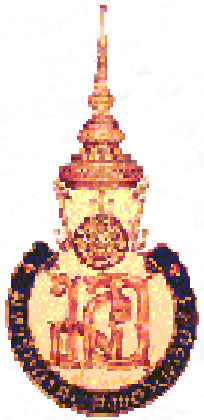
Process units needed to make biodiesel continuously



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Department of Mechanical Engineering
Prince of Songkla University
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Why continuous?

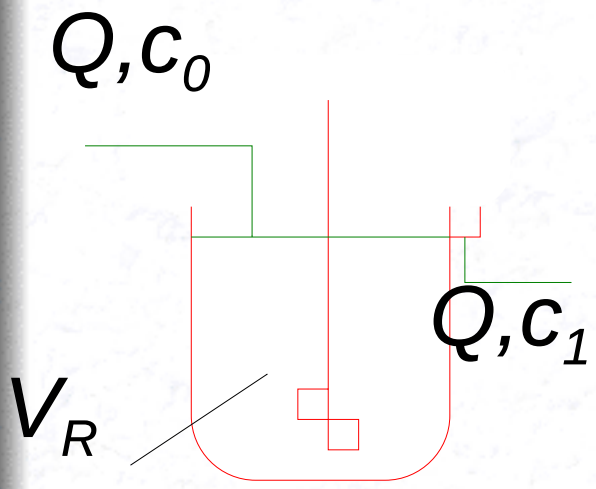
- For a reactor having volume V_R and mean residence time T, throughput $=V_R/T$
- For the same reactor used batchwise, throughput is $V_R/(T+t)$ where t is the turn-around time between batches

So the same reactor volume will provide more product when operated continuously

Continuous Reactors

- Easy to control
  - Automated easily
- Quality control is good with a consistent product being produced
- Are smaller than a batch reactor producing at the same rate

Stirred-tank or Plug-flow?



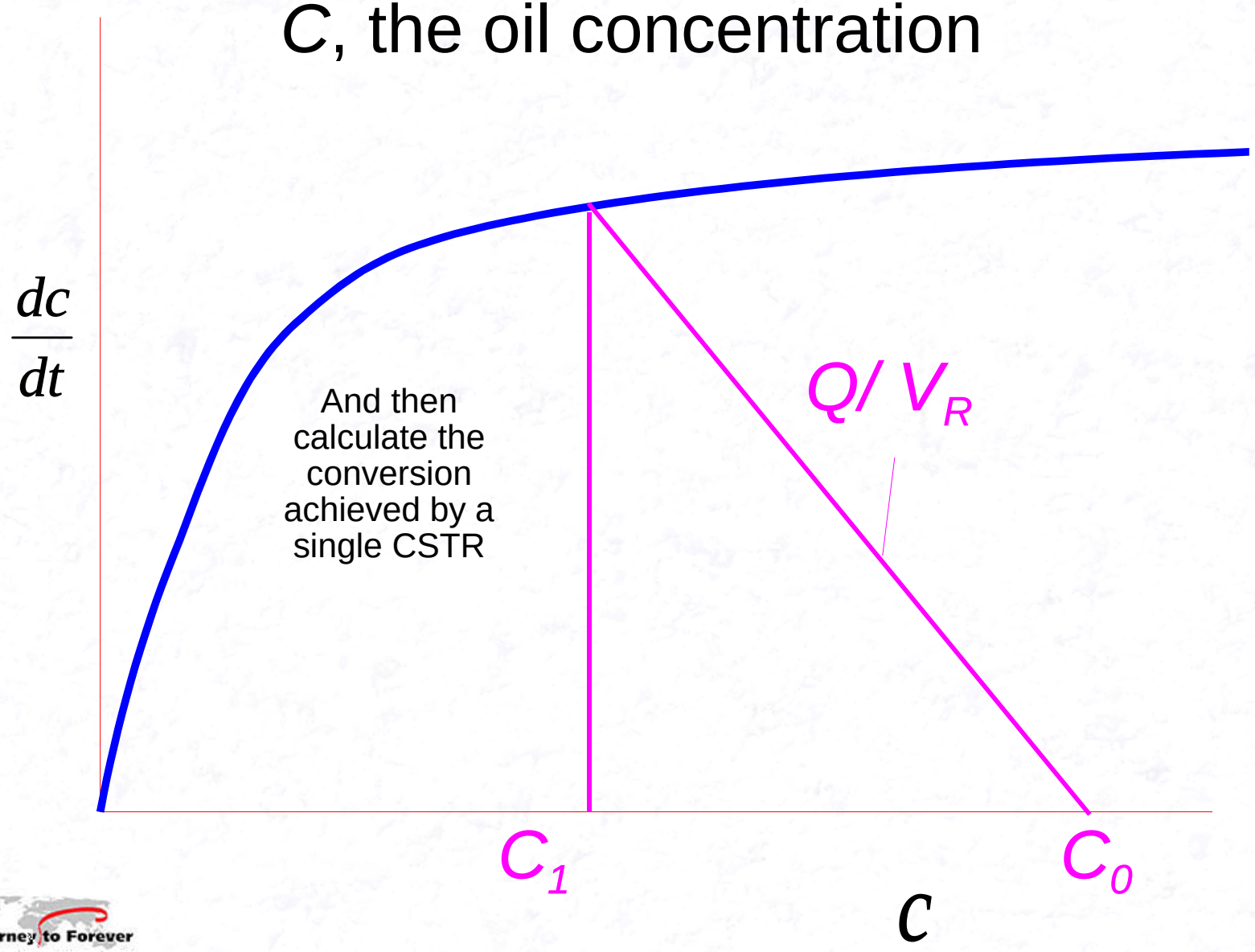
*Where **c** is the concentration of the reactant/unit volume*

Mass balance gives:

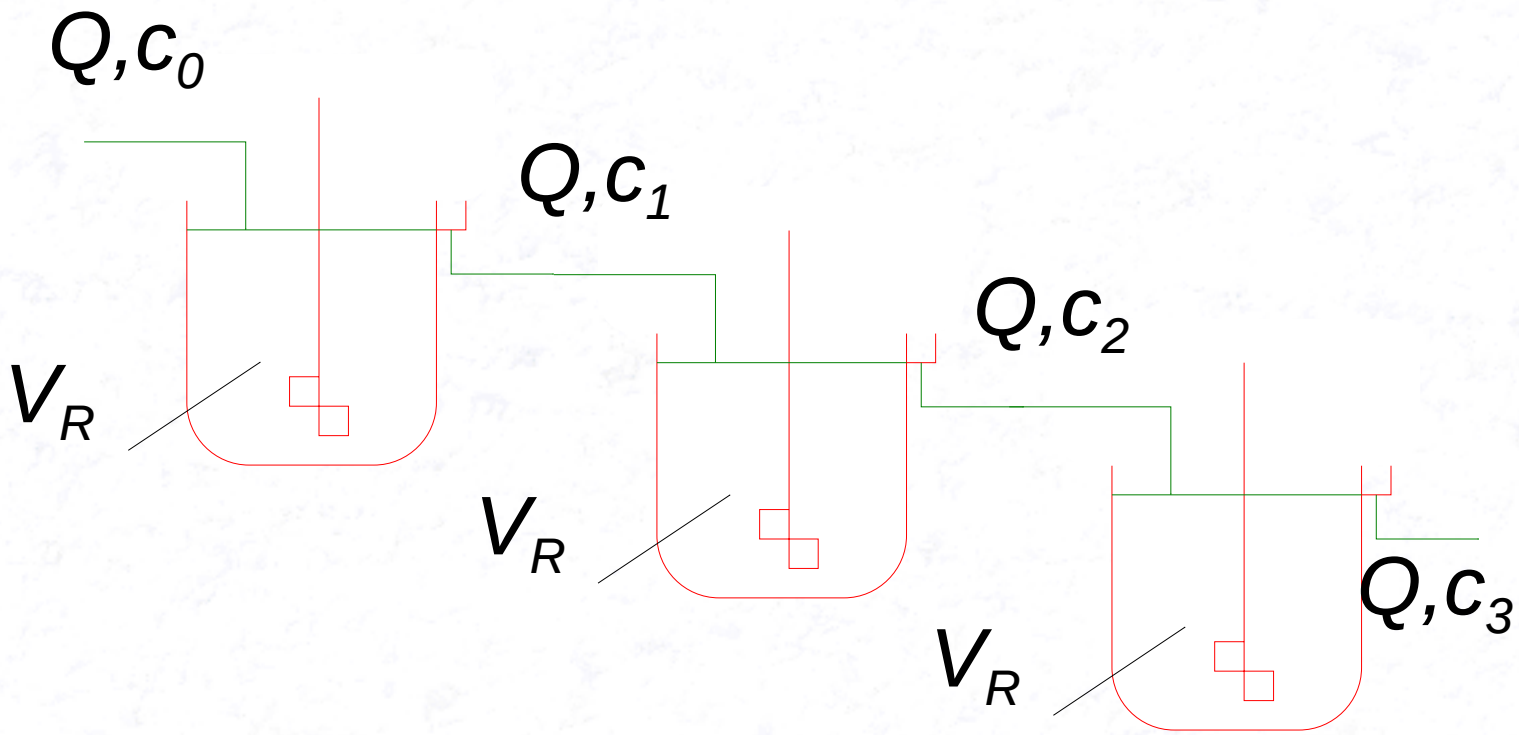
$$Qc_0 = Qc_1 - V_R \frac{dc}{dt}$$

$$so \quad \frac{dc}{dt} = \frac{Q}{V_R}(c_0 - c_1)$$

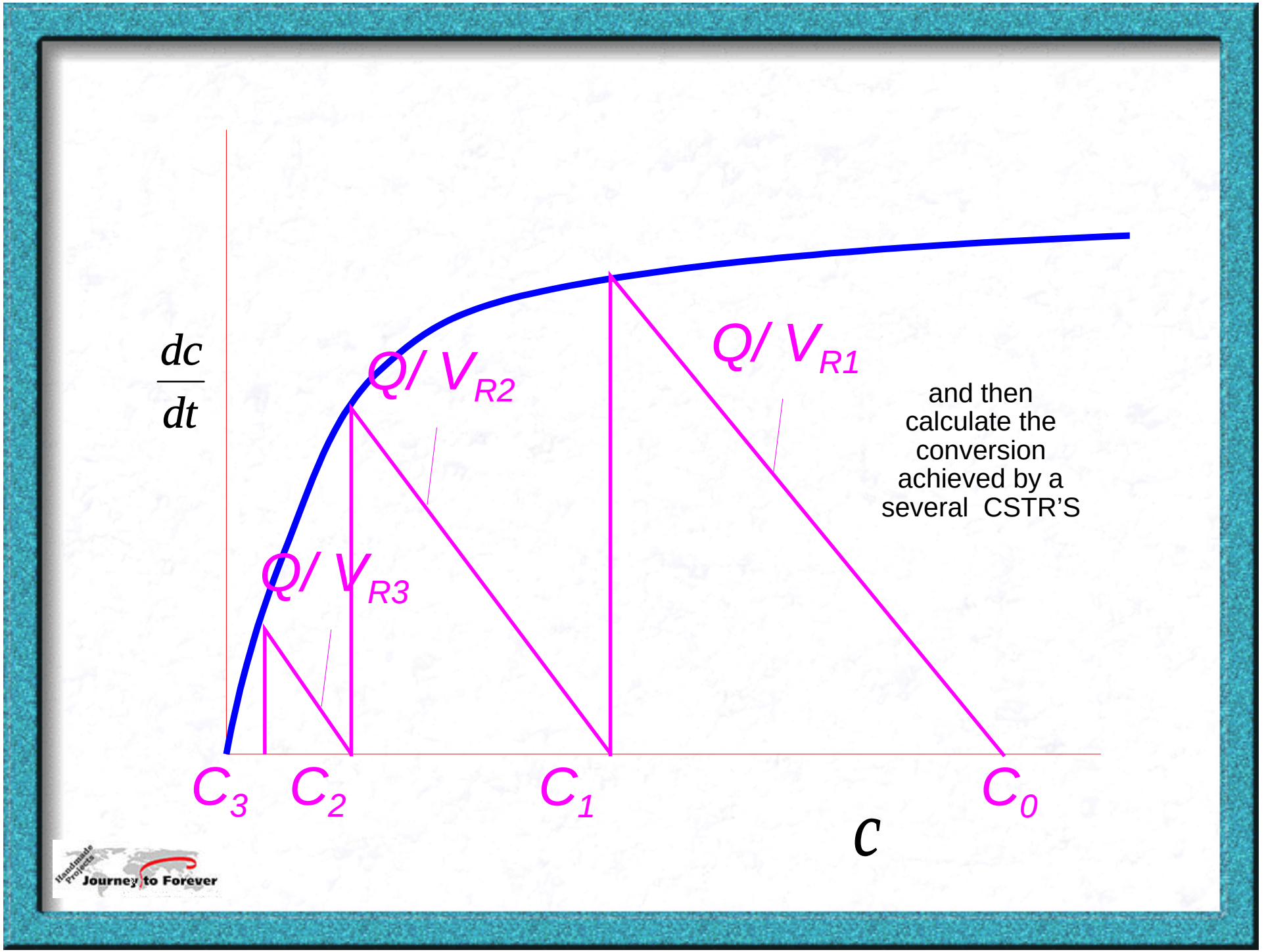
We can measure how *dc/dt* varies with *C*, the oil concentration



