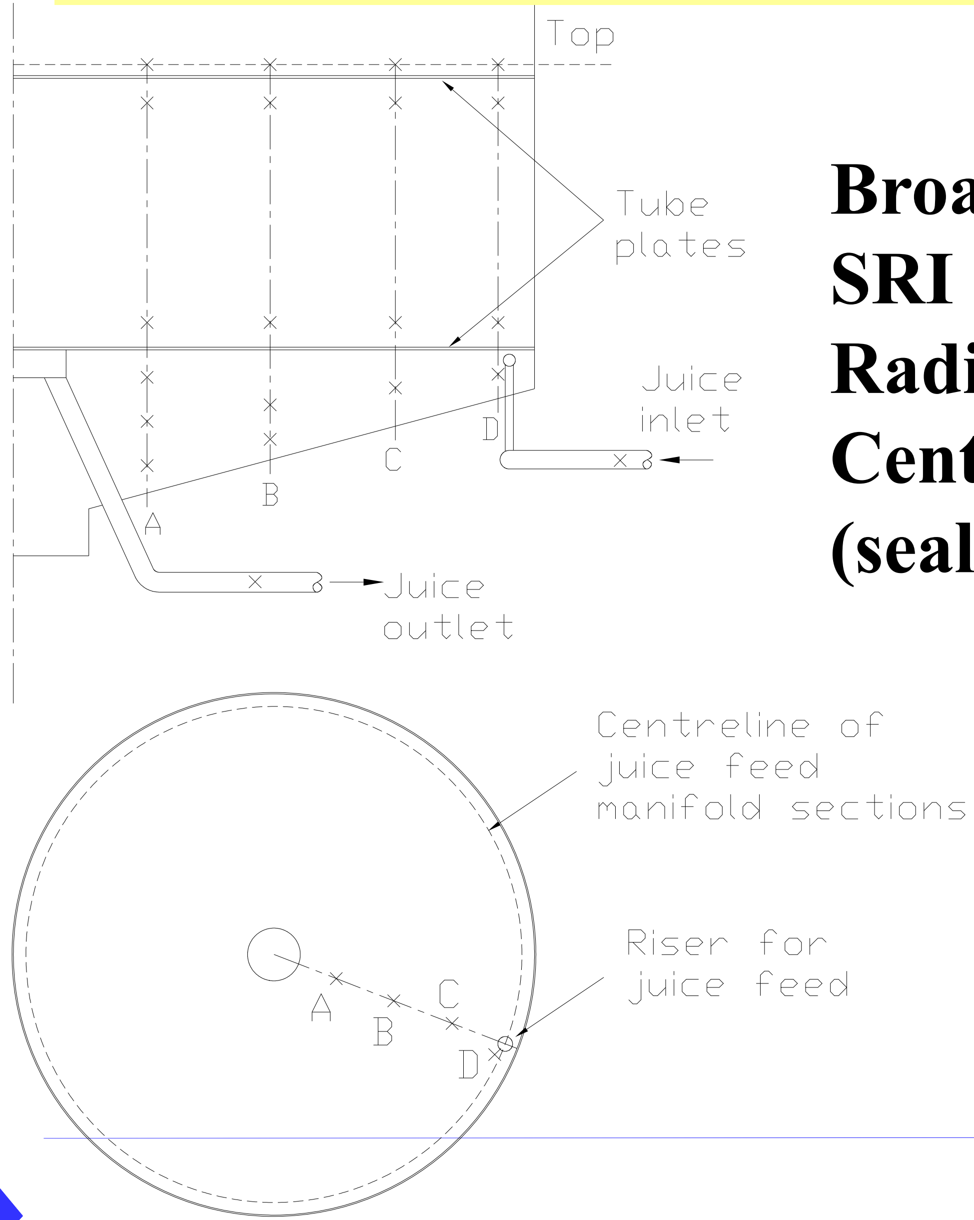
Collect sample every 2 minutes for 60 to 70 minutes

Analyse for refrac. brix

Results for Tully #4 evaporator
Juice brix throughout vessel is at the outlet brix

