IEA-FBC International Energy Agency

- Fluidized Bed Conversion

Coal Combustion in Fast-bed Regenerator of CaO-Looping (Ca-L) Process

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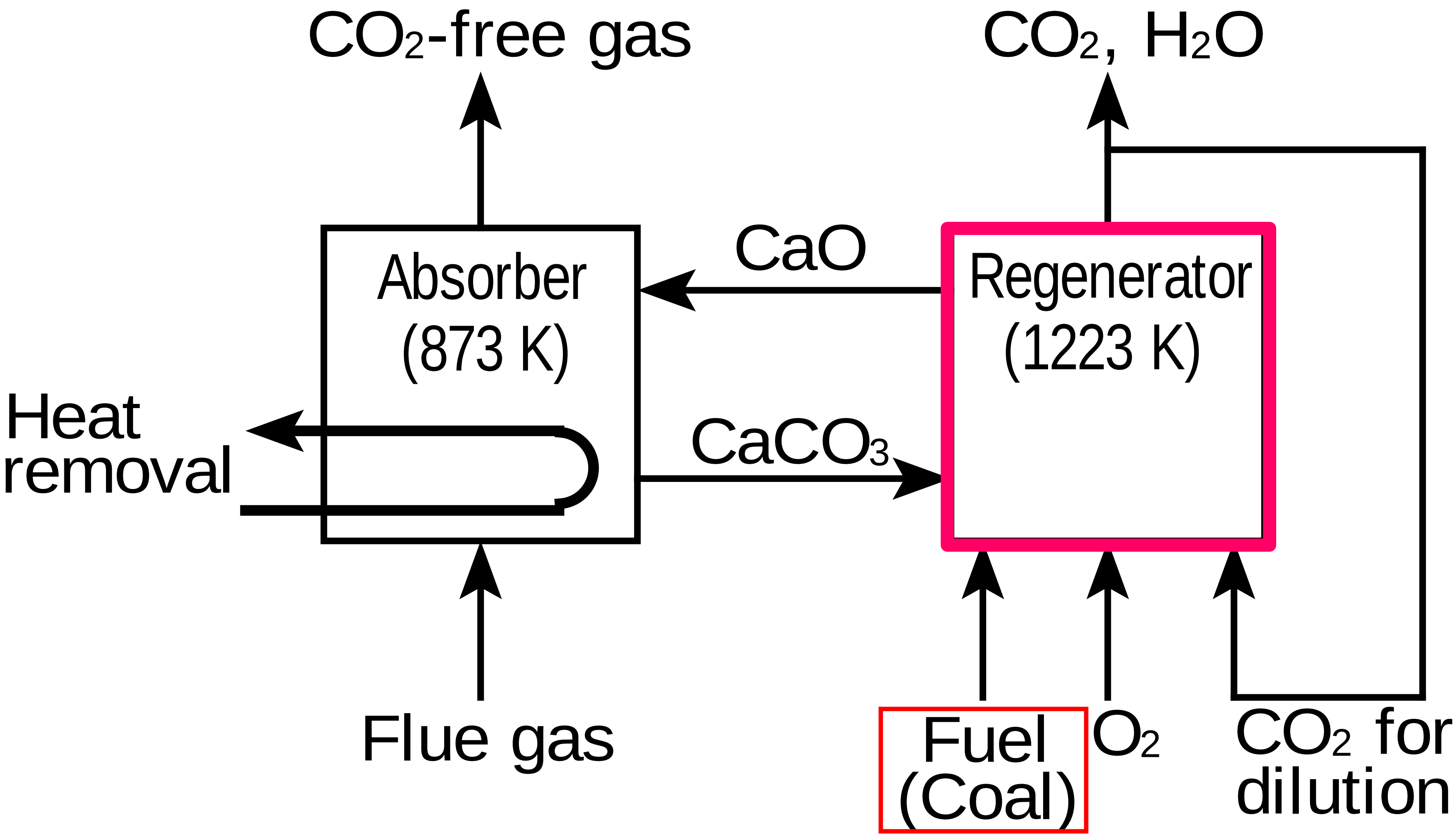
CaL (CaO-Looping) process

CaL process consists of a CO_2 absorber and a CaO regenerator. In the regenerator, coal is burned to supply heat for $CaCO_3$ decomposition.



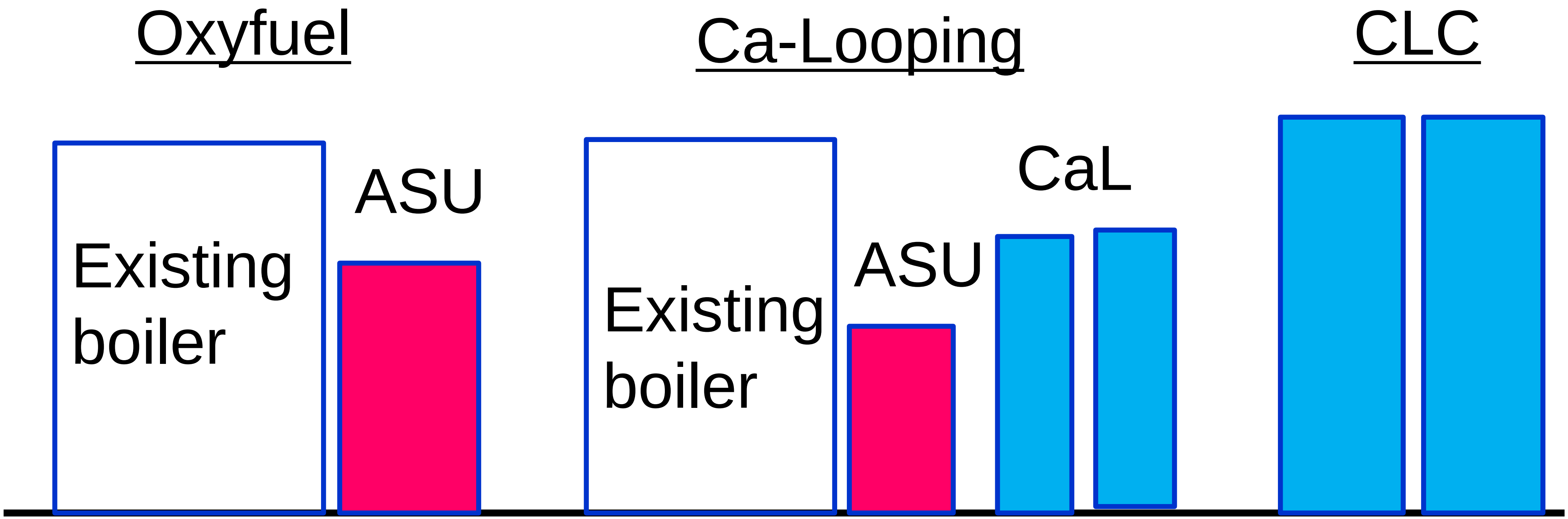
Three scenarios of introducing CCS-ready power plants

Use of existing boiler or completely new system?

Oxyfuel = existing boiler + ASU

CaL = existing boiler + ASU +CaL (twin-FB)

CLC = totally new plant (twin-FB)



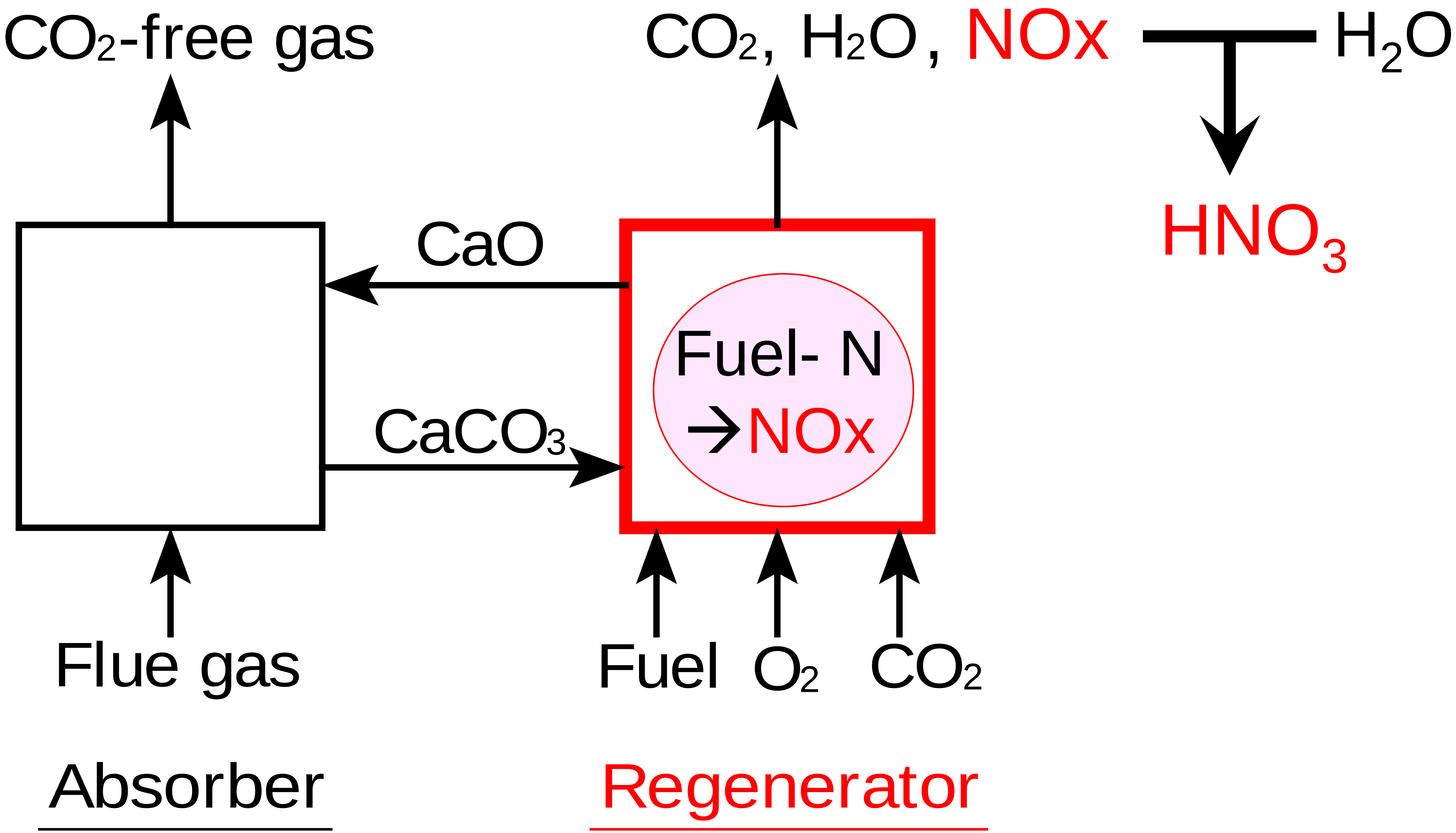
Feature of coal combustion in regenerator (in comparison with ordinary oxy-fuel CFBC)

- Adiabatic combustor (no boiler tubes)
- Sufficient solid residence time for both calcination and combustion is required.
- Control of solid circulation rate is required.

