CO_2 Capture Utilizing Solid Sorbents

CO_2 Capture & Separation
Capture Technologies (2) Session

Fifth Annual Conference on Carbon Capture and Sequestration

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May 8-11, 2006

National Energy Technology Laboratory

Office of Fossil Energy

Goals

- **Short term goals : Develop cost effective technologies to separate/capture CO_2**
  - Both pre and post combustion gas streams
  - Superior to the existing capture techniques

- **Long term goals : Accomplish NETL/DOE carbon sequestration road map plan**

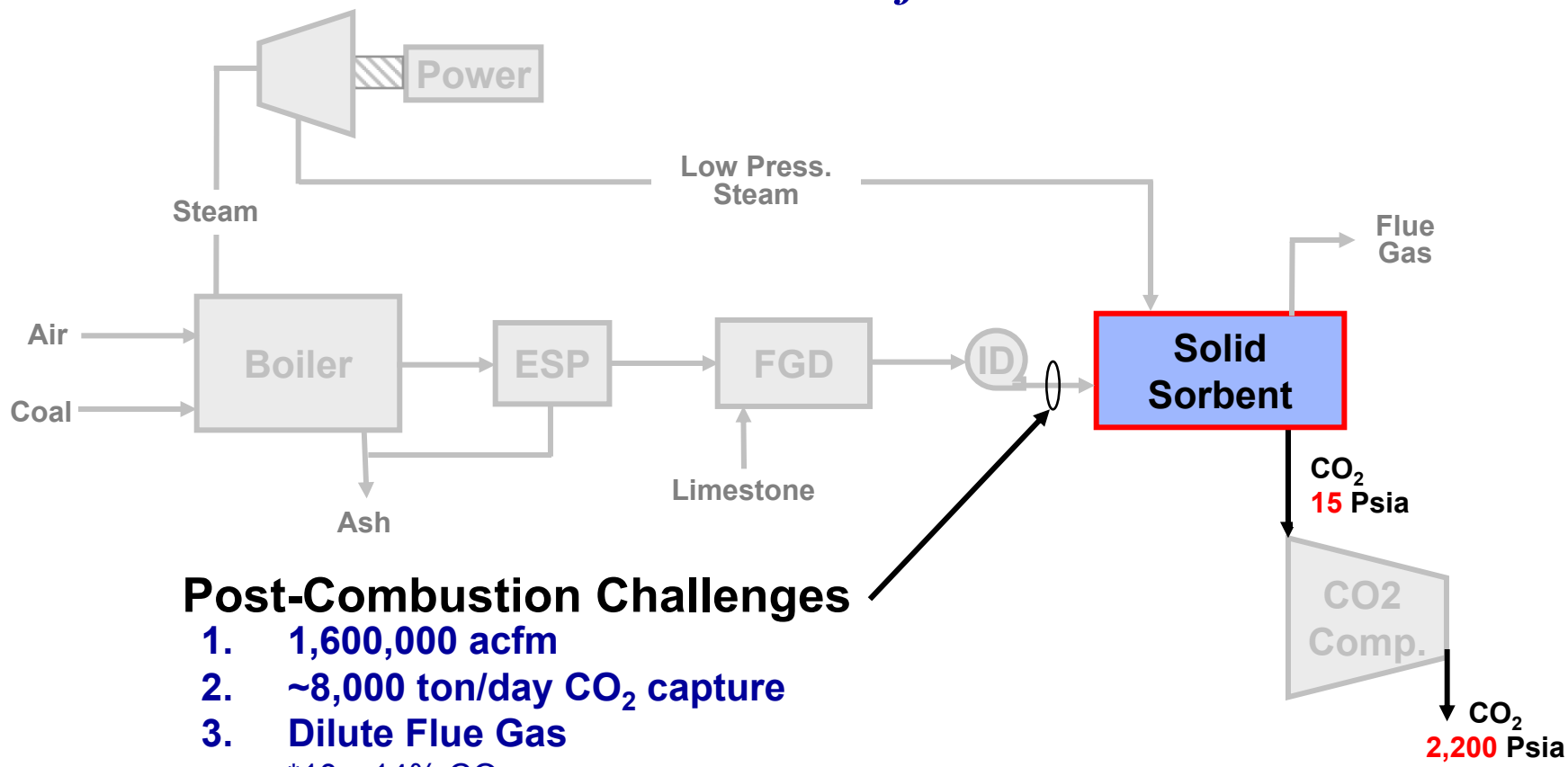
Sorbent Description

- **Polar organic liquids (amines, glycols and ethers) trapped inside the unit layers of the clay**
- **Small amount of water was utilized to pelletize**
- **At low pressures – chemical interaction**
- **At high pressures -Physical & chemical interaction**
- **Advantages**
  - Readily available materials – low cost
  - Easy preparation technique
  - No corrosion problems
    - CO_2 loadings and concentration of active materials not limited
  - No liquid wastes generated
  - Low regeneration temperature and regeneration energy

NETL Steam Tolerant Low Temperature Sorbent (NETL –LT) Development CO_2 Capture Temperature at 25-60 ^{0}C

Low Pressure Tests Post Combustion Gas Streams

Current Project - Solid Sorbents
PC With Solid Sorbent CO_2 Capture
Where does it fit?