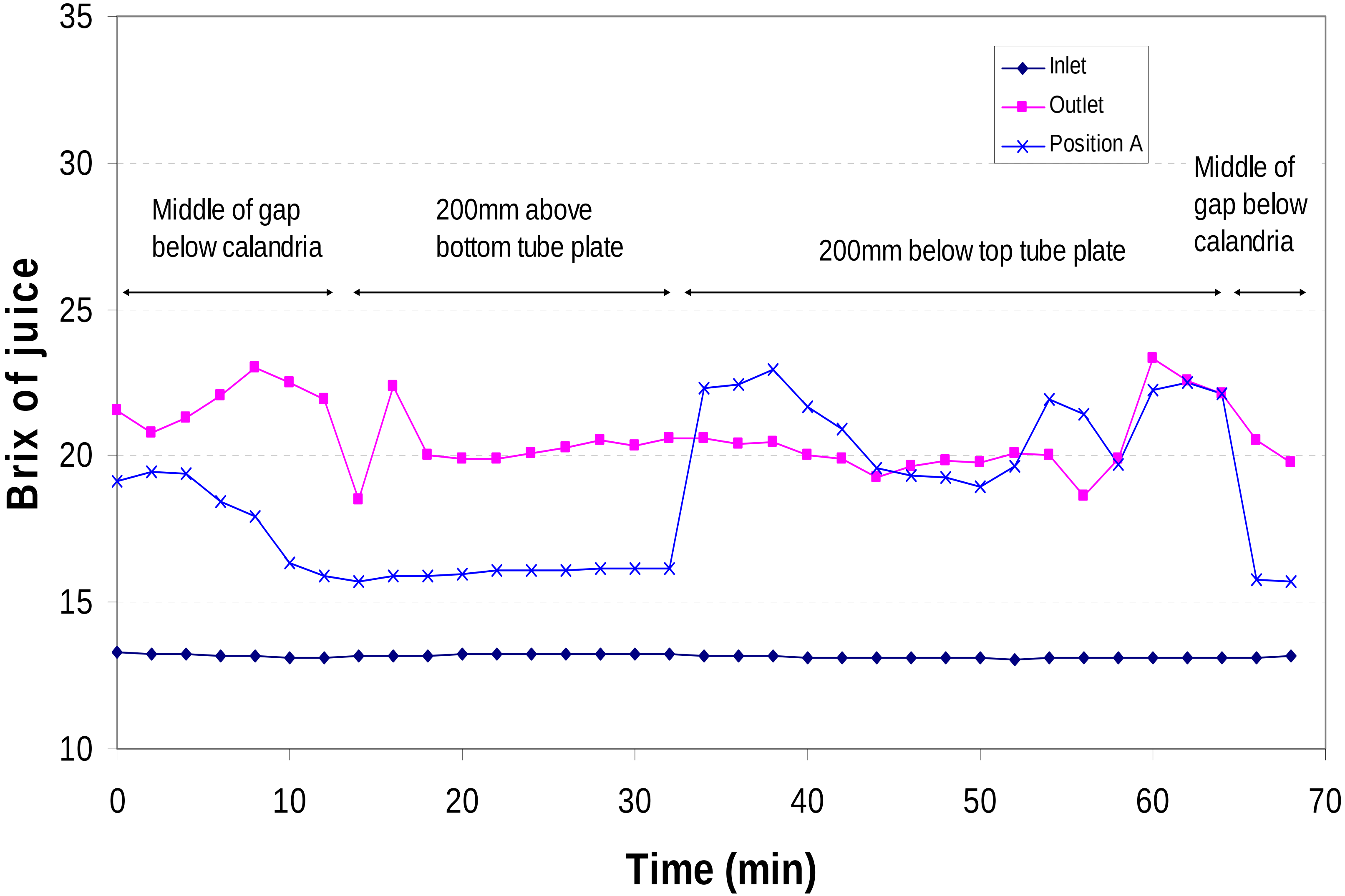


Juice sampling in SRI Robert evaporator



Broadwater #1 evaporator
SRI design evaporator
Radial steam flow
Central juice downtake (sealed type)

Sampling at position A Broadwater #1
Juice below calandria is at intermediate brix



Tube data

- Diameters:

  38, 44 and 50 mm

- Lengths

  1.8 to 4 metres

- Material

  - Stainless steel (304); brass, carbon steel

Properties of effect position

Position	HTC $W.m^{-2}.K^{-1}$	Brix %	BPE °C	Temp. °C		Pressure kPa (g)
Steam				121		104
1	3000	20	0.5	113	8	57
2	2500	24	0.6	106	7	24
3	2000	31	0.8	95	11	-16
4	1500	42	1.4	80	15	-54
5	600	68	4.3	54	26	-86

Good HTC but large temperature difference at tail end

Temperature difference (ΔT) of vapour

- Temperature difference of vapour is sum of three components
  - Actual driving force for heat transfer
  - Boiling point elevation
  - Effect of hydrostatic head on juice at the base of the tube. In 3 m long tube:-
    - **1 °C at first vessel**
    - **10 °C at final vessel**

Need minimum ΔT actual

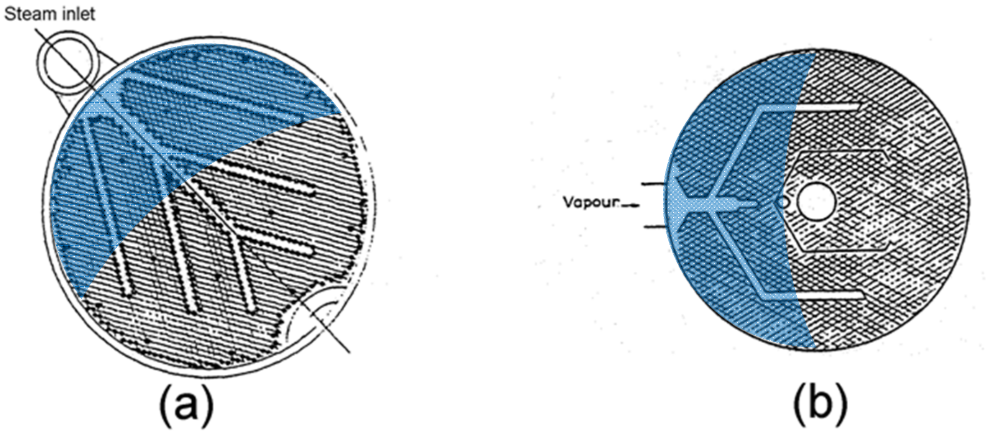
for fully wetted rising film boiling

For 2 m tube

Number	Min ΔT actual, °C
1	5
2	5
3	6
4	8
5	11

What if low vapour rate passes to a Robert evaporator?

Low vapour condensation coefficient (vcc; kg/h/m²)



Regions of poor mixing and overconcentration. Problems for the final vessel if target syrup brix is 70⁺

Need greater than a certain minimum vcc to guarantee wetting and good mixing through the vessel

