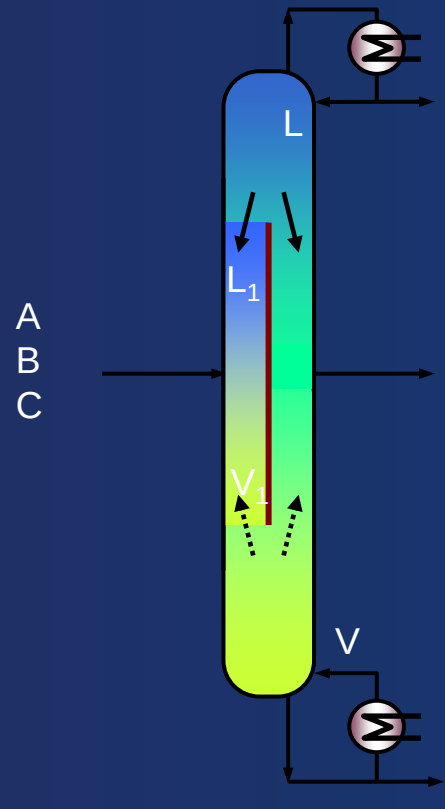
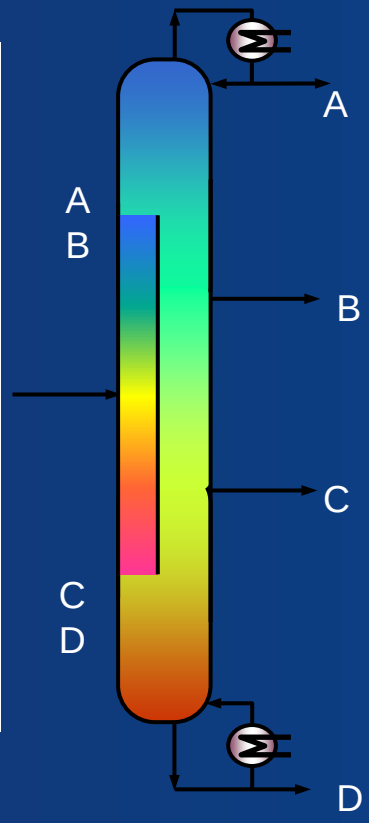
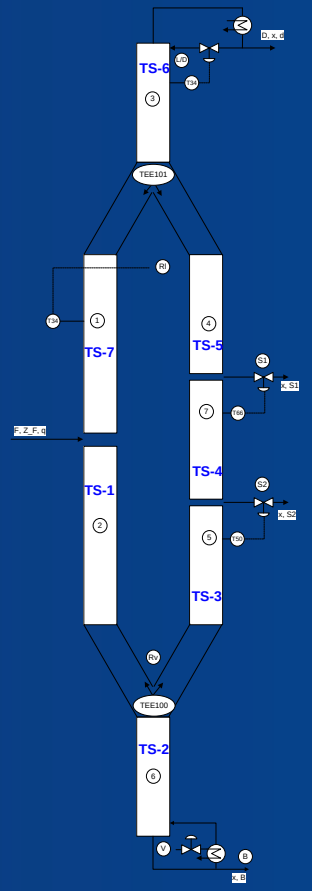






DWC Workshop – NTNU Trondheim – 5-6 October 2023

SINTEF NTNU

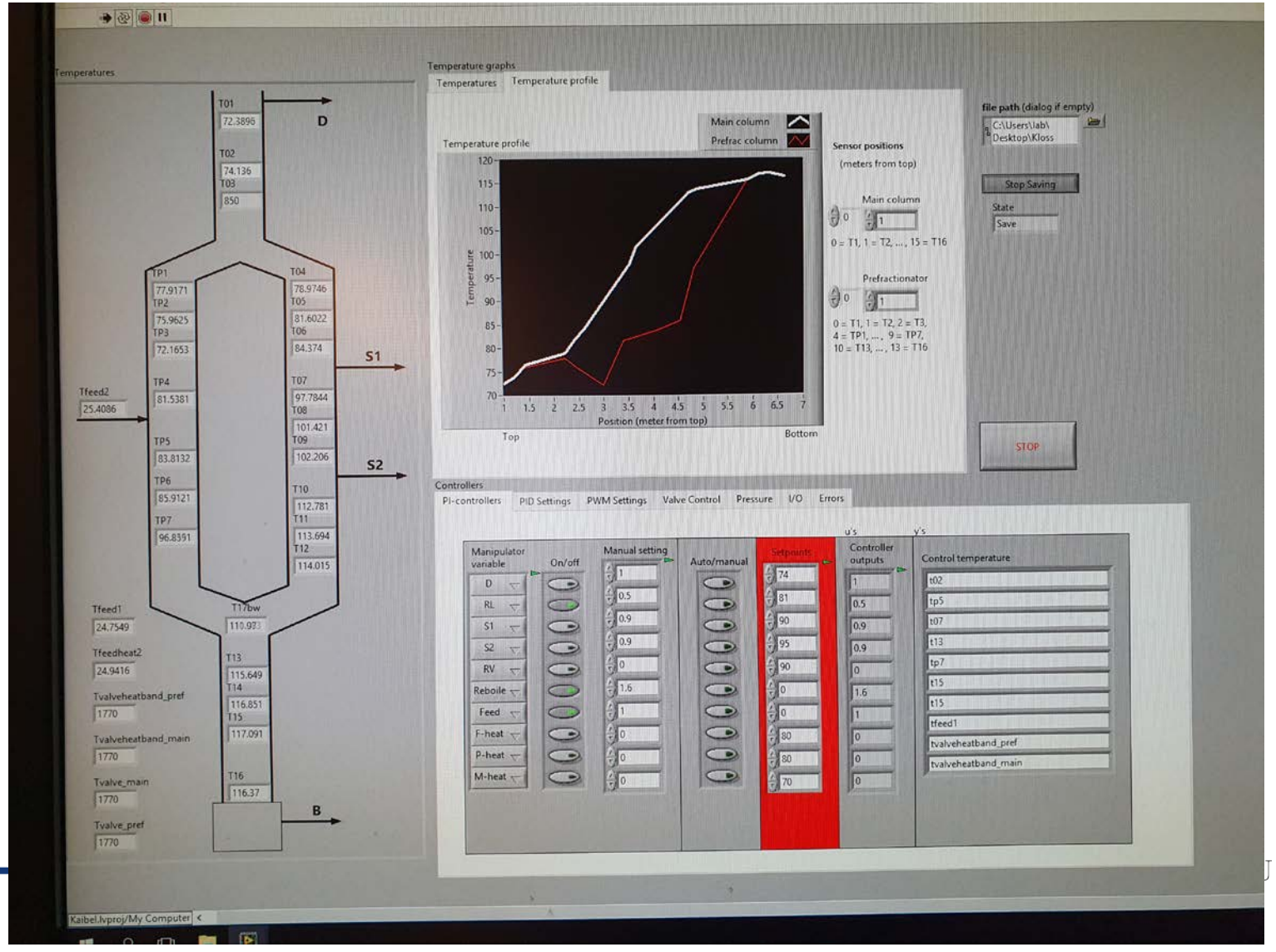
Experimental vapor split with application to Kaibel column (based on PhD work of Dwivedi)