Anticipated problems with regenerator (1)

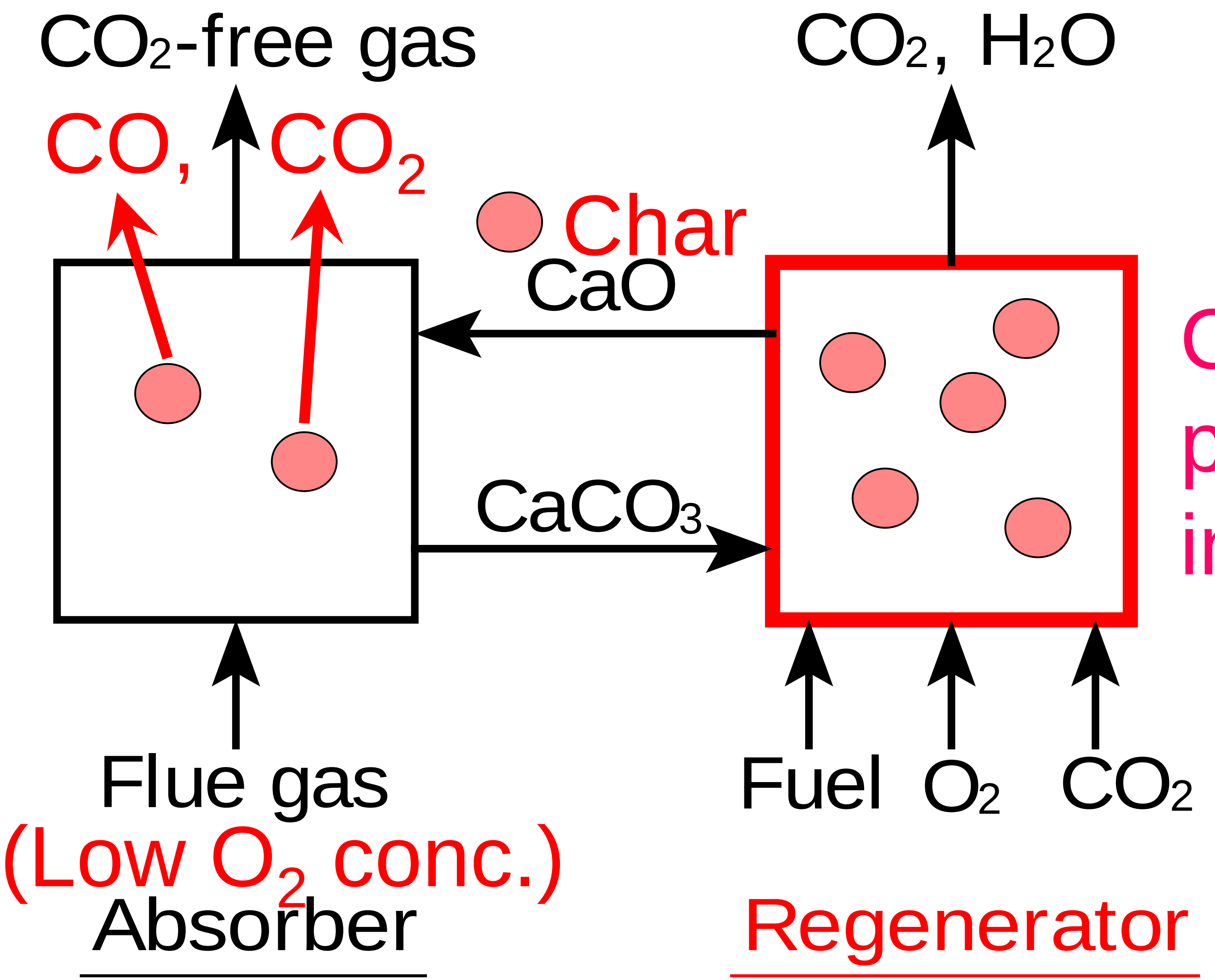
Coal combustion at high temp. & in high O_2 conc.

→ NOx formation → HNO_3 during compression



Anticipated problems with regenerator (2)

Coal combustion → Char formation in regenerator
→ Char transportation to absorber → CO and CO_2



Objectives of this work

A bench-scale fluidized bed solid circulation system was operated using inert sand bed. Coal combustion experiments were conducted using oxygen-enriched air to evaluate

- NOx formation in regenerator,
- formation of CO and CO_2 in absorber, and
- effect of fuel type on emissions.

Objectives of this work (continued)

Carbon capture by porous material (porous CaO), is proposed as an approach to stabilize volatile matter combustion in regenerator.

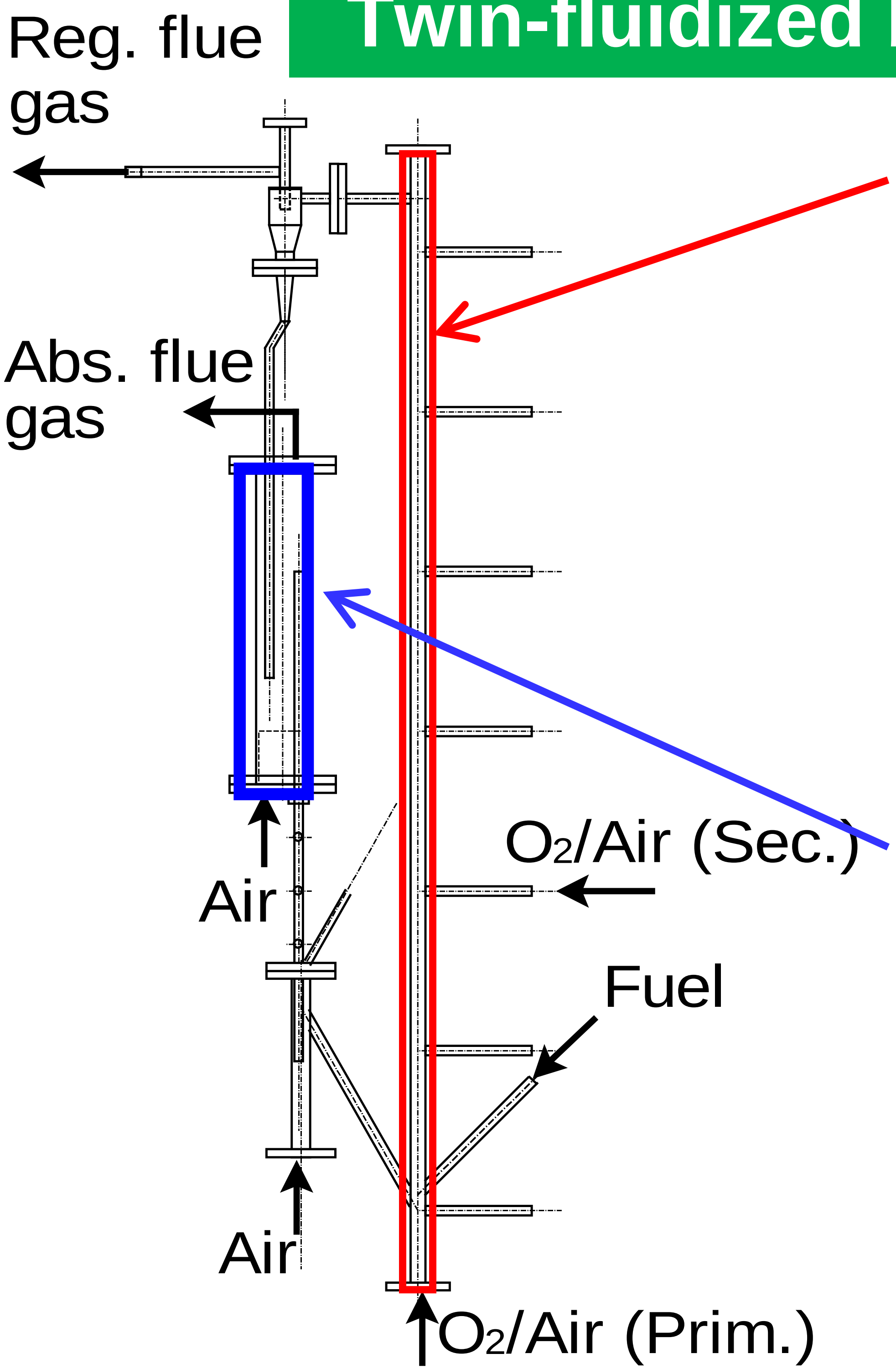
Experimental

(1)Coal combustion experiments using a bench-scale solid fluidized bed circulation system

(Detail will be published soon in "E.J. Anthony honor issue" of ***FUEL***.)