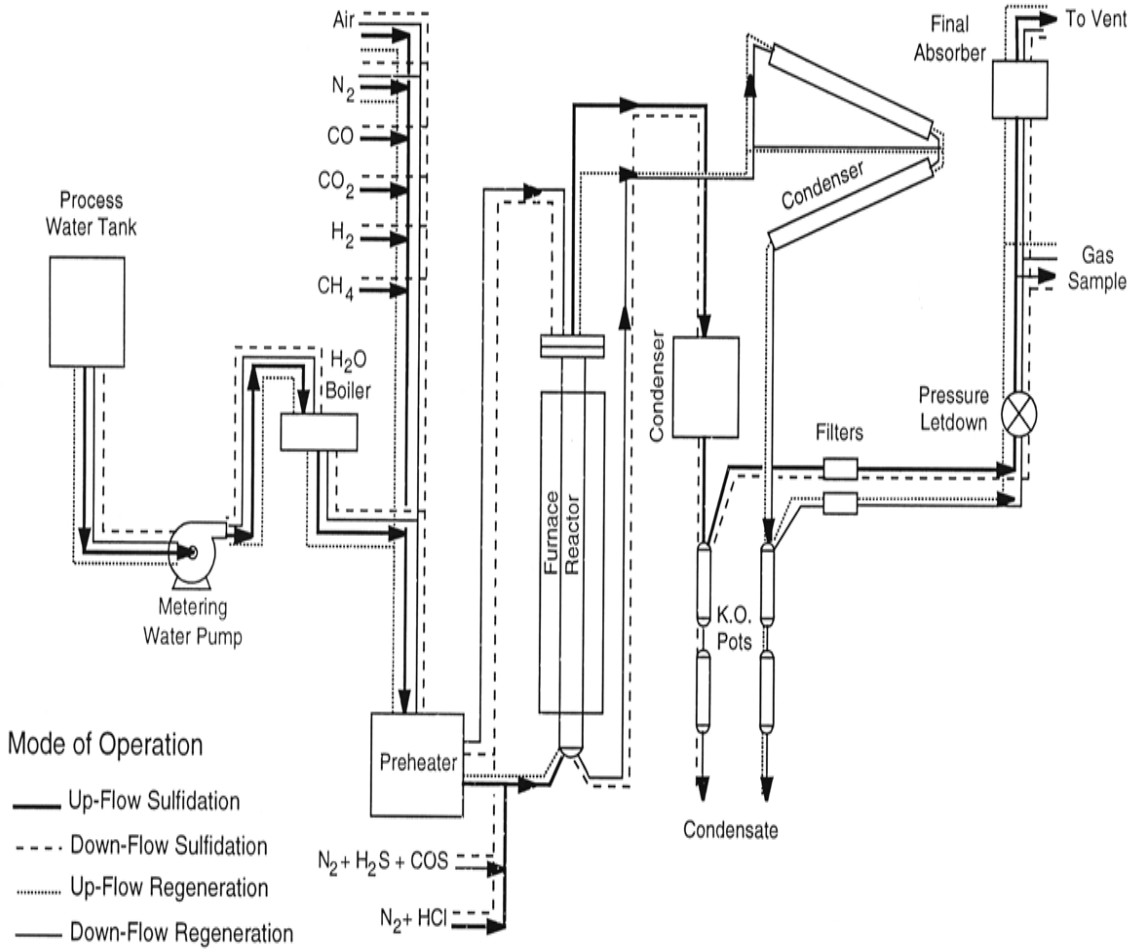
Post-Combustion Challenges

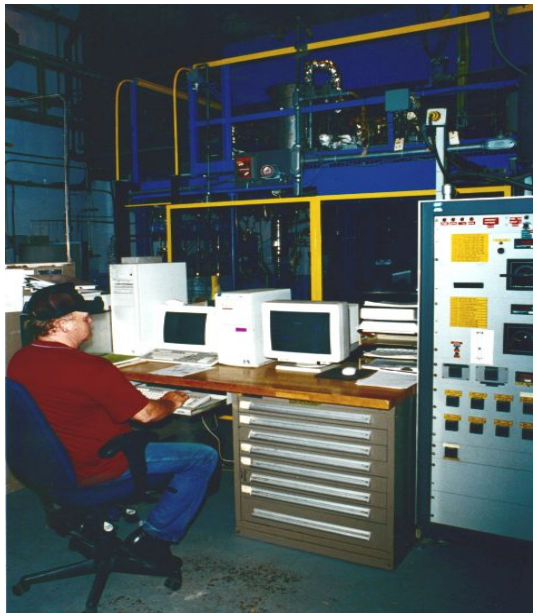
1. **1,600,000 acfm**
2. **~8,000 ton/day CO_2 capture**
3. **Dilute Flue Gas**
   *10—14% CO_2
4. **Low Pressure Stream—17 psia**
   *Decreased separation driving force

Bench Scale Flow Reactor Atmospheric Tests With Large Scale Preparation of NETL-LT

- Industrial level preparation at Sud Chemie
- Bench scale reactor tests – two inch diameter reactor with six inch bed height
- ~350 grams of sorbent
- Tests at both 500 hr^{-1} and 1000 hr^{-1} space velocity
- Temperature of the CO_2 sorption – 30-50°C
- Temperature of regeneration – 80°C

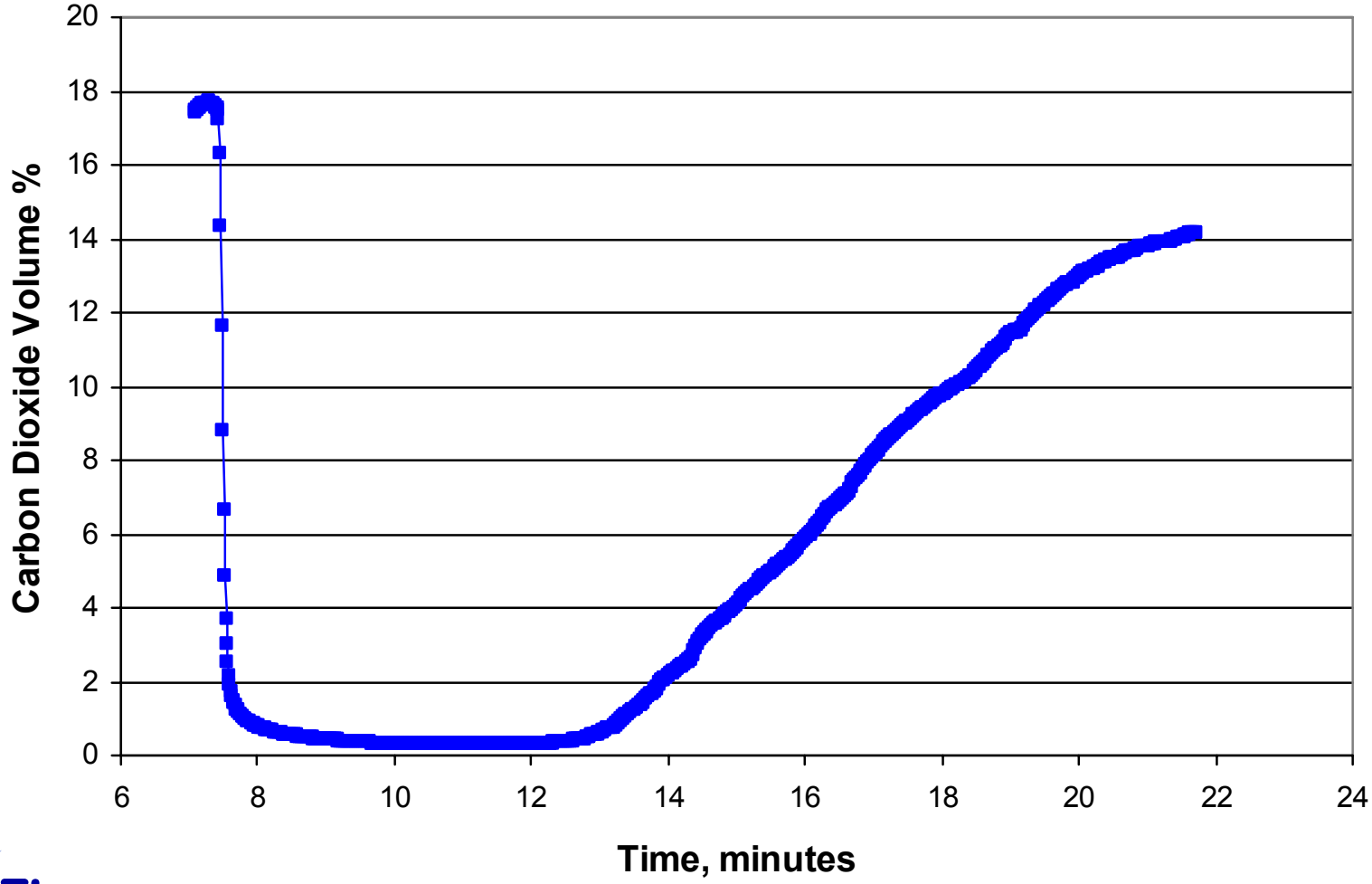
Flow Diagram of the High Pressure Bench Scale Flow Reactor