Ivar J. Halvorsen and Benedikt Stefan Kloss

Extract from EFCE Bergen Meeting 2012

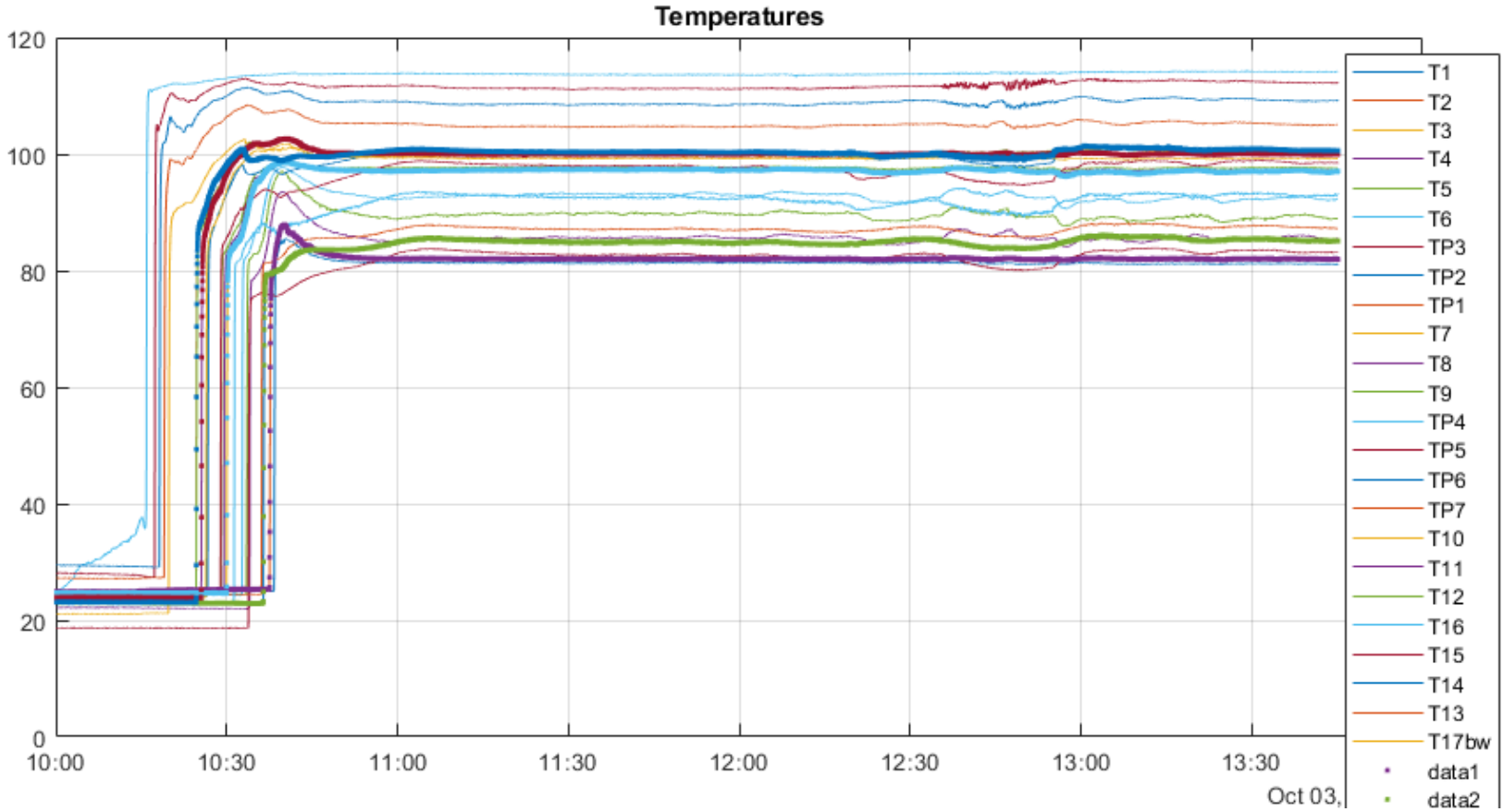
Some results from recent runs

- Running with 3 components
  - Ethanol
  - Propanol
  - Butanol
- Controllers
- D: T02, Rl->TP2
- S2: T11, Rv->TP6
- Fixed boilup



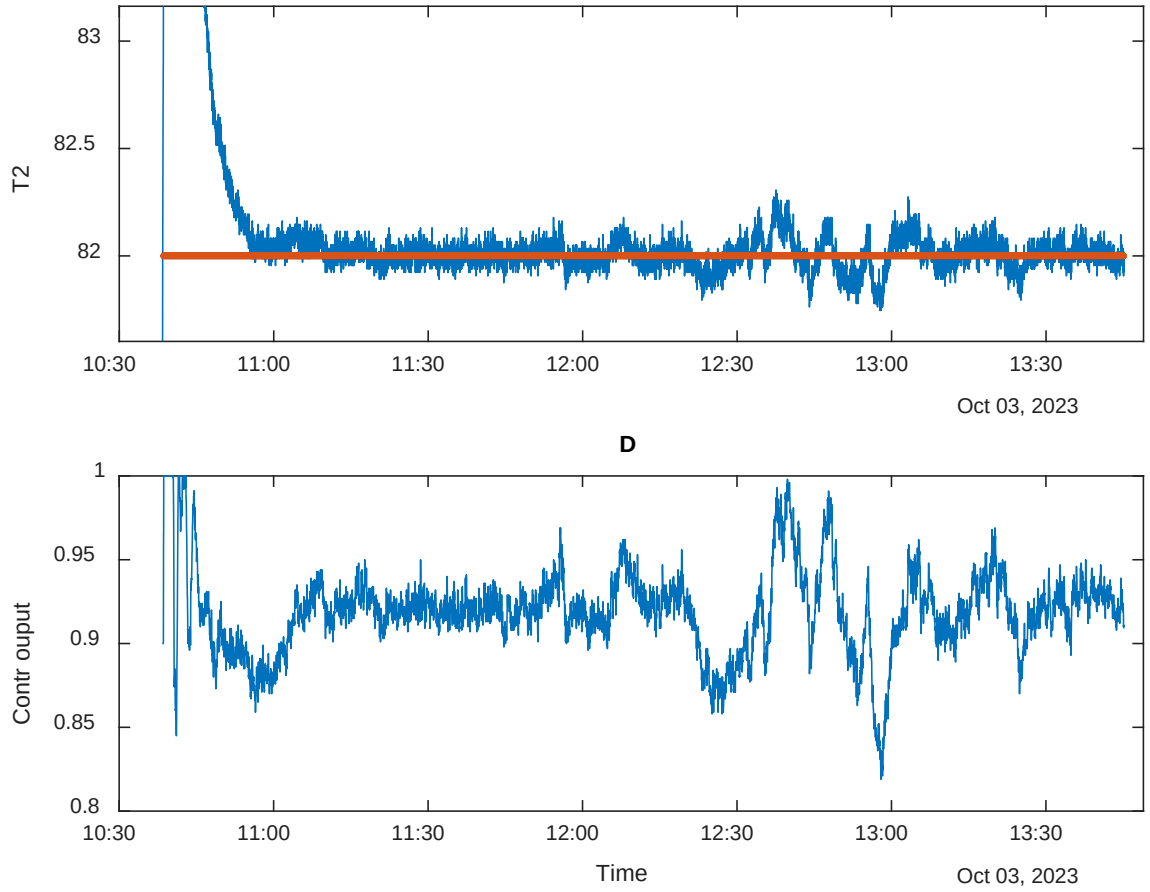
Startup

- Startup is quite simple!
- Heat front move upwards, with total condensation at the front by heating of column&internals
- Top controller activated immediately
- Add feed and go on



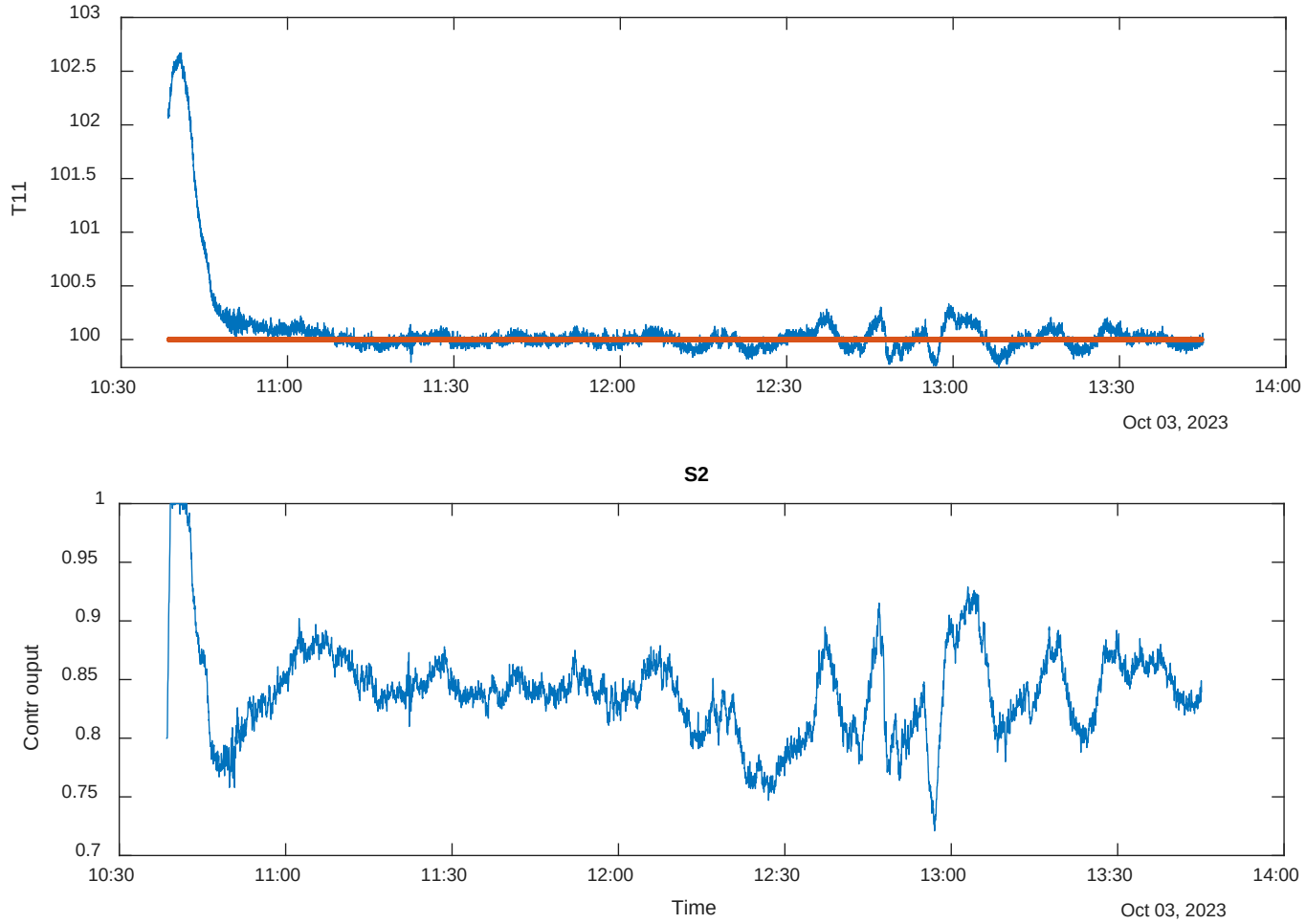
Controlling top by manipulating D-product