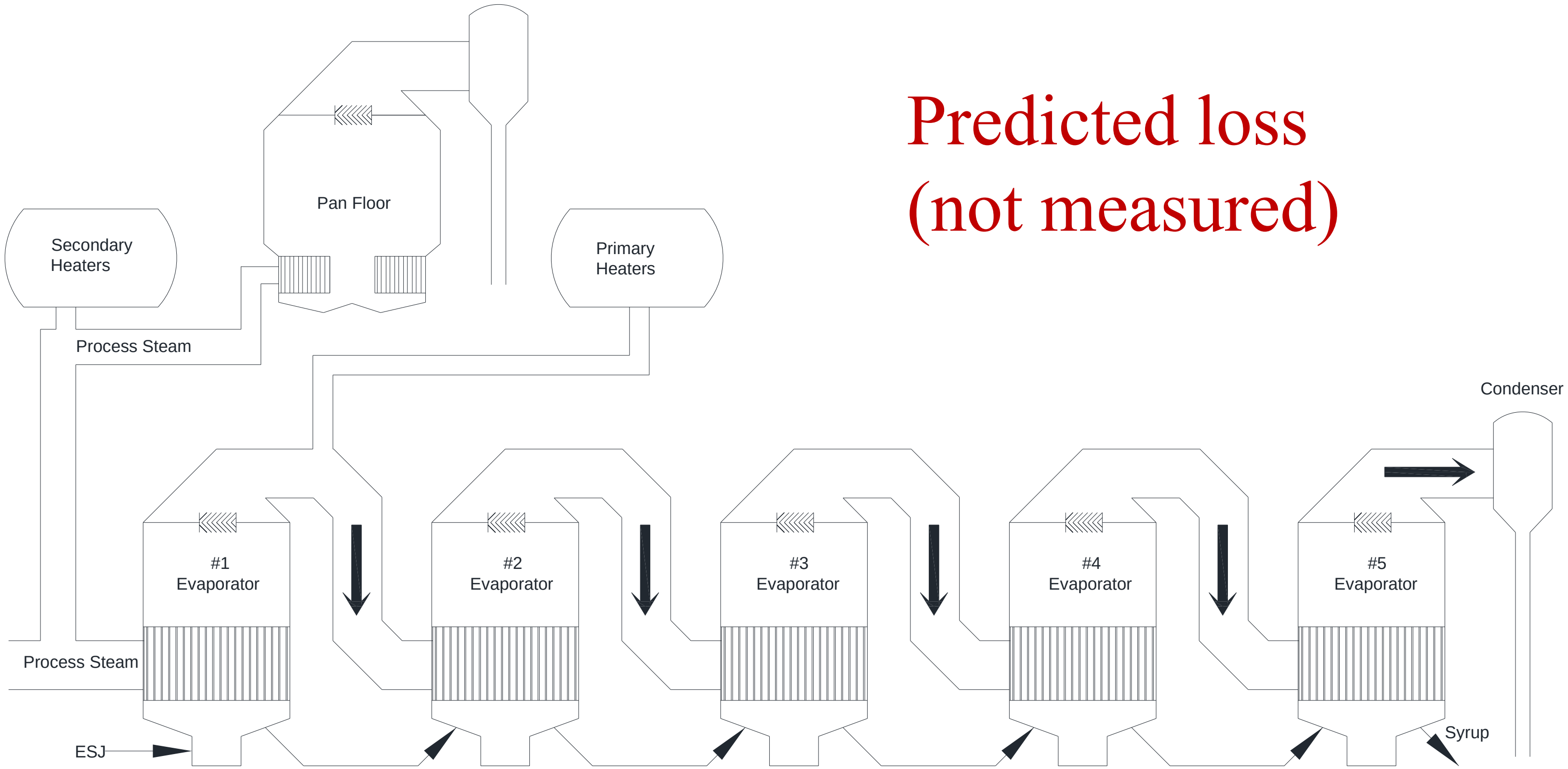
Sucrose losses (1)

- Entrainment of juice droplets
  - Robert design is good
    - Ample height to disengage droplets
    - Sufficient area to install louvres/centrifugal separator

Sucrose losses (2)

- Inversion losses
  - Function of temp, brix, pH and residence time
  - Highest losses early in set
  - Typical Robert evap 8 to 10 L/m^2 of HSA
  - Steam efficient evaporator sets have more area (and residence time) early in the set
  - Longer tubes of smaller diameter provide lower juice volume per m^2 of HSA ($\rightarrow$ 7 L/m^2)

