Flexibly Operated Capture Using Solvent Storage (FOCUSS)

Results

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SSE Thermal's Strategy

VISION: To be the leading provider of flexible energy in a net zero world

STRATEGIC PRIORITIES

OPTIMISE OPERATIONS	ACCELERATE DECARBONISATION	UNLOCK HYDROGEN
Deliver the flexible energy required by a renewables-led power system	*Deliver the enduring low-carbon power generation required for net zero*	*Support the accelerated development of a low-carbon hydrogen ecosystem*

2030 GOALS

- Reduced carbon emissions by >70% and on course to deliver SSE's Net Zero by 2040 target
- Deliver extended operational and commercial contribution from existing assets
- >2.5GW of low-carbon flexible generation
- 150GWh of low-carbon H2 storage
- >250MW of low-carbon H2 production

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Flexibly Operated Capture using Solvent Storage

Partners: University of Sheffield, AECOM | **Budget:** £670K (Grant[1] £515K) | **Schedule:** May 2022 to March 2025

Aim: Demonstrate cost-effective and high CO_2 capture levels during plant start-up, shutdown and transients

Department for Energy Security & Net Zero
Funded by

SSE Thermal
Project Lead

AECOM
Partner

The University Of Sheffield. Energy Institute. | Translational Energy Research Centre.
Partner

NC National Carbon Capture Center
Research collaborator

Supported by Industrial Engagement Group

Disclaimer: The contents of this presentation do not necessarily represent SSE's views but rather, the conclusions of the FOCUSS project

[1]Funded by the CCUS Innovation 2.0 Call

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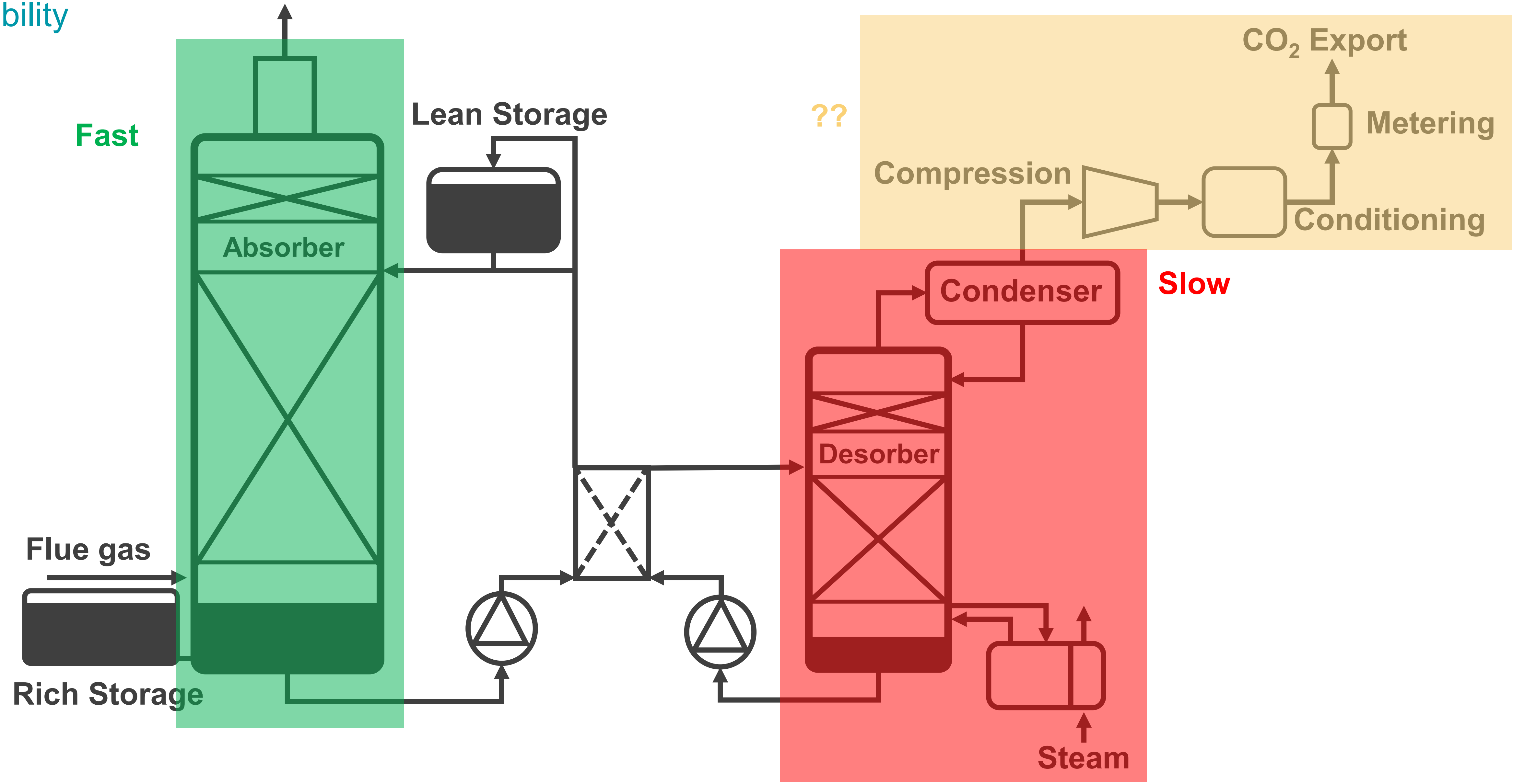
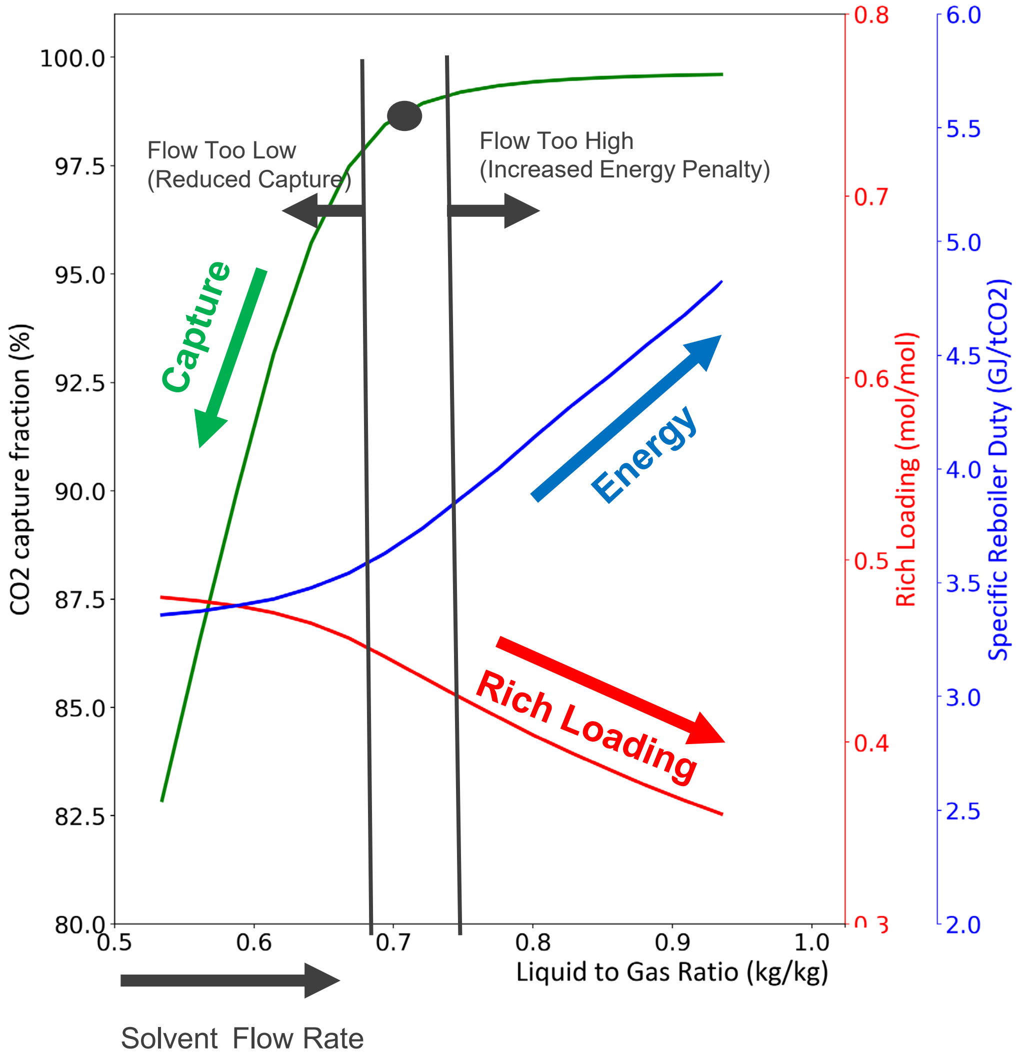
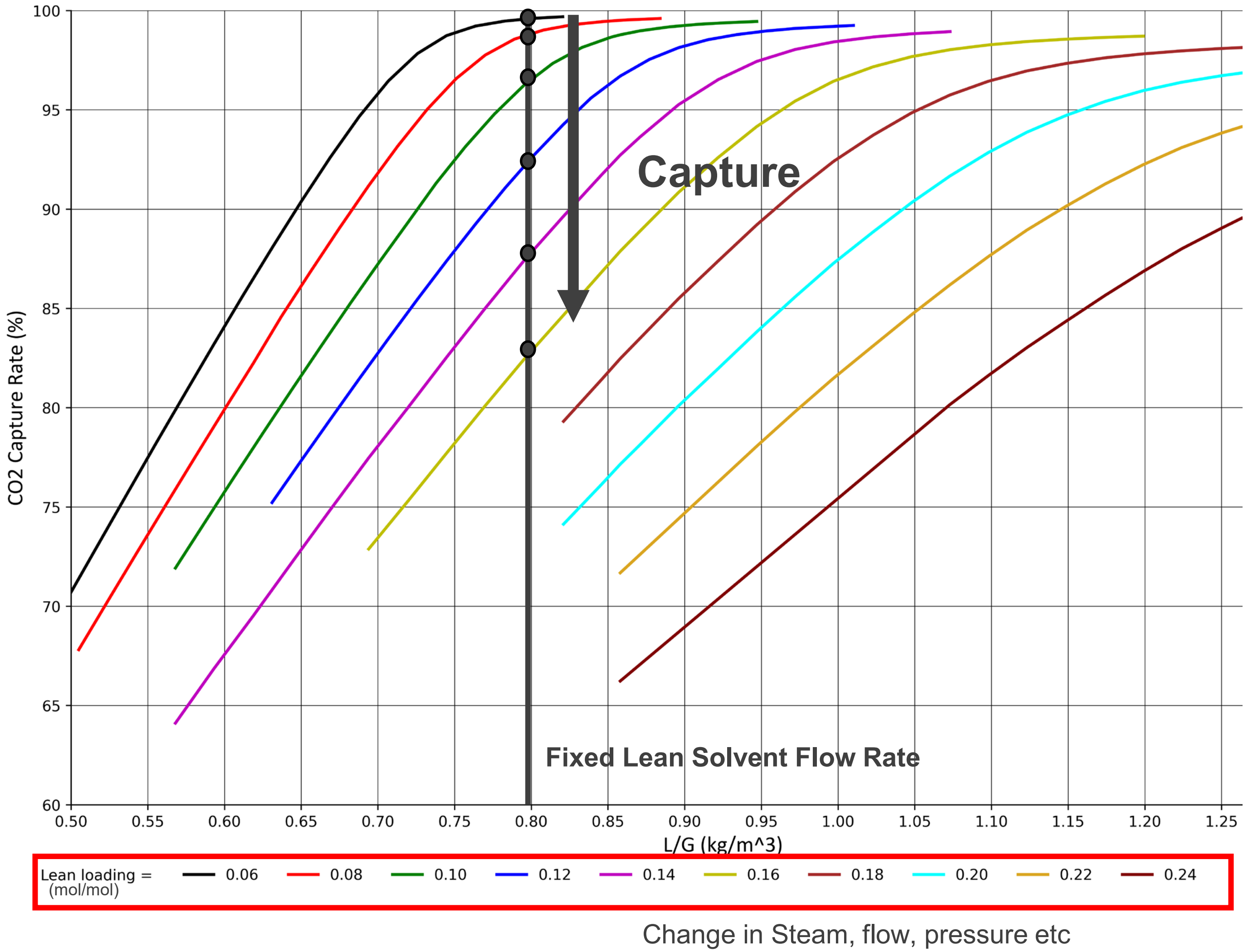
Flexibility