Stirred-tank Reactors



They can be connected to each other in cascade:

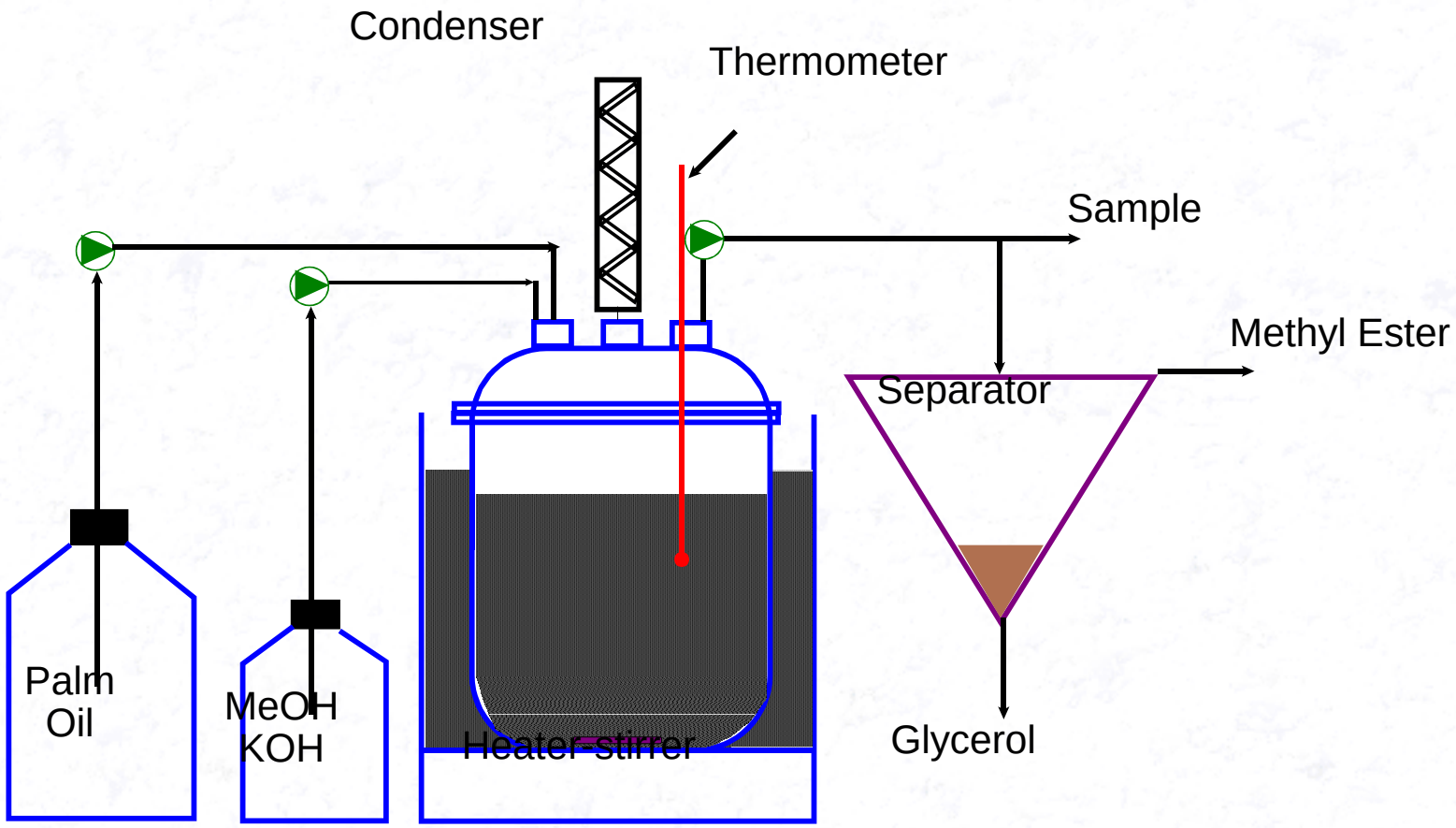

$\frac{dc}{dt}$
Q/ V R2
Q/ V R1
Q/ V R3
and then calculate the conversion achieved by a several CSTR'S
C3
C2
C1
C0
C

Conclusion

The more continuous stirred tanks we have in series, the better conversion we get.

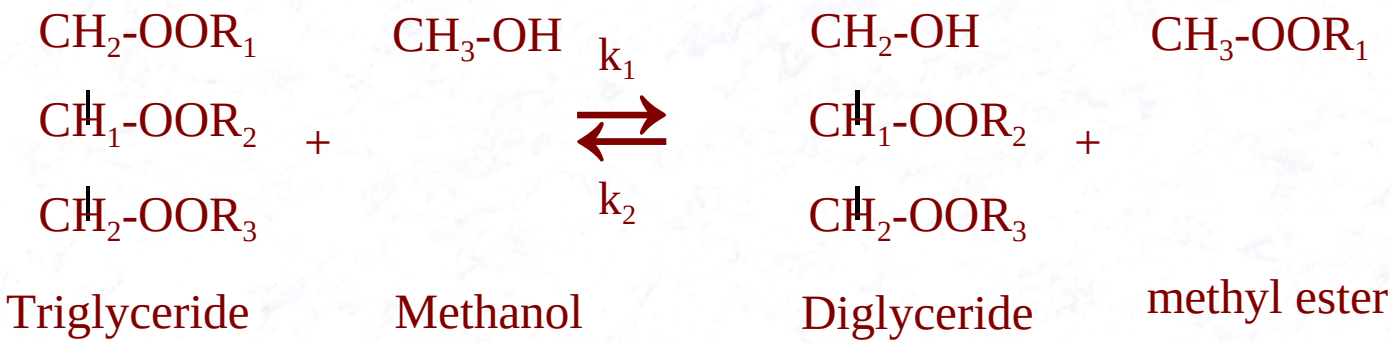
A large number of CSTR's in cascade gives the same results as a plug-flow reactor (PFR)

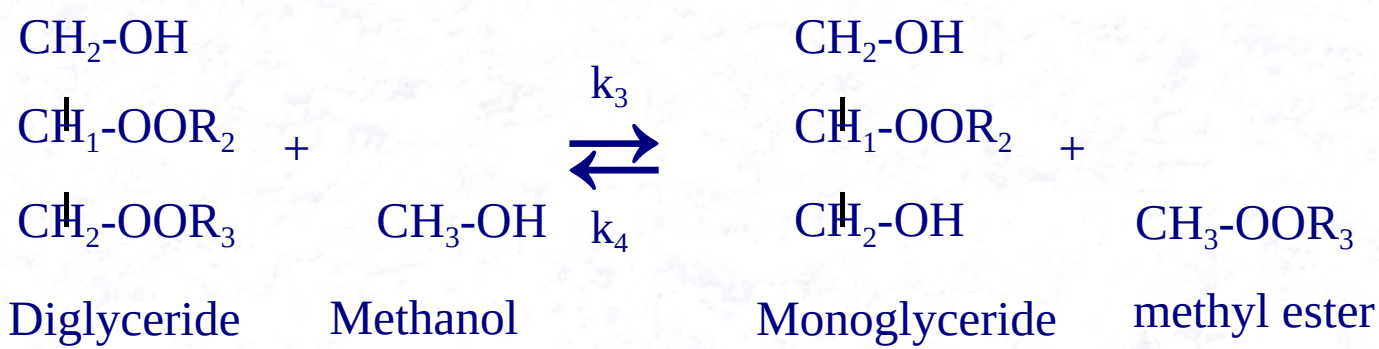
The laboratory equipment used by Darnoko & Cheryan is a simple one-stage CSTR