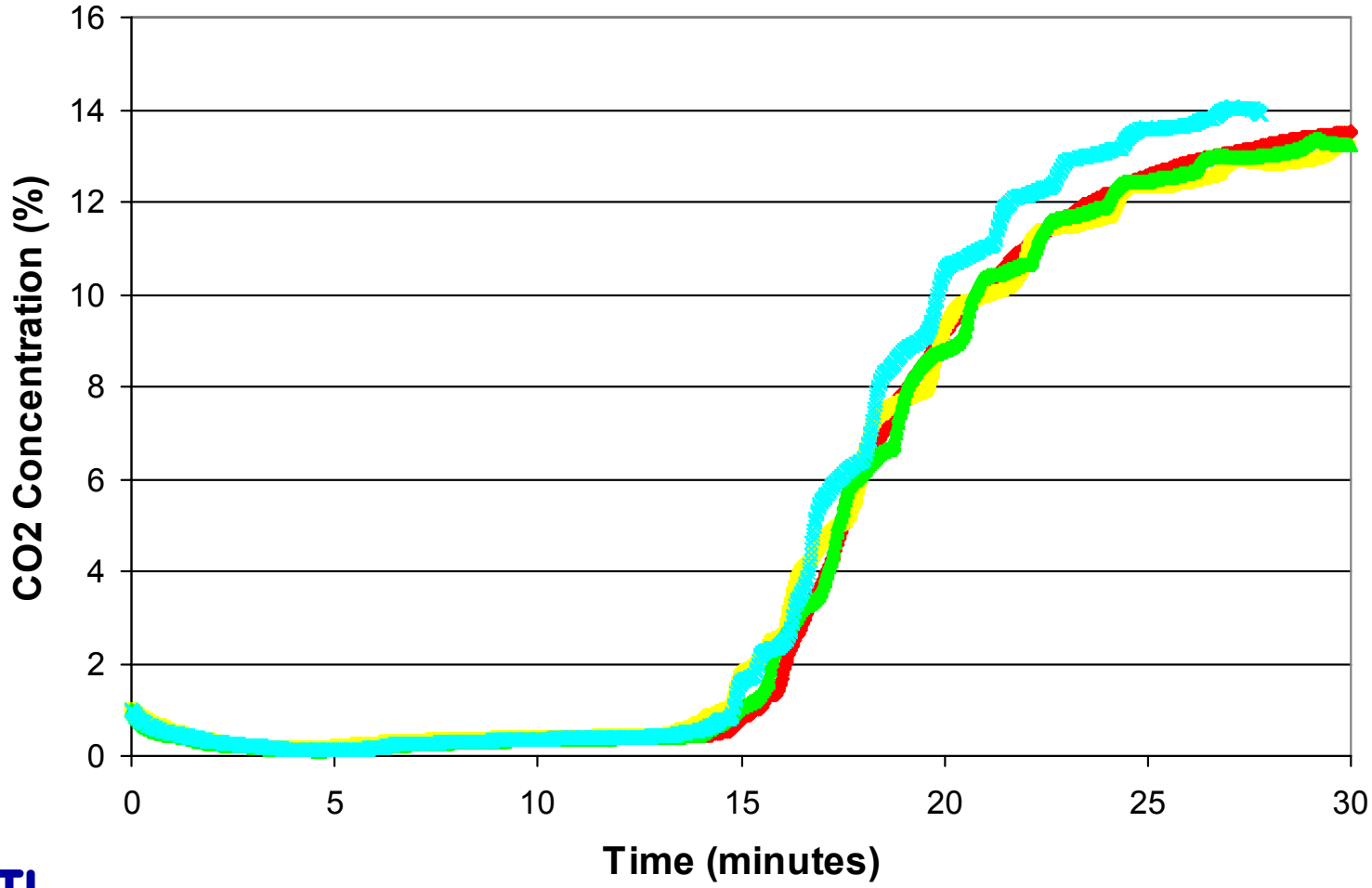
Adsorption of CO_2 on NETL-LT in Atmospheric Bench Scale Reactor- 1000 hr^{-1}Space Velocity, 25-30 ^0C

(17% CO_2, 3%O_2, 80% N_2,)



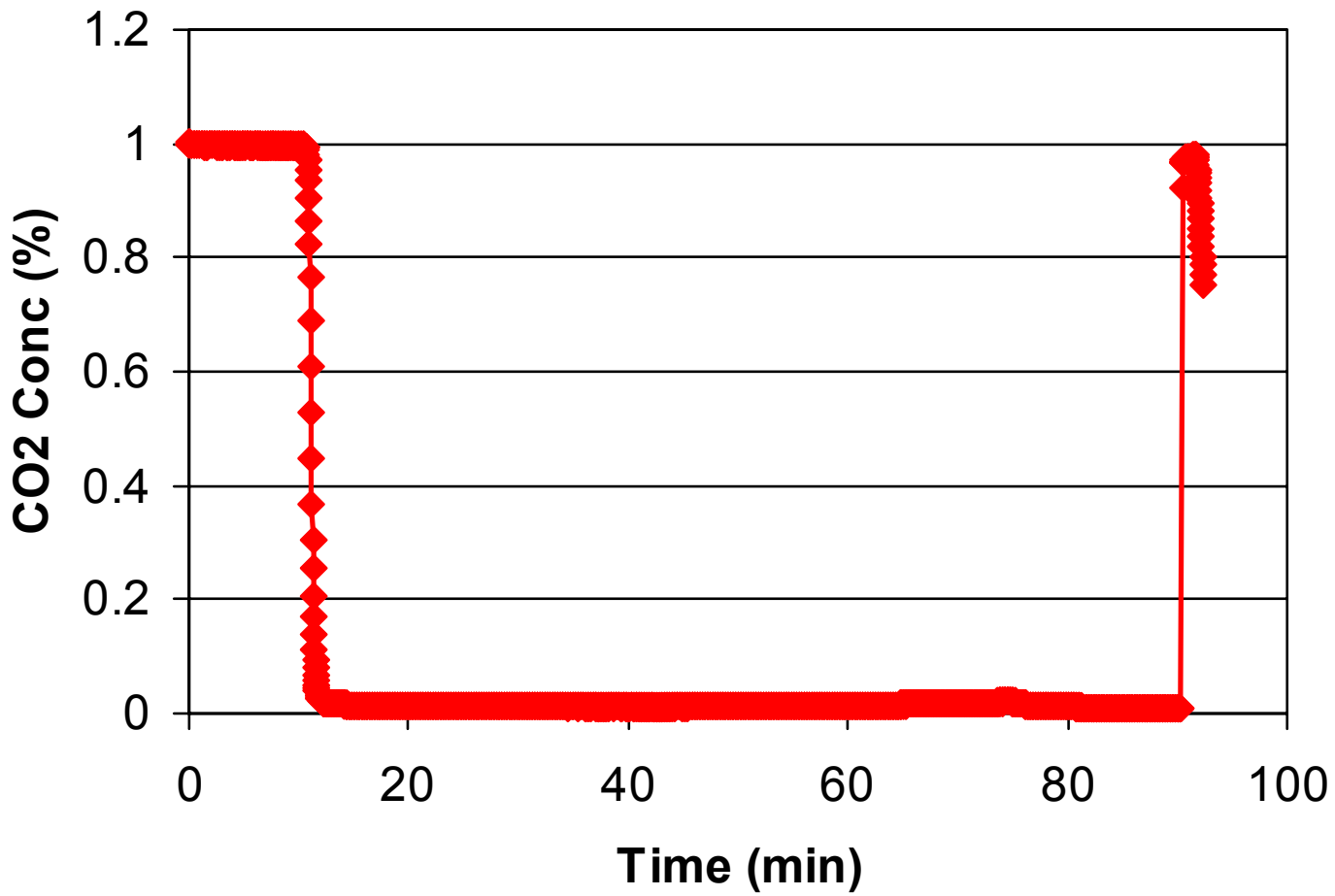
Multi Cycle Sorption of CO_2 on NETL-LT in Atmospheric Bench Scale Reactor