Solvent Storage For Control?





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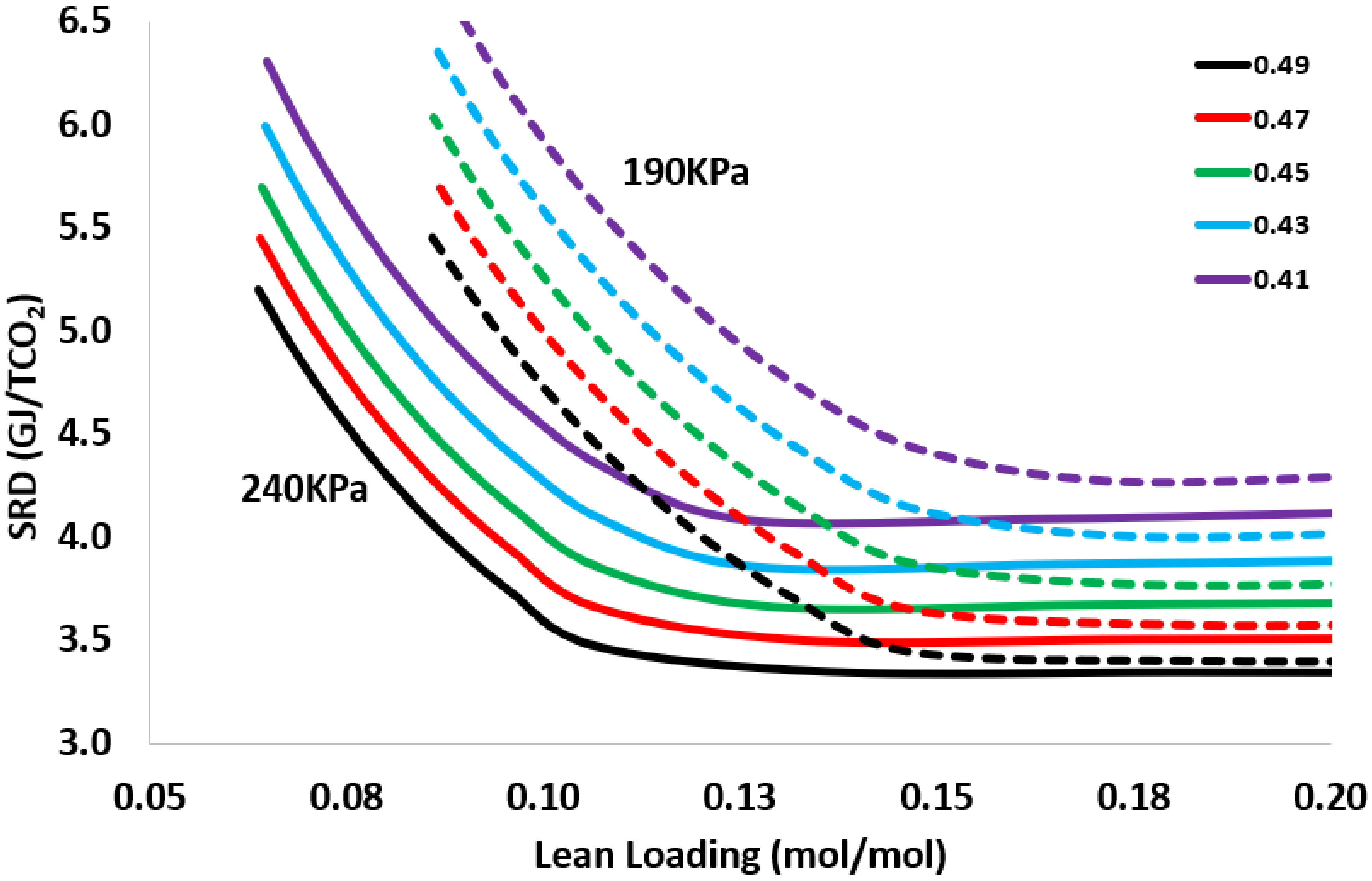
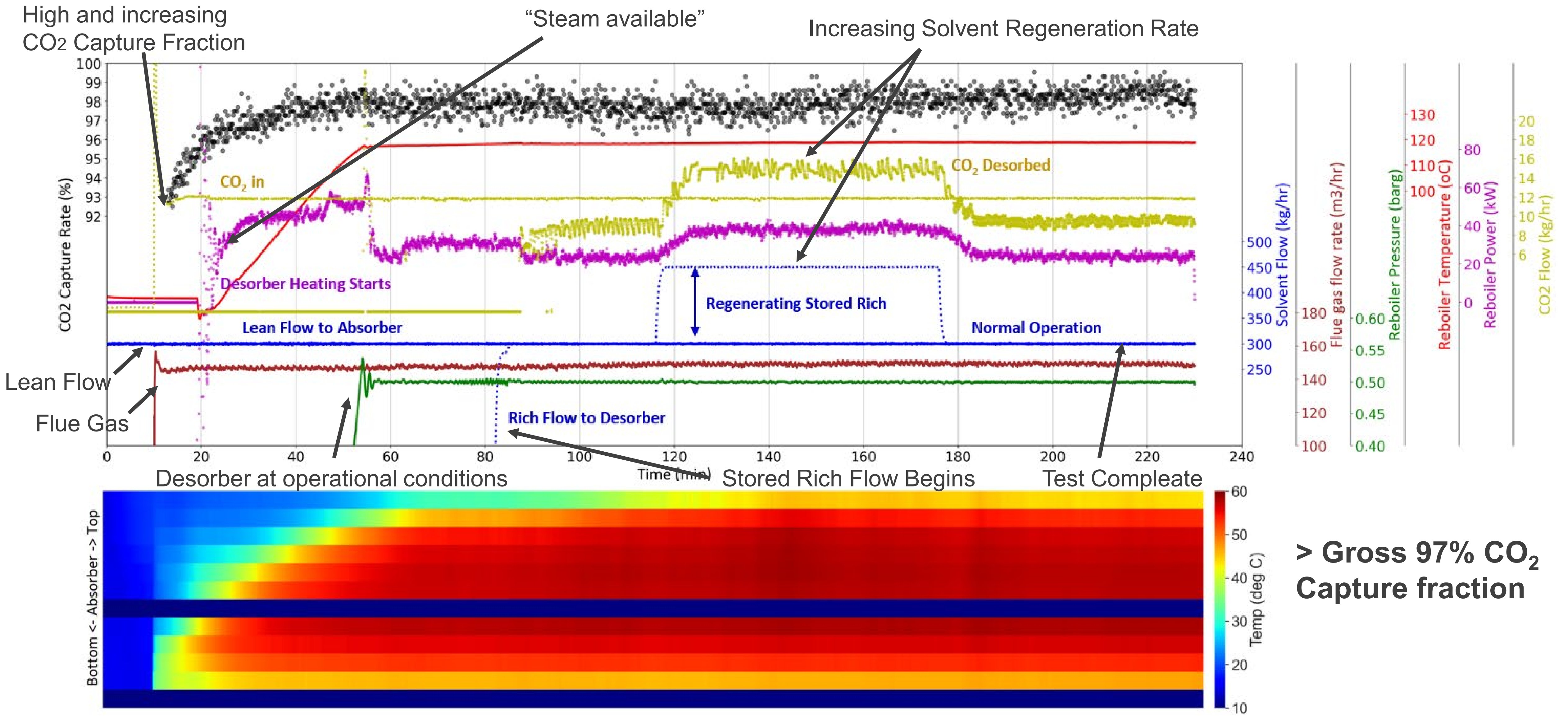


