DESIGNING CONTINUOUS PANS FOR LOW ENERGY CONSUMPTION

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For the Processing Section of this Workshop, presentations were called for on 4 topics. Two of these were:

- Pan design
- Energy utilisation

DOES PAN ENERGY MATTER?

From Energy Balance for the Ubombo 500 TCH Mill (excluding irrigation, co-gen & refinery):

Power (Cane prep, Extraction, Factory)	16%
Pans (batch and continuous)	30%
Other process heating & evaporation	54%
Total	100%

Pan usage is high because boiling is in single effect & condensing

HOW CAN CVP DESIGN SAVE ENERGY?

For energy-efficiency, must design CVPs to be able to:

1. Maximise the proportion of crystallisation done in continuous (vs. batch) pans
2. Operate on low grade vapours – i.e. at low ΔTs
3. Operate without mechanical stirrers
4. Maximise A and B pan exhaustions in order to minimise the overall amount of pan boiling
5. Produce uniform-sized crystals, to minimise re-boiling sucrose lost in centrifugation and affination
6. Operate with long intervals between CVP boil-outs
7. Possibly use vapour recompression

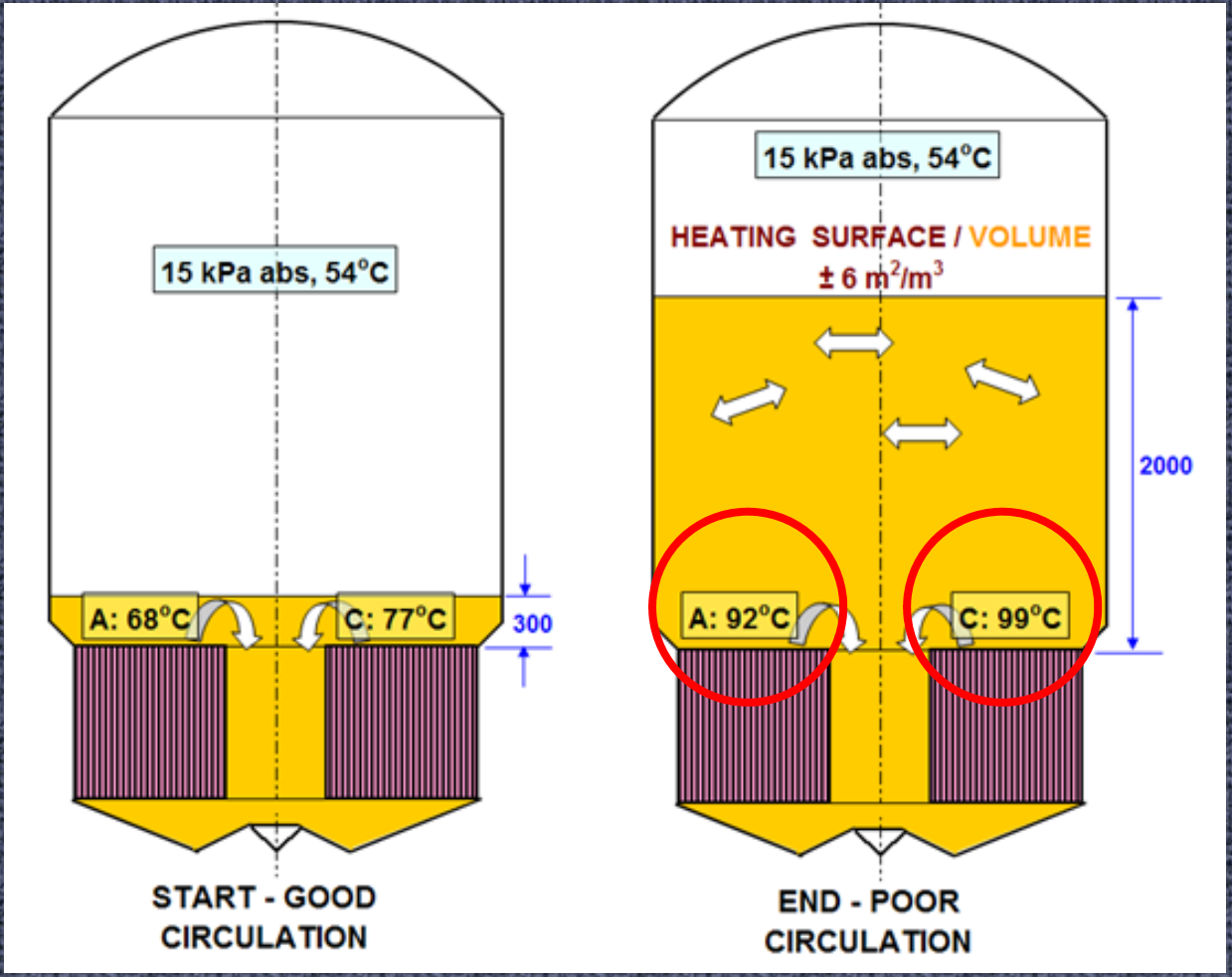
1. Design pan to -

MAXIMISE THE PROPORTION OF BOILING DONE IN CVPs

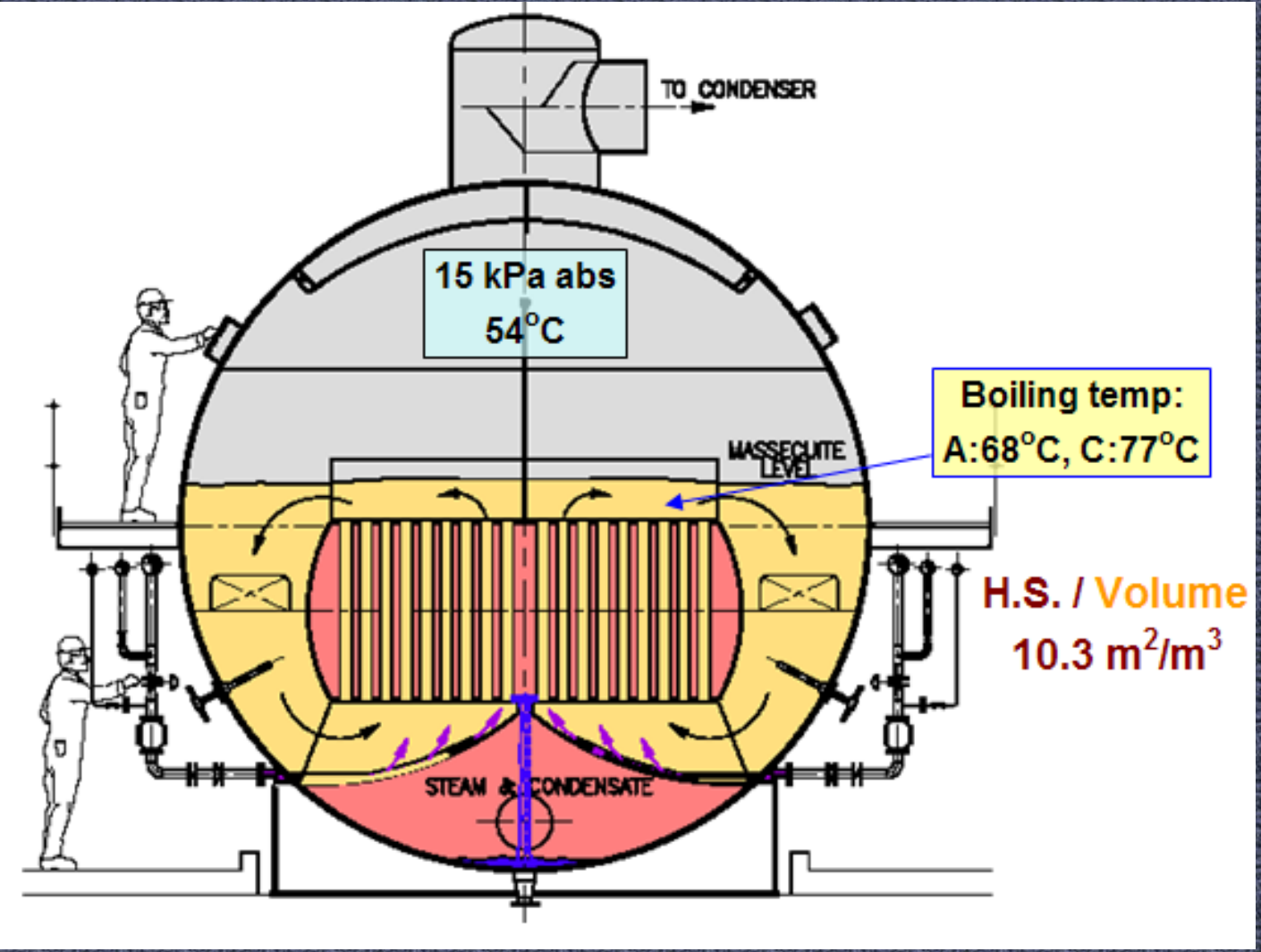
CVPs use less energy than batch because:

- Steam demand is steady, with few stops
- No wasteful steaming out between boilings
- No breaking / re-establishing of vacuum
- Can use lower vapour grades

BATCH PANS' HIGH HEADS = HIGH BOILING POINTS:



CVPS' LOW HEADS = LOWER VAPOUR GRADES:



TO MAXIMISE THE BOILING IN CVPs:

Batch pans are needed for seed boilings (graining or conditioning magma)

Usually transfer to continuous when crystals at 60%-65% of desired size, leaving crystal size ratio of ± 1.6 for the CVP

But ***can*** switch much earlier, as soon as clean crystal population is established, leaving ratio of 2.0 or more for CVP ***- provided that the CVP has good plug flow characteristics*** (will return to this point)

2. Design pan to -

OPERATE ON LOW GRADE VAPOUR (i.e. AT LOW ΔTs)

Vapour 1 (V1) has already evaporated ± its own mass of water in the evaporators, V2 twice its mass and V3 three times its mass. Lower grade vapours therefore use less total energy.

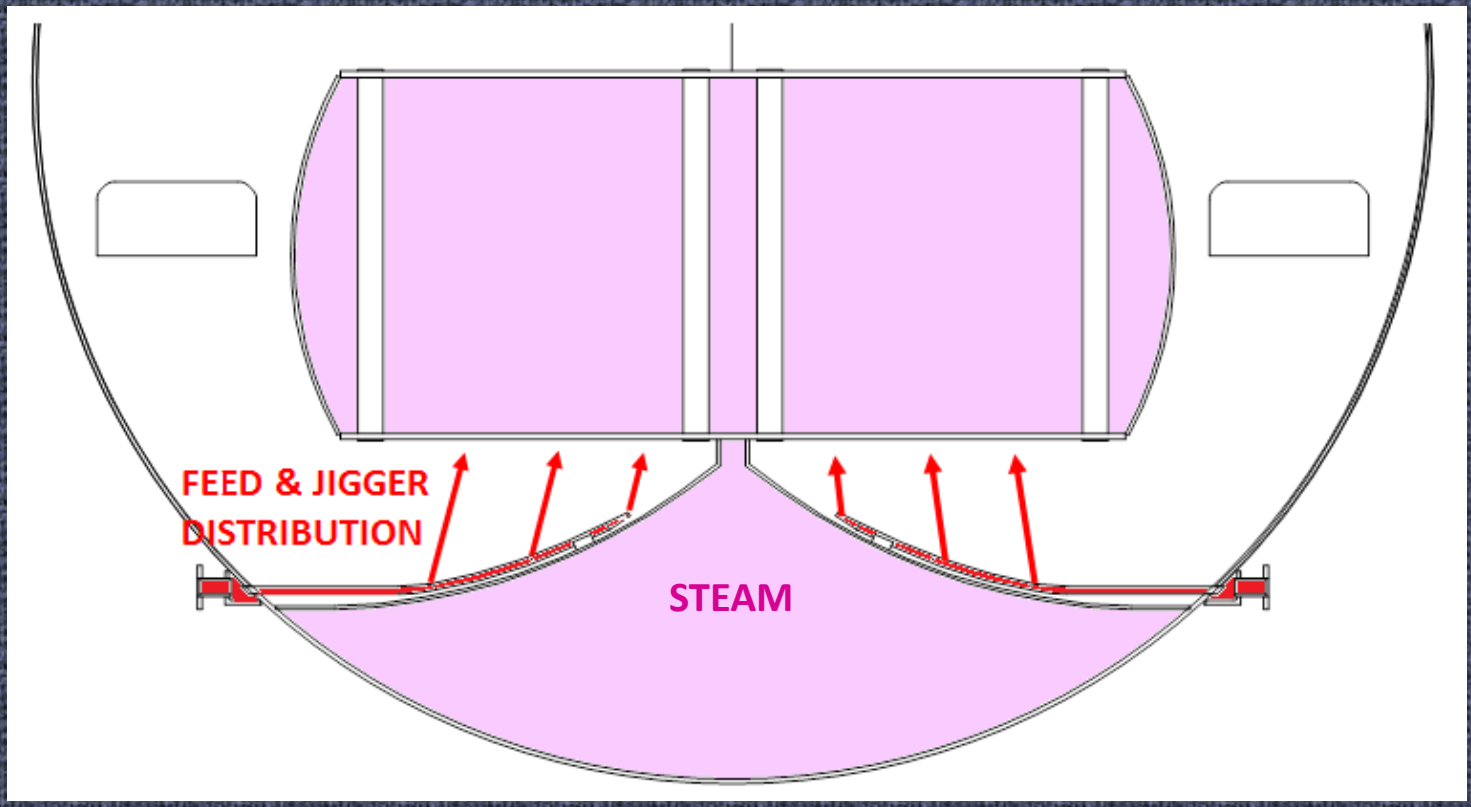
Pan boiling pressure is usually fixed by the condensers and/or process wishes.