17% CO_2, 3% O_2, 80% N_2, 500 hr^{-1} space velocity, 25-40 ^0C



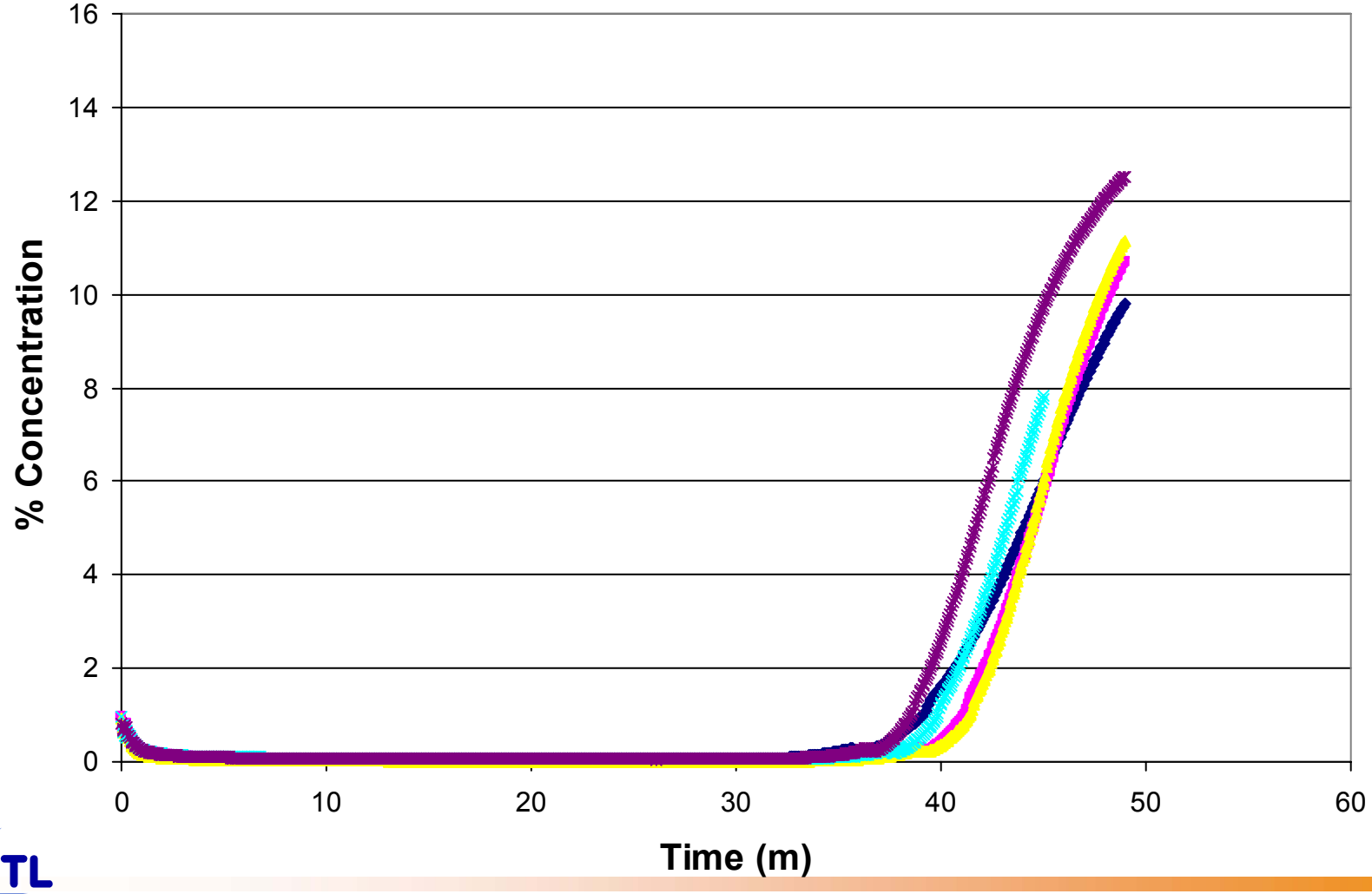
Lab Scale Reactor Tests With Sud Chemie Prepared NETL-LT Sorbent

(1% CO_2, 99% N_2, and Saturated With Water Vapor)



Sorption of CO_2 on NETL-LT at 60°C in Atmospheric Lab Reactor

(15% CO_2, 3%O_2, 82% N_2, and Saturated With Water Vapor)



Results of the Systems Analysis

Comparison of Solid Sorbent With Liquid Amine Systems

- **Uses less energy for regeneration**
  - Do not heat water
  - Use less stripping steam to regenerate CO_2
  - Δ T for regeneration
    - Solid sorbent = 30°C
    - Liquid amine = 60°C
  - Total regeneration energy
    - Solid sorbent = 773 btu/lb CO_2
    - Liquid amine = 1,934 btu/lb CO_2
- **Less parasitic power load**
- **Higher carrying capacity of the sorbent**
  - Decrease in volume by 5 times to treat equivalent amount of CO_2

Summary of the Atmospheric Flow Reactor Tests With NETL-LT

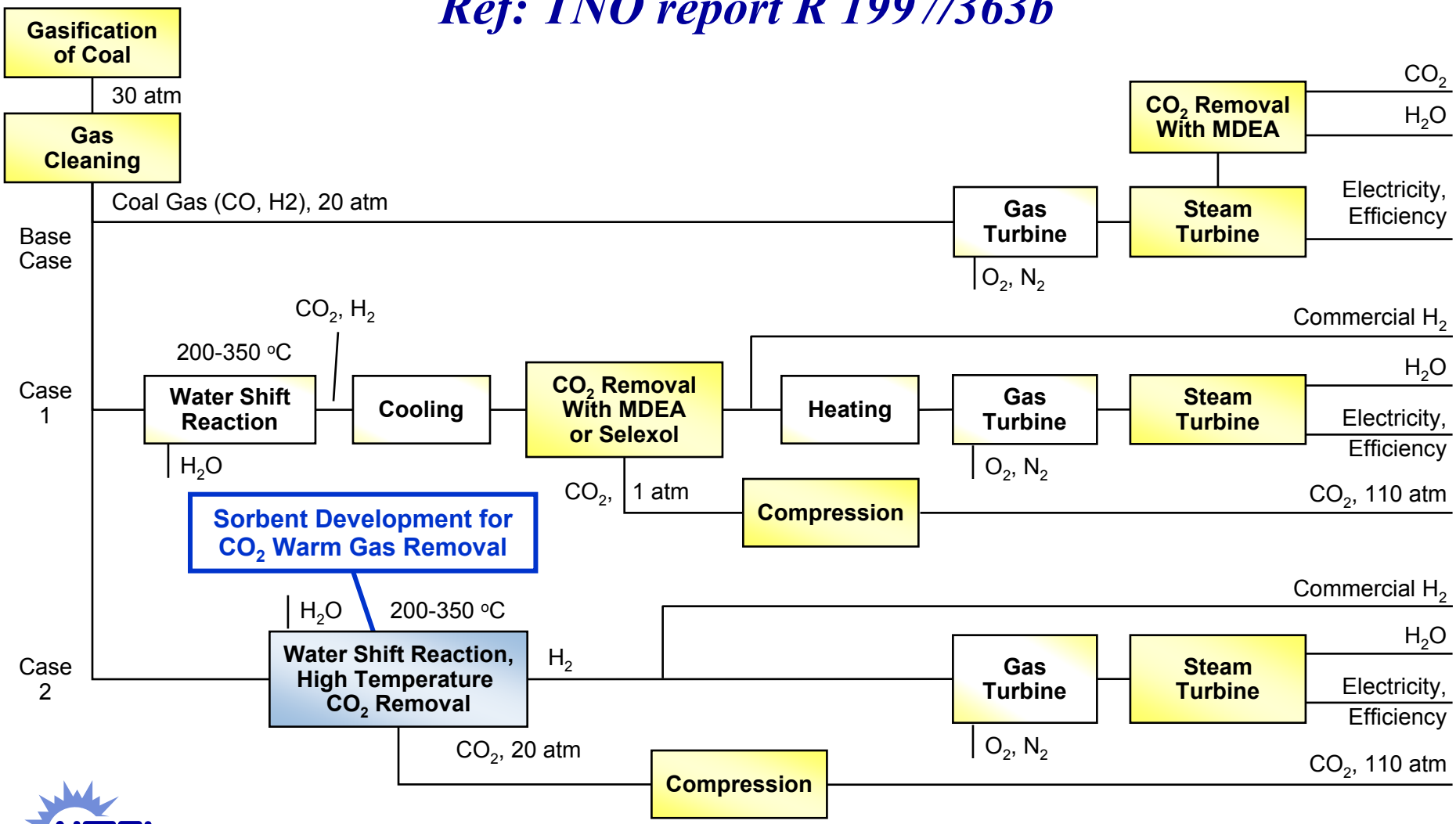
- **Stable performance during multi cycle tests at 25-50 ^{0}C after regenerating at 80 ^{0}C for one hour**
  - Regeneration did not affect the capacity and efficiency
- **CO_2 capture capacity of 1.5 – 2 moles/liter**
  - Capacity higher than that of liquid amine process
- **99% CO_2 removal during multi cycle tests**
- **Removal efficiency not affected at 60^{0}C**