FOCUSS Test Campaign



> Gross 97% CO_2 Capture fraction

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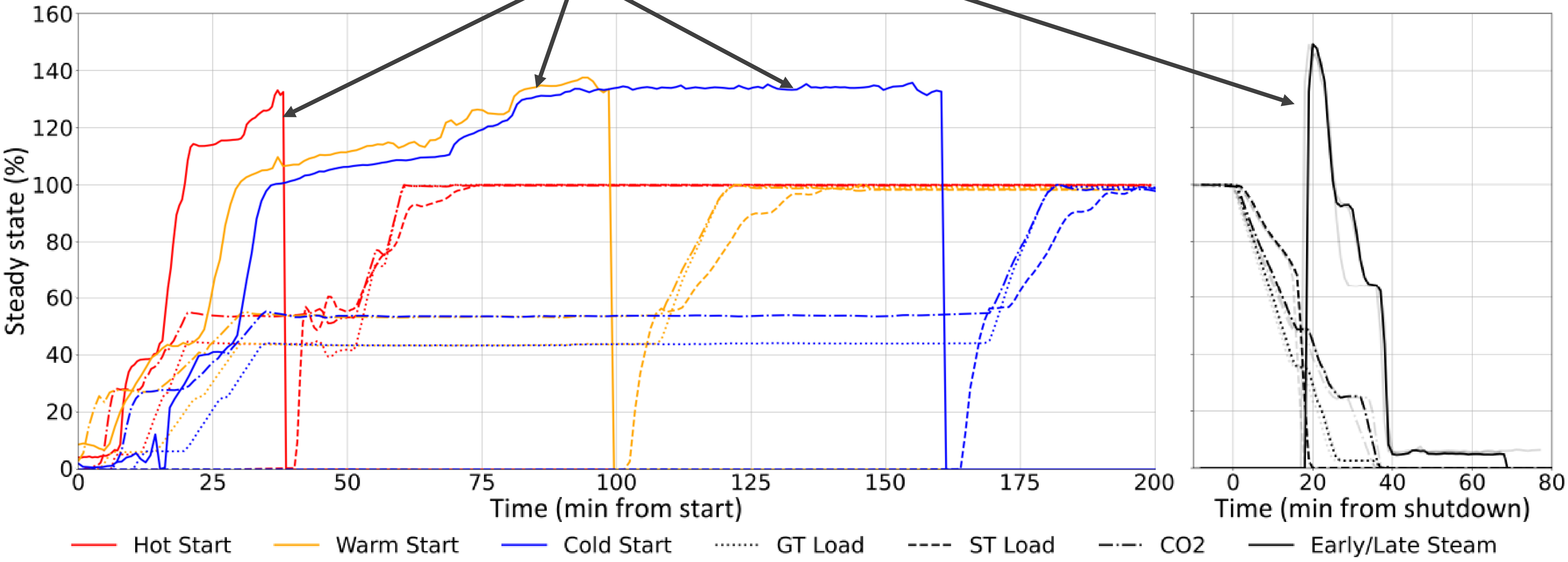
Early Steam

A CCGT start-up sequence produces steam that that cannot be admitted into the steam turbines

Normally bypassed and dumped into the condenser.

Investigates utilising this “Early Steam” & “Late Steam” for startup acceleration



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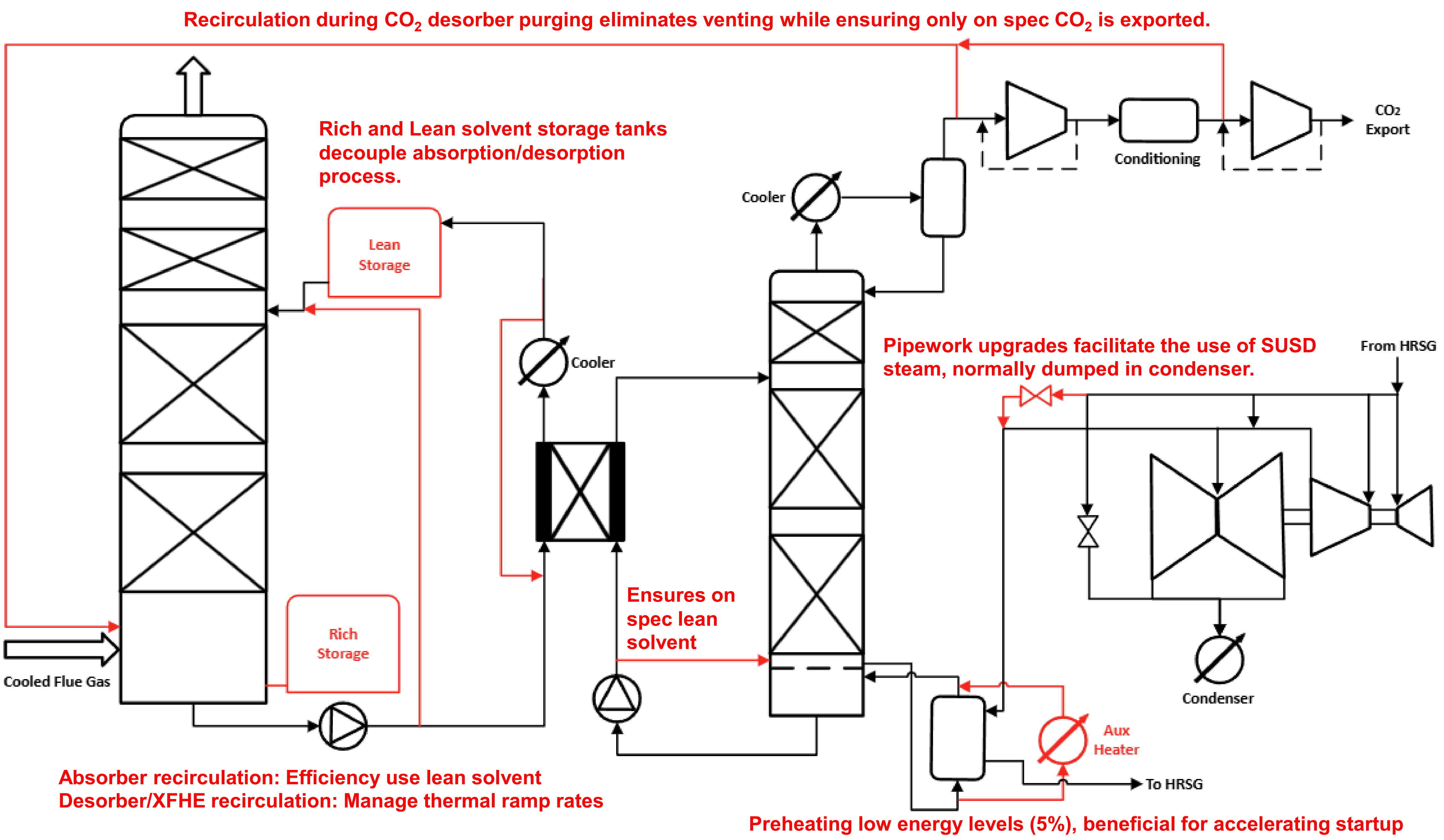
Early Steam