- Controller can be activated immediately after startup, when temperature is approaching setpoint



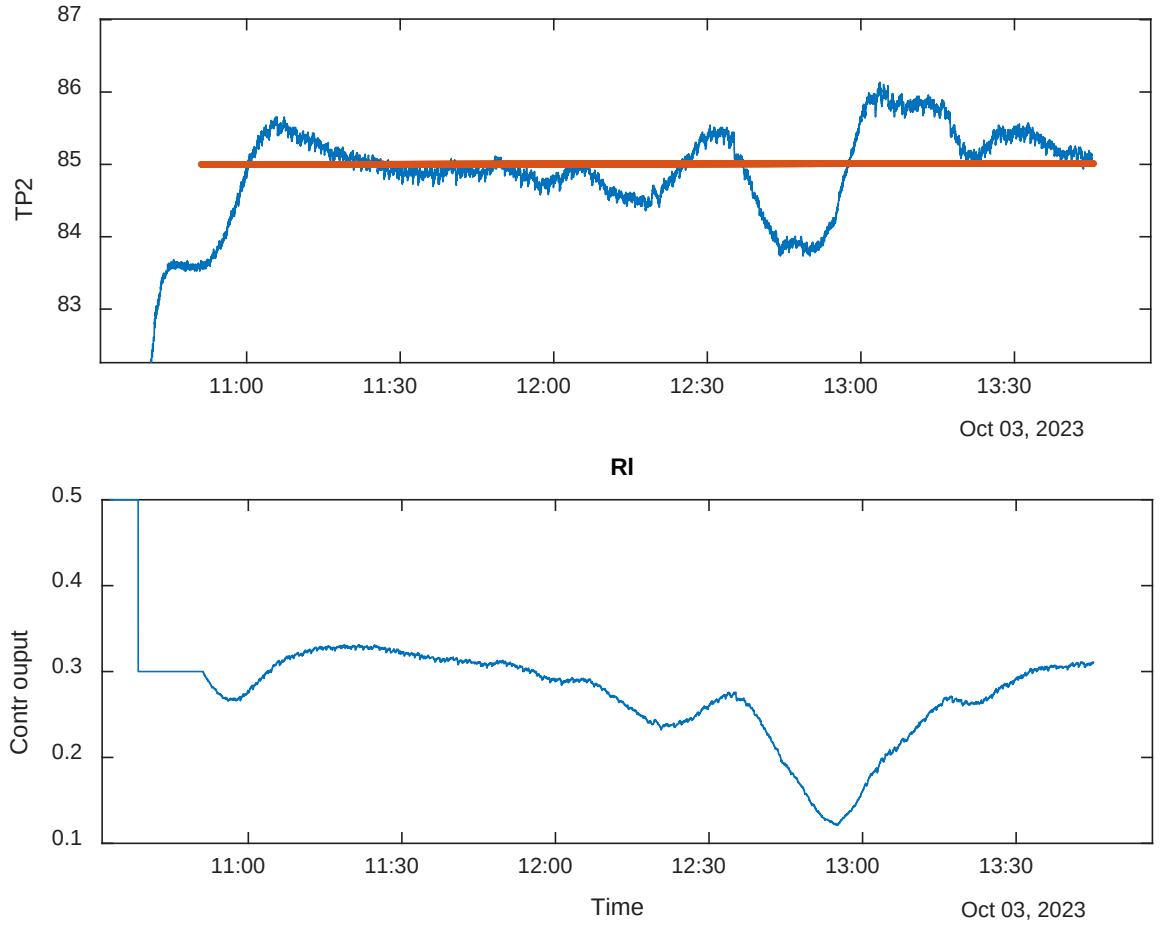
Control of sidestream by manipulating S2

- Control temperature just below S2 (T11)
- Temp-position depends on profile slope, AND the main impurity! This can be determined by Vmin-diagram



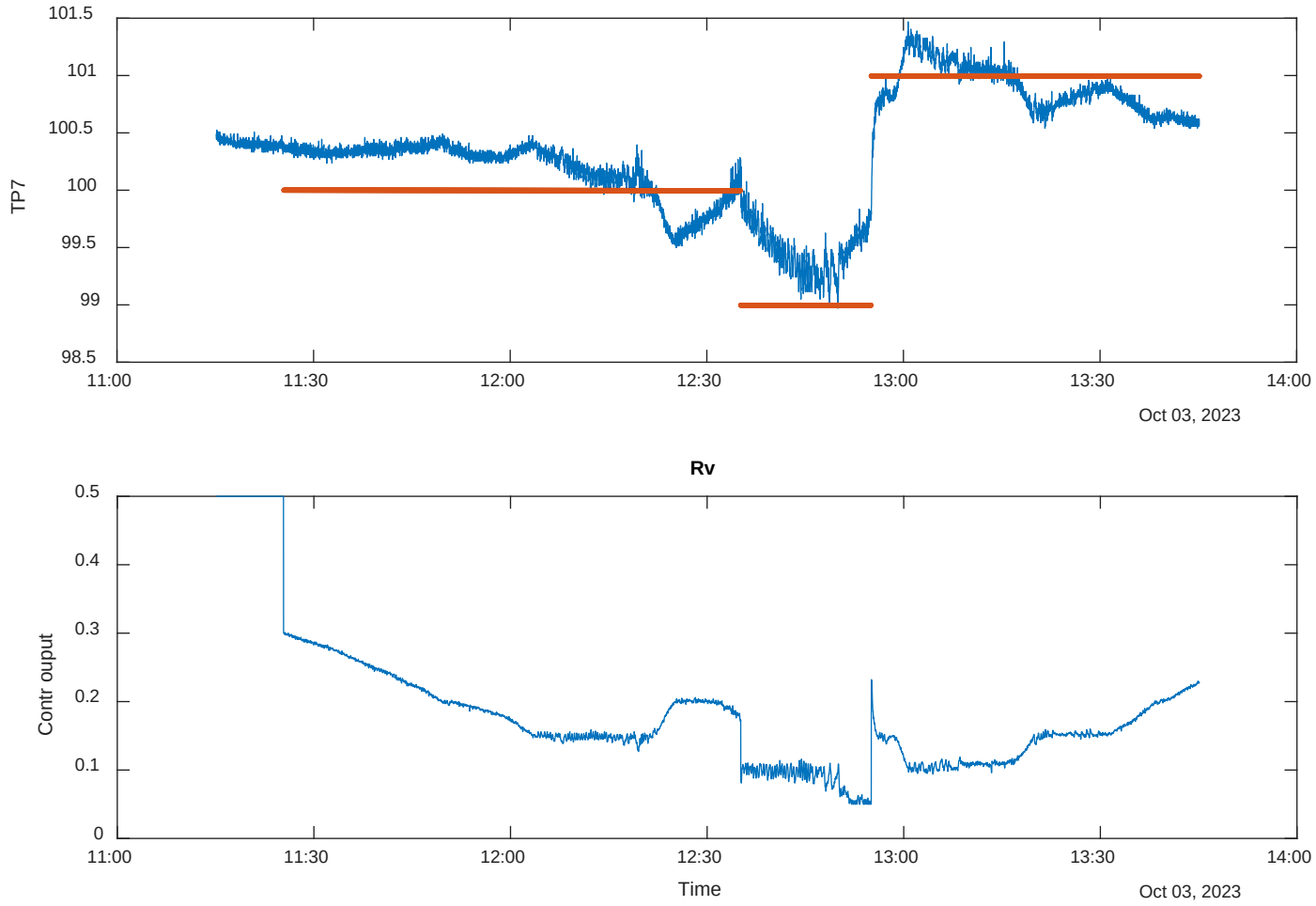
Controlling Prefrac top (Tp2) by Liquid split (Rl)

- For the prefractionator this is equivalent to using reflux in a conventional column
- Selection of temperature points are configurable