Low pressure vapour operation therefore requires low ΔTs and high HTCs.

FOR HIGH HTCs & LOW ΔTs, BOSCH USES:

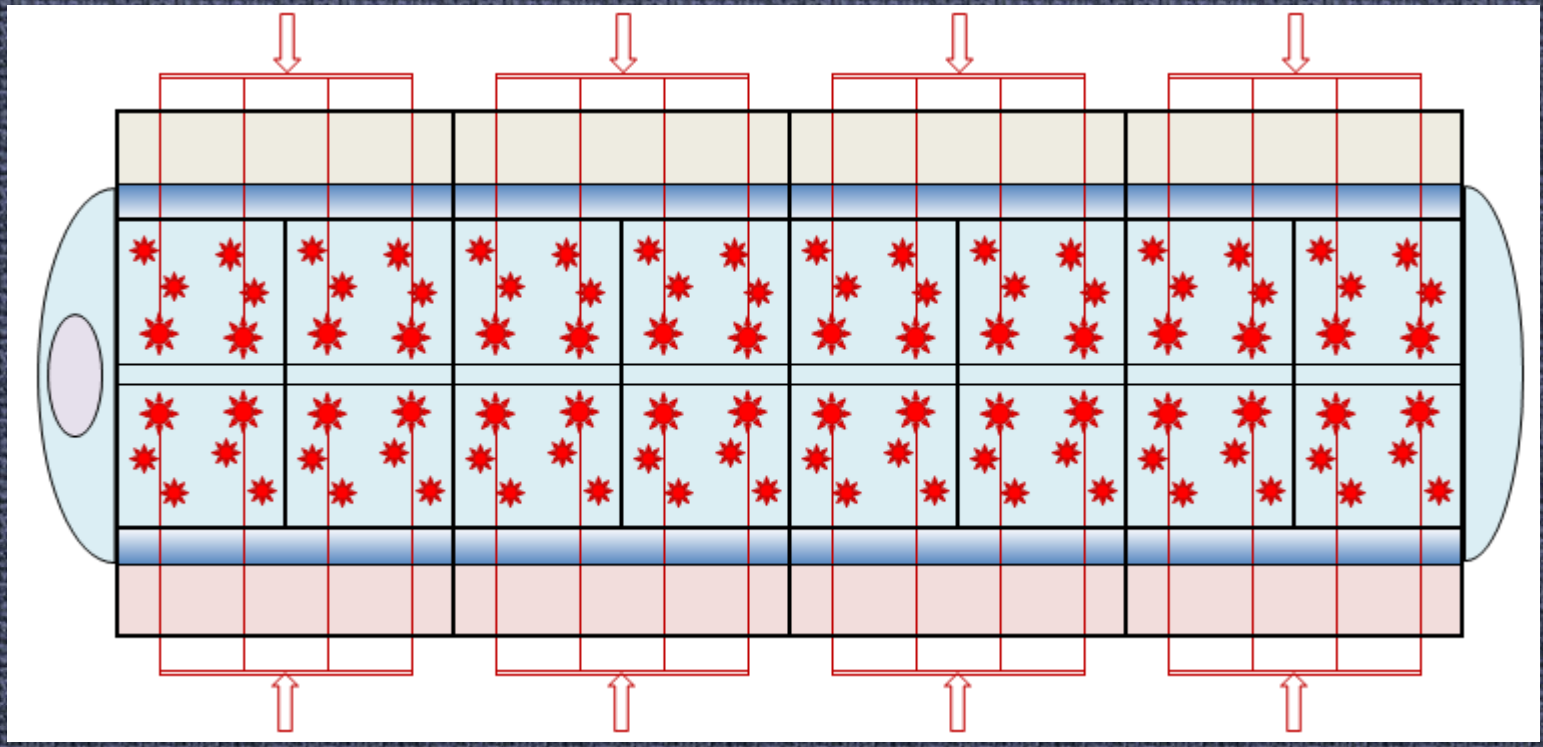
- Under-base heating from steam / condensate chamber
- Vertical boiling tubes within a good circulation profile
- Injecting flashing syrup/molasses feed and incondensable gas jiggers into the massecuite below the calandria