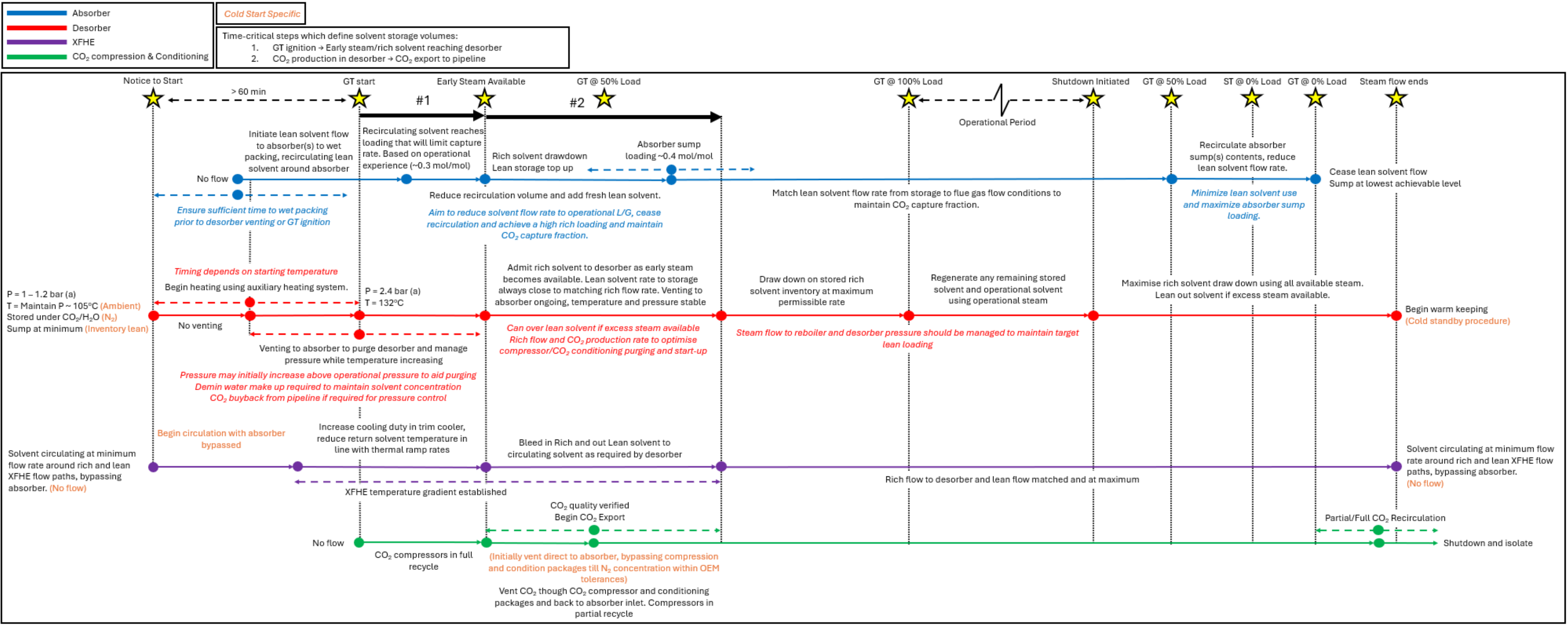
SU CO_2 Capture (%)			Increase in Nominal Inventory and Rich/Lean Storage Capacity
Hot	Warm	Cold	

RECOMMENDED PLANT MODIFICATIONS



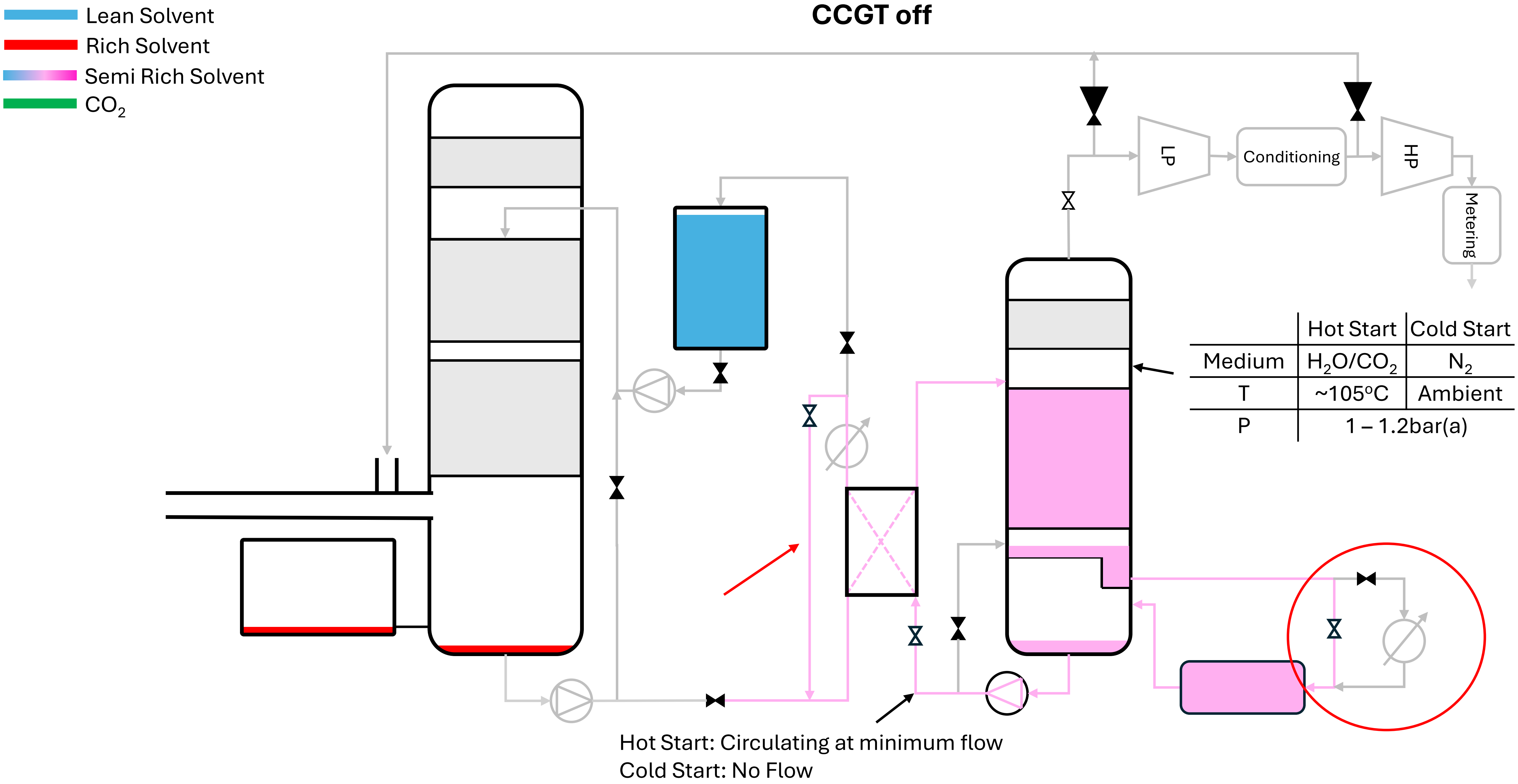
Recirculation during CO_2 desorber purging eliminates venting while ensuring only on spec CO_2 is exported.
Rich and Lean solvent storage tanks decouple absorption/desorption process.
Lean Storage
Cooler
Conditioning
CO_2 Export
Cooler
Pipework upgrades facilitate the use of SUSD steam, normally dumped in condenser.
From HRSG
Ensures on spec lean solvent
Rich Storage
Cooled Flue Gas
Condenser
Aux Heater
To HRSG
Absorber recirculation: Efficiency use lean solvent
Desorber/XFHE recirculation: Manage thermal ramp rates
Preheating low energy levels (5%), beneficial for accelerating startup