NETL Steam Tolerant Low Temperature Sorbent (NETL –LT) Development CO_2 Capture Temperature at 25-60 ^{0}C

High Pressure Tests Pre Combustion Gas Streams

Comparison of Different Options for CO_2 Removal and H_2 Production from IGCC Power Plants

Ref: TNO report R 1997/363b

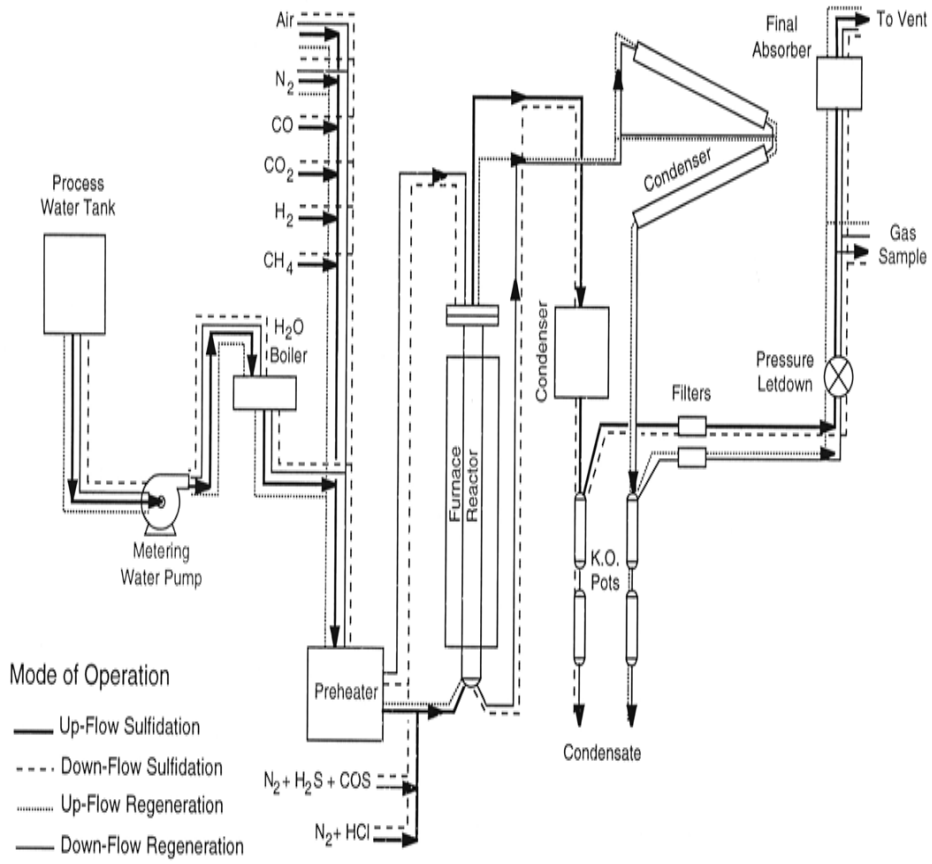


CO_2 Processing From Natural Gas

- **Upgrading for pipe line specifications**
  - Inlet 0-8%
  - Removal necessary - 2% or less
  - Pressure 1000-1200 psi

- **Liquefied Natural Gas**
  - Removal necessary – less than 50 ppm

Flow Diagram of the High Pressure Bench Scale Flow Reactor

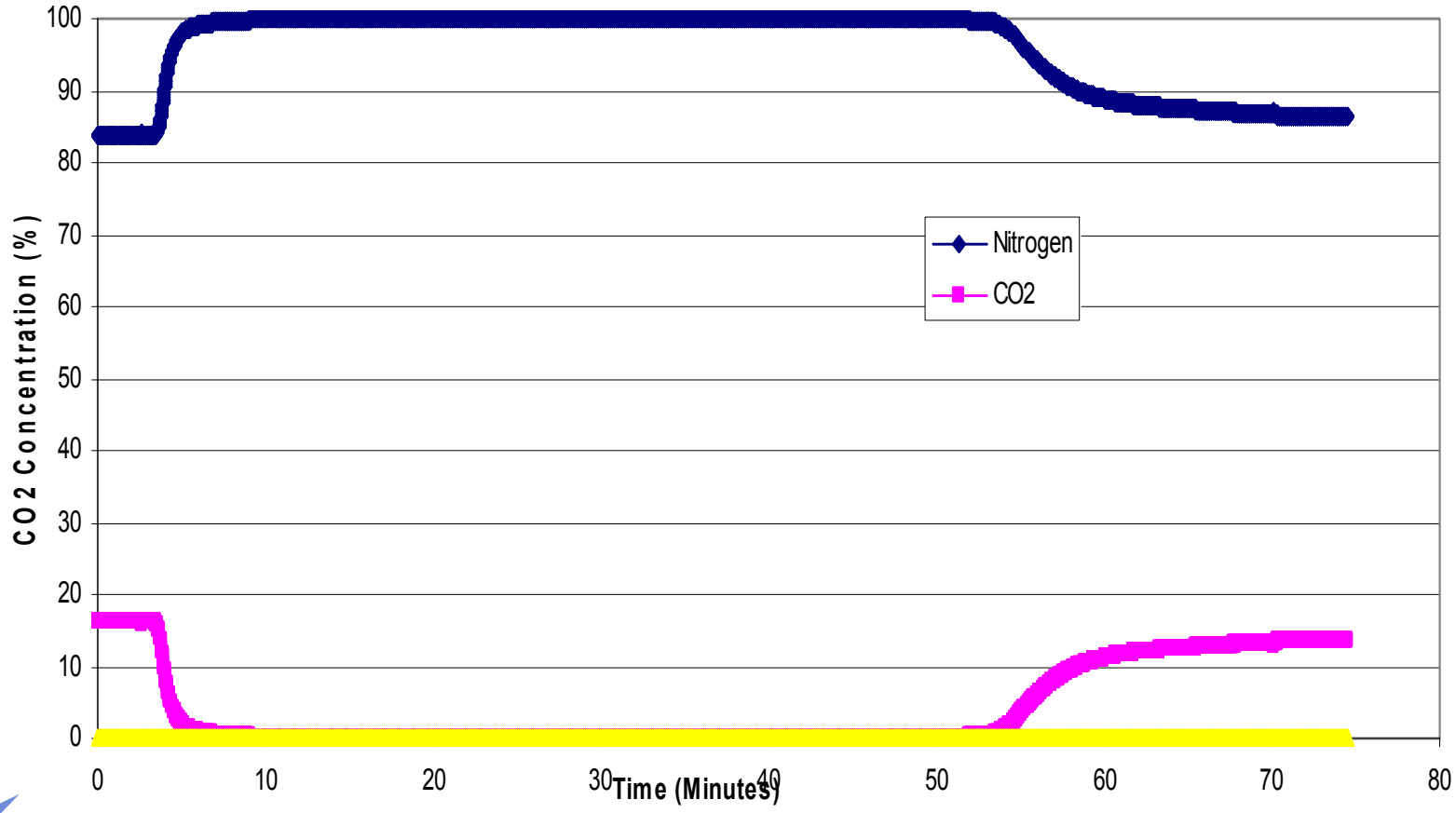


- **Extrudates prepared at Sud Chemie – commercial preparation**
- **~350 grams of sorbent**
- **CO_2 sorption –**
  - 16% CO2 /N2 and 28% CO2/N2
  - 1000 hr^{-1} space velocity
  - 30-50°C at 20 atm.
- **Regeneration**
  - Steam/N2
  - 1000 hr^{-1} space velocity
  - 80°C at 20 atm