(2) Volatile matter capture by porous solids (calcined limestone and porous alumina) at elevated temperatures using fixed bed reactors with different fuel-particle contact modes

Twin-fluidized bed solid circulation system



Regenerator: Fast bed

ID 2.2 cm, height 1.93 m

Gas vel. 2.7 m/s at 950 ^oC

O_2-enriched air feed (30% O_2)

Fuel feed

Absorber: Bubbling bed

ID 9.3 cm, bed height 0.3 m

Gas vel. 0.22 m/s at 600 ^oC

Air feed

Experimental (1) : Coal combustion in twin-fluidized bed solid circulation system

Fuel type:

High-volatile bituminous coal

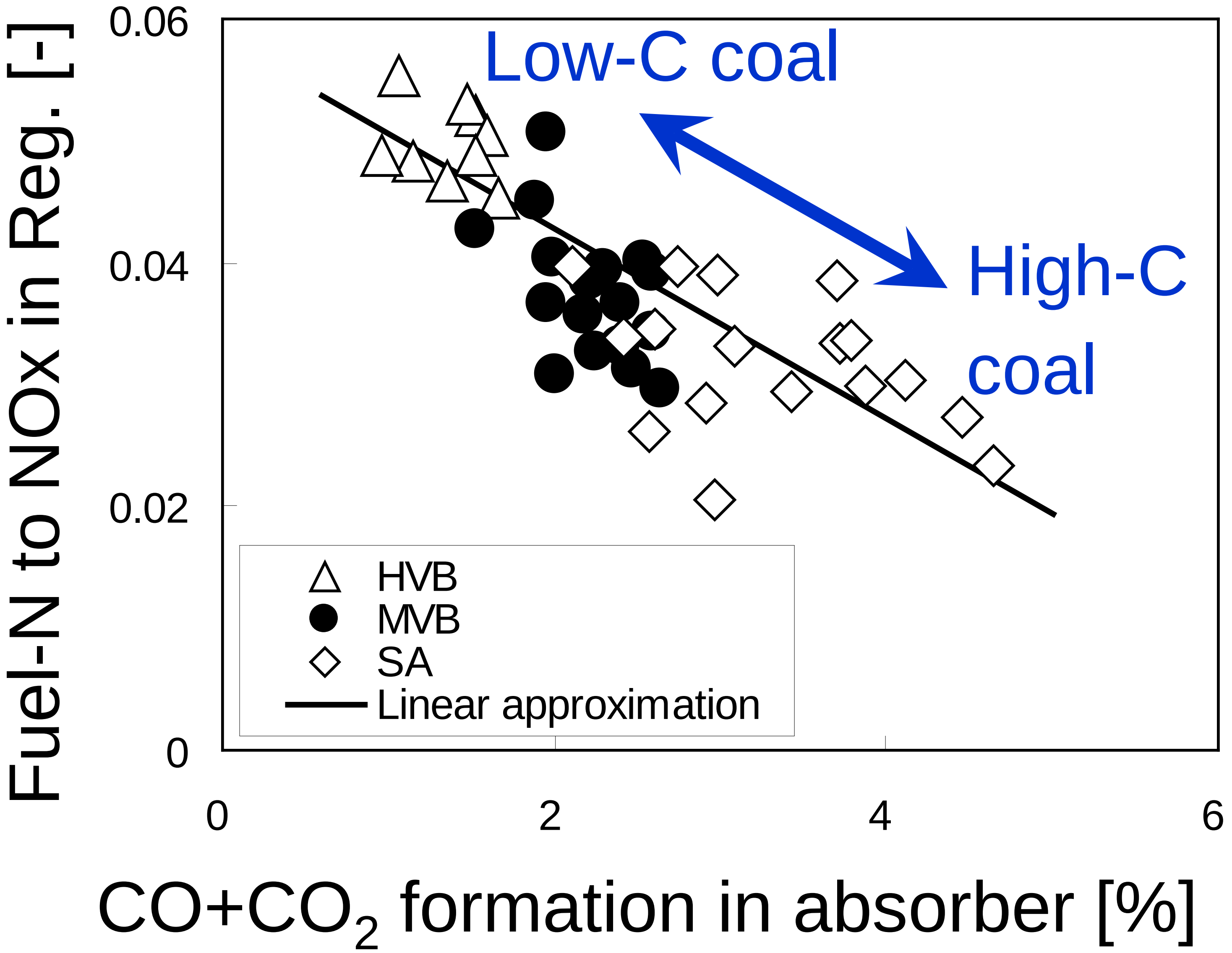
Medium-volatile bituminous coal

Semi-anthracite

- NOx emissions from regenerator.
- CO and CO_2 formation in absorber

Results of fluidized bed experiments

Relationship between NOx formation in regenerator and $CO+CO_2$ formation in absorber. (Gao, ***Fuel*** (in press))



High carbon coal

- ➢Low NOx
- ➢High $CO+CO_2$

<u>Mechanism</u>

NOx reduction by char in Reg. and transportation of char from to Abs.

Results of fluidized bed experiments

High-volatile coal

- Low $CO+CO_2$ emissions from absorber
- High NOx emissions from regenerator

(→ Reduction of NOx in back-pass possible)

Another problem of high-volatile coal

Rapid combustion of volatile matter in O_2-enriched gas

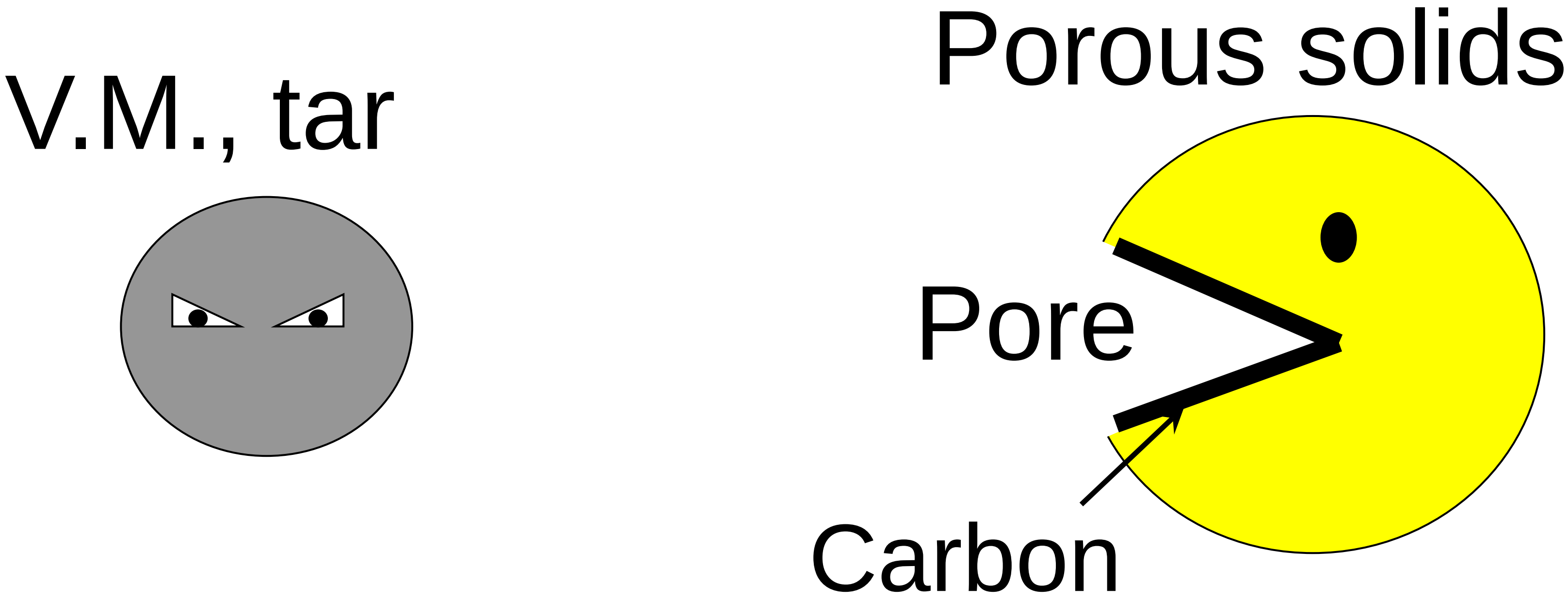
→High temperature flame → Ash fusion problem

Stabilization of volatile matter combustion is required.

Experimental (2) Volatile matter capture by porous solids (calcined limestone and porous alumina) at elevated temperatures using a fixed bed reactor

Porous solids can capture volatile matter at elevated temperatures and form carbon deposit within the pores.

Capacitance effect



Porous particles capture V.M. at high temperatures; carbon deposit is formed within pores.