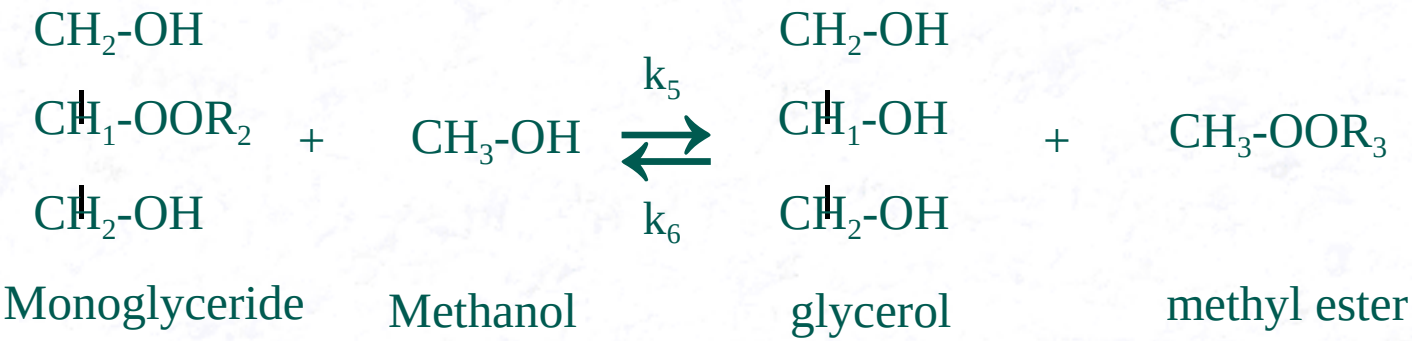


D. Darnoko and Munir Cheryan: "Continuous Production of Palm Methyl Esters" : JAOCS, Vol 77 no 1 2 (2000)

Typical reactions taking place







The Rate Equations

$$\frac{d[TG]}{dt} = -k_1[TG][A] + k_2[DG][E]$$

$$\frac{d[DG]}{dt} = k_1[TG][A] - k_2[DG][E] - k_3[DG][A] + k_4[MG][E]$$

$$\frac{d[MG]}{dt} = k_3[DG][A] - k_4[MG][E] - k_5[MG][A] + k_6[GL][E]$$

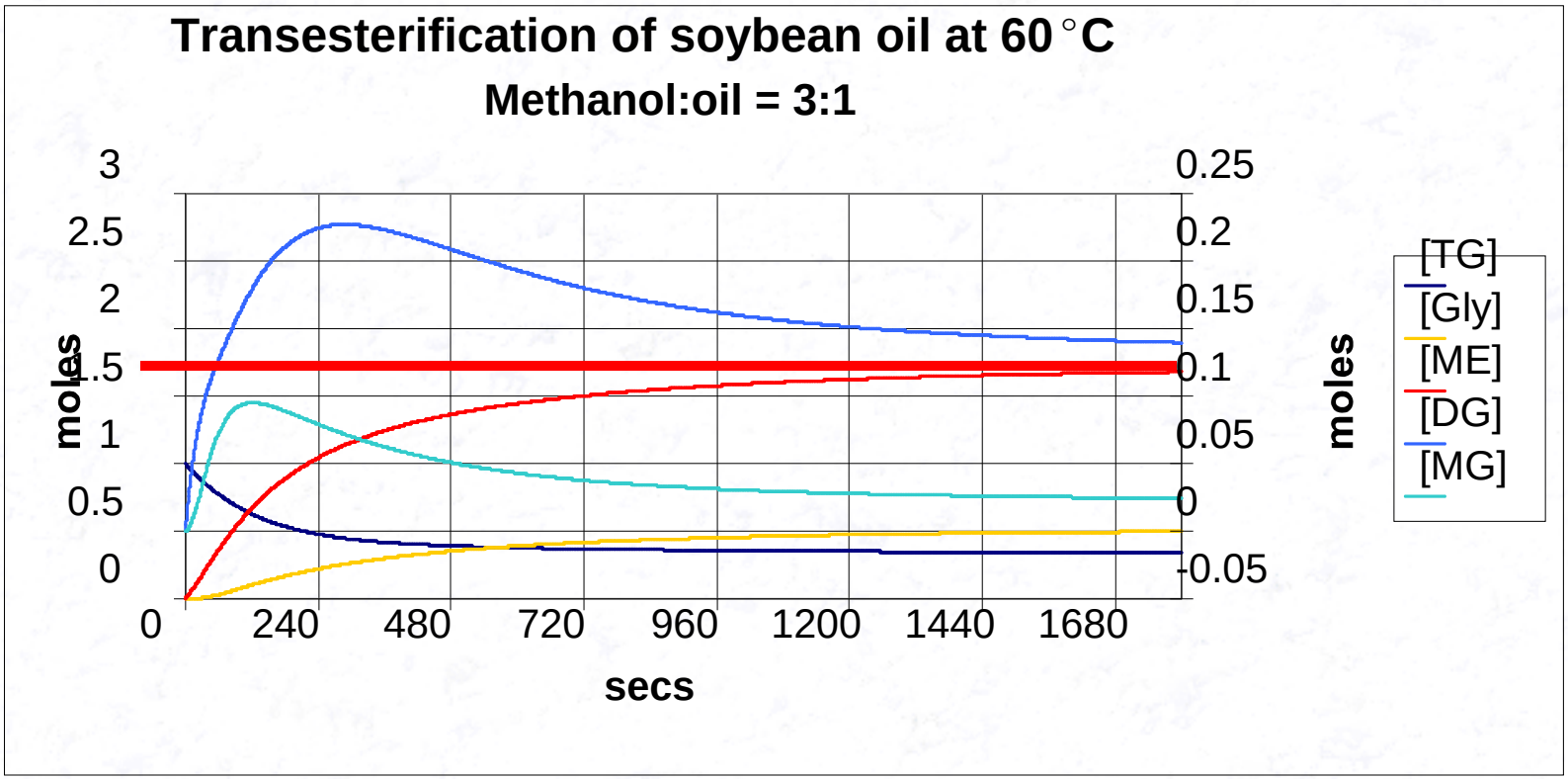
$$\frac{d[GL]}{dt} = k_5[MG][A] - k_6[GL][E]$$

$$\frac{d[E]}{dt} = k_1[TG][A] - k_2[DG][E] + k_3[DG][A] + k_4[MG][E] + k_5[MG][A] - k_6[GL][E]$$

$$\frac{d[A]}{dt} = -\frac{d[E]}{dt}$$

where [TG] denotes the molar concentration of the triglyceride,
[DG] of the diglyceride,
[MG] of the monoglyceride,
[A] of the methanol
and [E] of the ester.

The effect of increasing methanol concentration



From data supplied by Noureddini and Zhu

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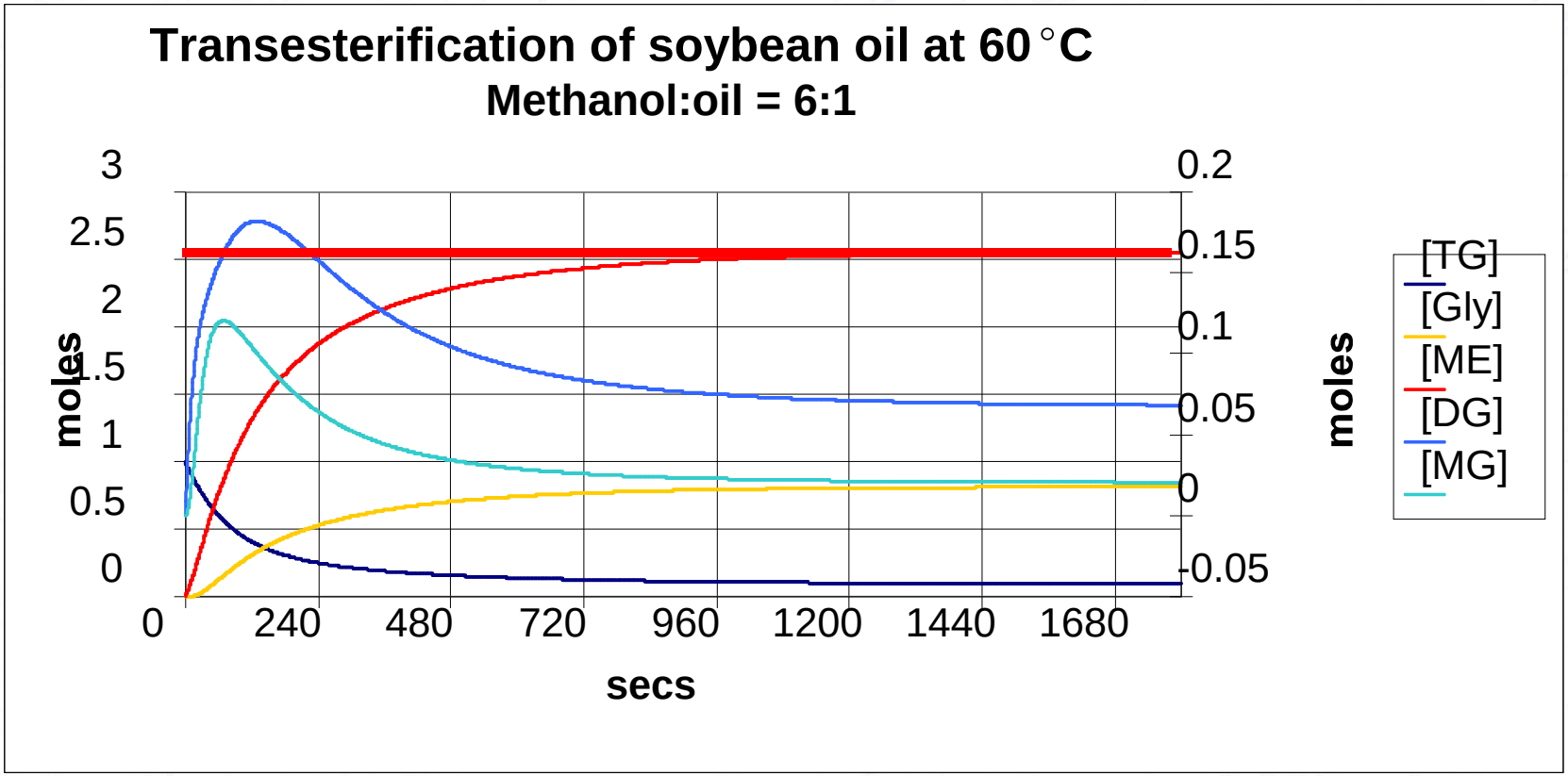
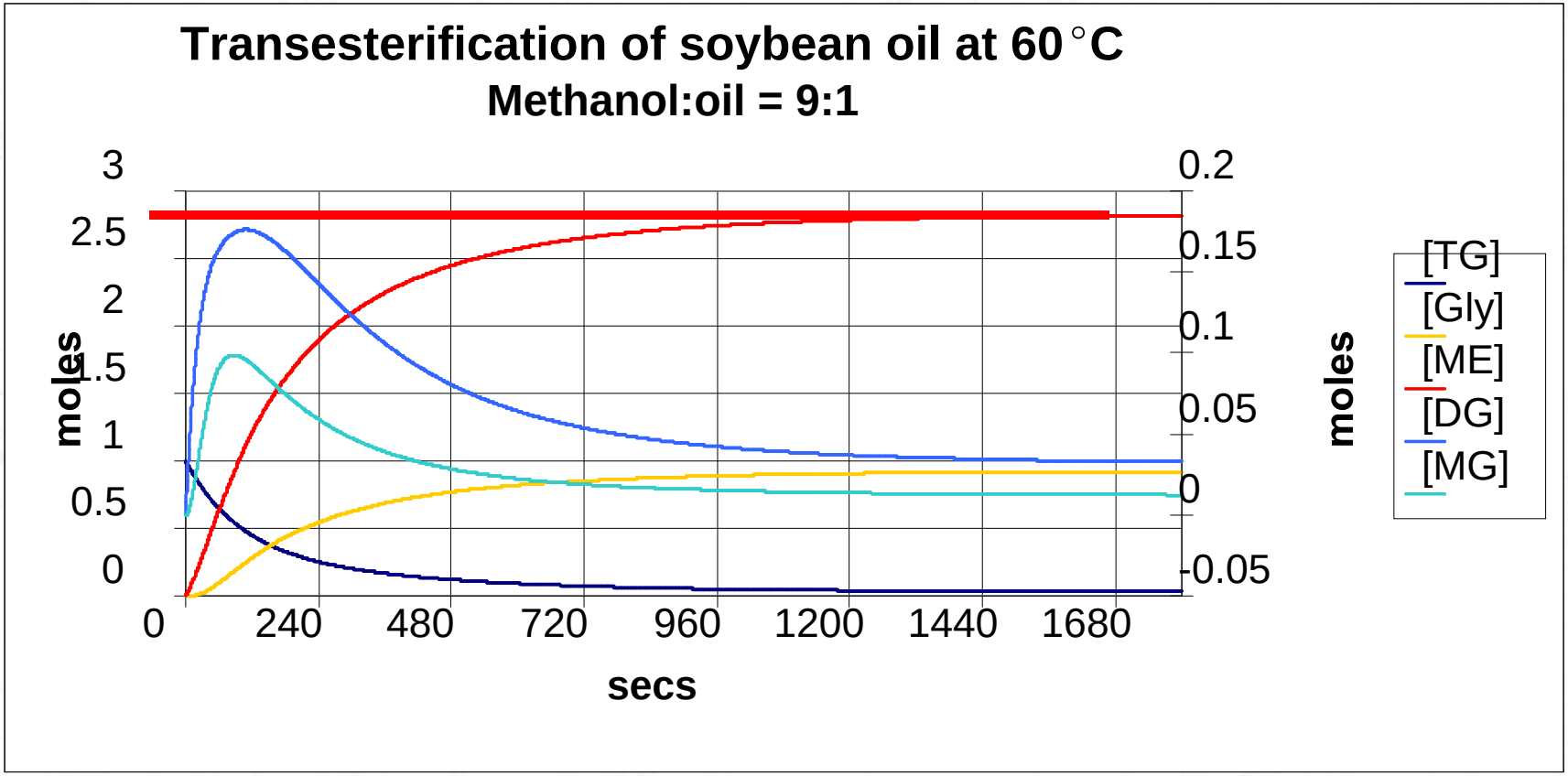