RECOMMENDED STARTUP SEQUENCE



Absorber
Desorber
XFHE
CO_2 compression & Conditioning
Cold Start Specific
Time-critical steps which define solvent storage volumes:
1. GT ignition → Early steam/rich solvent reaching desorber
2. CO_2 production in desorber → CO_2 export to pipeline
Notice to Start
> 60 min
GT start
#1
Early Steam Available
#2
GT @ 50% Load
GT @ 100% Load
Operational Period
Shutdown Initiated
GT @ 50% Load
ST @ 0% Load
GT @ 0% Load
Steam flow ends
Initiate lean solvent flow to absorber(s) to wet packing, recirculating lean solvent around absorber
Recirculating solvent reaches loading that will limit capture rate. Based on operational experience (~0.3 mol/mol)
Rich solvent drawdown
Lean storage top up
Absorber sump loading ~0.4 mol/mol
No flow
Ensure sufficient time to wet packing prior to desorber venting or GT ignition
Reduce recirculation volume and add fresh lean solvent.
Aim to reduce solvent flow rate to operational L/G, cease recirculation and achieve a high rich loading and maintain CO_2 capture fraction.
Match lean solvent flow rate from storage to flue gas flow conditions to maintain CO_2 capture fraction.
Recirculate absorber sump(s) contents, reduce lean solvent flow rate.
Minimize lean solvent use and maximize absorber sump loading.
Cease lean solvent flow
Sump at lowest achievable level
Timing depends on starting temperature
Begin heating using auxiliary heating system.
P = 1 – 1.2 bar (a)
T = Maintain P ~ 105°C (Ambient)
Stored under CO_2/H_2O (N_2)
Sump at minimum (Inventory lean)
No venting
P = 2.4 bar (a)
T = 132°C
Admit rich solvent to desorber as early steam becomes available. Lean solvent rate to storage always close to matching rich flow rate. Venting to absorber ongoing, temperature and pressure stable
Draw down on stored rich solvent inventory at maximum permissible rate
Regenerate any remaining stored solvent and operational solvent using operational steam
Maximise rich solvent draw down using all available steam.
Lean out solvent if excess steam available.
Begin warm keeping
(Cold standby procedure)
Venting to absorber to purge desorber and manage pressure while temperature increasing
Can over lean solvent if excess steam available
Rich flow and CO_2 production rate to optimise compressor/CO_2 conditioning purging and start-up
Steam flow to reboiler and desorber pressure should be managed to maintain target lean loading
Pressure may initially increase above operational pressure to aid purging
Demin water make up required to maintain solvent concentration
CO_2 buyback from pipeline if required for pressure control
Begin circulation with absorber bypassed
Increase cooling duty in trim cooler, reduce return solvent temperature in line with thermal ramp rates
Bleed in Rich and out Lean solvent to circulating solvent as required by desorber
Solvent circulating at minimum flow rate around rich and lean XFHE flow paths, bypassing absorber. (No flow)
XFHE temperature gradient established
Rich flow to desorber and lean flow matched and at maximum
Solvent circulating at minimum flow rate around rich and lean XFHE flow paths, bypassing absorber.
(No flow)
CO_2 quality verified
Begin CO_2 Export
Partial/Full CO_2 Recirculation
No flow
CO_2 compressors in full recycle
(Initially vent direct to absorber, bypassing compression and condition packages till N_2 concentration within OEM tolerances)
Vent CO_2 though CO_2 compressor and conditioning packages and back to absorber inlet. Compressors in partial recycle
Shutdown and isolate

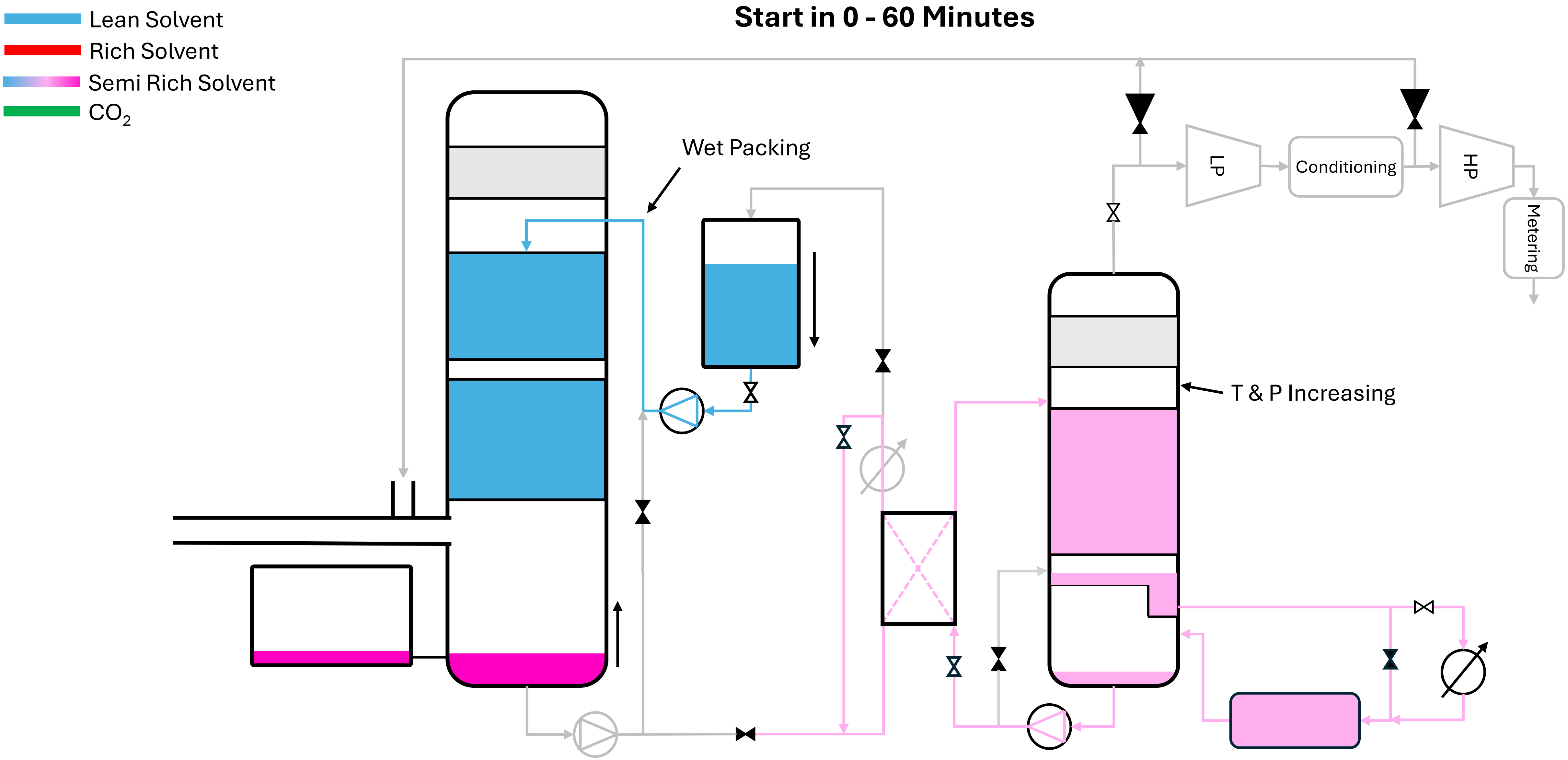
CCGT off



	Hot Start	Cold Start
Medium	H_2O/CO_2	N_2
T	~105°C	Ambient
P	1 – 1.2bar(a)	