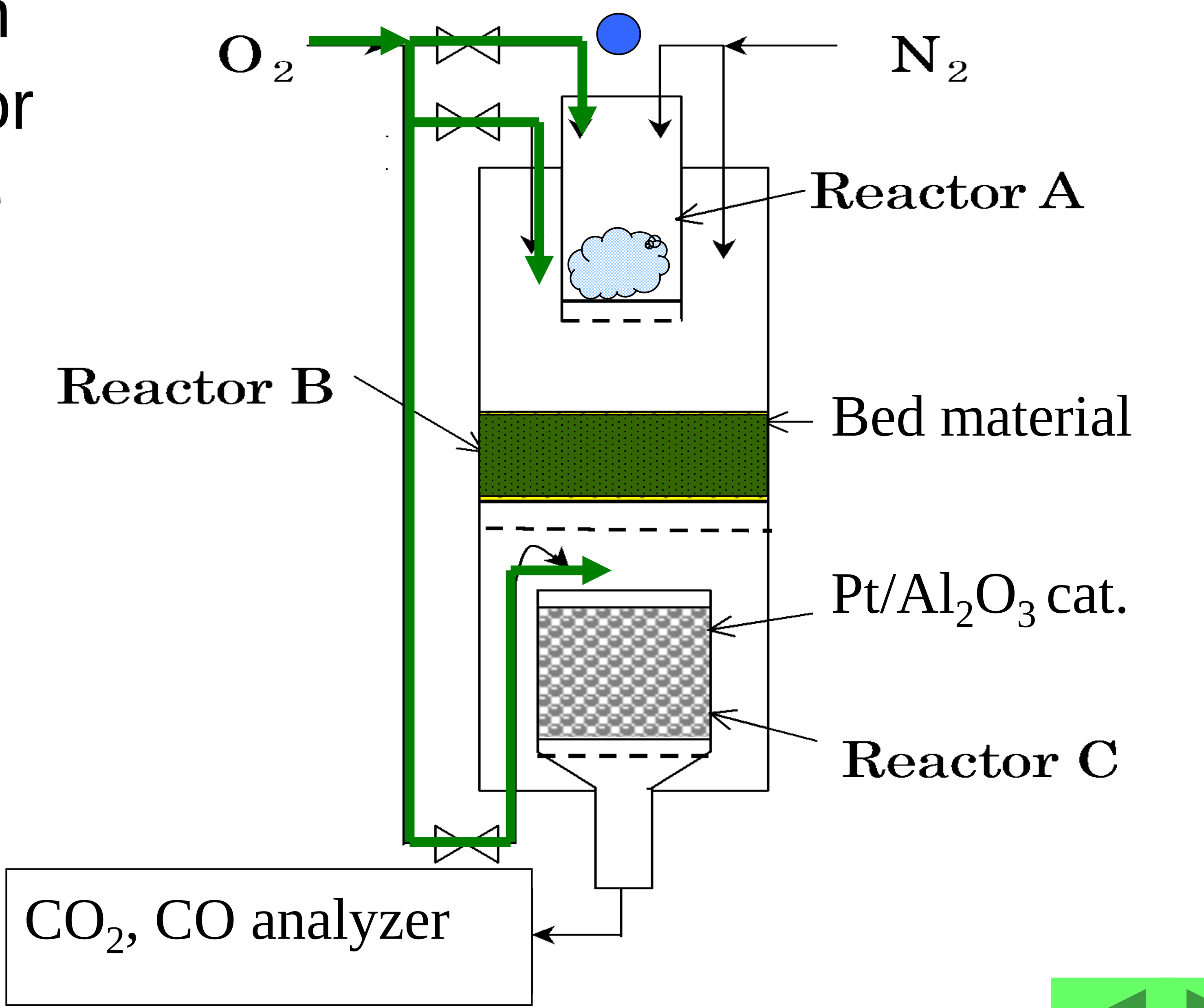
→ Increased residence time of V.M.

Fixed bed reactor

Step1: Evolution of V.M. in reactor A. V.M. capture in reactor B.

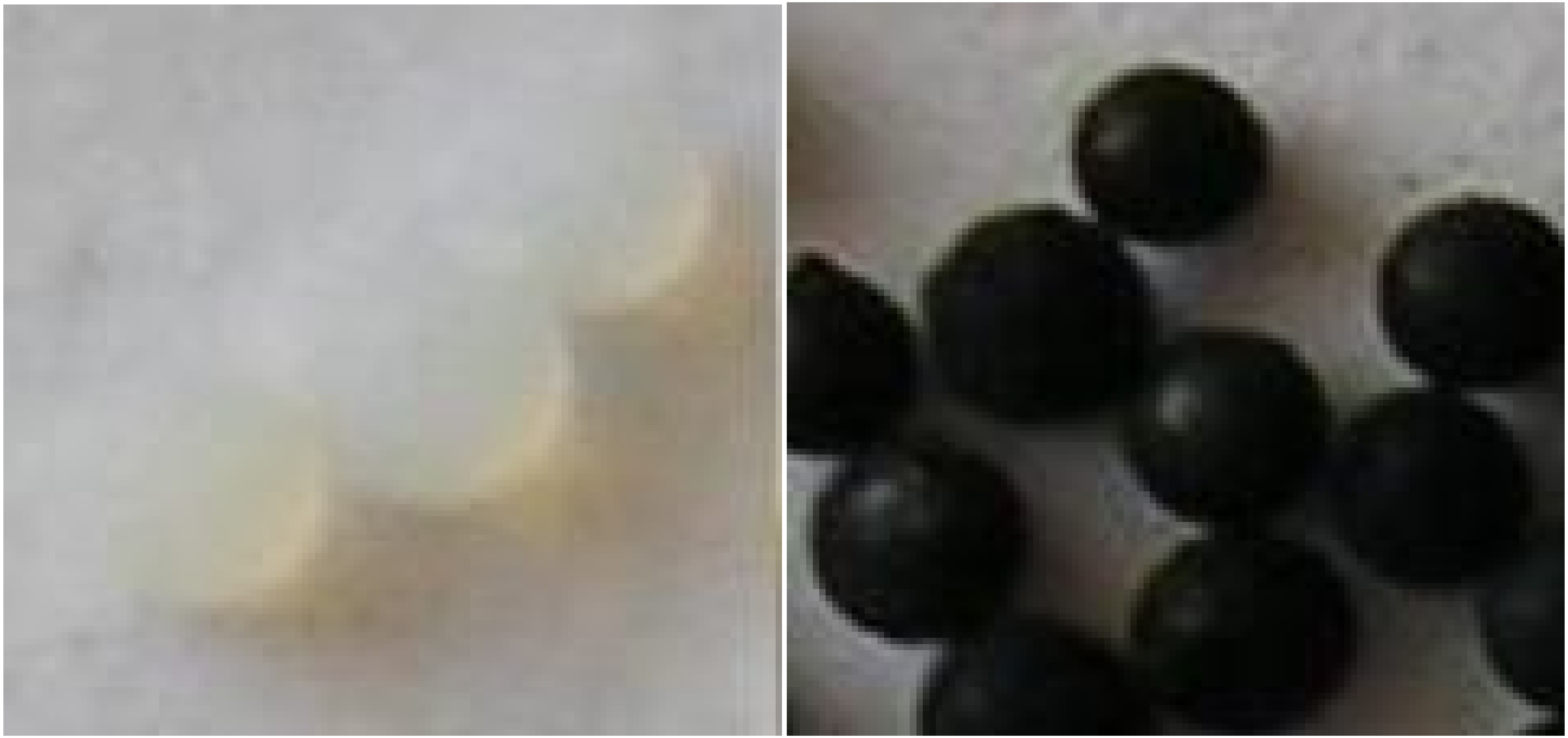
Step2: Deposit combustion.

Step3: Char combustion in reactor A.



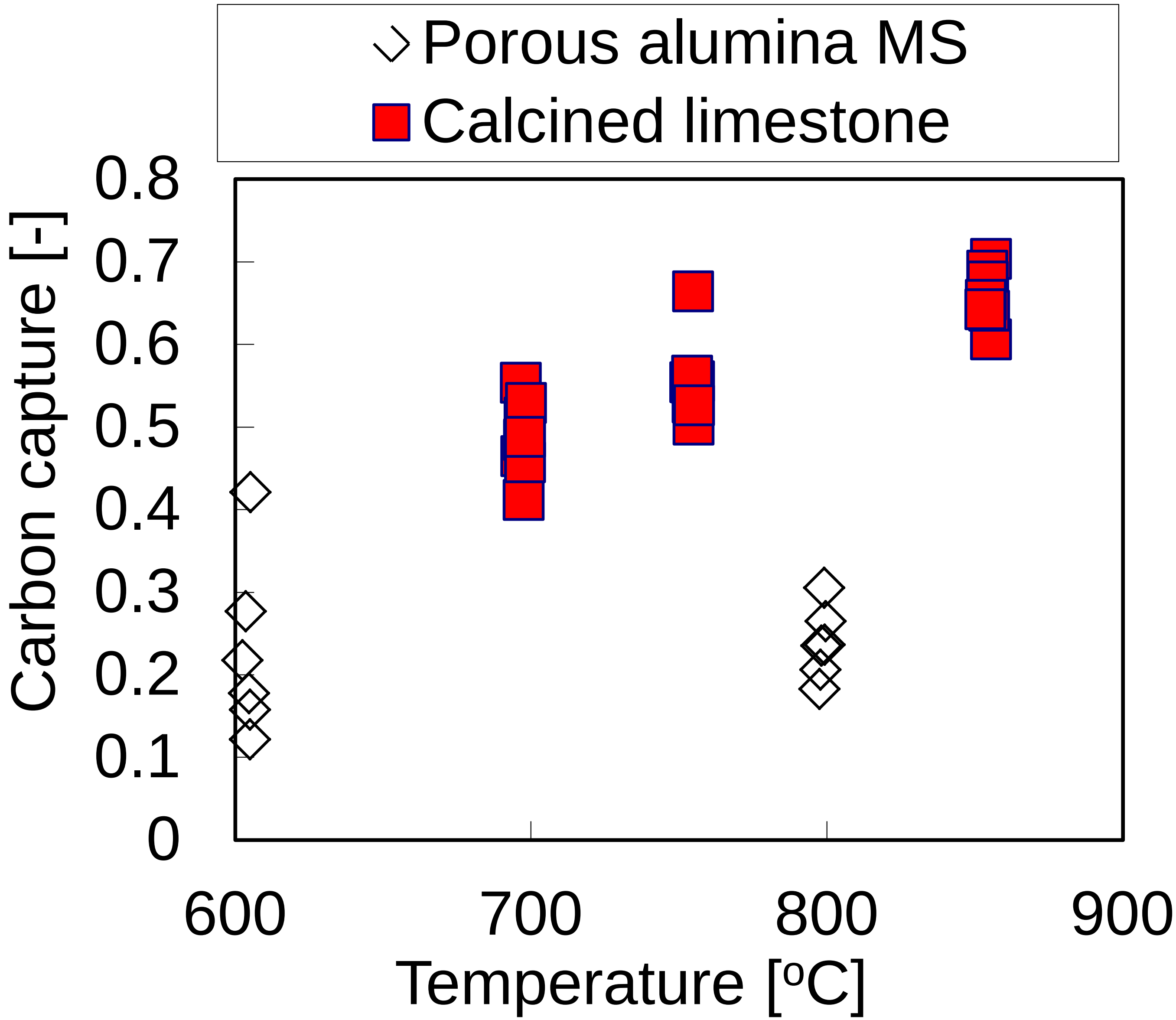
Example of carbon deposit formation

Raw porous alumina (left) and carbon-loaded porous alumina (right)