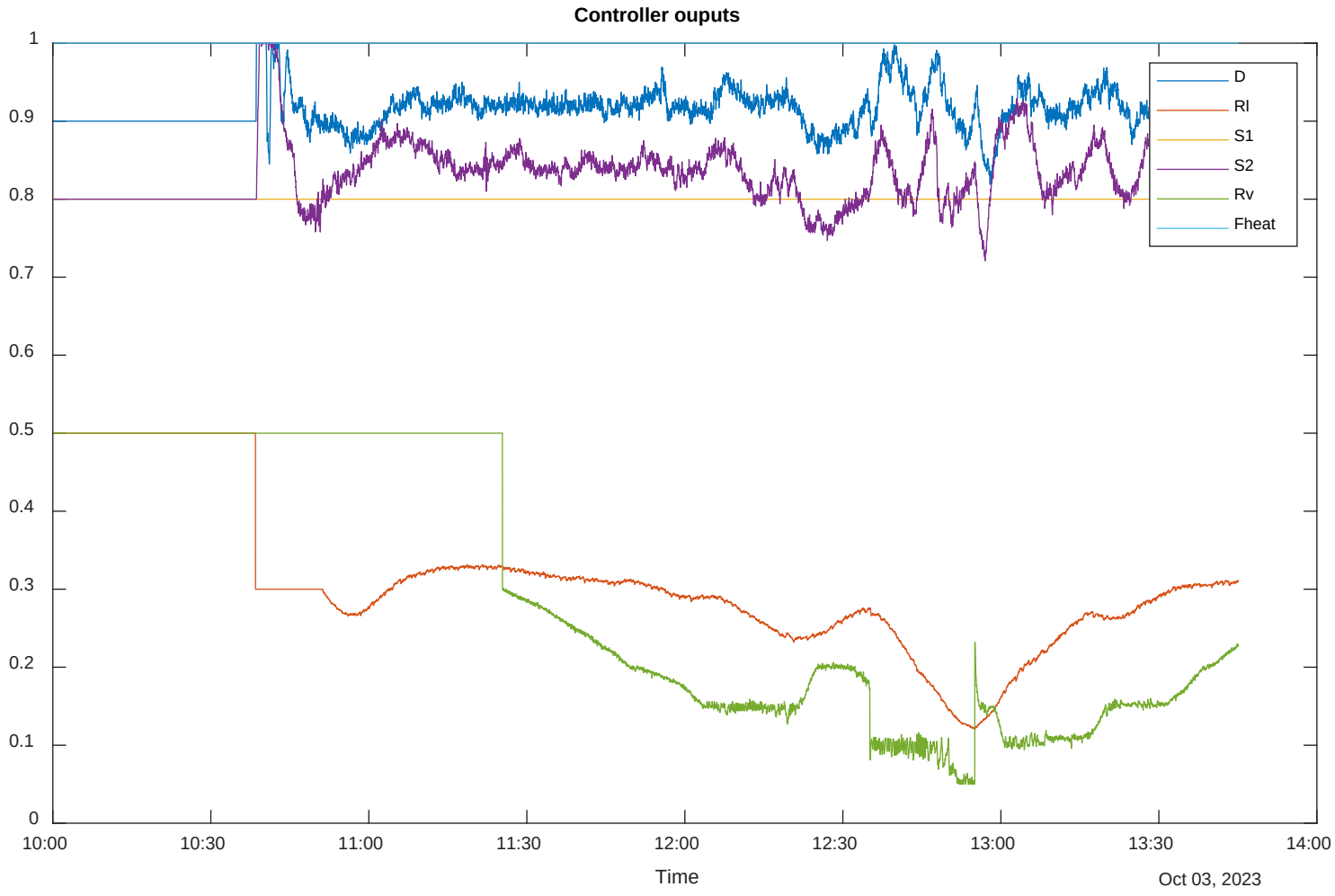
Active vapor split control

- Successful two-point control of prefractionator, using Rv in combination with RI
- Observe that the setpoint changes cause the upset in other loops
- No systemetic tuning yet.