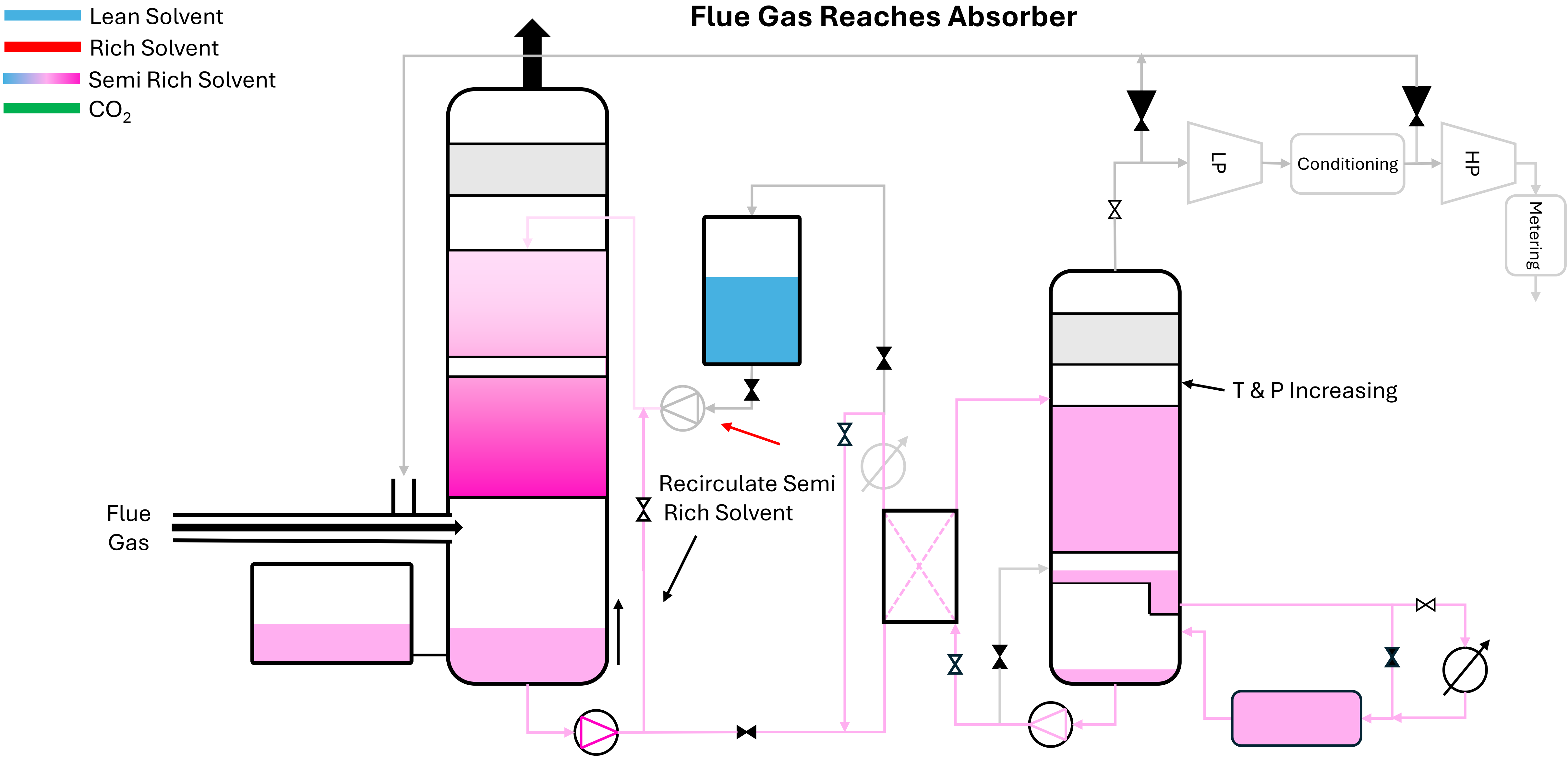
- Hot start: Flow should be circulating though the Cross HX and reboilers (bypassing the absorber) to maintain HX temperatures.
  - Auxiliary boiler can be used to maintain temperature.
- Cold start: Flow can be stopped and the desorber stored under pressure with an inert gas (i.e. N_2)

Start in 0 - 60 Minutes



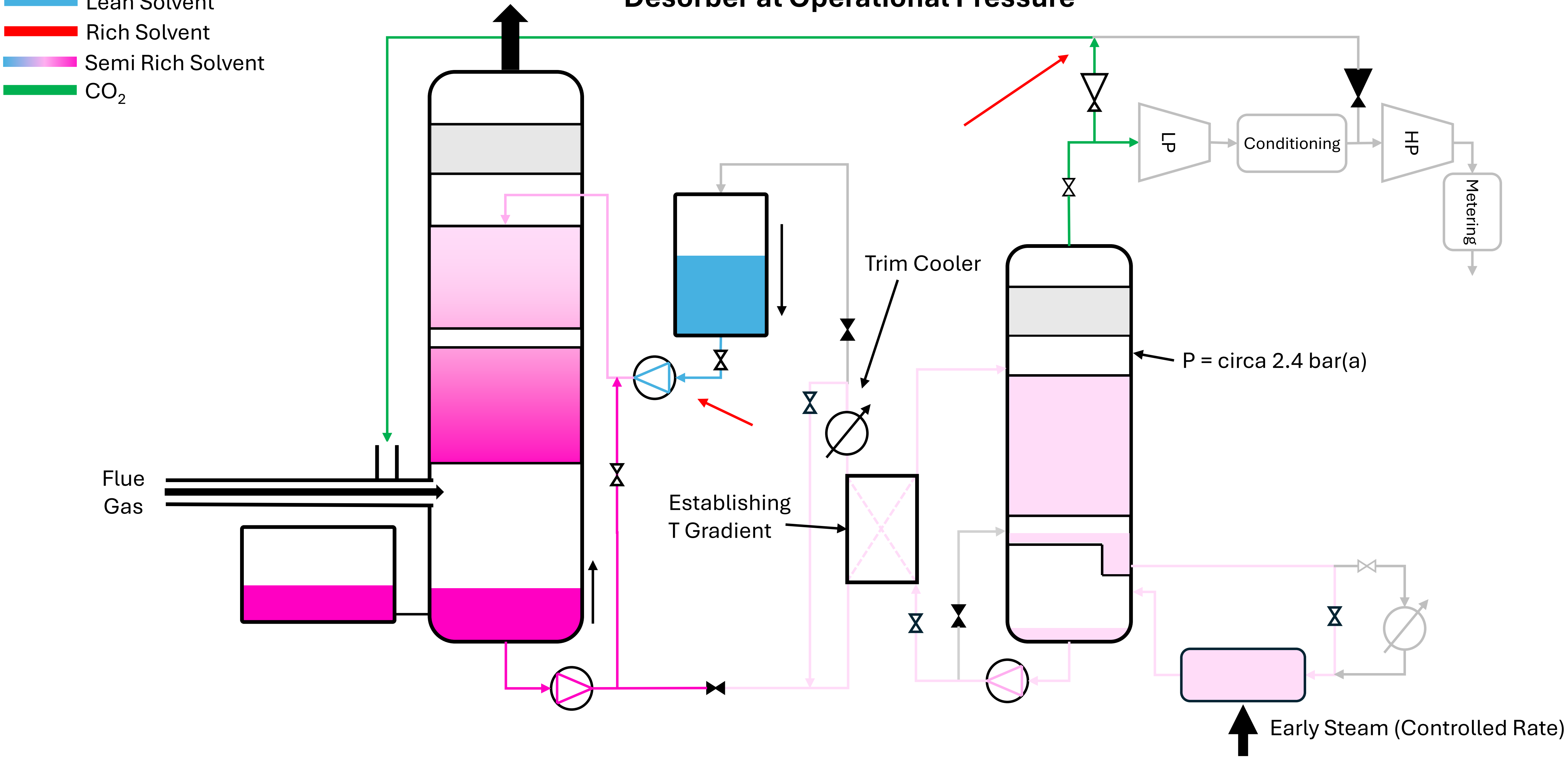
- Temperature should be increased within the desorber system using the auxiliary heater within heat exchanger thermal ramp rate limits (~ 1.7°C/min). Pressure within system will increase alongside temperature.
- At a suitable time before the start (circa 10min), initiate lean solvent flow from storage to the absorber to fully wet packing