FEED & JIGGER INJECTION IN BOSCH CVPS



HEATING + FEED/JIGGER INJECTION BELOW CALANDRIA

FEED & JIGGER INJECTION IN BOSCH CVPS



USUALLY 12 INJECTION POINTS PER COMPARTMENT

USING LOW GRADE VAPOUR AT LOW ΔTs:

These features enable 'A' pans in Mauritius and Thailand to operate on V3 at supply pressures < 80 kPa abs.

'B' pan in Brazil operates with calandria pressures of 65-80 kPa abs

Bosch heat transfer coefficients are above the norms expected from CVPs:

HTCs from 11 Bosch CVPs in Mauritius, Vietnam, Thailand, Reunion and Brazil:

Pan Duty	Final Brix (°) (refractometer)	HTC ($W/m^2.K$)
A pans (7 off)	92.0 – 94.6	400 - 540
B pans (2 off)	91.6 - 95.2	330 - 440
C pans (2 off)	96.2 – 97.2	220 - 230

3. Design pan to -

AVOID ENERGY-INTENSIVE MECHANICAL STIRRERS

With their low boiling heads, CVPs with good natural circulation generally should not require supplementary stirring.

If needed (e.g. for final high-brix stages), Moor (2002) showed that incondensable gas pressure is always sufficient for this to be used to provide “free energy” jigger stirring.

4. Design pan for -

HIGH EXHAUSTIONS = ENERGY SAVING

"Exhaustion" is the proportion of total sucrose in a massecuite that is deposited onto crystals.

Higher A and B pan exhaustions (= higher crystal contents) means less sucrose left in molasses and hence less boiling to recover this sucrose.

Requirements for good exhaustions are:

- Vigorous circulation to promote sucrose deposition
- Sufficient crystal surface & residence time for this deposition
- High final brixes to reduce sucrose solubility and force sucrose out of solution

HIGH EXHAUSTIONS → ENERGY SAVING

These criteria are all met in the Bosch CVP design.
This results in high exhaustions as well as high HTCs.
From the 11 pans in the previous table:

Pan Duty	Final Brix (°) (refractometer)	HTC ($W/m^2.K$)	Pan Exhaustion (%)
A pans (7 off)	92.0 – 94.6	400 - 540	66.8 – 80.5
B pans (2 off)	91.6 - 95.2	330 - 440	71.0 – 72.5
C pans (2 off)	96.2 – 97.2	220 - 230	63.6 - 65.4

Most of these data are from normal operation, with brixes and exhaustions not optimised

5. Design pan to -

PRODUCE EVEN-SIZED CRYSTALS, TO MINIMISE RE-BOILING FROM WASHINGS

Good pan exhaustions can be undone by losses of fine crystals through screens or dissolution from excessive washing in centrifugals or affination.
Poor CVs and high % fines exacerbate these losses.