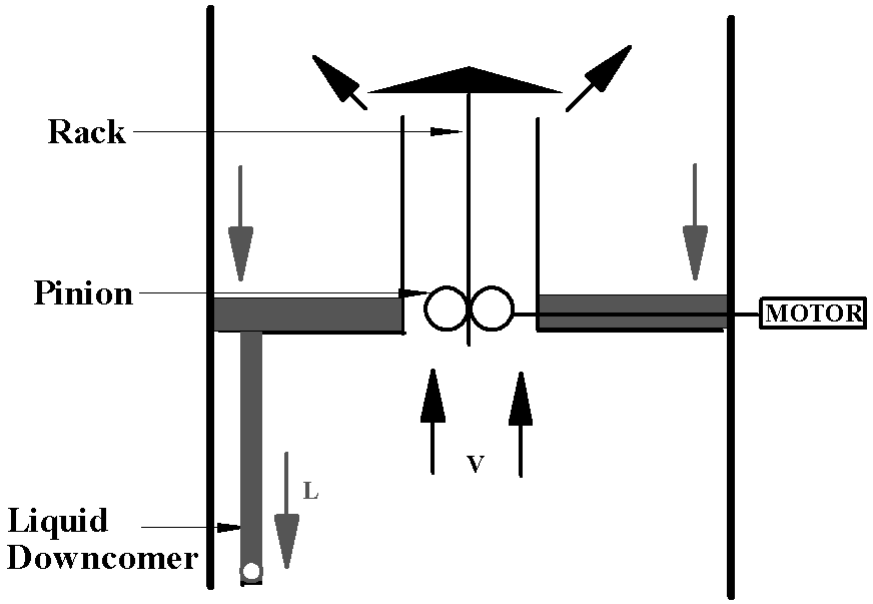


Manipulated variables in this run

- Feed 2 liters/h
- Rebiler: 1.8 kW

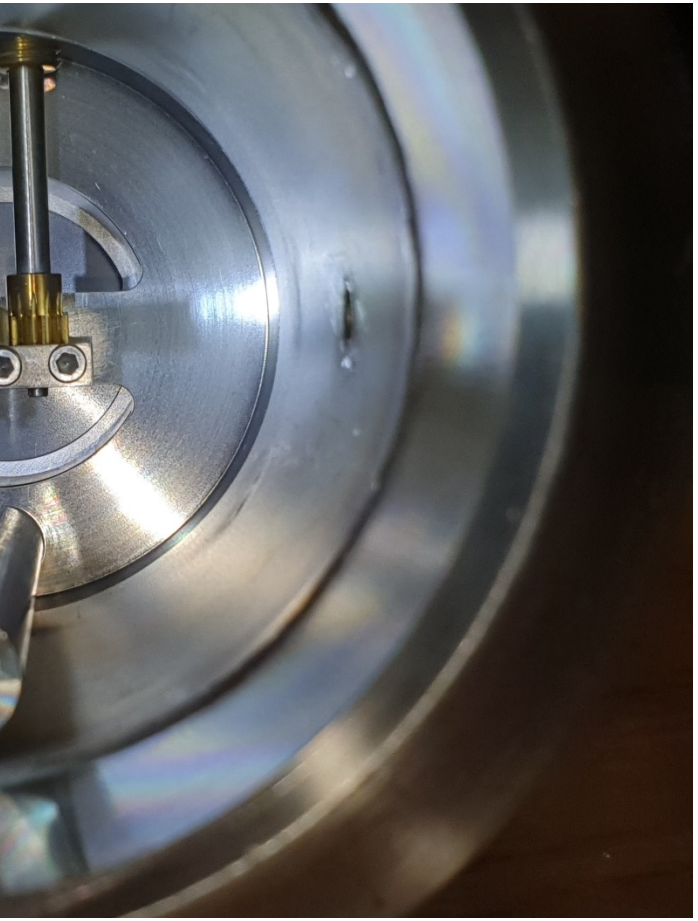


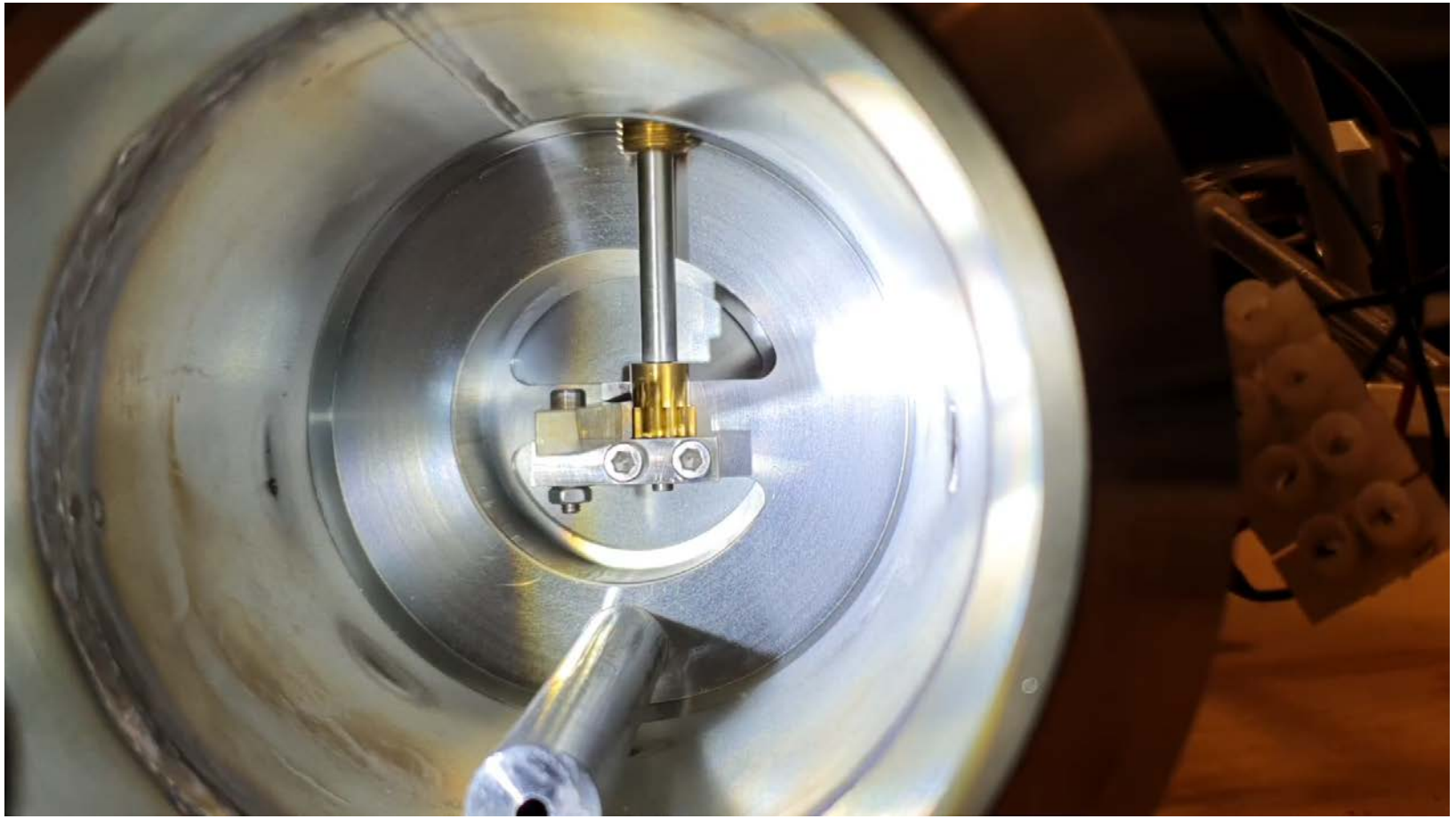
Vapor valves



Schematic of the vapor split valve

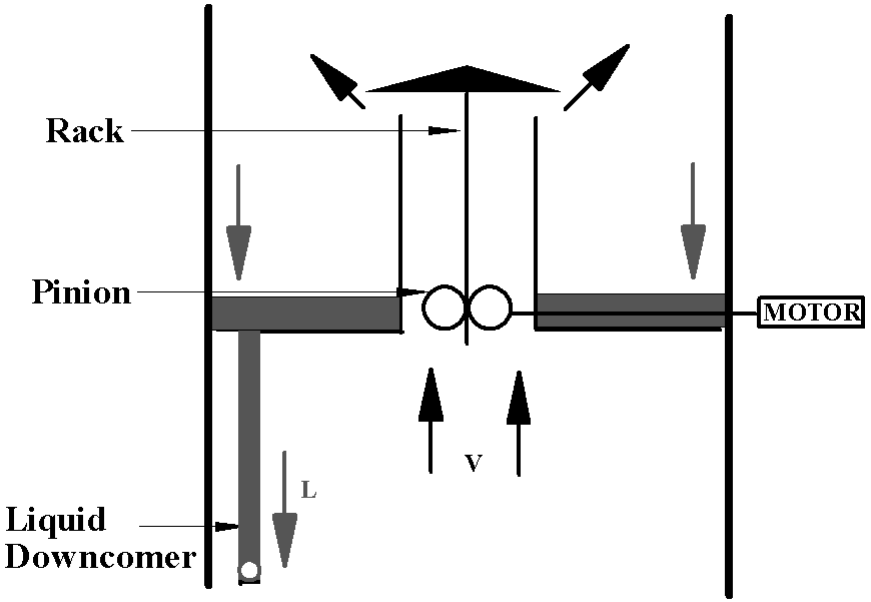
From top left: Valve in fully open position
Top right: Rack and pinion arrangement





The vapor valves are simple – but works

- Some practical issues with the liquid downcomer , may be clogged by fragments from Rashig rings
- The vale is overdimensioned:
  The active choking occur only below 5-10% opening
- Not practical for open loop use (inaccurate).
- But USE IN FEEDBACK loop,
- The controller ensures correct opening.
  Need only a rought monotonic characteristic and fast action



Some other issues on Vapor valves

- Downcomer construction must be adjusted/robustified
- Sizing and valve characteristic should better adapted (E.g. realize a "equal percentage characteristic")
- It must be FAIL-SAFE OPEN
- Robustness and reliability for an industrial implementation must be focused.
- E.g. maintenance access.
- ALWAYS use in (fast) FEEDBACK control
- Because it is very difficult to predict the exact characteristic form the opening.

Switching funnels

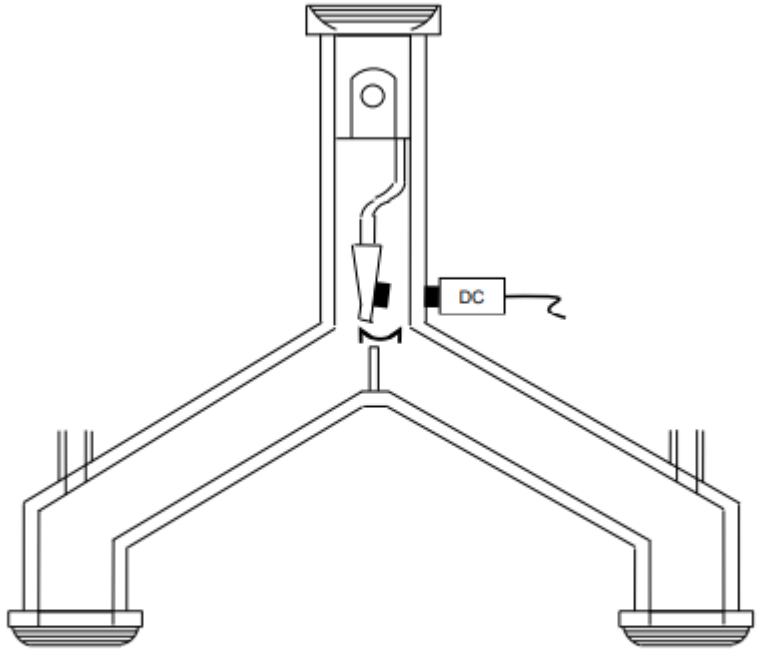
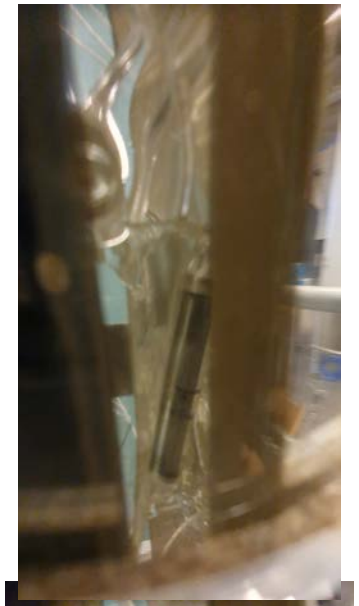


Figure 7.5: Detail of the liquid split section. The solenoid operates the swinging funnel which distributes the liquid reflux to either prefracionator (left) or main column (right). (The nozzles shown on either side are for inserting temperature measurements inside the column.)

Figure 7.2: Side-stream product draw. Swinging funnel inside column section directs the liquid to the product line or as reflux.