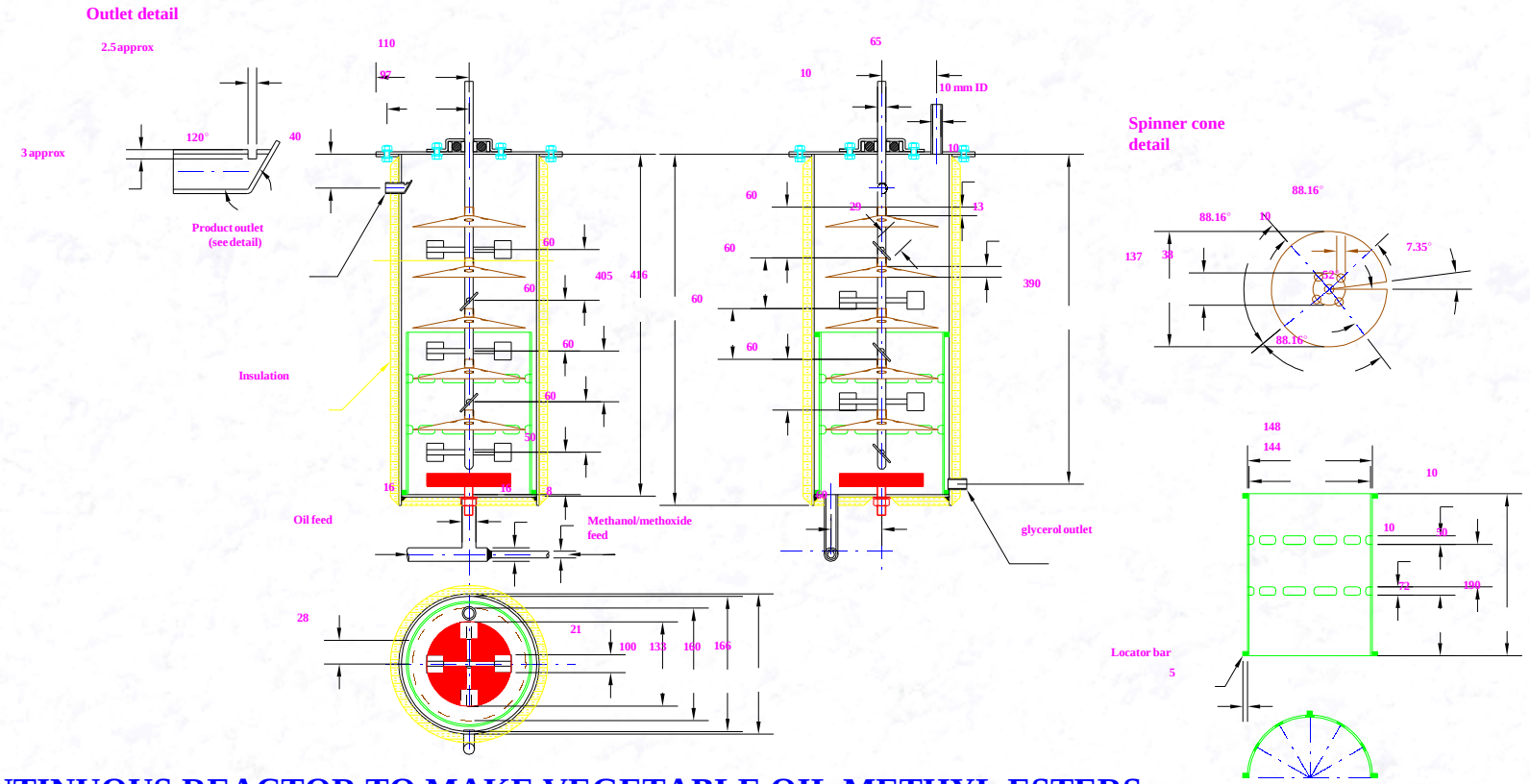
From data supplied by Noureddini and Zhu



From data supplied by Noureddini and Zhu

Pilot-plant

5 litre, 6 CSTR in cascade



CONTINUOUS REACTOR TO MAKE VEGETABLE OIL METHYL ESTERS

Designed and drawn by Michael Allen,
Visiting Professor
Prince of Songkla University
Last Revised September 2003

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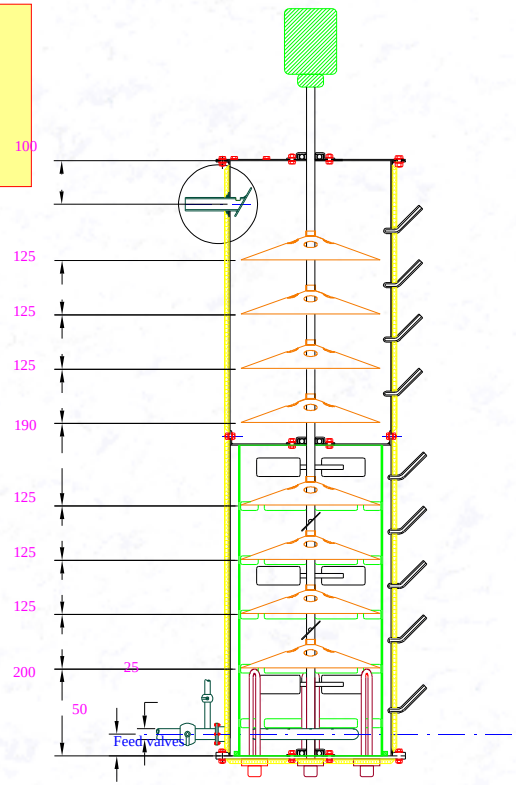
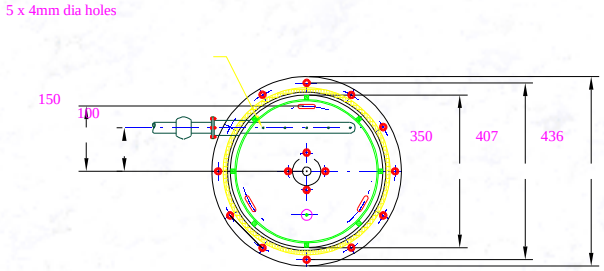
DeepThort 5 — 100 litre Continuous Transesterification Reactor

9 CSTR's in cascade

Side view





View on base

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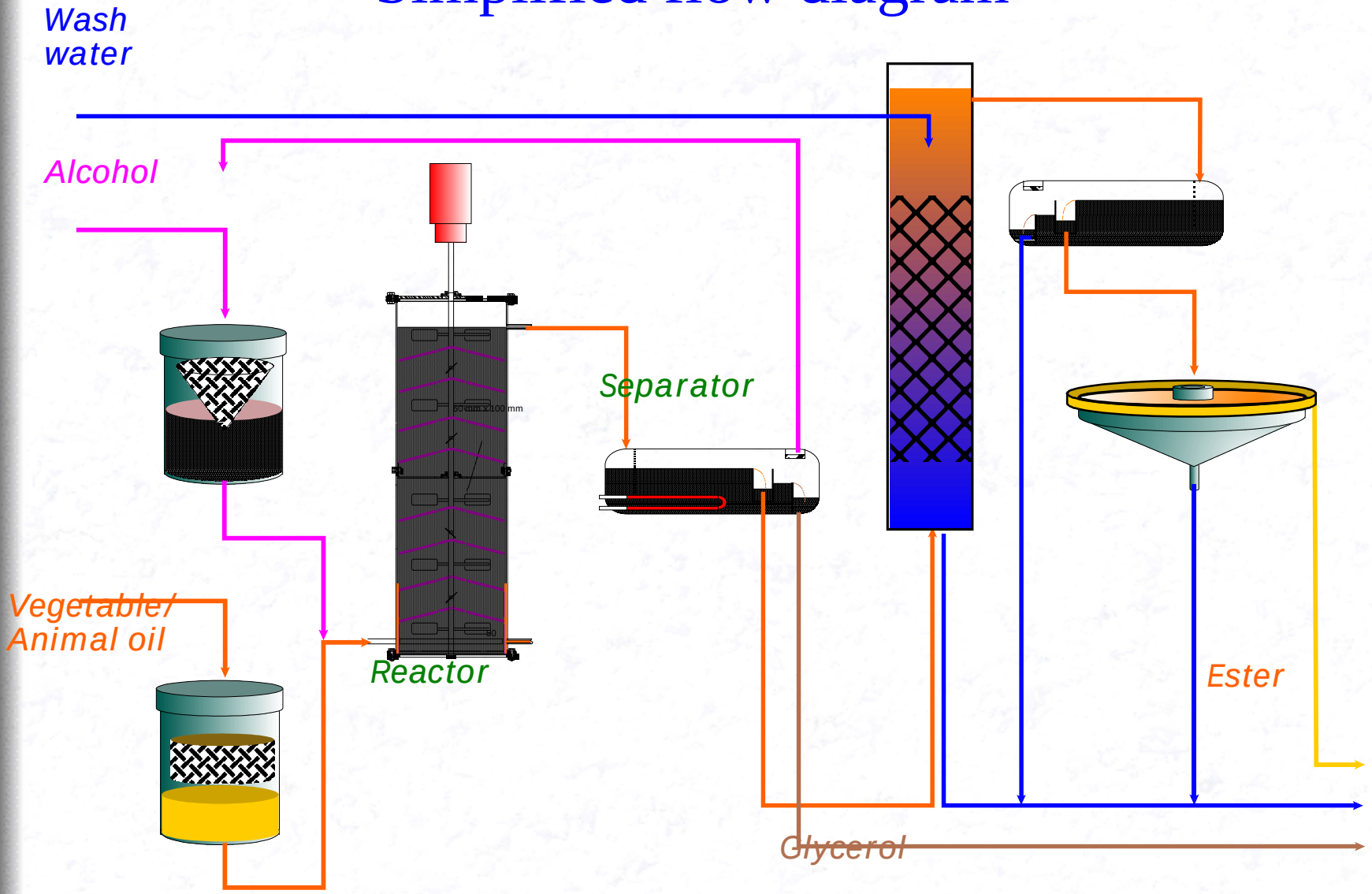
Simplified flow diagram