Good CVs require:

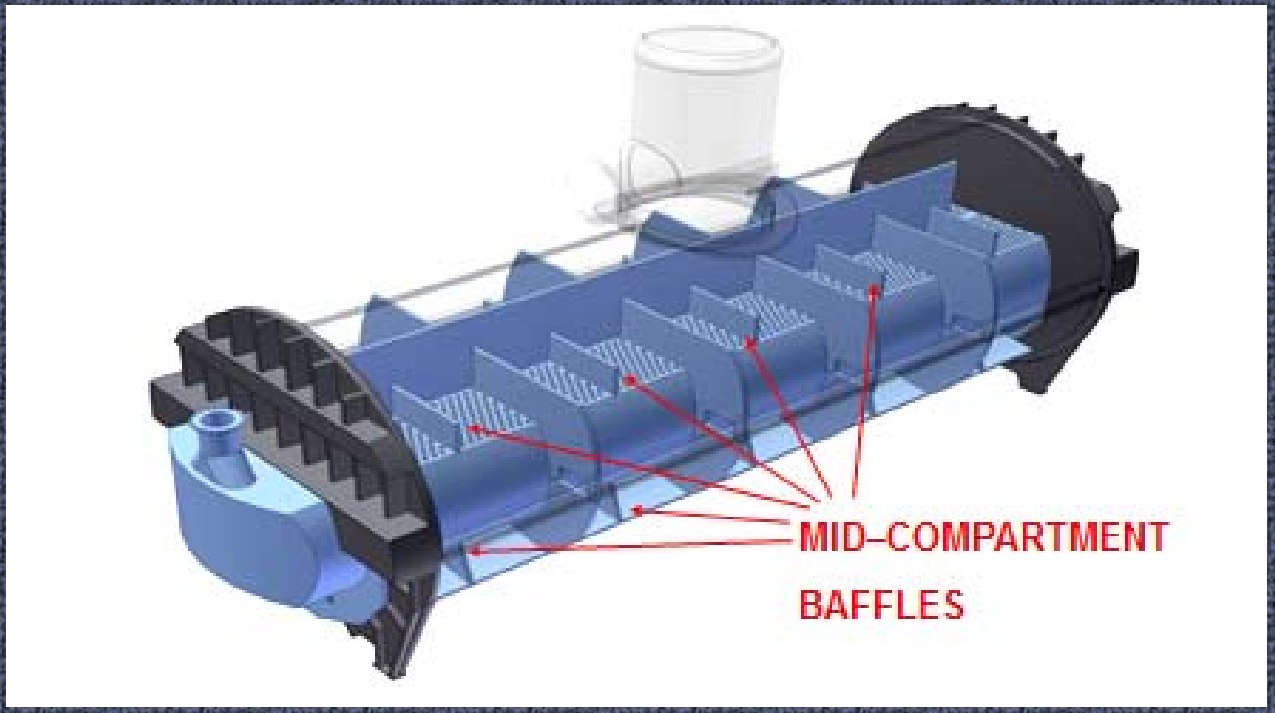
- Good seed quality
- Steady operation with good brix control
- Most importantly, plug flow (good crystal residence time distribution) through the CVP.

Plug flow is measured by tracer testing and expressed as "the equivalent number of well mixed tanks-in-series".