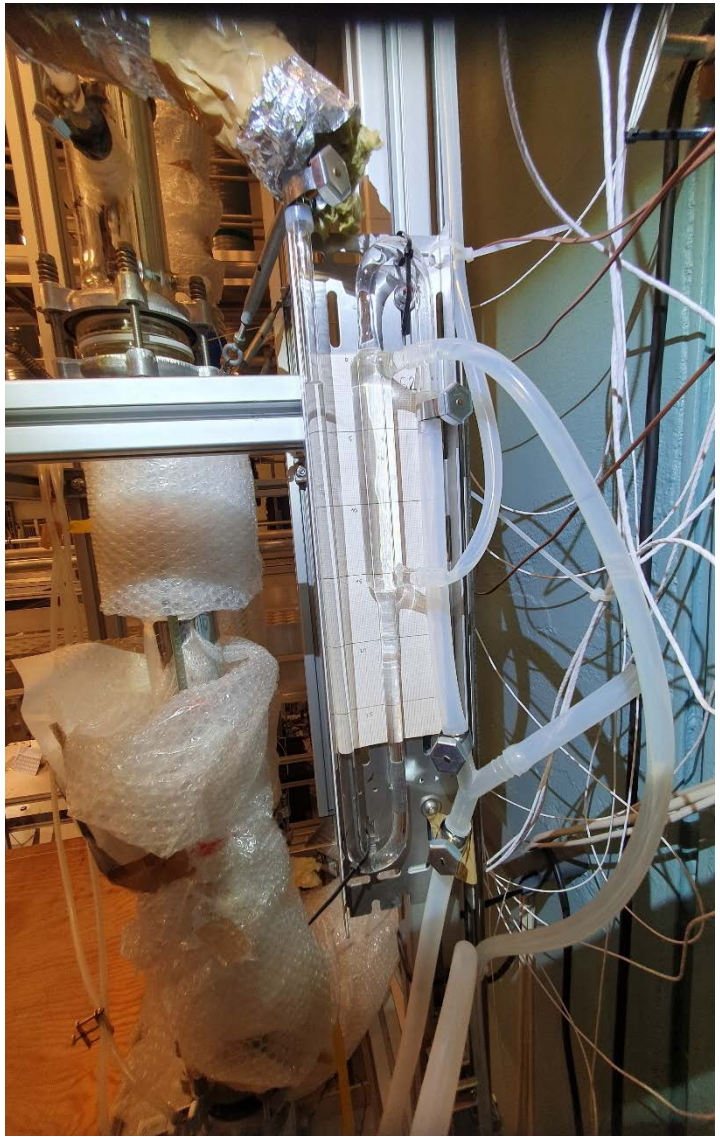
Switching funnels for products

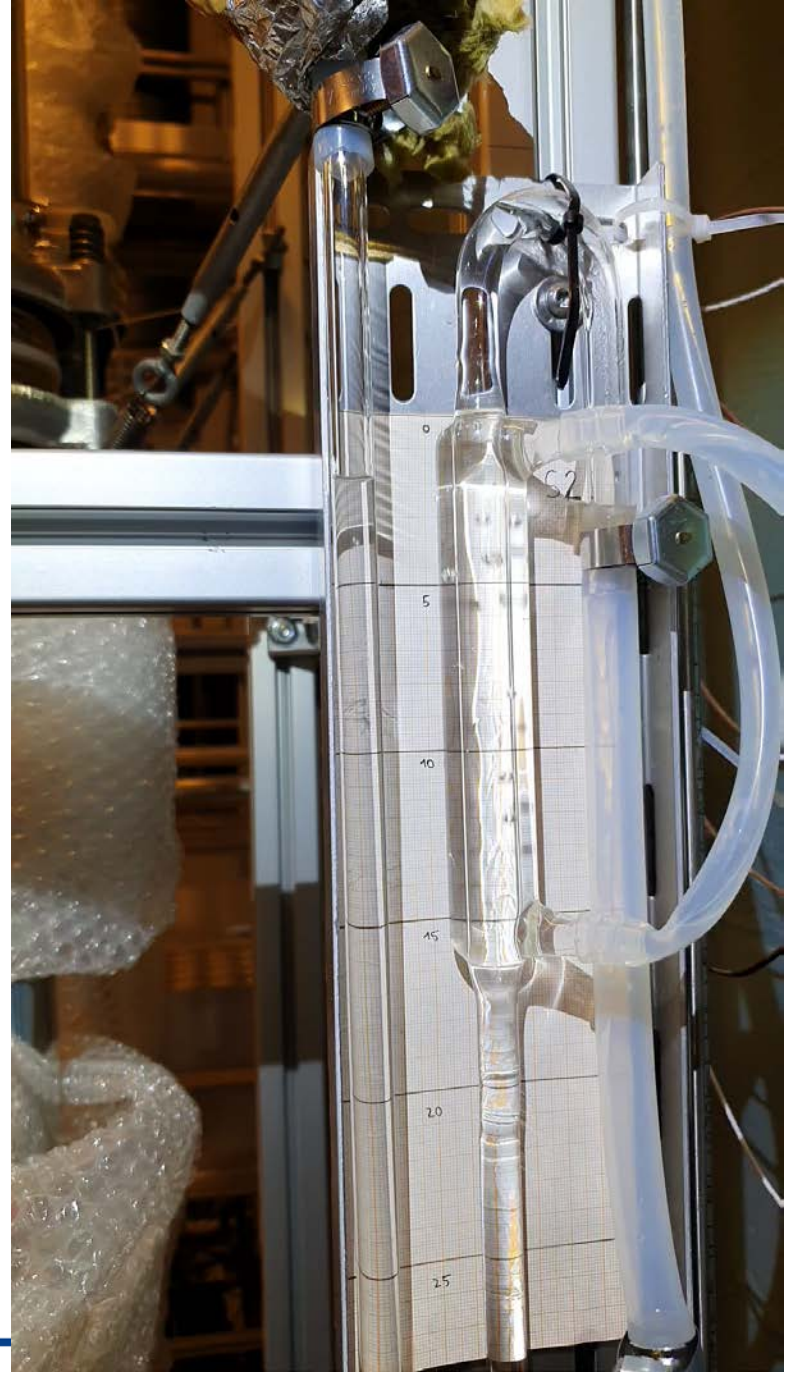
- Pulse Width Modulated
- SMART PWM ensure high resolution
- 8-12 sec basic switching time
- Value : Fraction of liquid down the column. Rest to side



Product Draws

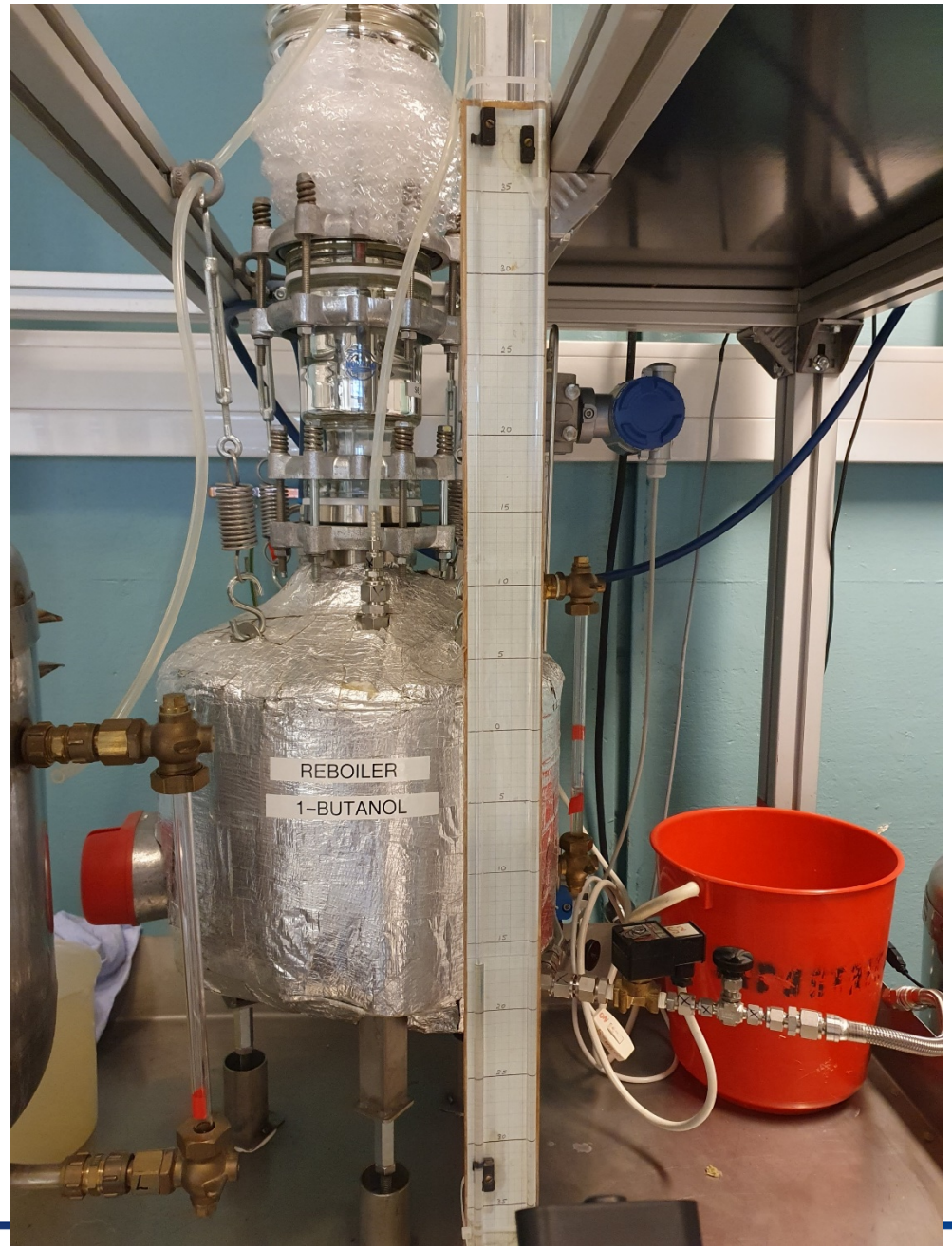
- Product cooler
- Liquid lock (U-tube) prevents vapor escape
- 8-12 sec basic switching time
- Product rate: Internal liquid rate times (1-u) where u is controller signal