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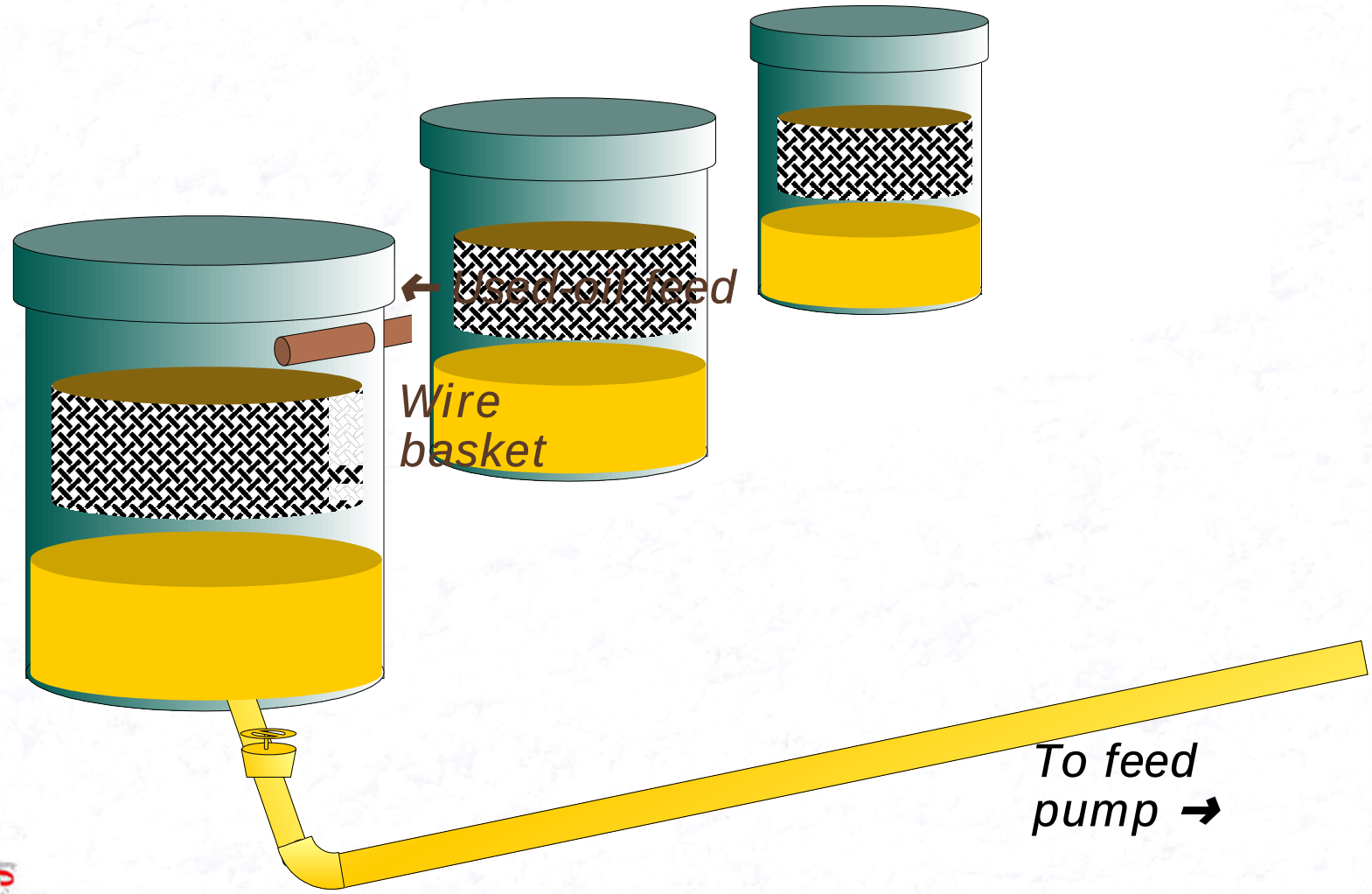
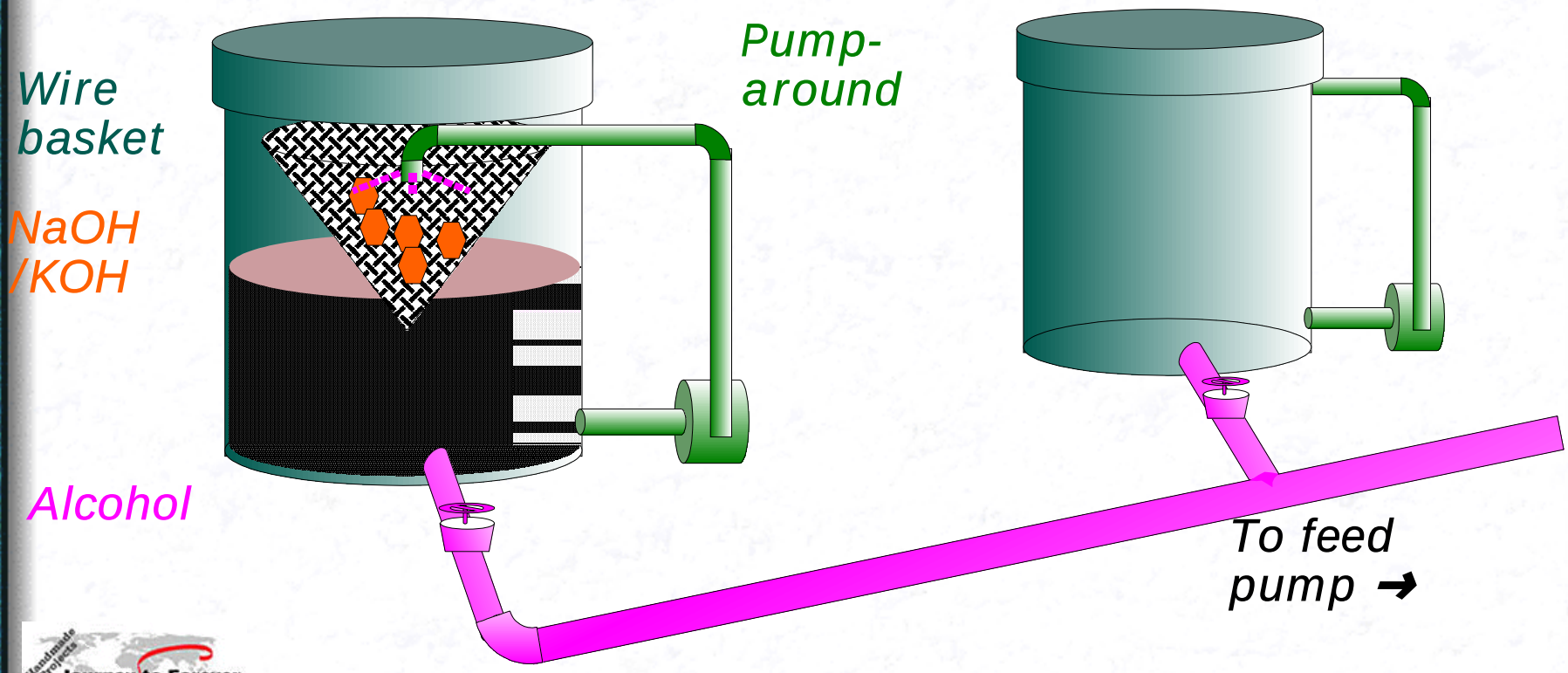
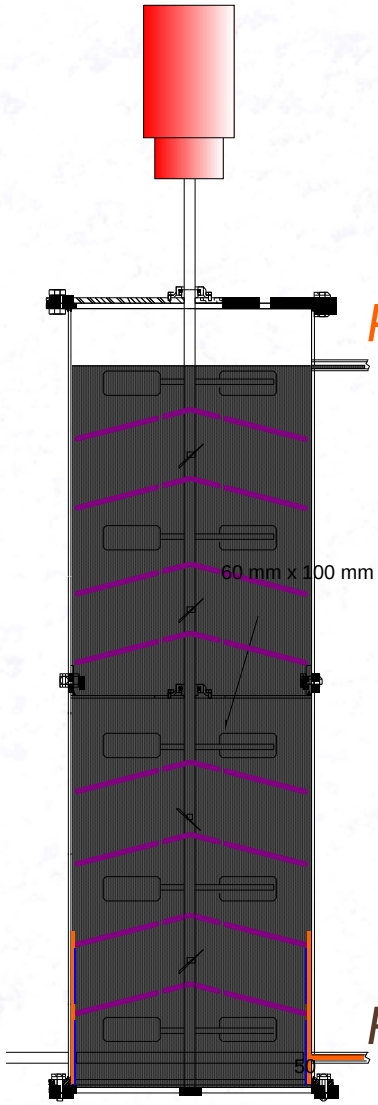
Oil strainer



Methoxide/Ethoxide mixer



Reactor



Product ➜

Feed ➜

Reactor glycerol➜

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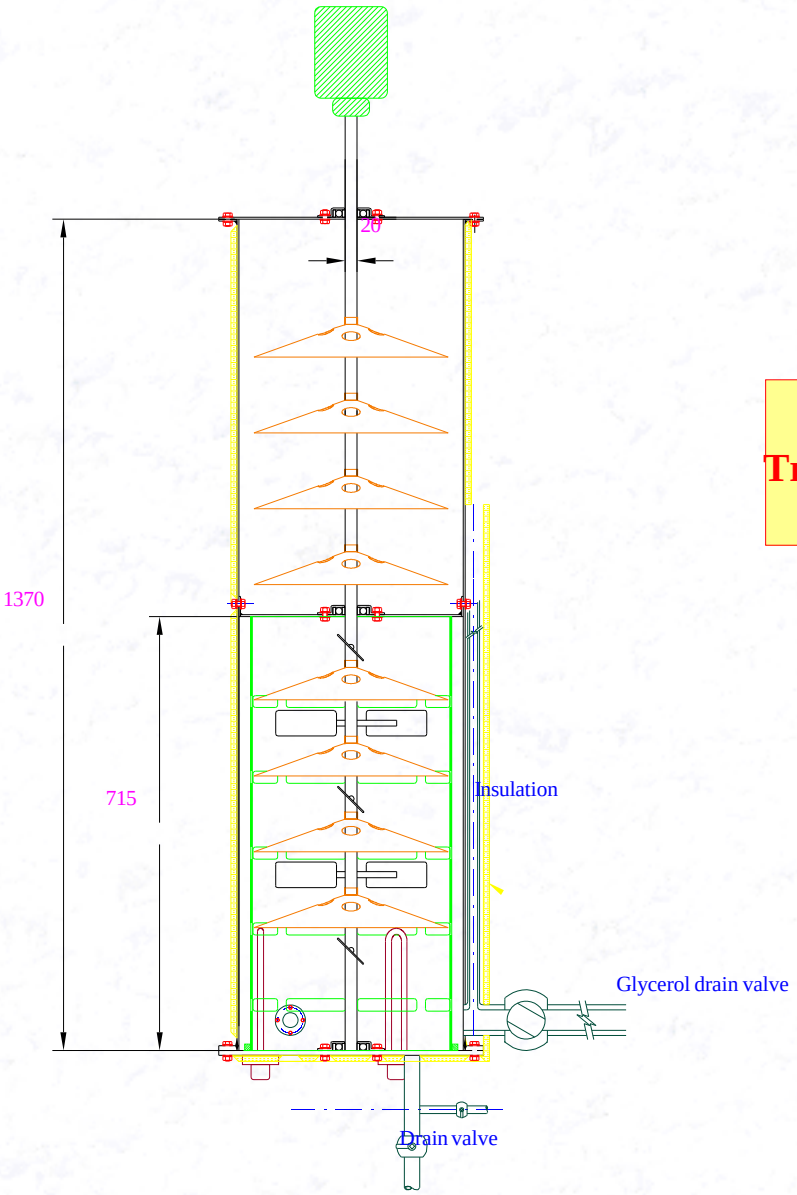
DeepThort 5
Continuous
Transesterification Reactor



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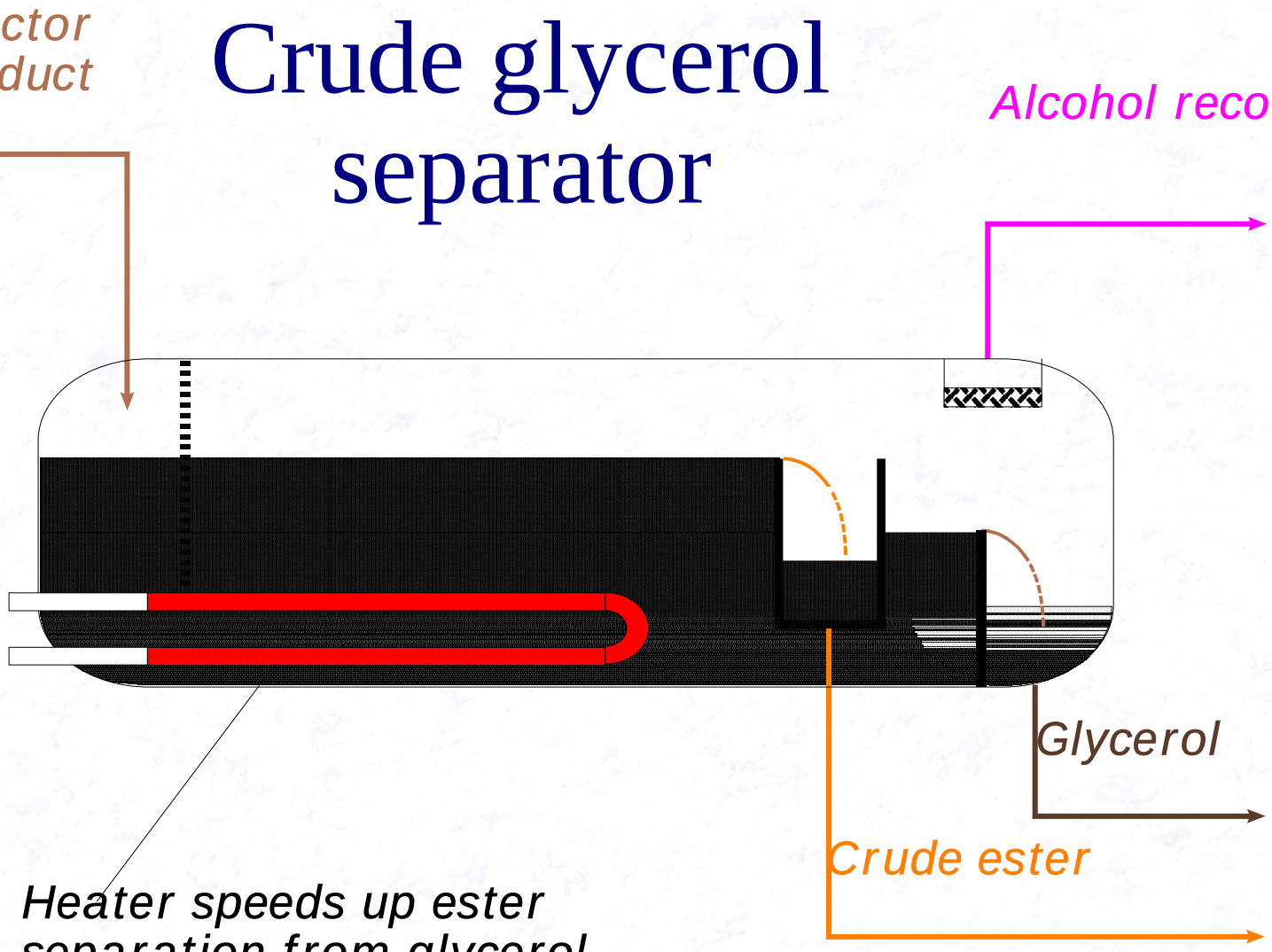
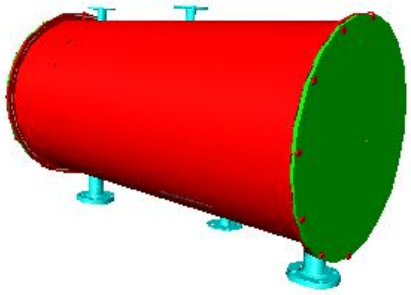
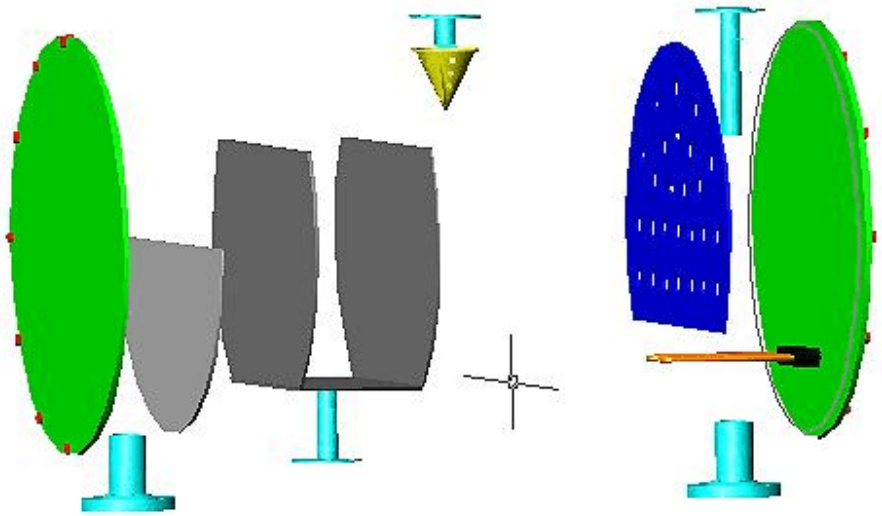
Crude glycerol separator