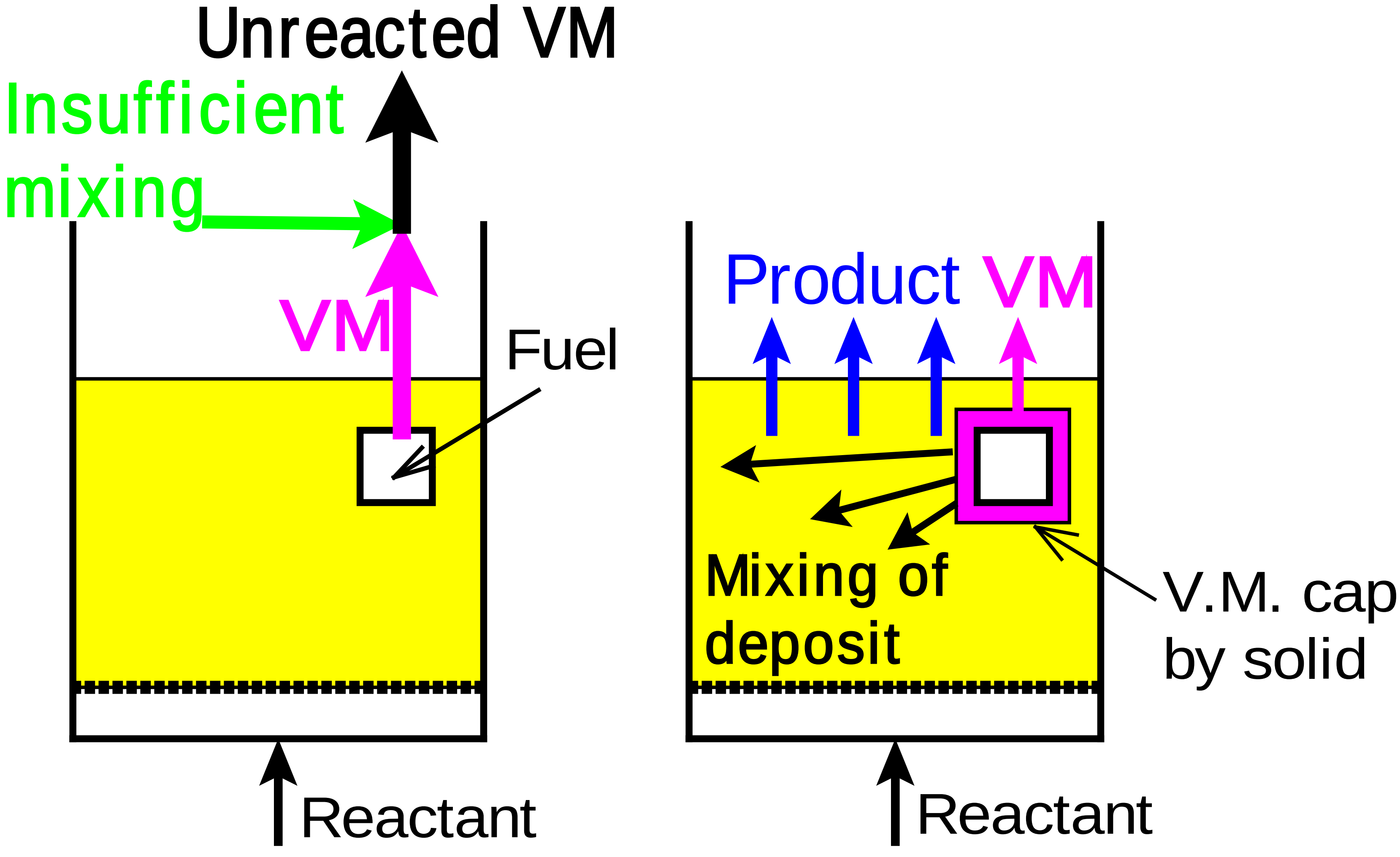
Volatile matter capture by calcined limestone

Calcined limestone can capture volatile matter at elevated temperatures and form carbon deposit.



Effect of carbon capture on VM combustion (in BFB)

Carbon capture stabilizes the combustion of high-VM fuels



(a)Sand bed (b)Porous particle bed

Effect of carbon capture on VM combustion (in BFB)

Bench-scale BFB experiment

Cross section:16cmx4cm

Height: 1m, Bed = 10cm h.

Bed temp.: 670 – 700ºC

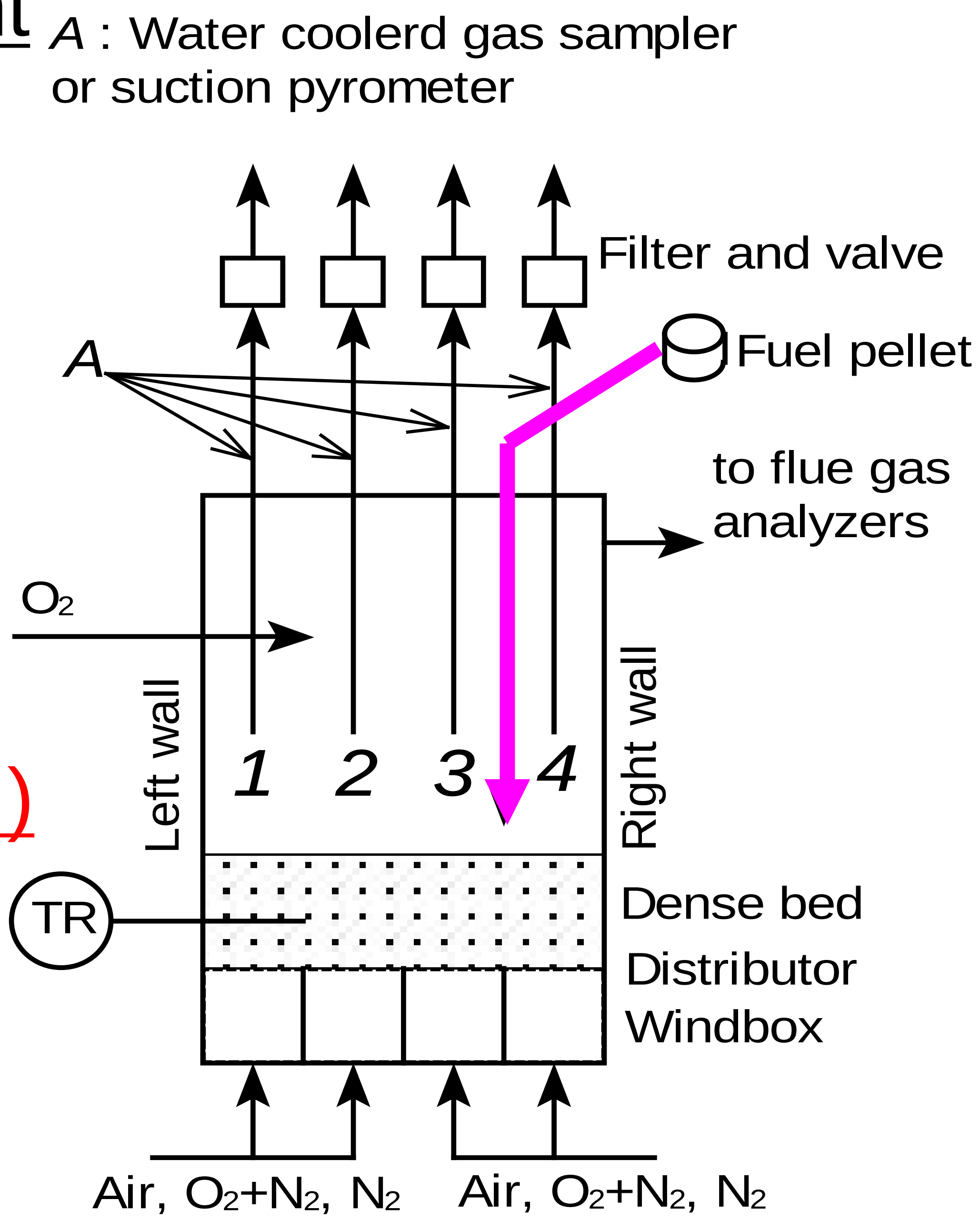
Freeboard temp.: 800ºC

Bed materials:

Non-porous sand bed

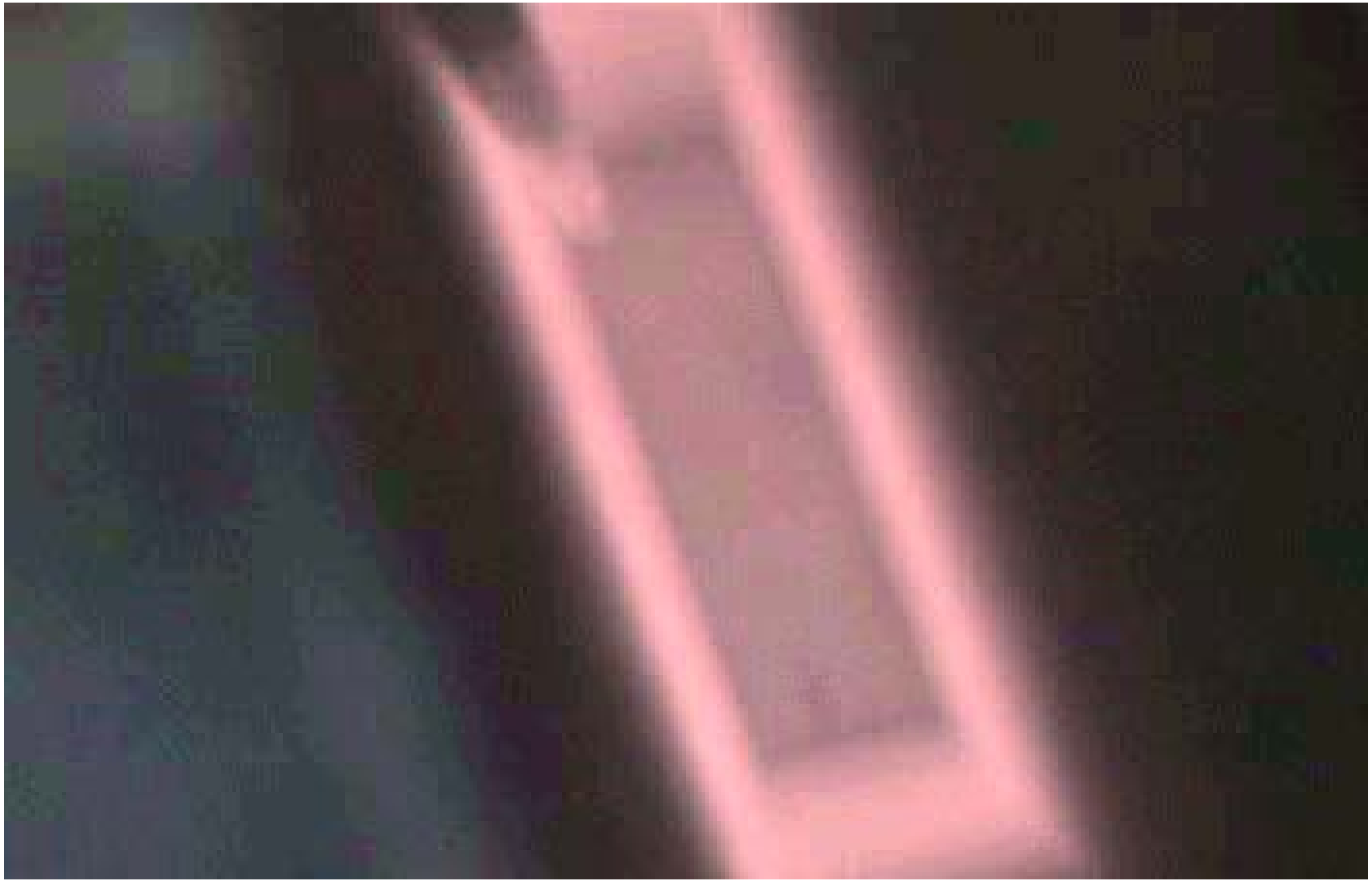
Porous alumina (not CaO!)

A PE pellet (1 cm diameter, 1 cm length) was dropped onto the bed.



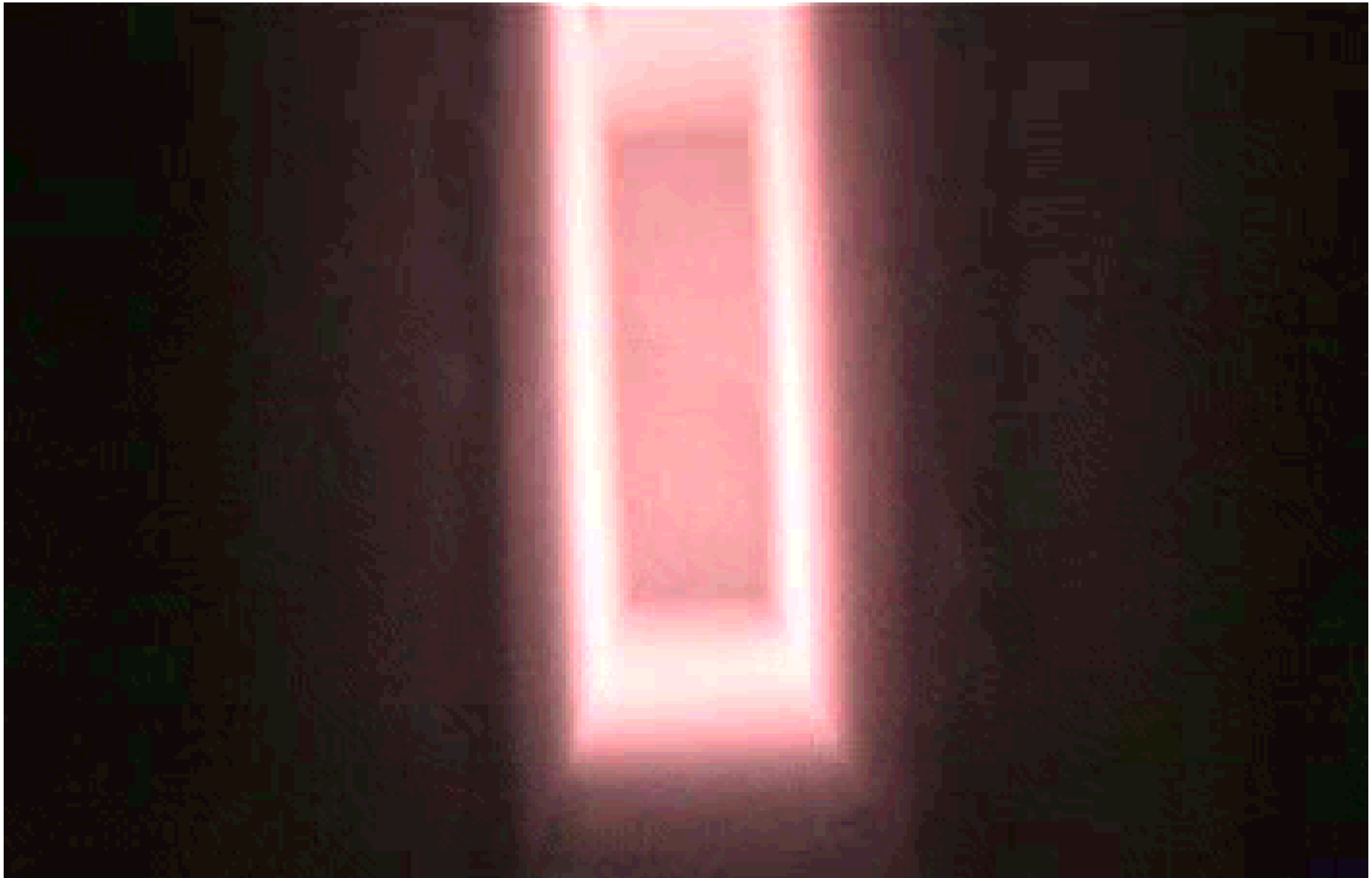
Visual observation from top of BFBC during plastic pellet combustion in ***non-porous sand bed***

Uncontrollable flame combustion



Visual observation from top of BFBC during plastic pellet combustion in ***porous BM bed***

Flame formation was suppressed. Carbon deposit combustion was observed.