Reboiler

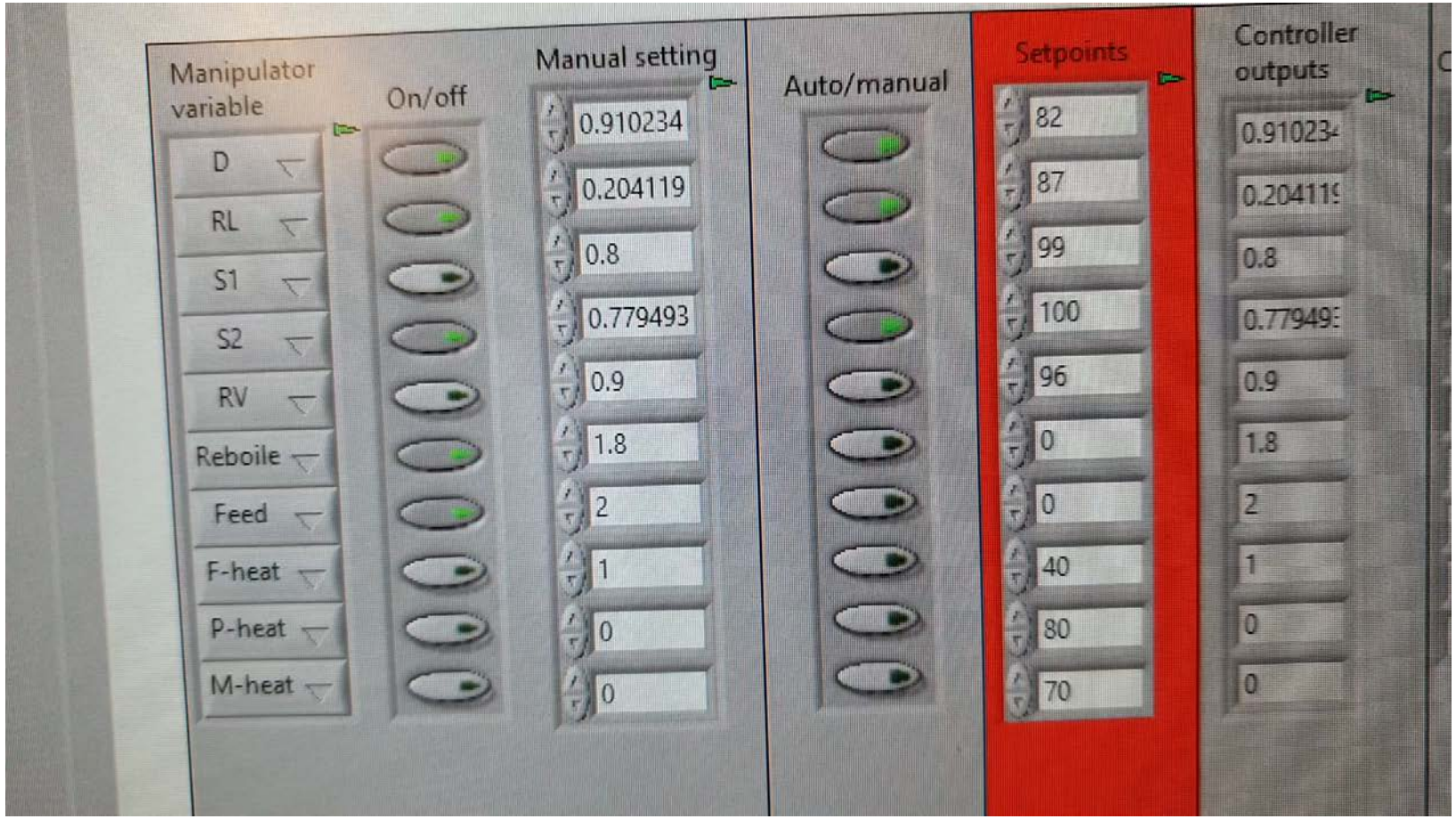
- Electric heater
- Typically operated between 1.5-2 kW
- Continuous variable power (thyristor control)

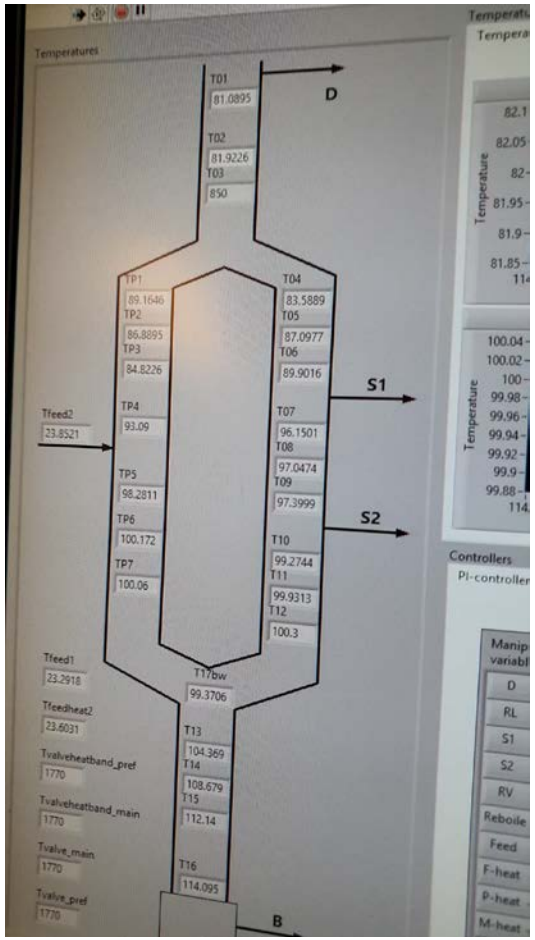


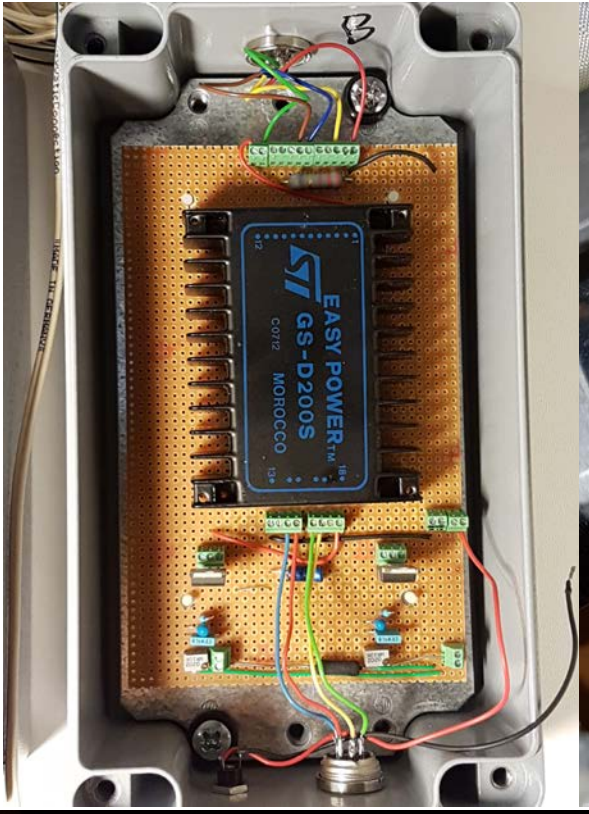
Feed

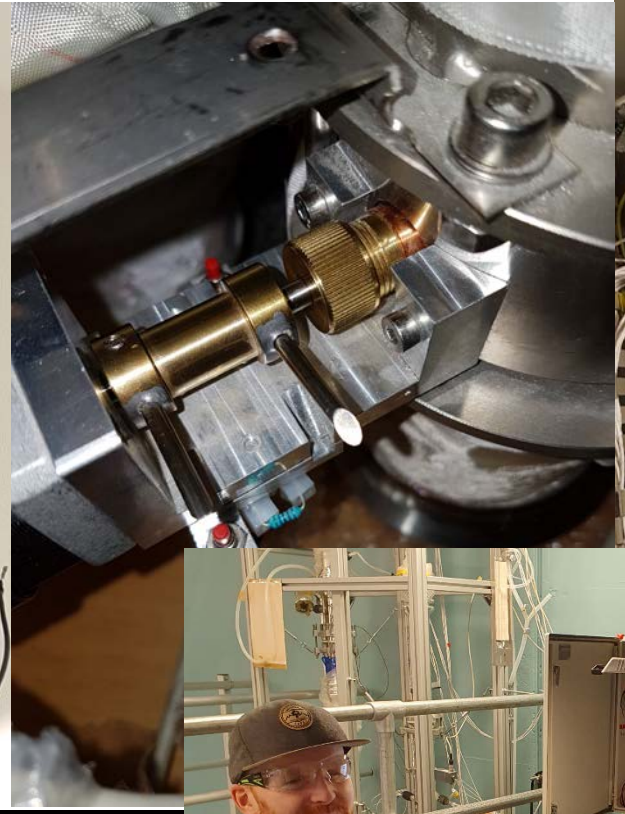
- Dosing pump 0-10 l/hour
- Usual feed 2-3 l/hour
- Products can be rerouted to feed tank, enabling long runs
- Feed heaters allows for feed temperature control