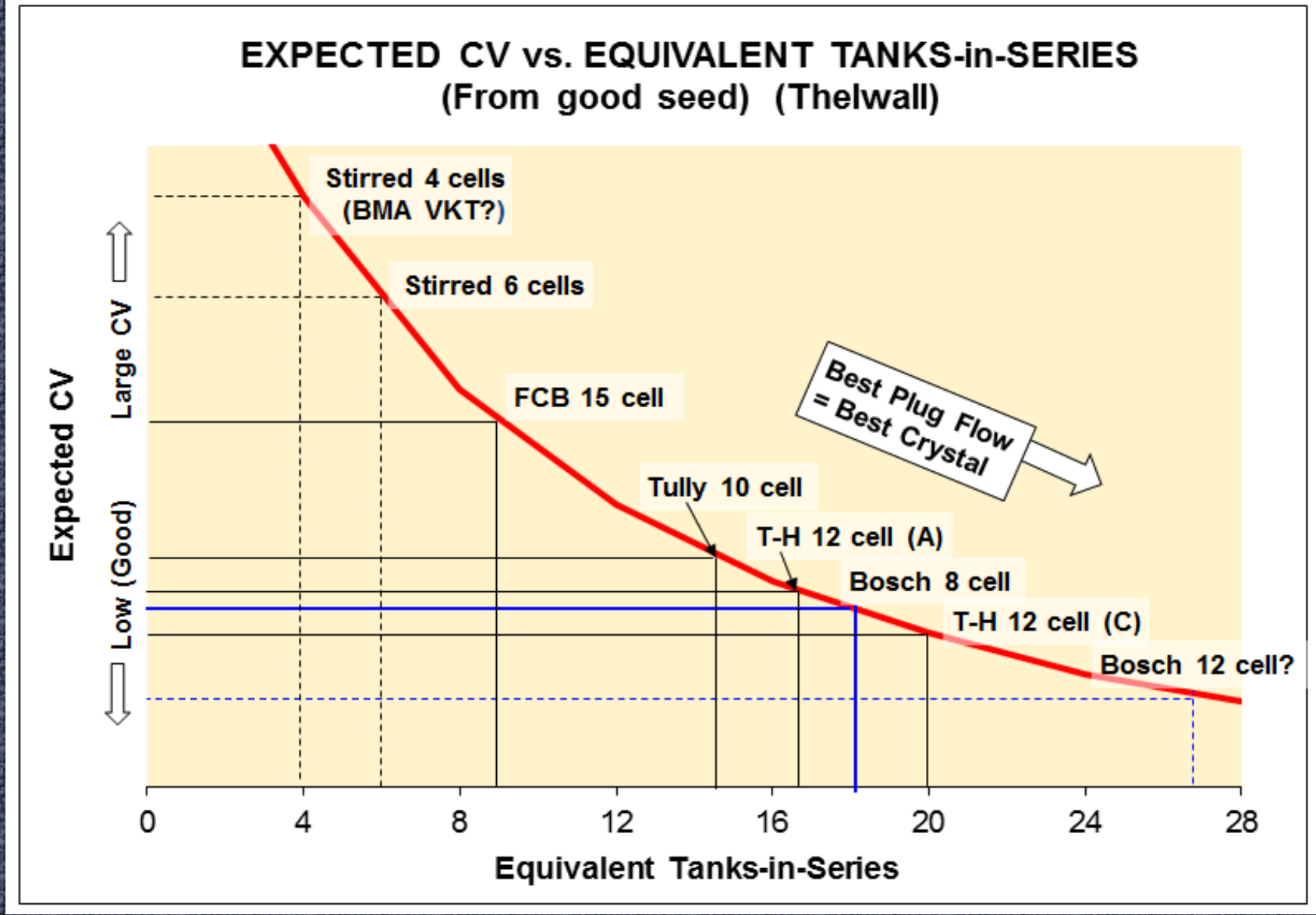
Many tanks-in-series = good plug flow.

ACHIEVING PLUG FLOW

Well-designed horizontal CVPs with vertical tubes can produce t-i-s values larger than their number of compartments, because there is some plug flow even within each compartment. Bosch reinforce this with additional flow baffles in the turbulent zones:



RESULTS FROM LITERATURE:



6. Design pan for -

LONG INTERVALS BETWEEN BOIL-OUTS

CVP boil-outs waste energy – both in boiling the low brix wash material and re-establishing production. To reduce frequency of boil-outs:

Need a "clean" flow profile, without stagnant zones and no cold bottom build-ups

Practise (automated) on-line steam-outs. Suspend boiling for ≤ 5 minutes - 'melts out' surface deposits

PAN DUTY	STEAM-OUT FREQUENCY	BOIL-OUT INTERVALS
A PANS	2 – 3 TIMES / DAY	3 – 5 WEEKS
B PANS	ONCE / DAY	8 – 12 WEEKS
C PANS	ONCE - TWICE / WEEK	1/2 – FULL SEASON

PS. Boil out with clear juice (not water) & return washings to CJ

7. Design pan for -

USE OF VAPOUR RECOMPRESSION

May be warranted where factory's energy balance is exhaust-dependent (not if HP-dependent).

Involves extracting boiled-off vapour and compressing this back to the pan supply steam conditions. Either by mechanical means (MVR) or thermo-compression.

Because of their stable operation, CVPs are suited to this - usually with MVR because of the high pressure ratio. Common in beet factories and refineries but rare in cane factories.

Bosch design is suitable due to its low ΔP capability.

CONCLUSIONS

Crystallisation is a large user of energy

CVP design can reduce this energy

Conserve energy! Choose carefully!

Thank you !