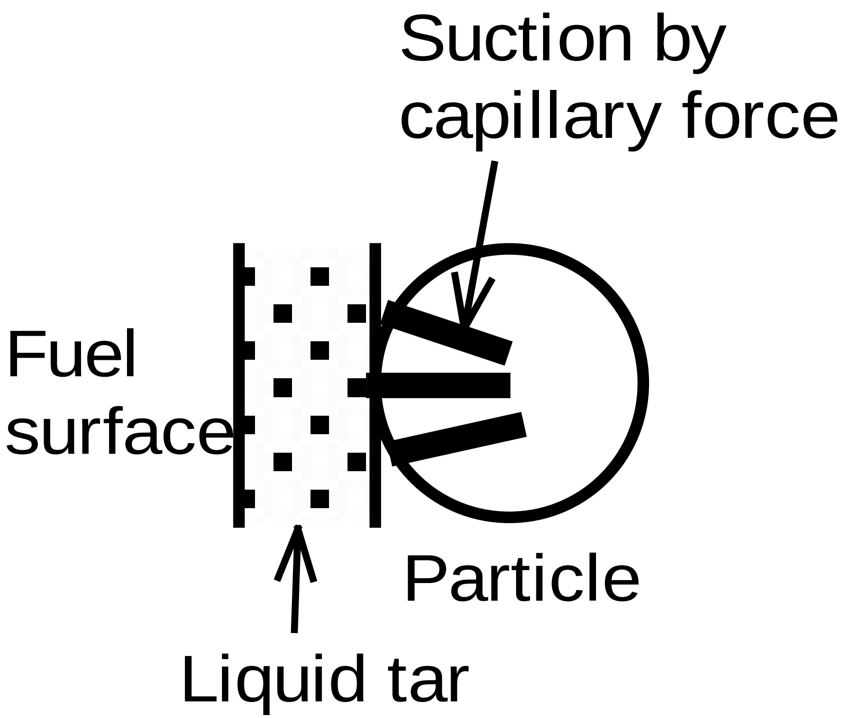


For more effective volatile matter capture

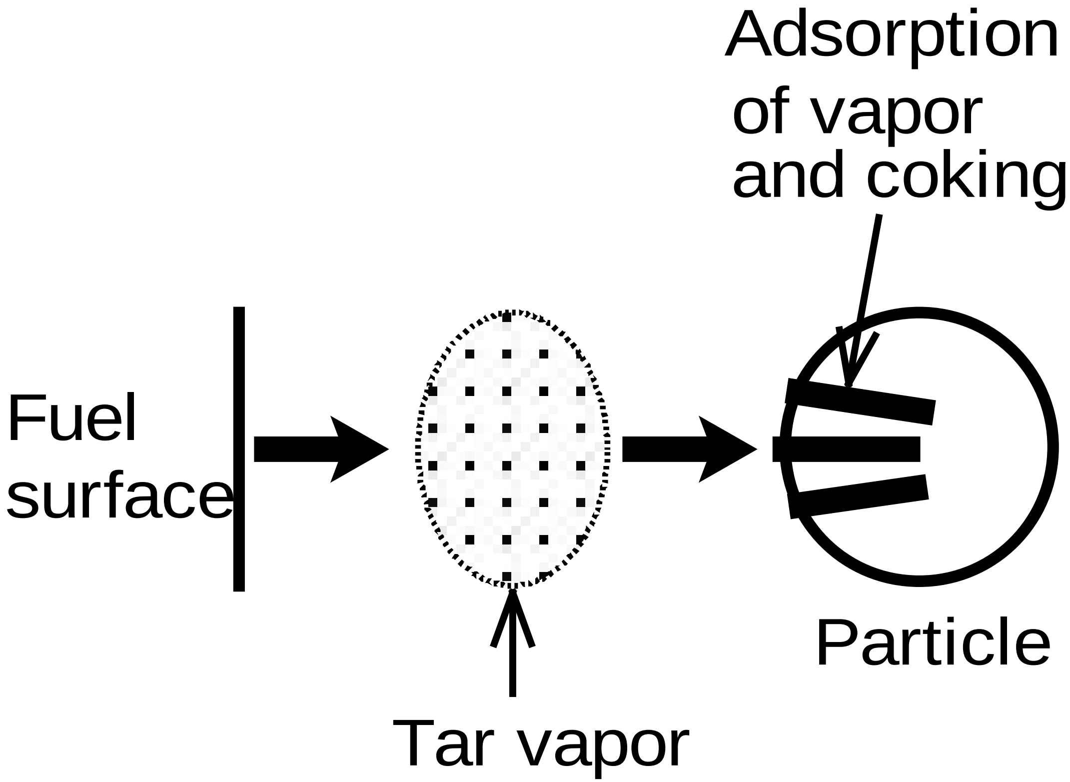
"Direct" contact or "Remote (Indirect)" capture of vapor?

Direct: Porous particles contact fuel surface → BFBC

Remote: Vapor is captured → CFBC



(a)Direct capture mode

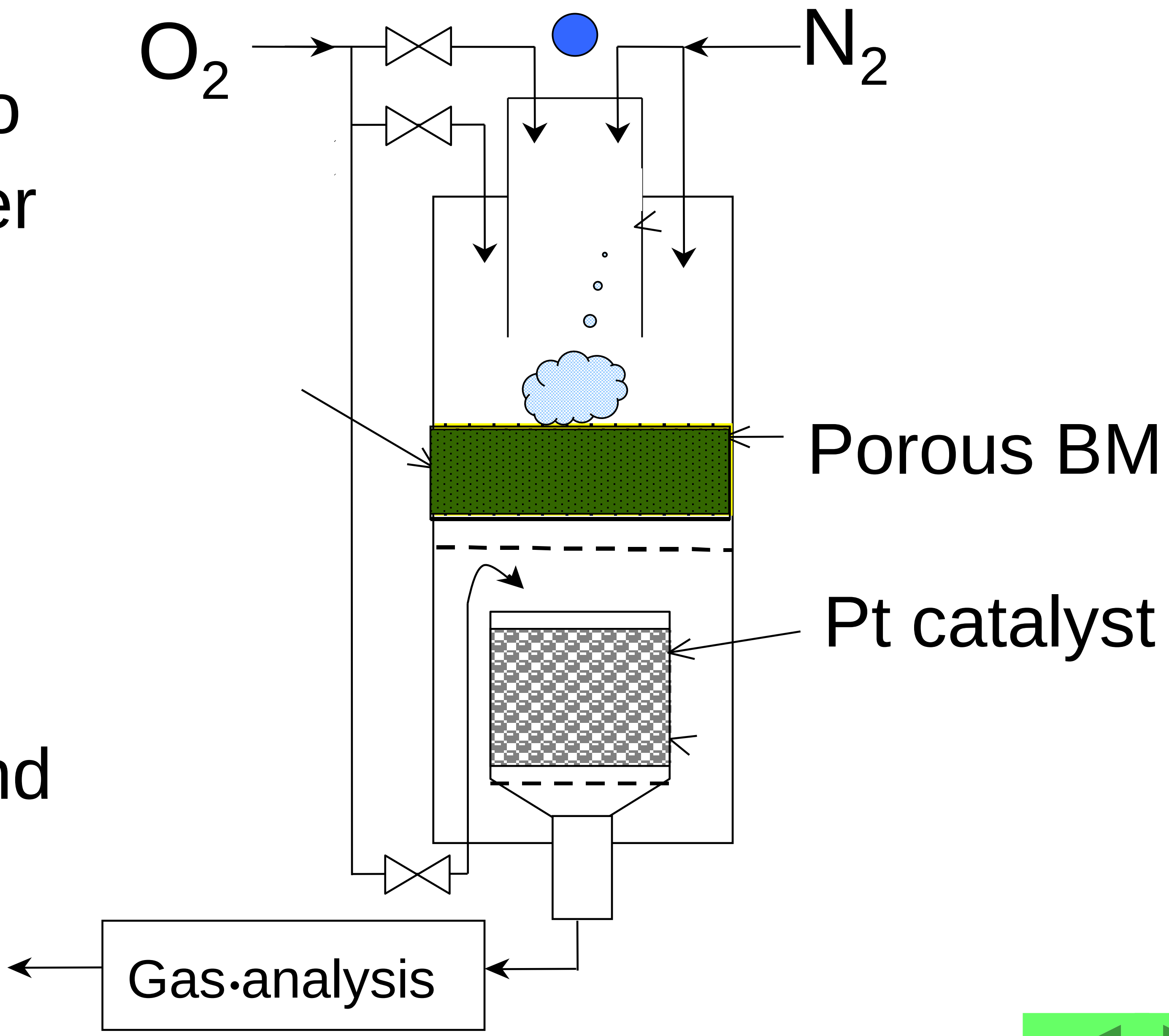


(b)Remote capture mode

Fixed bed for "Direct" Contact

Step1: Fuel (PE) pellet was fed onto the fixed bed under N_2 feeding.

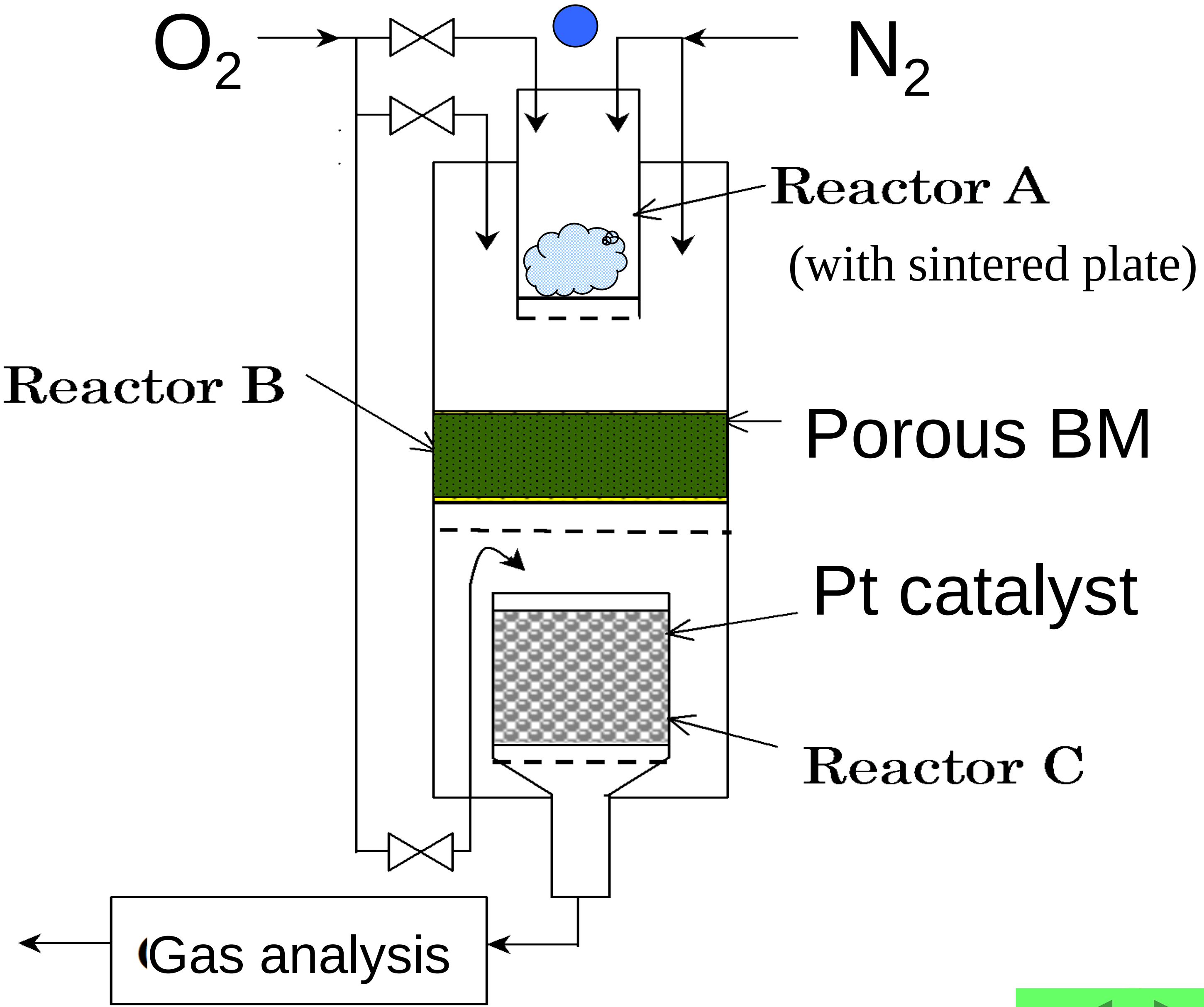
Step2: Captured carbon was determined by burning it and measuring CO_2 and CO.