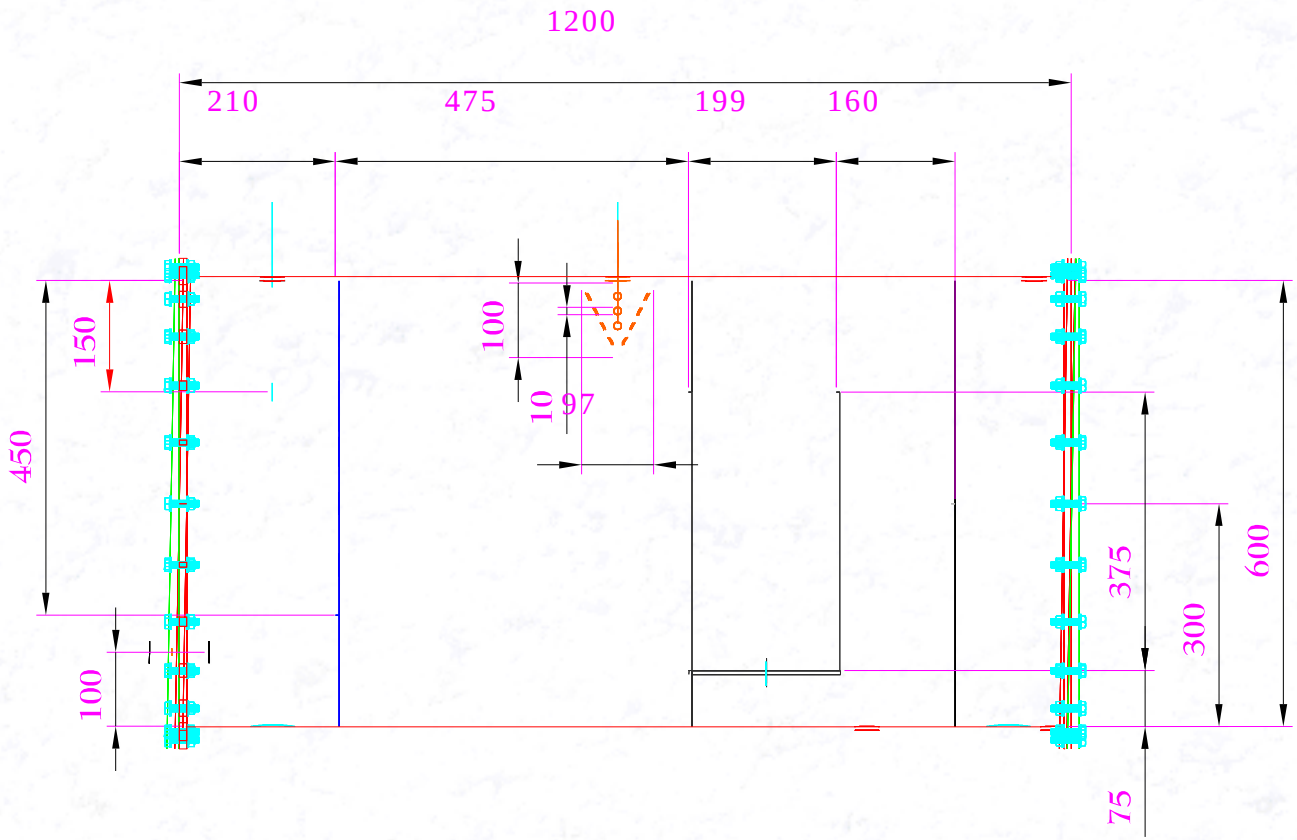
`External view



`Internal view



SOME DIMENSIONS OF THE SEPARATOR



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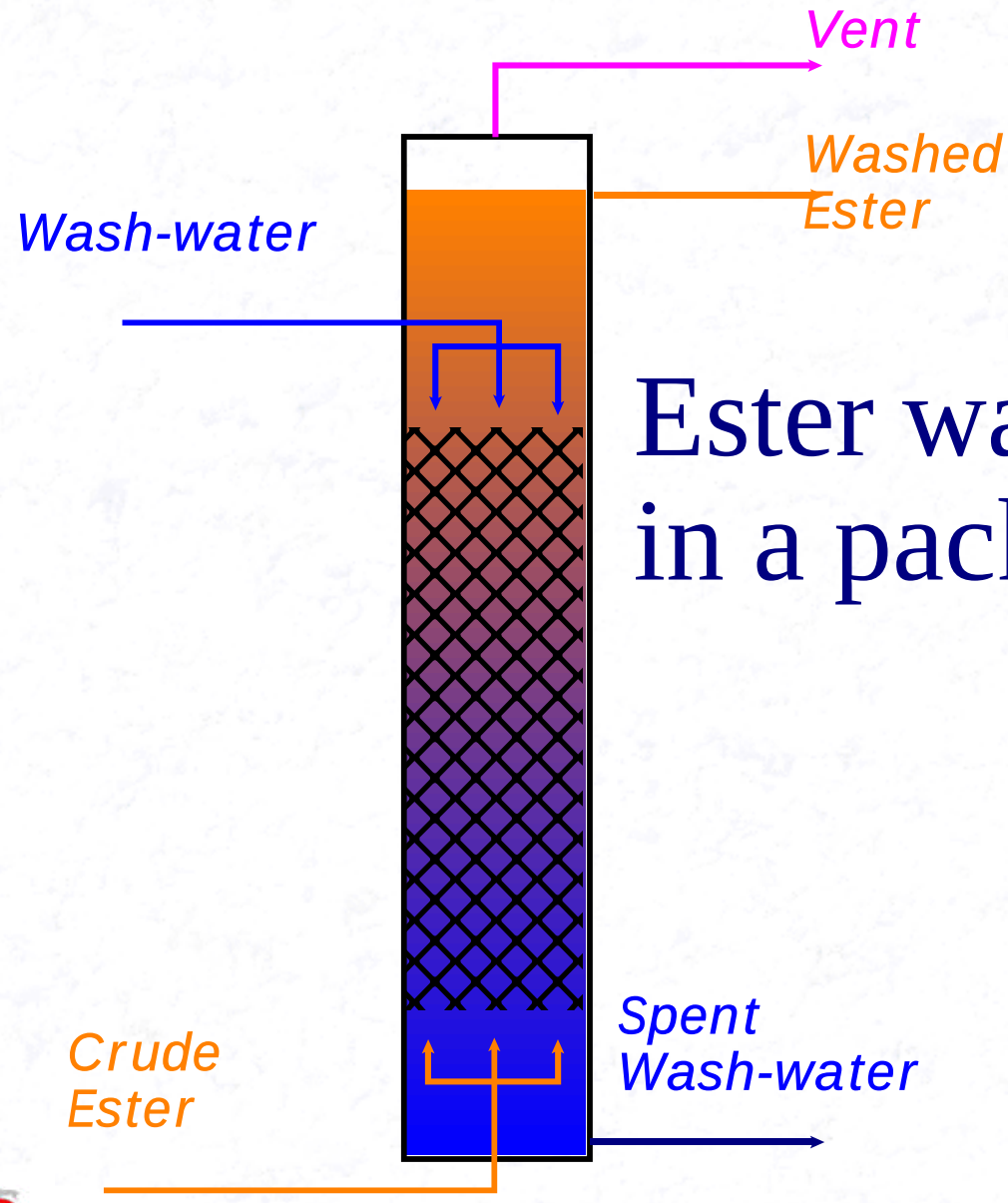
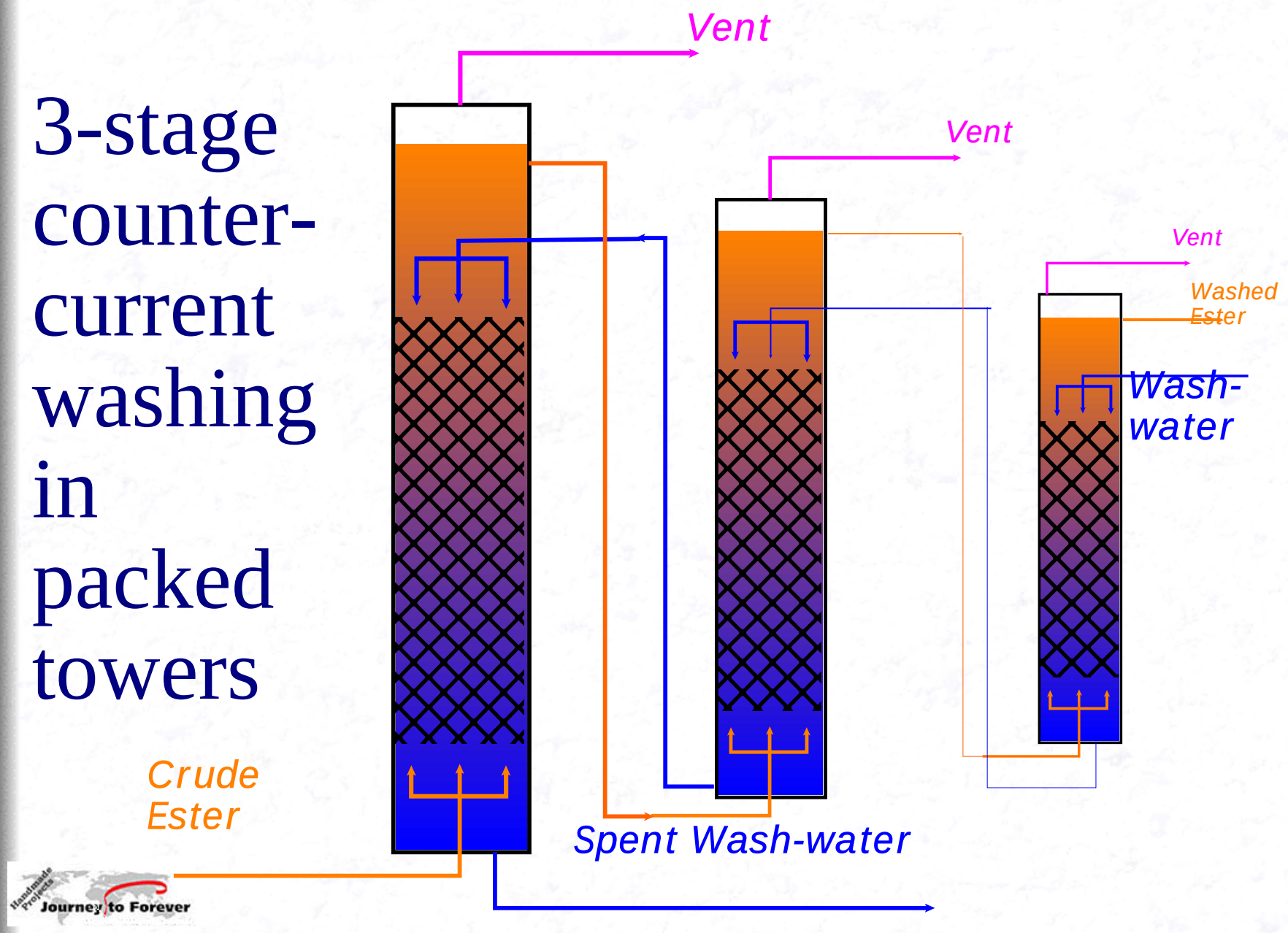