NETL-LT Extrudates Prepared at Sud Chemie

Bench Scale Tests With Sud Chemie Prepared Extrudates at High Pressure (20atm)

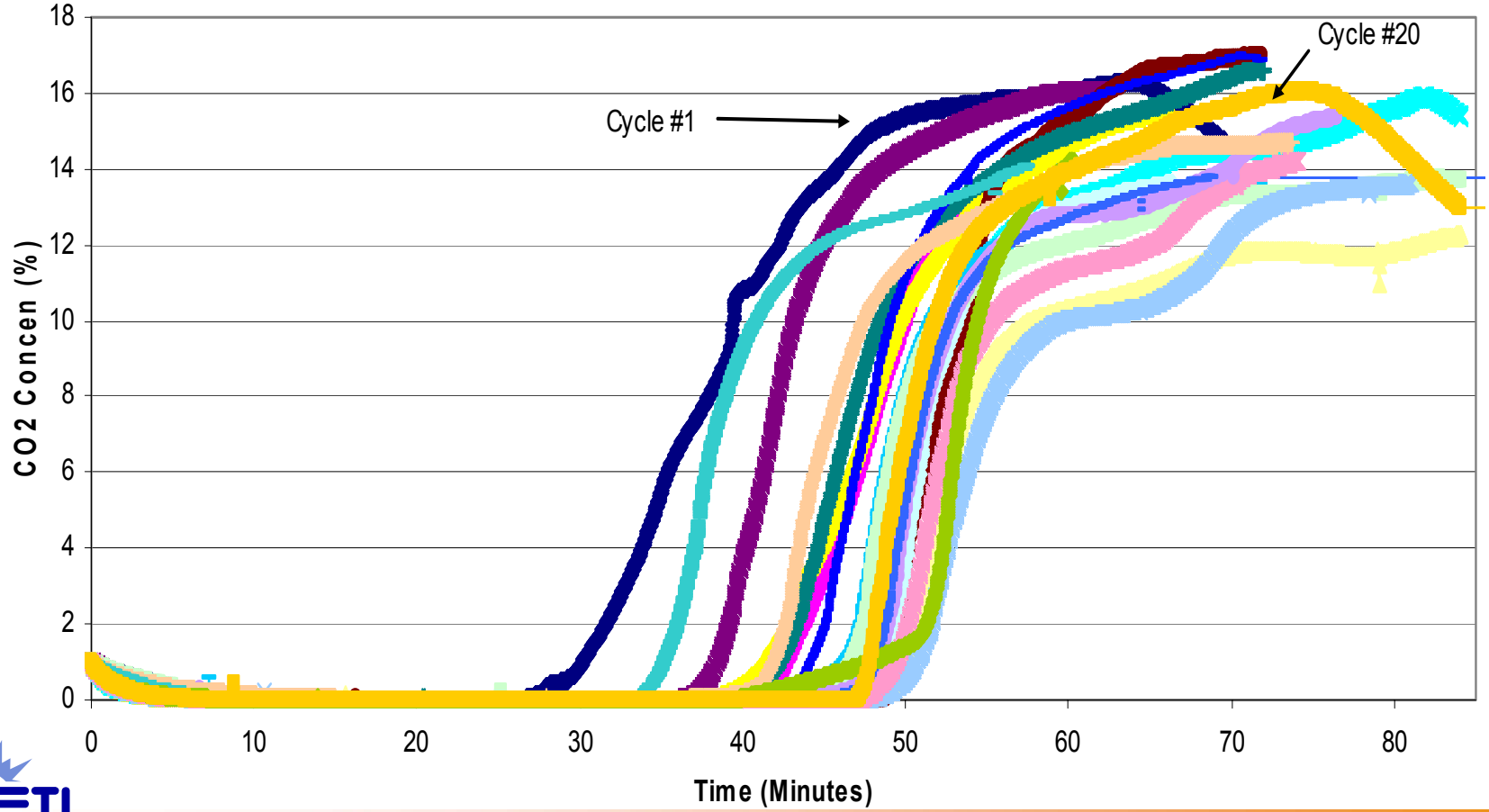
1000 hr^{-1} space velocity, 30 ^0C - 16% CO_2, 84% N2



Twenty Cycle Bench Scale Tests With Sud Chemie Prepared Extrudates at High Pressure (20atm)