Flue Gas Reaches Absorber



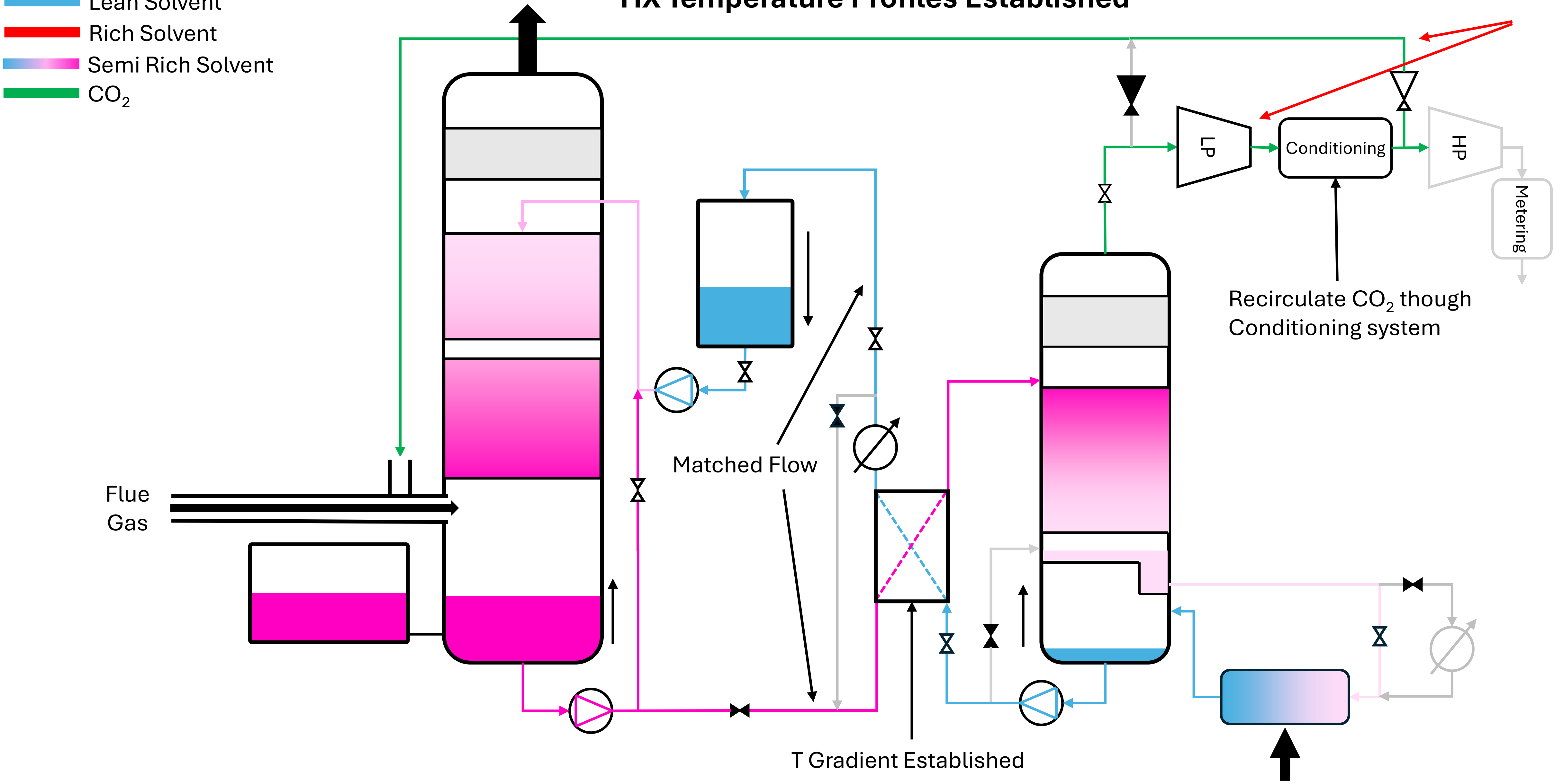
- Flue gas reaches the absorber and CO_2 capture begins
- Recirculate semi rich solvent from the absorber sump back towards the lean solvent inlet until such time as the CO_2 exit concentration begins to drop
- Desorber pressure approaches operational pressure

Desorber at Operational Pressure



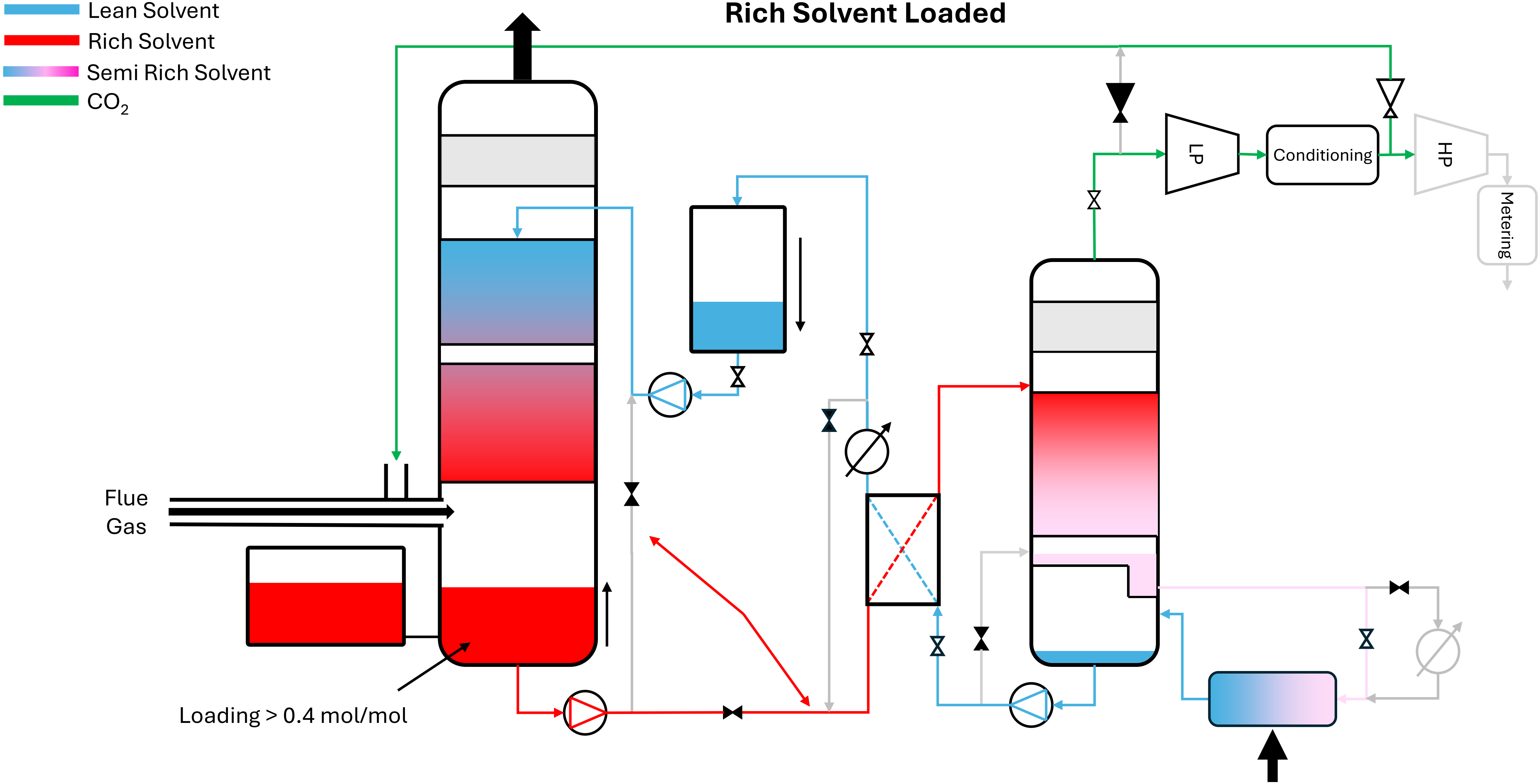
- Once Desorber reaches operational pressure, begin venting of contents back to absorber at a rate required to maintain constant pressure. Venting should continue until concentration is within the operational limits of the Compressor & Conditioning equipment. Swap from auxiliary to early steam heating
- Operate the trim cooler to establish the temperature gradient within the cross HX. Heating/cooling input and at rate required by thermal ramp rates
- Bleed in lean solvent to the circulating semi lean solvent in absorber to maintain target exit CO_2 concentration