Ester washing in a packed tower

3-stage counter-current washing in packed towers



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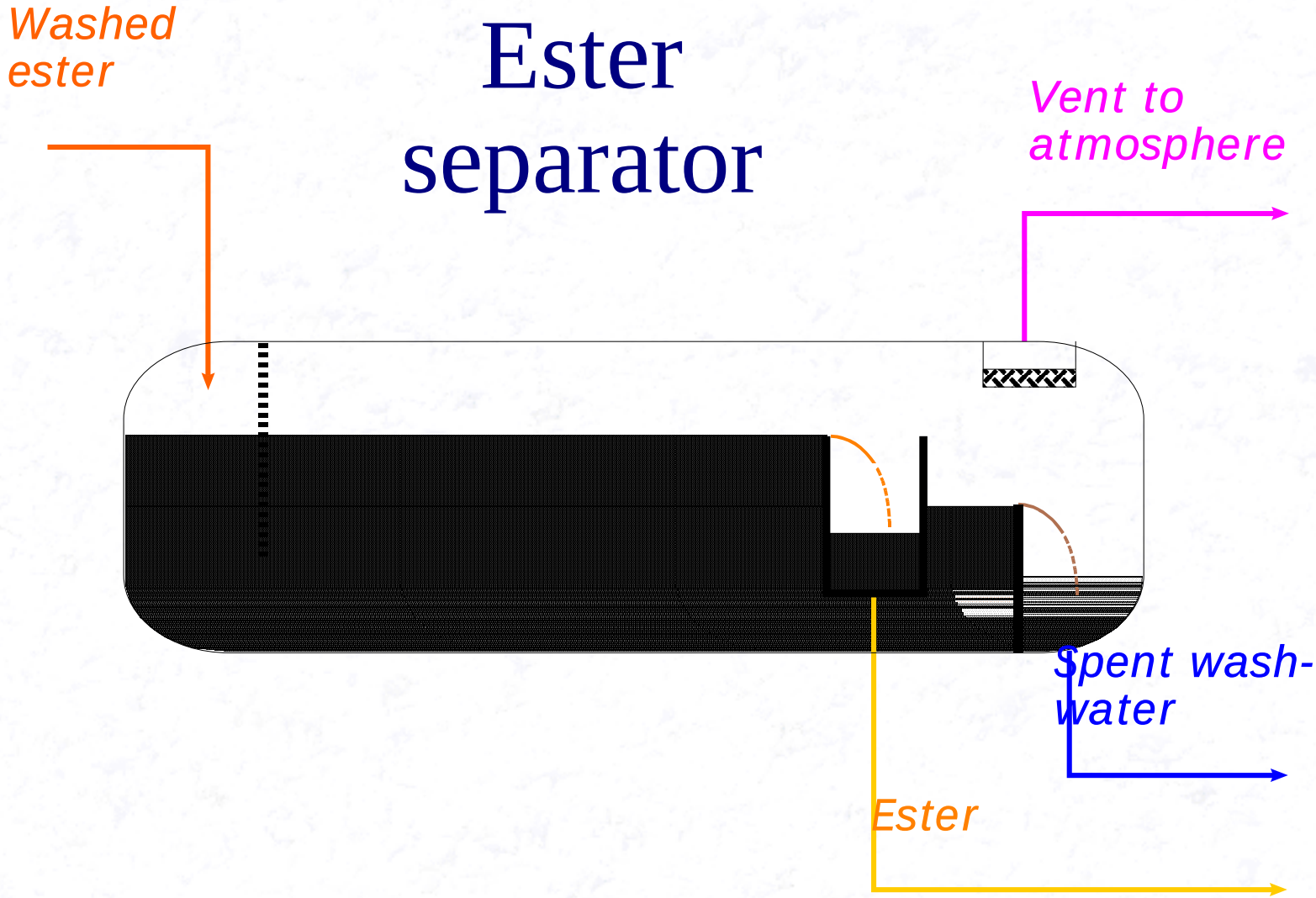
Ester separator



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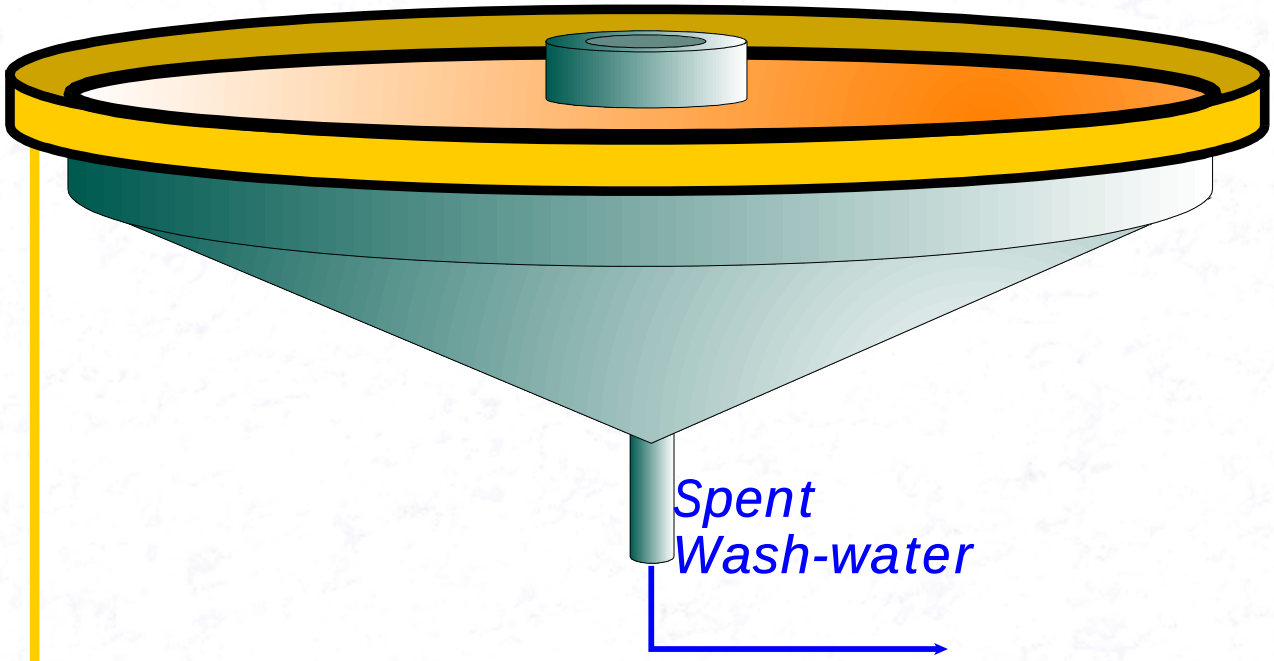
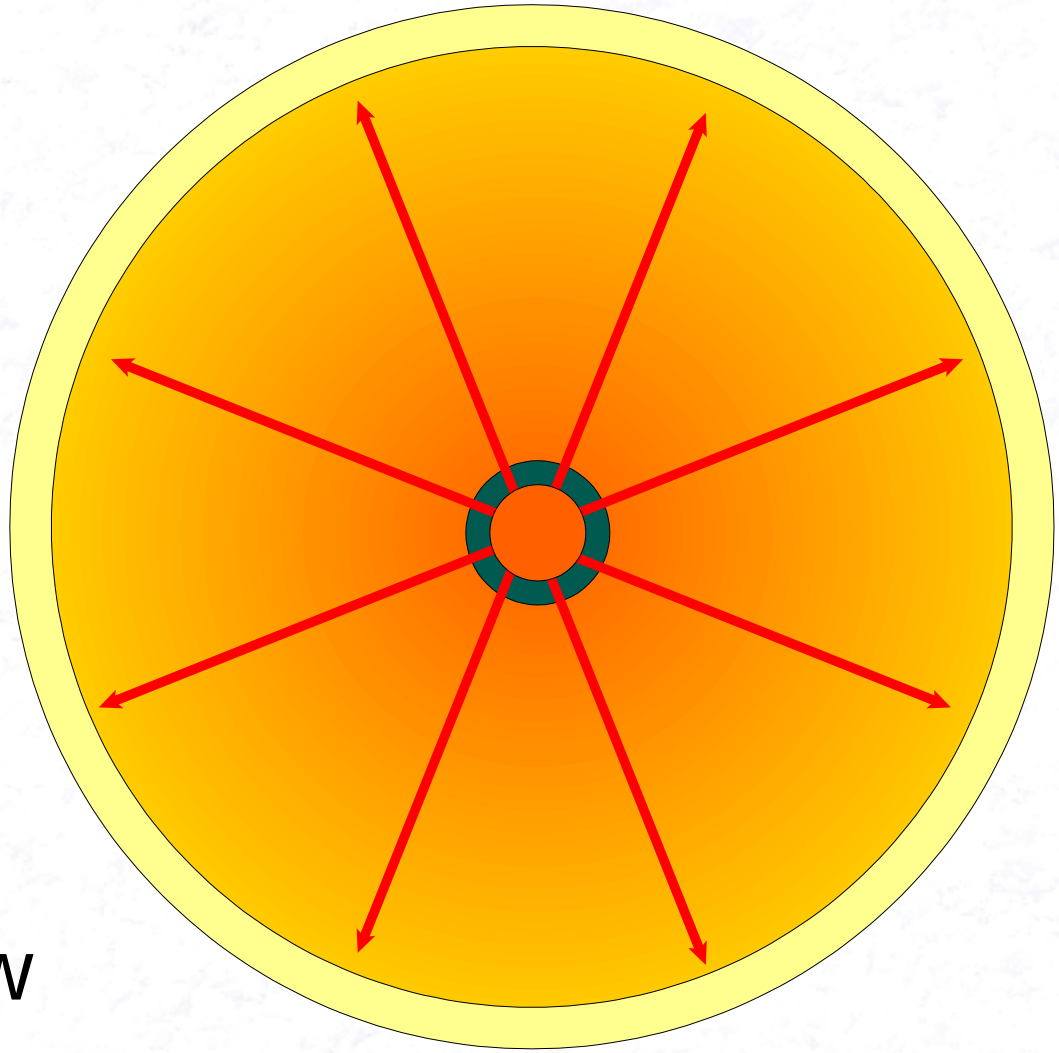
Ester clarifier