1000 hr^{-1} space velocity, 30 ^0C - 16% CO_2, 84% N2

Regeneration – 20 atm & 80 ^0C with steam/nitrogen



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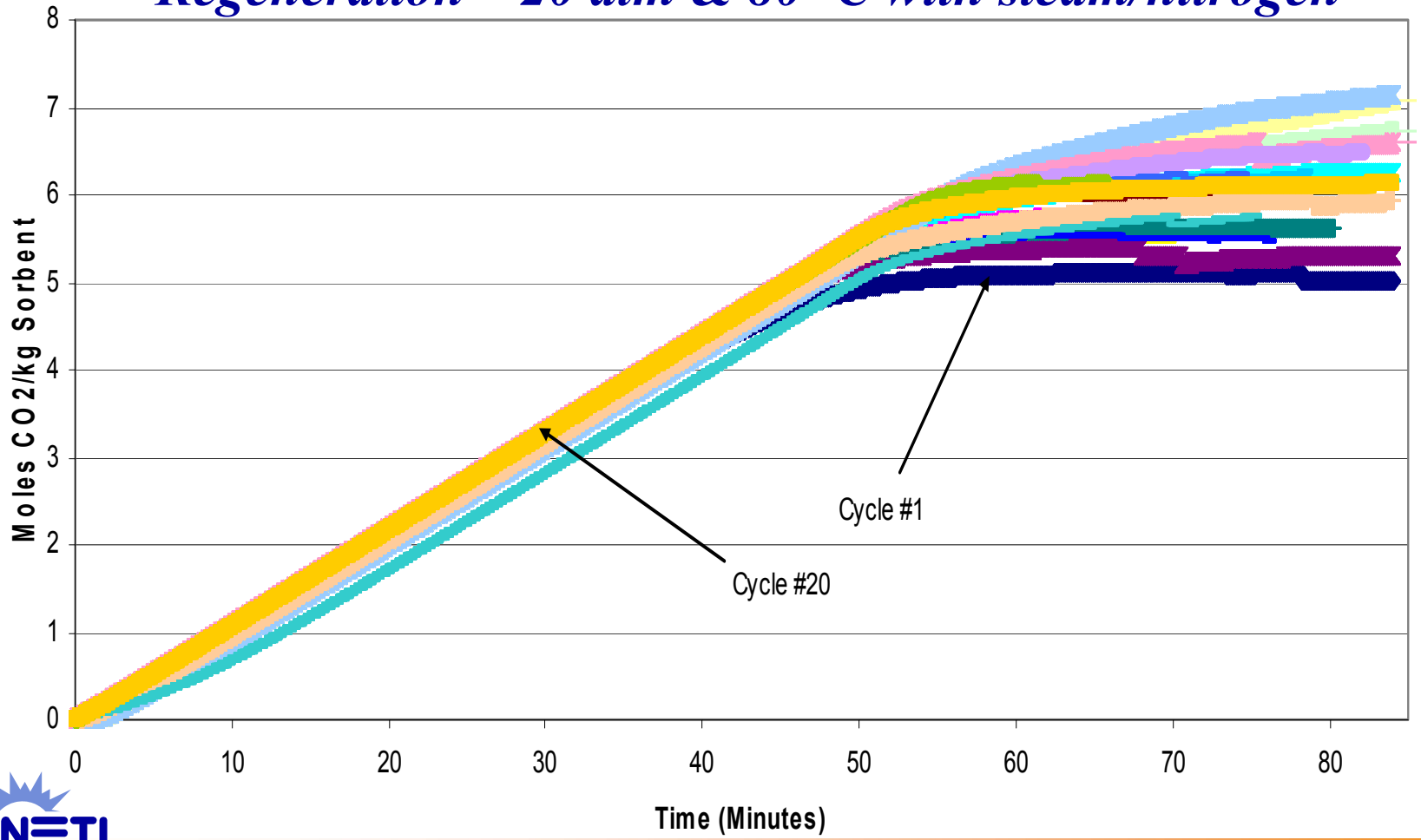
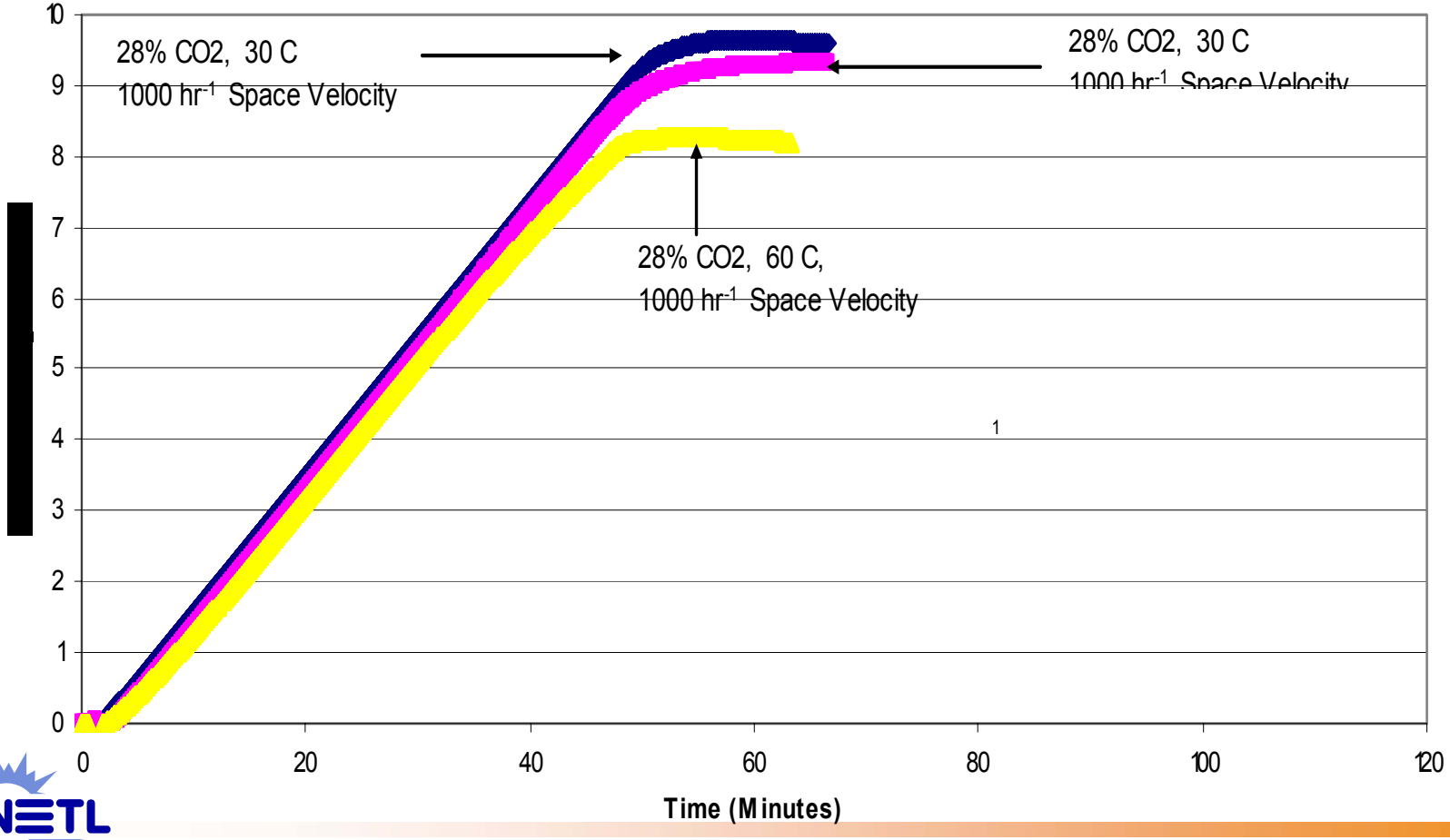


Effect of Concentration and Temperature on CO_2 Sorption at High Pressure (20atm)

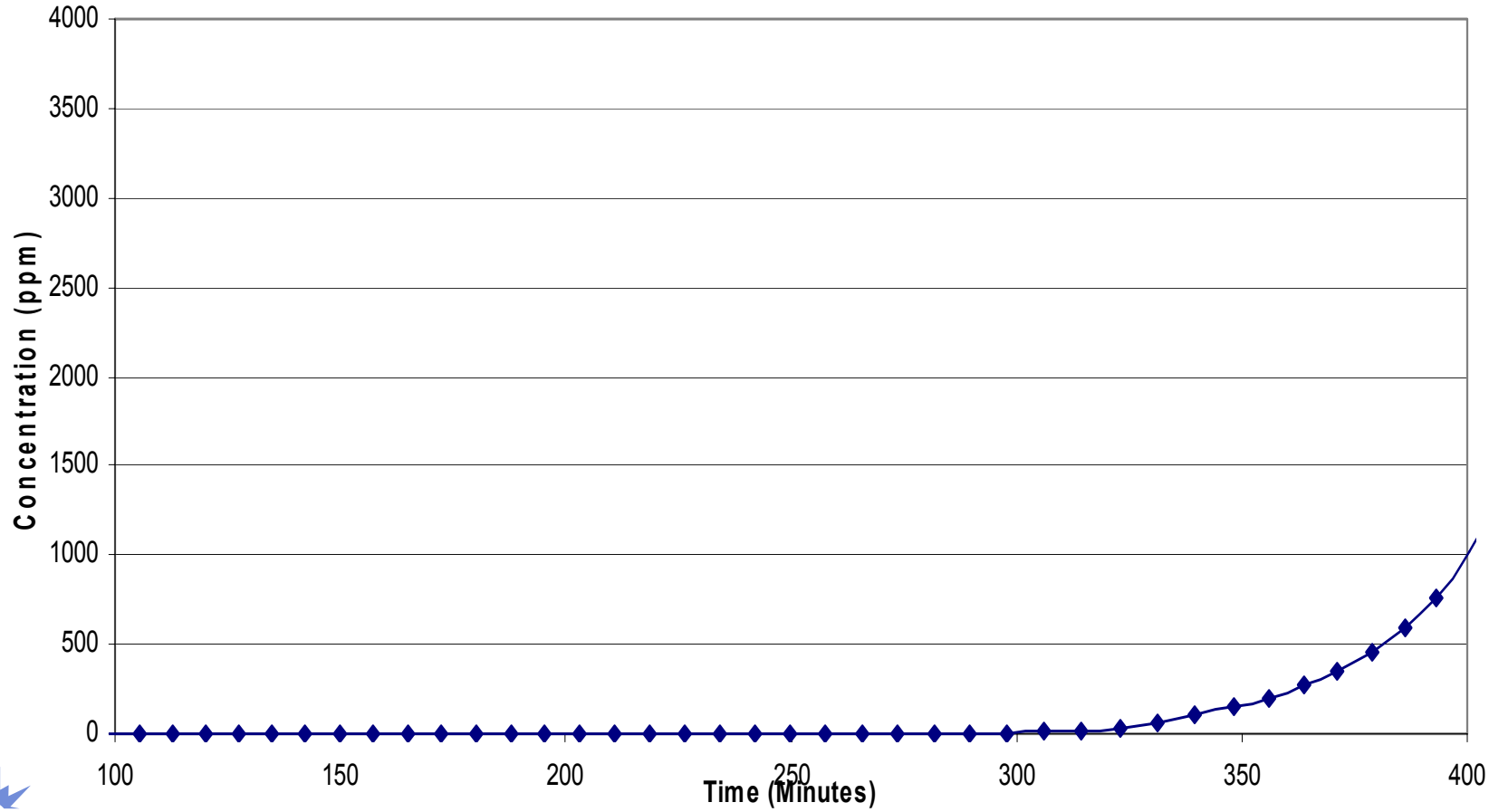
1000 hr^{-1} space velocity, 30 ^0C - 28% CO_2, 72% N2
Regeneration – 20 atm & 80 ^0C with steam/nitrogen