Fixed bed for “Remote” mode

Step1: Fuel (PE) pellet was fed onto the sintered plate of Reactor A. Volatile matter passed through the fixed bed.

Step2: Captured carbon was determined.



Bed materials (Alumina)

	MS	MS-1B	Activated Bauxite
Size	0.75mm	0.4mm	0.4mm
Al_2O_3	91.32	84.7	69.4
SiO_2	n.a.	2.2	7.2
MgO	0.15	0.0	0.0
CaO	0.07	0.8	0.3
TiO_2	n.a.	1.1	13.0
Fe_2O_3	0.54	5.8	8.4
SO_3	2.10	3.8	0.8
Others	n.a.	1.6	0.9
Area [m^2/g]	187	195	124

実験条件

Temp.：650～850℃

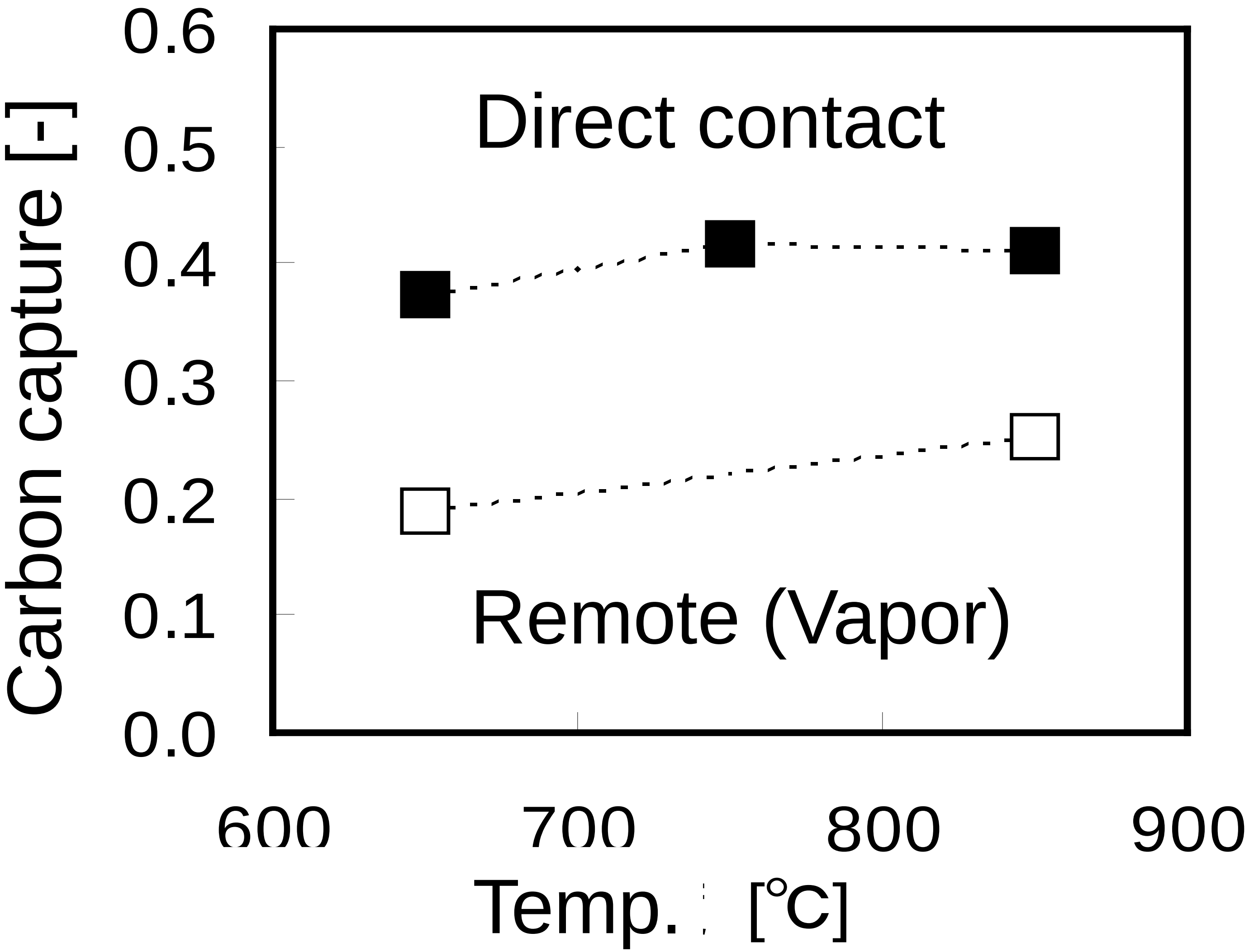
Gas flow rate: 2.2　Nl/min

Fuel：PE pellets (VM 100%)

Packed bed volume：26cm^3

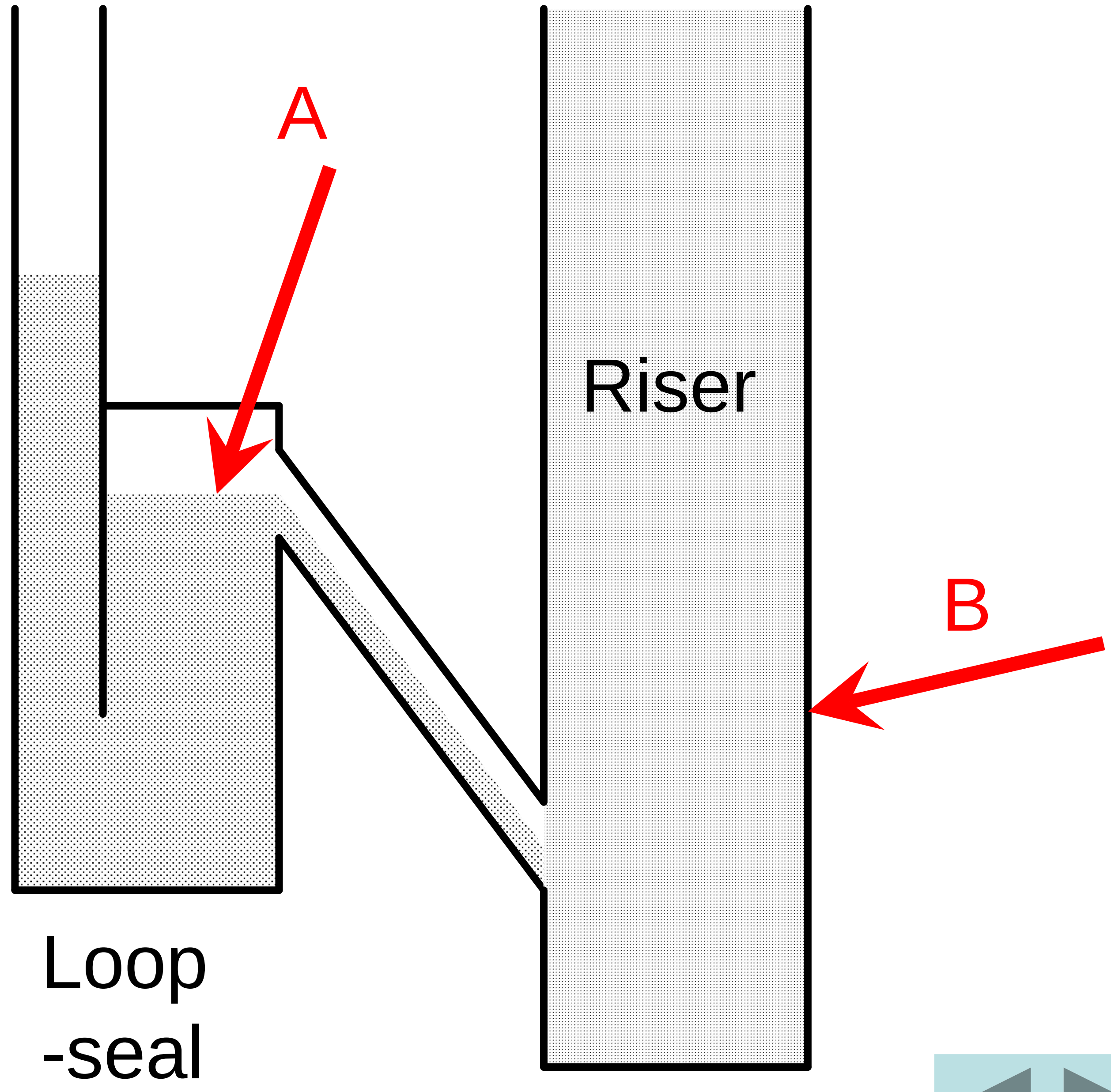
Effect of contact mode on carbon capture (MS porous alumina, 0.4 mm)

Direct contact between fuel and porous BM was favorable for VM-carbon capture in comparison to remote (via gas phase) VM vapor capture.



Proposed fuel feed points

Fuel feed to solid dense zone (A) is considered to be favorable for VM capture in comparison to solid lean zone (B).



Conclusions

Char formation in regenerator

→ Reductant of NOx in regenerator

→ Source of CO and CO_2 in absorber

High V.M. fuel is favorable for CO control.

However, high-volatile fuels may have a problem of uncontrollable volatile matter combustion under O_2-enriched and high-temperature conditions.

Capture of volatile matter by porous CaO particles may solve problems with rapid VM combustion.

Acknowledgements

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