Washed Ester



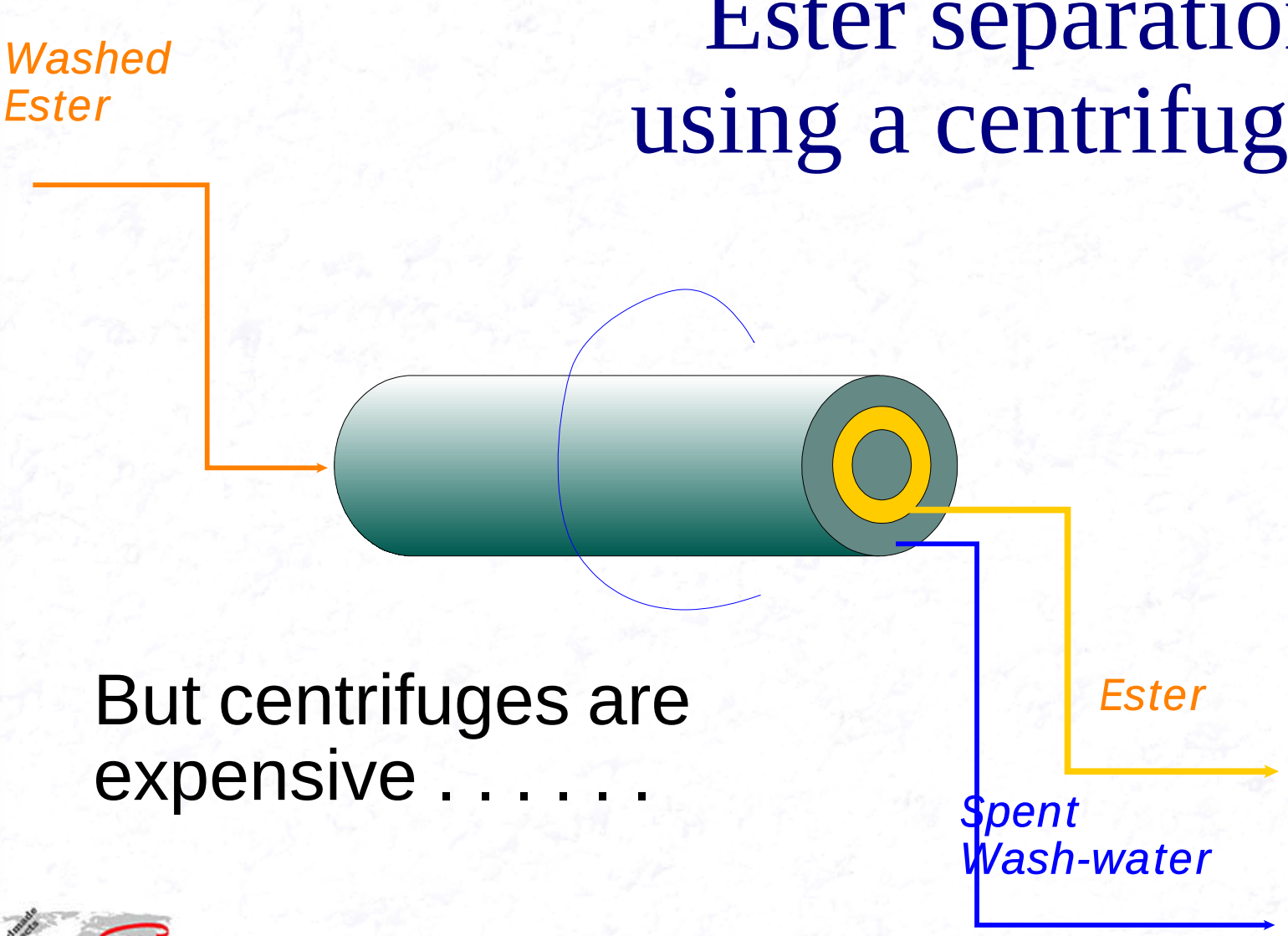
Ester

Ester clarifier



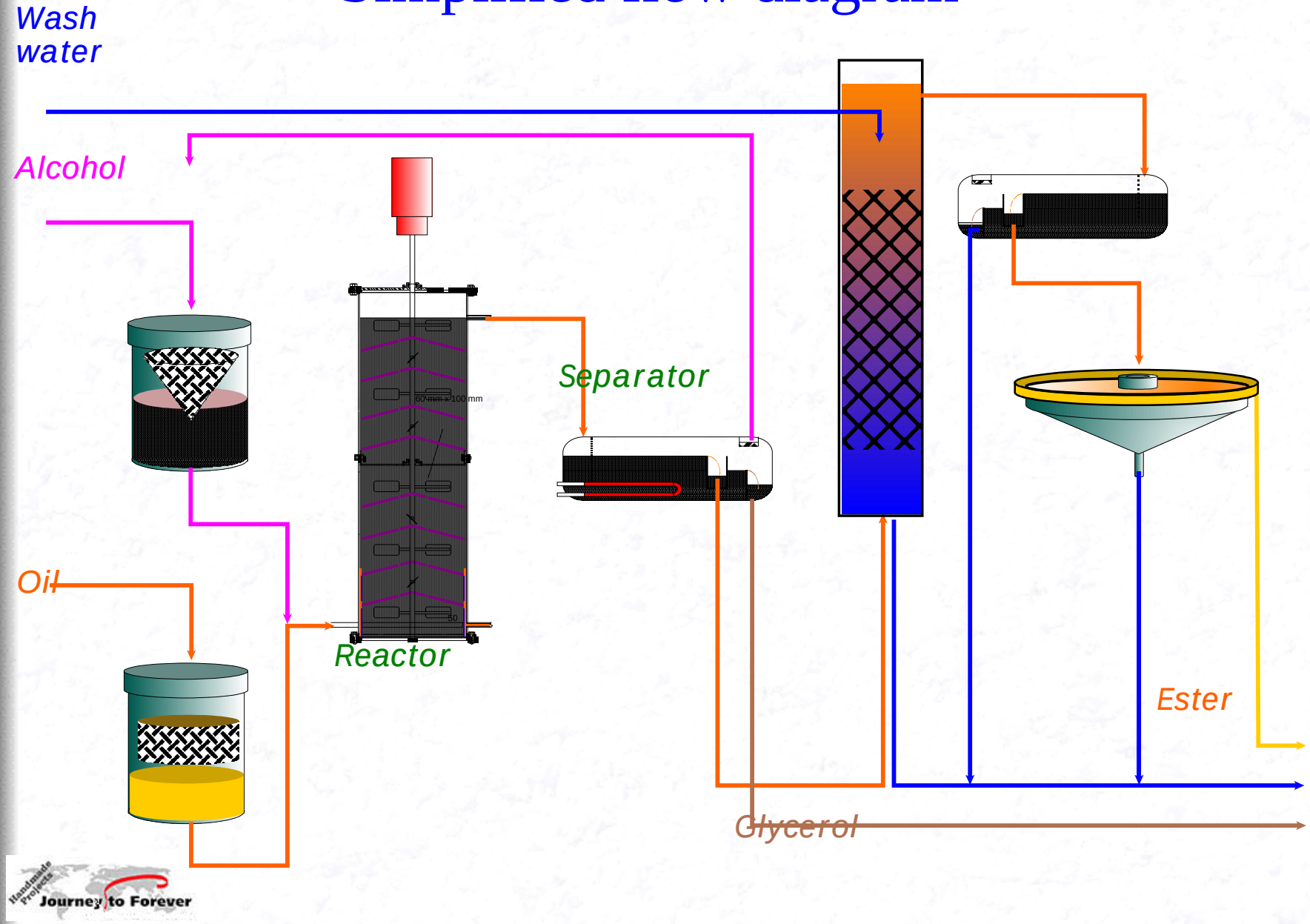
Plan view

Ester separation using a centrifuge

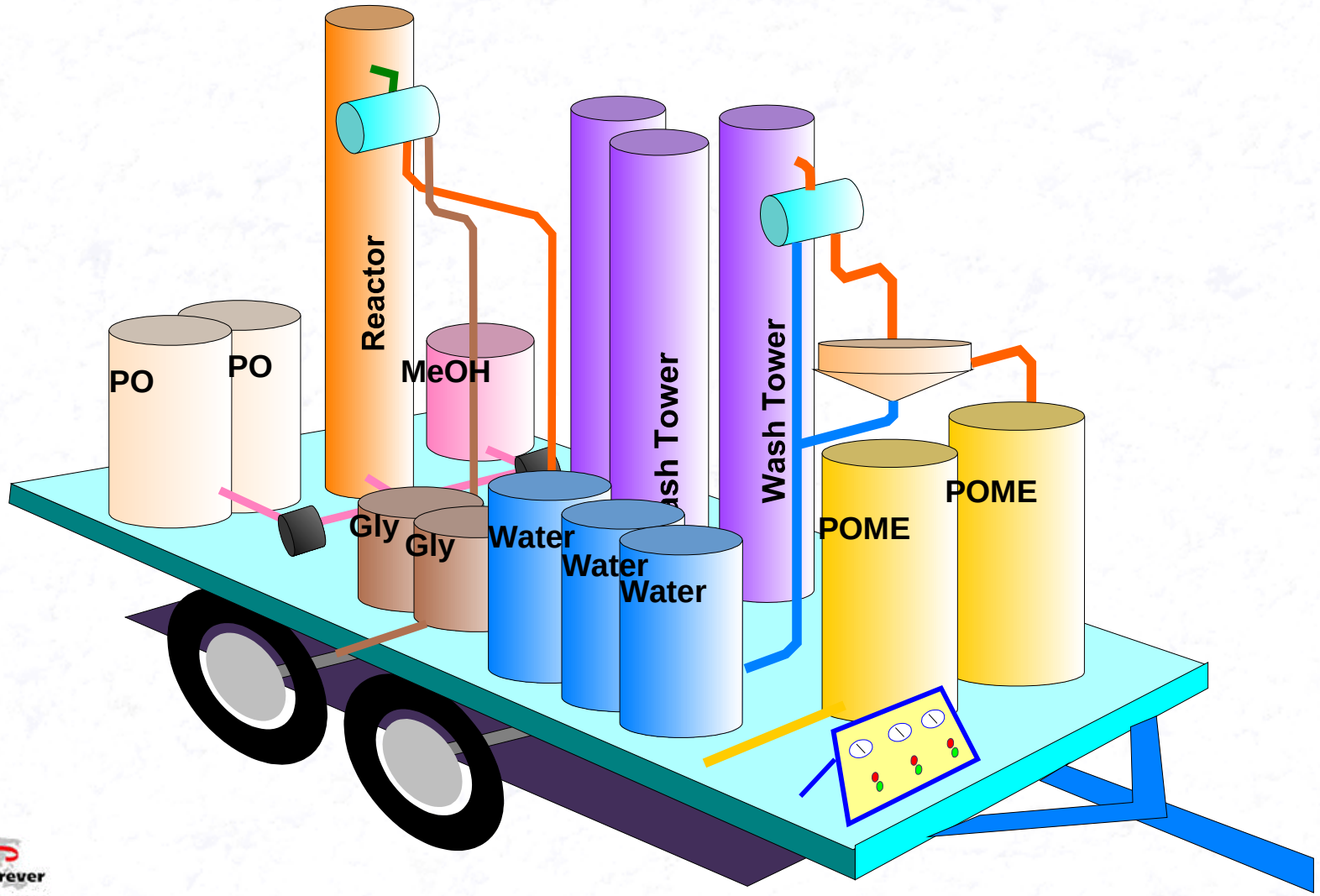


But centrifuges are expensive . . . . . .

Simplified flow diagram



Mobile Palm Oil Transesterification Unit



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Patent Rights

There are several possibly unique features to my reactor design for the transesterification of oils:

1) The oil and the alcohol are introduced into the base of the reactor co-currently so that the alcohol can rise through the reacting fluids (Methanol and ethanol have a lower density than vegetable oil or the esters);
2) The spinning cones create separate CSTR's within the body of the reactor;
3) The cones also slightly reduce the glycerol concentration in the upper part of the reactor thus improving the yield and purity of the ester formed.
4) They also have the effect of recycling some catalyst and excess methanol back to the base of the reactor.

Patent Rights

The main reason for placing my intellectual property into the public domain is to ensure that it is NOT patented.

The only “payment” I require from any user or developer is that :

1) They acknowledge Michael Allen and JourneyTo Forever as their source;

2) That they challenge any person or company who would seek to remove this information from the public domain by patenting, licensing or otherwise restricting access to it.

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ALL CARE TAKEN BUT ABSOLUTELY

NO RESPONSIBILITY, NO WARRANTIES,

NO GUARANTEES !

Handmade Projects
Journey to Forever

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