NETL-LT Extrudates Prepared at Sud Chemie – After Reaction

Sorption of H_2S With Sud Chemie Prepared NETL Extrudates

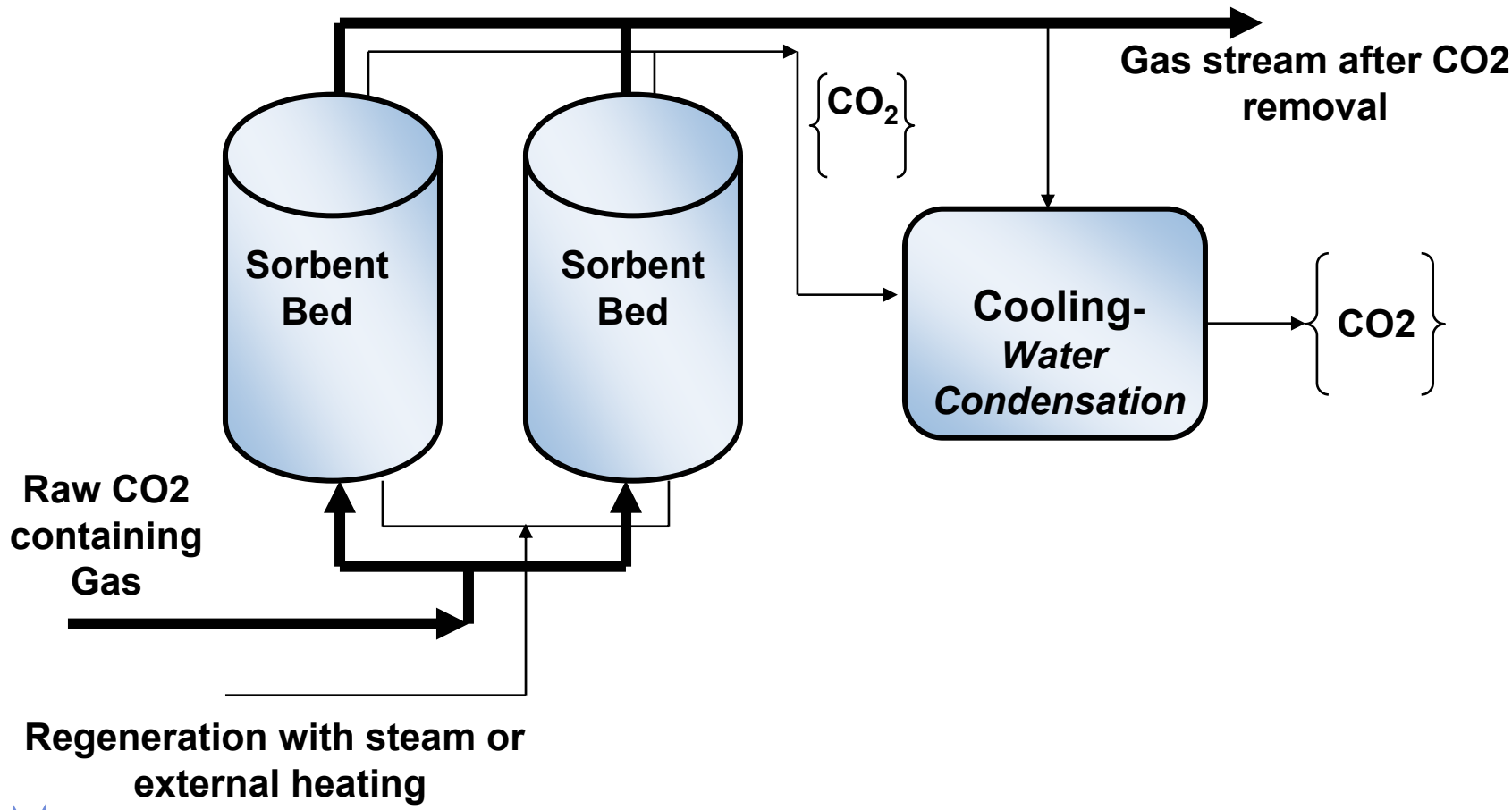
20 atm and 30 ^{0}C, 2000 ppm inlet H_2S



Regeneration of the Solid Sorbent by Lowering the Pressure - Conditions Similar to That of Selexol

- Absorption was performed at 30 C at 20 atm
- Regeneration at 30 C and at 1 atm
- Cycle following the regeneration had the same breakthrough time
- Process could be operated at the same conditions as that of selexol process
- CO_2 capture capacity of the current sorbent ~ 6-9 moles per liter
- CO_2 capture capacity of selexol process < 1 mole/liter
- Solid sorbent has a significanty higher capacity than that of selexol
- Amount of solid necessary for processing the same amount of CO_2 will be low.

Possible Reactor Configurations for Commercial Scale Tests
Fixed Bed Operation



Other Possible Reactor Configurations

- **Moving bed operation**
  - Current preparations of spherical pellets are suitable
  - Some improvement in attrition resistance may be necessary
- **Fluidized bed operation**
  - Smaller particles (~100 microns) than that in current preparations
  - Modifications with binders will be necessary to get higher attrition resistance

Summary of the Sud Chemie Prepared High Pressure Sorbent Tests

- **Sorbent performed well during high pressure multi cycle tests**
  - 99% CO_2 removal
  - Excellent CO_2 removal capacity 6-9 moles CO2/liter of the sorbent
- **Stable reactivity after regeneration at high pressure**
  - Sorbent can be regenerated at 80 ^{0}C at 20 atm in presence of steam
- **Sorbent can also be regenerated at 30 ^{0}C and at 1 atm**
- **Increase in capacity at higher CO_2 concentrations**
- **Capacities are significantly higher than that of selexol**
- **Sorbent also removes H_2S at 20 atm**

Partners for Corporative Research Agreements

- Patent issued for this work
- NETL is seeking industrial partners who could utilize the sorbent for any application
- Collaborative research can be conducted under corporative research agreements with NETL
- Sorbent can be modified to be suitable for the industrial application

Conclusions

- Performs well at both at low and high pressure
- Achieved 99% removal at 1000 hr^{-1} space velocity
- Steam does not affect the sorbent
- Capture capacity increased with increasing pressure (6-9 moles/liter) at 20 atm
- Better capacities at higher CO_2 concentrations
- Stable reactivity during 30 cycle high pressure tests
- Patent issued
- Seeking industrial partners to conduct corporative research with NETL