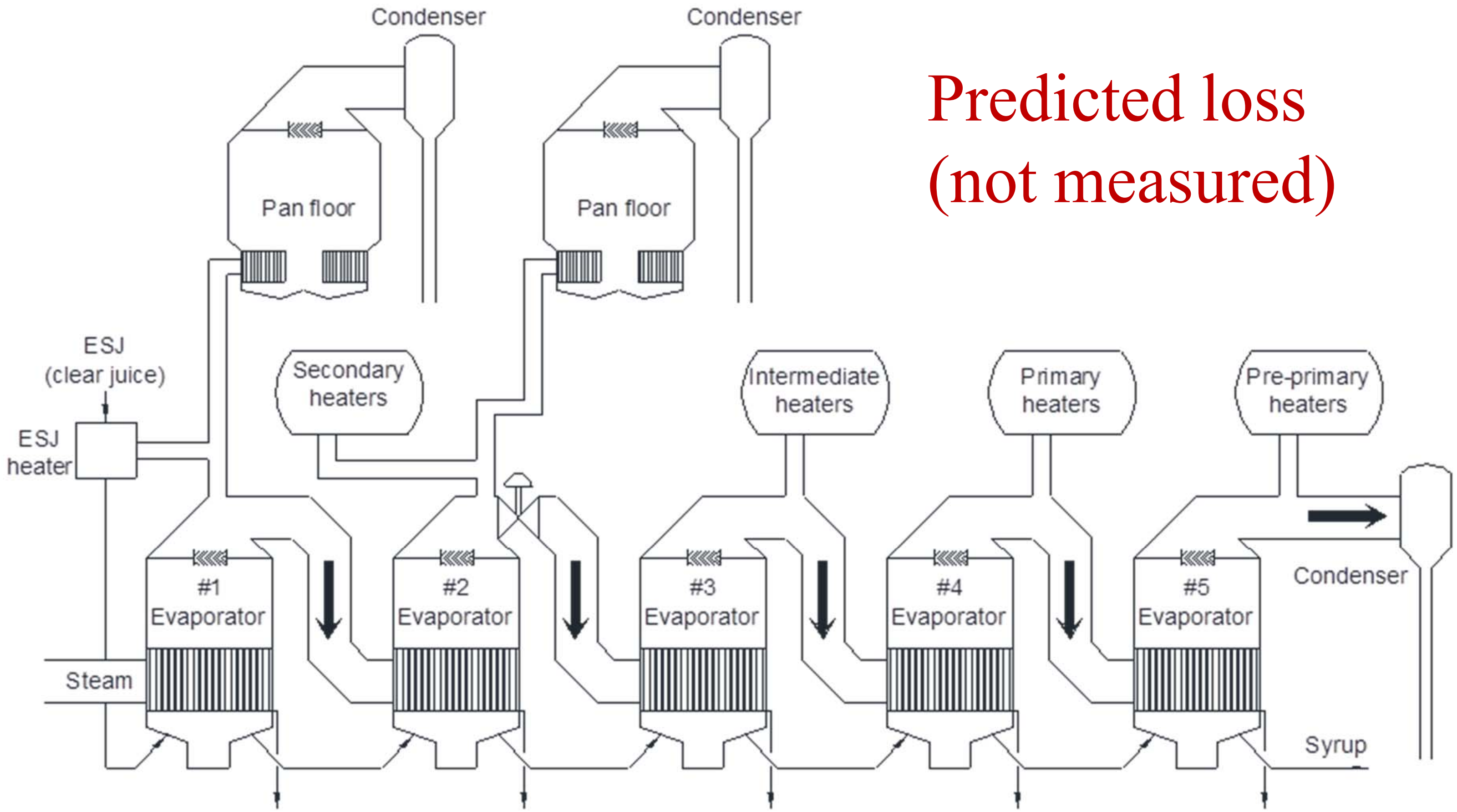
Example of factory with low process steam efficiency



Predicted loss
(not measured)

Time, min	5.0	4.4	5.8	8.5	19.5	∑ 43.2
Suc loss %	0.07	0.03	0.01	0.003	0.0002	∑ 0.11

Example of factory for high process steam efficiency



Predicted loss
(not measured)

Time, min	10.0	15.6	7.4	7.3	6.9	∑ 47.2
Suc loss%	0.25	0.15	0.02	0.003	0.0002	∑ 0.42

Summary for Robert evaporators

Advantages:

- Simple design
- Robust design
- Easy access to all sections for repair, hydraulic or mechanical cleaning
- Well suited to chemical cleaning
- Good heat transfer performance
- Good opportunity for de-entrainment of juice
- No pumps required to transfer juice
- Simple control can work well

Summary for Robert evaporators

Disadvantages:

- Needs minimum vapour rate (vcc) and temperature difference for effective operation
- Large minimum temperature difference for the final vessel (hydrostatic head and rising film)

$\rightarrow$ reduces capacity of the set

- Long residence time (so potentially large sucrose losses through inversion) Magnitude of losses uncertain? Problem likely to be greater for steam efficient configurations

Discussion