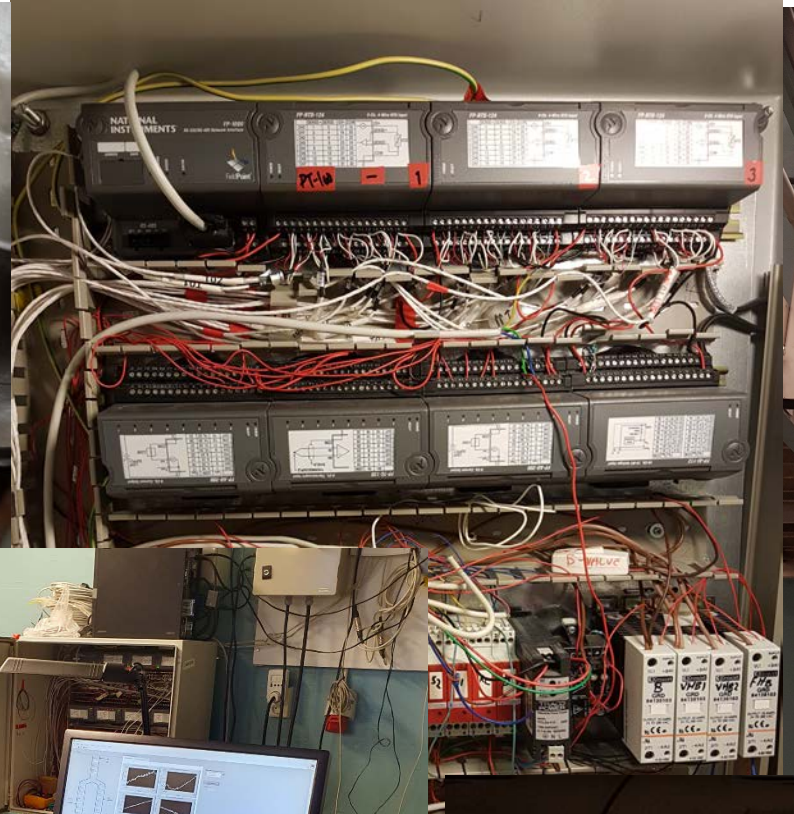
Operator station (LabView)

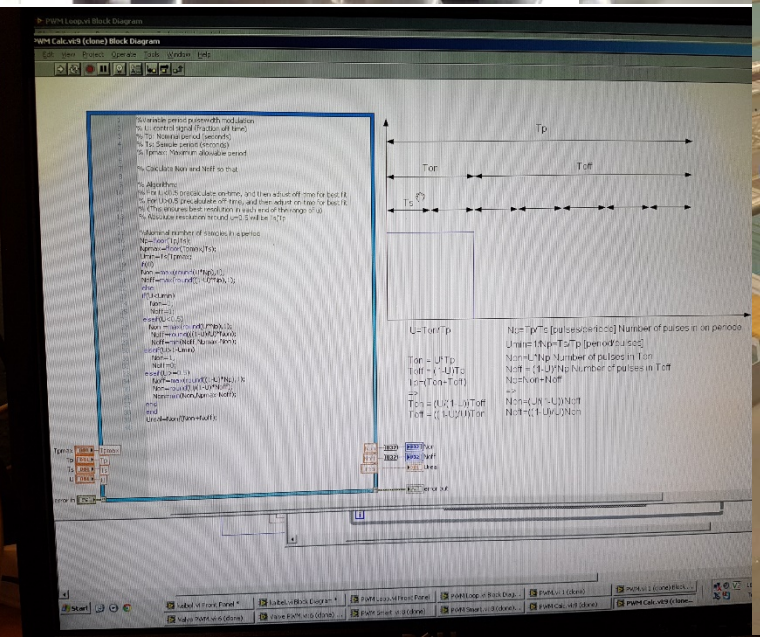


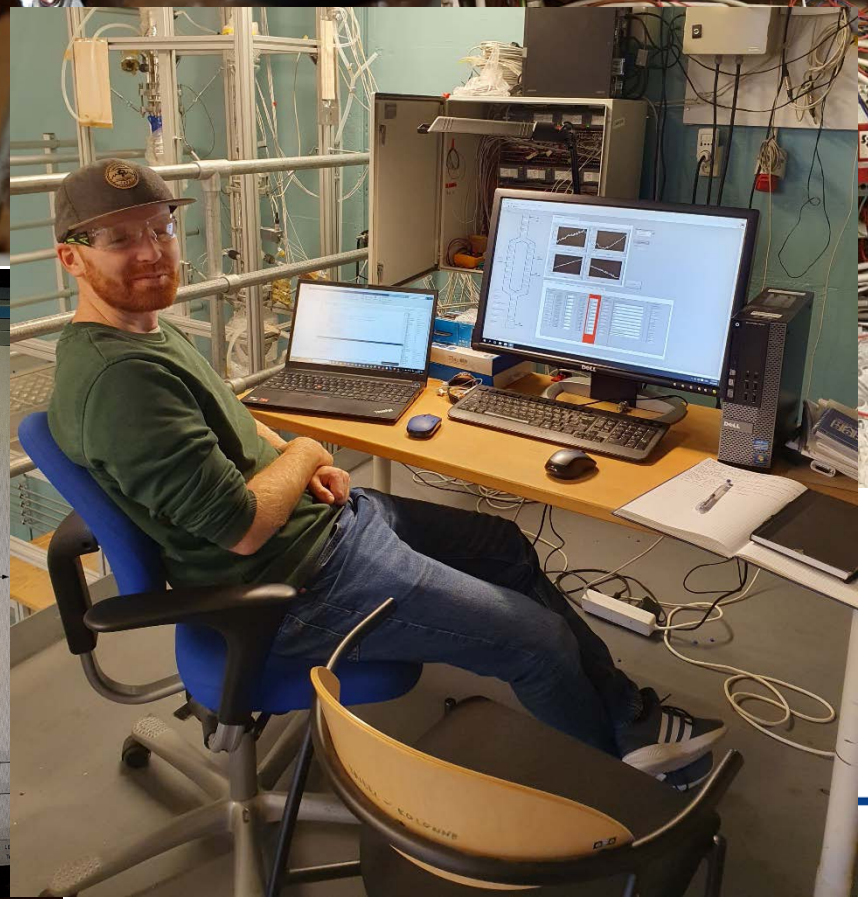


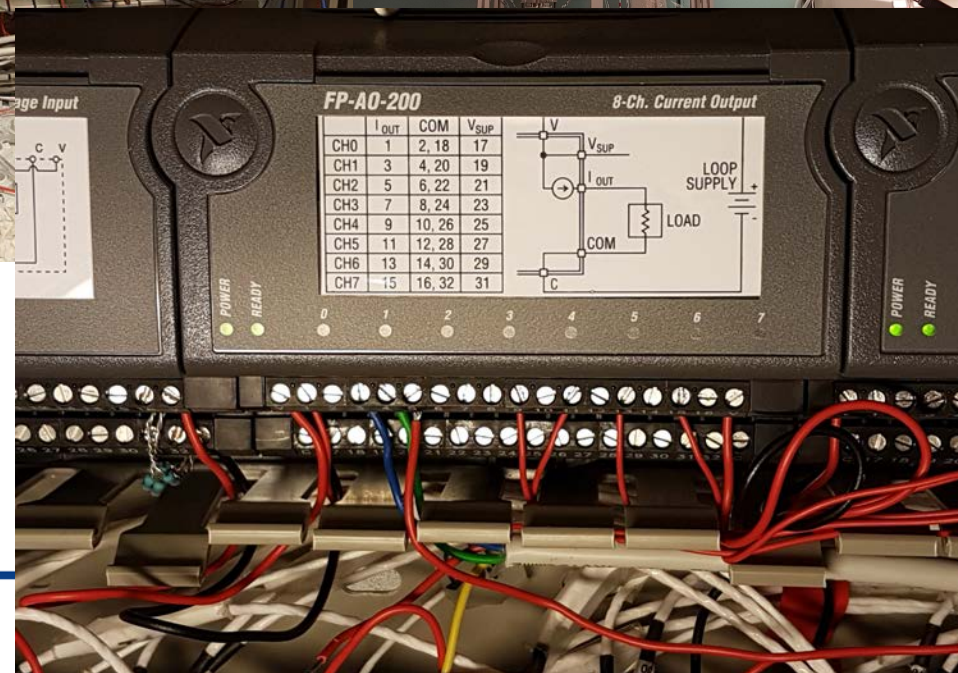

EASY POWER
GS-D200S
MOROCCO






PWM Loop.vi Block Diagram
PWM Calc.vi9 (clone) Block Diagram
Tp
Ton
Toff
Ts




FP-AO-200
8-Ch. Current Output
CH0 1 2, 18 17
CH1 3 4, 20 19
CH2 5 6, 22 21
CH3 7 8, 24 23
CH4 9 10, 26 25
CH5 11 12, 28 27
CH6 13 14, 30 29
CH7 15 16, 32 31
LOOP SUPPLY
LOAD
COM
POWER
READY