HX Temperature Profiles Established



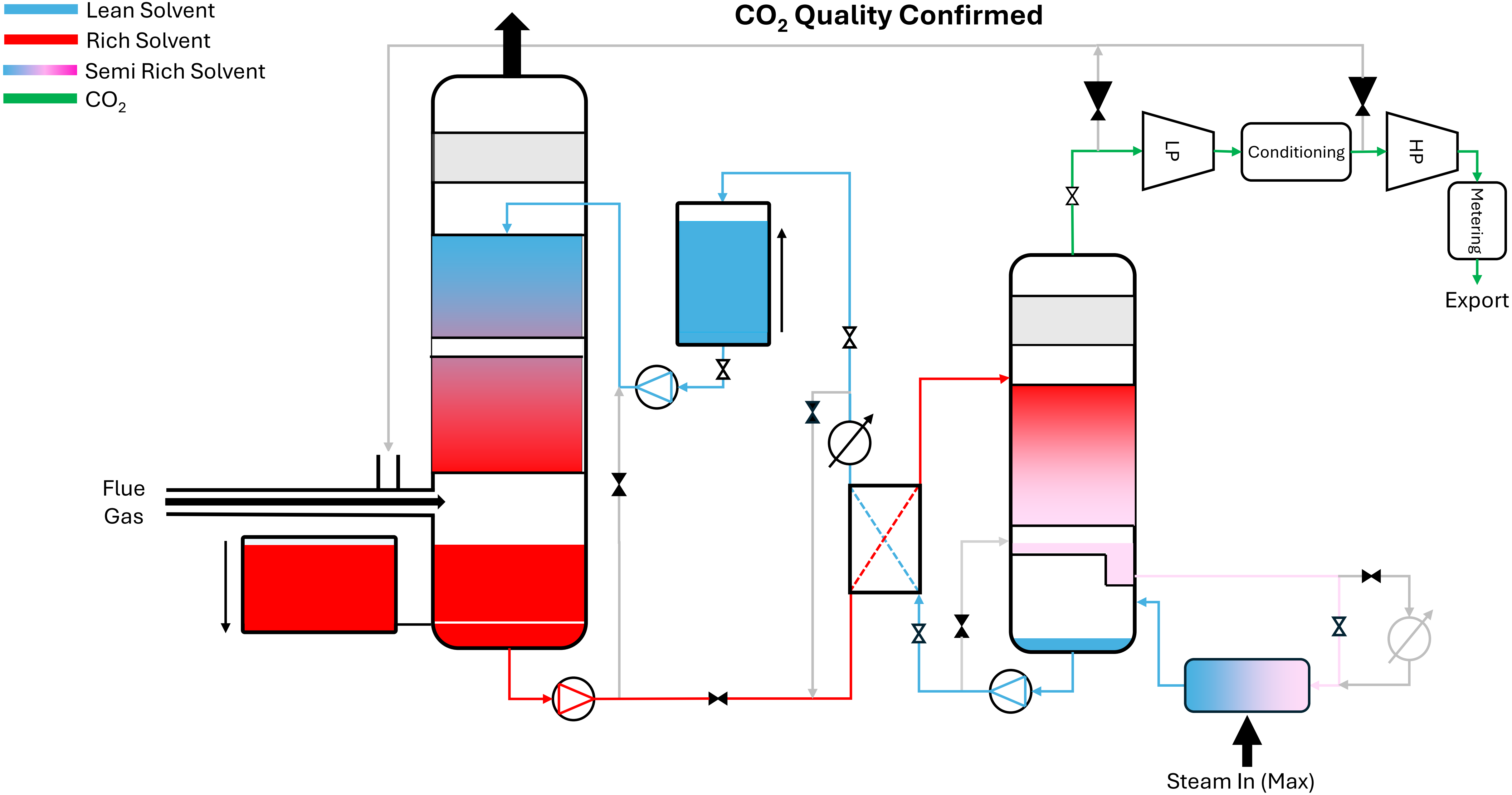
- HX Temperature profiles are established, and lean solvent is being produced in the desorber.
- CO_2 quality is sufficient to admit to Compression & Conditioning system, continue venting to absorber.
- Bleed in rich solvent at a rate sufficient to produce minimum flow rate of CO_2 for conditioning and matched with lean solvent flow rate.

Rich Solvent Loaded



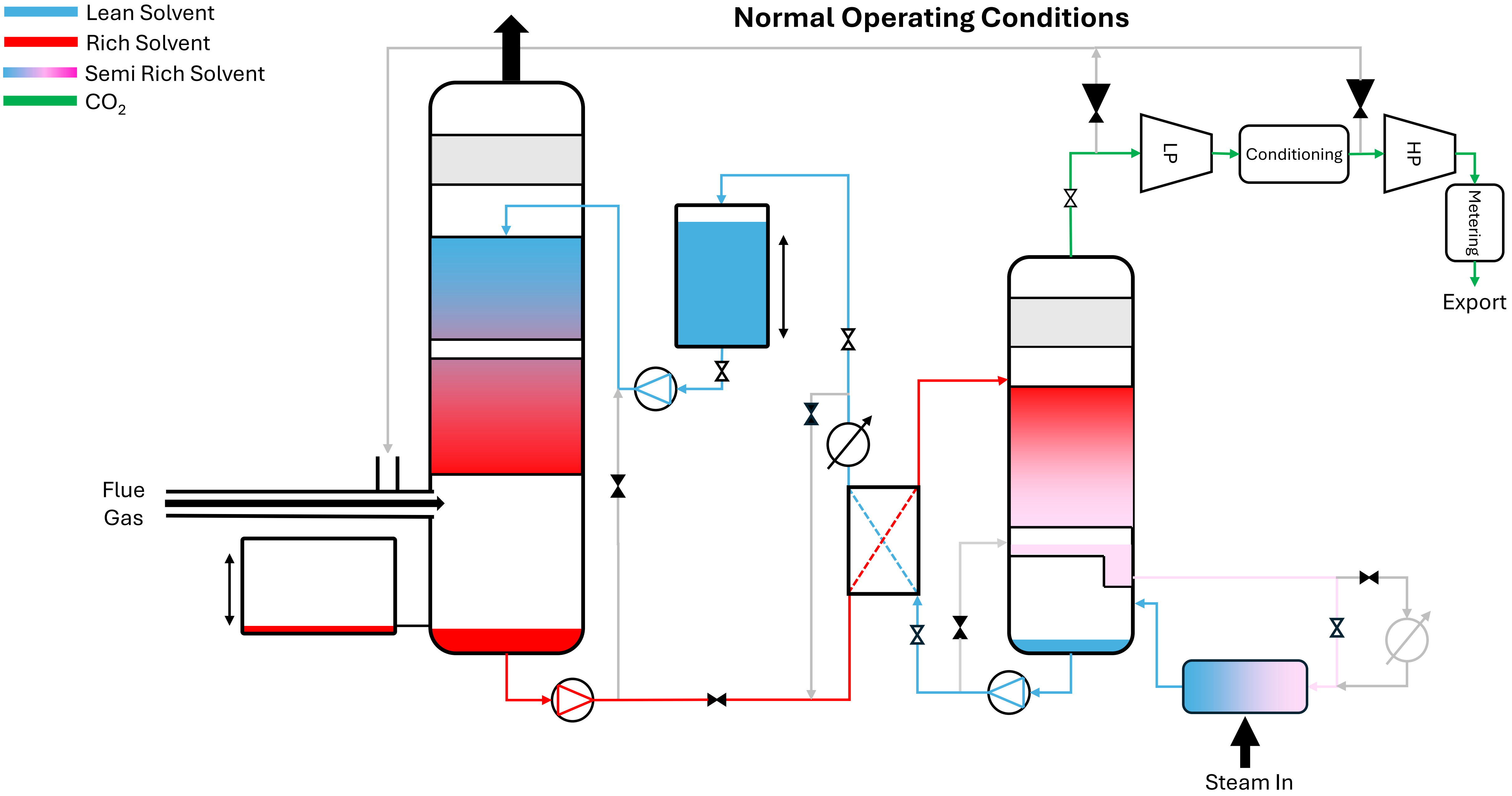
- Rich solvent in absorber sump at > 0.4mol/mol. Cease recirculation in absorber loop

CO_2 Quality Confirmed



- CO_2 Quality has been confirmed, and CO_2 export can begin
- Input maximum steam flow into desorber, drawing down on stored rich solvent inventory at maximum rate

Normal Operating Conditions



- Rich solvent inventory has been reduced to minimum levels with the lean inventory regenerated. Levels of lean and rich solvent expected to vary during normal operations to facilitate operational flexibility.

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Deliverables

Deliverable	Title
D1	Project Management Plan
D2	Industrial Requirements Report
D3	Interim Modelling Report
D4	Interim Test Report
D5	Final Modelling Report
D6	Final Test Report
D7	Standard Design Note
D8	Final Report and Workshop

All open source and to be published: Carbon Capture, Usage and Storage (CCUS) Innovation 2.0 programme - GOV.UK

THANK **YOU**

For more information:
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